

The role of green innovation in bridging financial development and sustainable economic practices in South Asian countries.

Sadaf Ambreen¹, Jahangir Alam²

ABSTRACT

Author's Affiliation:

¹PhD Scholar (Shifa Tameer
Millat University Islamabad.
sadaf.ambreen@iiu.edu.pk

²PhD Scholar (Shifa Tameer
Millat University Islamabad.
jahangir.alam@kiu.edu.pk

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Corresponding author(s):

Sadaf Ambreen¹
sadaf.ambreen@iiu.edu.pk

Objective: This study examines the impact of green innovation on the connection between financial development and sustainable development in South Asia. It closes a gap in the corpus of previous research by investigating whether green innovation increases financial development's contribution to sustainable development.

Design/methodology/approach: Dynamic panel data for South Asian countries from 2001 to 2023 is used in the study. The Generalized Method of Moments (GMM) is used to evaluate the relationship between the study variables and handle any endogeneity. The analysis is done using E-Views. The study's theoretical underpinnings are endogenous growth theory, natural resource-based theory, and institutional theory. Foreign direct investment and commerce are two more explanatory factors.

Findings: The findings demonstrate the importance of financial development in promoting long-term economic growth and the usefulness of green innovation in strengthening this relationship. The results demonstrate how stable financial institutions and supporting financial policies enhance long-term economic growth. Green innovation and a strong banking sector could assist stabilize the South Asian region's economy and improve living conditions.

Practical Implications: The results will be useful to policymakers and stakeholders in the financial sector who want to design evidence-based policies that simultaneously promote green innovation, sustainable development, and financial development. Supporting financial institutions and implementing sustainability-focused financial rules can help achieve long-term economic and environmental goals.

Originality/value: By combining dynamic panel data and the GMM estimate approach to assess the moderating impact of green innovation on the financial development–sustainable development nexus in South Asia, the study advances the subject. It offers a regional viewpoint that can help practitioners and politicians create finance systems that support sustainable development goals.

Keywords: Financial Literacy, Financial Knowledge, Financial Attitude, Financial Inclusion, Financial Behavior, Financial Capability, Mediation, PLS-SEM, Pakistan

1| INTRODUCTION

Environmental climate change and global climate body changes threaten economic growth and human sustainability in developed and underdeveloped countries (Tol, 2009). Moreover, many researchers and policymakers are exploring a solution to the environmental climate change crises (Young, 2020). In addition, recent research significantly explores the factors that can protect against climate change, concentrating mainly on underdeveloped economies (Ganda, 2020) (Kaklauskas, 2020) (Wang, 2021) to research the climate change problems. Most recently, developed economies have relied on clean energy, green innovation, and effective resource use to cope with climate change challenges while keeping sustainable economic development intact (Gambhir, 2014) (Dogan, 2016) (Bilgili, 2016) (Inglesi-Lotz, 2018) and (Dogan, 2016) (Santos, 2019) (Li, 2021). Green innovation and climate change have recently brought substantial attention as they influence the global environment and sustainable economy (Ali, 2020). Financial development appears to contribute to successfully enhancing the ecosystem quality and facilitating a sustainable economy in South Asian countries. Green innovation includes an essential path to achieving sustainable economic development. It fosters protection and improves ecological quality, enabling industries to provide environmentally focused products and services (Li, 2021). According to Hayat et al., (2018) well-recognized financial development system can help decrease lending costs enhance foreign direct investment, and lower emissions by promoting energy efficiency. The past studies investigated the relationship between financial development and environmental quality which addresses the direct effects (Liu et al., 2022). Moreover, many studies have attempted to fund the association between financial development and environmental indicators, resulting in unsatisfying (Bui, 2020). Even though many researchers explore financial development which causes a rise in investing sources for the energy sector, the outcomes are decreased CO₂ emissions. Meanwhile, past studies explore the direct relationship between financial development and the environment and its implication for enhancing environmental quality (Li X. O., 2022) (Liu et al., 2022). However, the indirect effects of energy demand, consumption, and financial development on a sustainable economy are yet ignored. In South Asian countries including eight states comprising Pakistan, Afghanistan, Bhutan, Bangladesh, India, Maldives, Nepal, and Sri Lanka home-based 1.8 billion people, secretarial for around 25% of the world populace (bank, 2023). The states are categorized by quick economic growth industrialization, and urbanization, which have led to substantial resource deficiency and climate change (IPCC, 2013). The mixture of green innovation with an economic system is a vital step to attaining a sustainable financial system, especially in South Asian countries, which are characterized by rapid, high ecological, social-economic instability and industrialization. Green innovations start with the expansion and adoption of ecologically friendly inventions, practices, and policies that aim to mitigate ecological harm while encouraging financial development. Examples comprise development in energy efficiency, renewable energy technologies, and waste management structures maintained by financial instruments like carbon credits, the impact of investing, and green bonds (Kashif, 2023) (Xu, 2023) Moreover according to UNEP, 2019 an increasing recognition of the need to implement sustainable economic practices and social welfare that provide balanced economic growth with ecological protection. Green innovation includes the expansion and execution of new technology and procedures that decrease environmental impacts and has developed a main strategy for attaining sustainable economic development (OECD, 2018). (Levine, 2005) states that financial development refers to the evolution and emerging Monterey system, which is also critical for sustainable economic practices. However, the relationship between sustainable economic development and financial development is complex and needs to be addressed in details studies to understand how green innovation can bridge this gap in the South Asian context. The theoretical basis of this research is grounded in ecological modernization theory, which proposes institutional innovation and technology can correspond to economic development with environmental sustainability. In South Asian countries, this theory highlights the impact of financial development on foreign investments in environmental sustainability that develop resilience and encourage comprehensive growth. For example, Bangladesh's microfinance drives renewable energy developments, India's solar energy development, and Pakistan's water preservation initiatives explain the transformative potential of bringing into a financial development system with sustainable economic

practices (Hossain, 2024) (Sharma, 2023). This study contributes to the literature on how financial development supports the adoption of bridge-green innovation and sees its implications for sustainable economic development in South Asian countries. In addition, firstly the role of green innovation moderates financial development and sustainable economic development in South Asian countries; secondly, the effect of financial development on sustainable economies in South Asian countries, this study gap is found by literature which is explained in the below table.

Table1. The gap is found with the help of the literature:

No.	Independent Variable	Dependent variable	Findings	Reference/ source	Results
1	Innovation	Sustainable development goals	The results suggest that the strength of cooperative integration, and diversification within the organization, the final market orientation, and attaining sustainable economic development favors technical innovation.	(Ullah, 2020)	Significant (positive)
2	Sustainable development	ESG sustainability	The bounding can be used to assistance comprehend the connections between ESG sustainability issues, sustainability performance, and SDGs, and calculate firms' performance growth towards attainment of SDGs.	(Khaled, 2021)	Significant (positive)
3	Green Innovation reporting	Financial performance (ROE)	The results demonstrate that firms' performance without SDGs is sustainably attained through enhanced financial performance. Therefore, the integration of SDGs into their policy leads to a low return on equity.	(Lassala, 2021)	Significant (Negative)
4	Green innovation	Sustainable development goals	The results suggest that green innovation has a significant impact on sustainable economic development, public engagement, and development of the environmental change. The government is behind the strengthening of green innovations and environmentally comprehensive activities.	(Ullah, 2020)	Significant (positive)
5	Green Innovation	Sustainable development goals	The results state that adopting ISO 56002-2019 green innovation organization system has abetted companies achieve sustainable economic goals.	(Khan, 2021d)	Significant (positive)
6	Sustainable Development Goal (SDG) Practices	Firms' Financial Performance Moderator (Green Innovation)	The findings state that green innovation has a positive impact on those companies that emphasize sustainable economic development and innovation which leads to better performance as compared to others.	(Mozas-Moral, 2020)	Significant (positive)

The latest research is explained in Table 1, which provides a combination of results on the relationship between green innovation reporting, SDGs, and the financial performance of firms. The results demonstrate that two research highlighted significant negative relationships between green innovation, SDGs, and the financial performance of firms (Parmentola, 2021), while on the other SDGs, nonfinancial firms have a significantly positive relationship (Khaled, 2021). Moreover, numerous research has identified the impact of green innovations on sustainable development goals and firms' performance demonstrating positive results regarding green innovation improving firms' performance (Khan P. A., 2020) (Tjahjadi, 2020) (Zhang, 2019, 2020a). Research by Tang et al. (2018) and (Asni, 2021) highlighted the effect of green innovation on financial development. Moreover, (Lin, 2020) underlined the situation of green innovation in moderating the risks related to organizations' economic performance. Nevertheless, two other studies explicitly explored the direct relationship between green innovation and sustainable economic development goals (Ullah, 2020), (Khaled, 2021) (Khan P. A., 2021d)). This investigation examines the importance of green innovation as a moderating factor between sustainable economic development and firms' financial performance.

2 | Literature Review

The natural resource-based view (NRBV) theory: suggests that firms can achieve a competitive advantage by leveraging their relationship with the natural environment (SL, 1995). This (NRBV) theory helps businesses identify and grow environmental capabilities as part of their main operations. By concentrating on areas such as green

innovation, environmental performance, and sustainable economic development, firms can decrease their environmental footprint while improving their status and competitive edge. The natural resource-based view theory highlights addressing socio-ecological needs for upcoming generations (Mohamed AA, 2022). It emphasizes how resource abilities can offer a permanent advantage by considering the impact of the natural environment on organizations' operations and sustainability development (Ferraris A, 2022) (Rehman SU, 2021). Moreover, the NRBV framework inspires organizations to improve firm performance and encourage innovation while highlighting shareholders in all activities (J, 2021). In emerging economies, ecological and social challenges are quickly increasing. Consequently, the NRBV theory provides valuable insights, exclusively in the industrial sector, by emphasizing the importance of firms' performance, and environmental capabilities. It discourses shareholders' environmental concerns, inspires firms to decrease their ecological impact, and supports them to expect future trends. This leads to stronger market positions and a change toward a sustainable economy. Furthermore, the NRBV theory helps businesses recognize the impact of ecological sustainability and green innovation as tactical resources. Therefore, Green innovation, in particular, can support firms to attain a lasting economic advantage (Khanra S, 2022). Environmental modernization theory proposes that environmental challenges can be addressed through technical innovation and influential reform. It advocates the combination of ecological considerations into sustainable economic and policy structures, highlighting that green innovation is important for sustainable economic growth. Financial development, in this framework, provides the essential capital and encouragement to support environmentally friendly projects (bank, 2023) (Xu, . Green innovation and industrial restructuring: Evidence from developing economies. *Journal of Environmental Economics*. Albort-Morant, G., Leal-Millán, A., & Cepeda-Carrión, G. (2016). The antecedents and consequences of eco-innovation: , 2023). In addition, analyzing this research with the help of NRBV theory can help organizations stand out by attaining long-term sustainable market development. It mainly provides benefits for manufacturing firms, as well as current performance development by incorporating the benefits of shareholders. Furthermore, it inspires firms to restructure processes and decrease the impact of environmental risks, which increases both ecological and financial performance. In summary, the combination of concepts like sustainable development, green innovation, financial performance (FP), and environmental value proposition (EVP), within this framework can give firms a competitive advantage and initiative their success. The objective of this study address the two most important research gaps recognized in the literature, this segment builds a strong foundation by studying existing research. The review emphasizes sustainable development as the dependent variable and firms' financial performance as the independent variable. In this research, green innovation is taken as the moderating variable. Moreover, the results are calculated using the World Development Indicators Data Bank (WDI).

2.1 Green innovation and financial development:

Financial systems play a vital role in supporting green innovation by utilizing resources for environmentally sustainable development. Instruments such as green bonds, green credit schemes, and carbon markets have been involved in financing renewable energy, sustainable infrastructure, and energy-efficient technologies. Empirical findings reveal that financial development in South Asia is gradually including environmental goals in their activities, determined by national policies and international structures like the Paris Climate Accord (Kashif & Shaheen, 2023; UNDP, 2022). The literature recognizes the multiple benefits of green innovation for industries. It improves their reputation, constructs shareholder confidence, and provides a modest advantage, exclusively for initial adopters (Chen, 2008). Furthermore, green innovation expands resource efficiency and decreases waste, leading to both sustainable development and financial development benefits (Albort-Morant et al., 2016). There is an emergent body of suggestions proposing that green innovation positively impacts financial development. By adopting sustainable developments, businesses can decrease costs, increase operational efficiency, and improve their market position (Hassani et al., 2021). Moreover, green innovation nurtures shareholder trust, which can lead to improved investments and higher stock values (Goyal et al., 2020). Despite the benefits, challenges persist in linking green innovation with financial development. Limited access to financial resources and high initial costs remain significant barriers for many firms, particularly in developing economies (Onyango and Ondiek, 2021). Furthermore, the lack of standardized

frameworks for measuring the financial impact of green innovation makes it difficult for investors to assess its long-term benefits (Calabrese et al., 2018).

2.2 Green Innovation as a Moderator:

Green innovation discusses the development or amendment of products, procedures, or services considered to decrease environmental damage and encourage environmental sustainability (Calza et al., 2017). Green functioning innovation emphasizes specifically improving a firm's efficiency in its procedures by incorporating ecologically friendly activities into its products, procedures, or services.

The term "green innovation" is also revealed by other names in research, such as environmental innovation, eco-innovation, and environmental innovation, depending on the framework. These inventions typically propose to measure and increase performance while decreasing environmental impact. Further researches agree that green innovation not only reduces environmental harm but also generates value for shareholders and strengthens firms operations. The emphasis on green innovation has developed during the present business revolution as ecological threats from previous business developments have become more obvious (Chen et al., 2018). Studies have shown that adopting green innovation activities gives industries a competitive advantage. Corporations benefit in numerous ways, including increased shareholder trust, improved reputation, and higher share prices, exclusively if they are the first to adopt such activities. Furthermore, green innovation expands a business's efficiency, profitability, and effectiveness, and offers both environmental and financial development (Chen, 2008). Different types of green active innovations have been recognized in the literature. These contain green innovation (Tariq et al., 2017), green procedure innovation (Xie et al., 2019), and green provision innovation (Khan and Johl, 2019; Calabrese et al., 2018), all of which are secured to improving corporate operations in a naturally sustainable way. Green innovation improves production by developing resource efficiency and decreasing environmental external problems. Empirical researches in South Asia highlight the encouraging impact of clean energy technologies and green finance on economic elasticity. Green finance, including green bonds, loans, and carbon credits, organizes resources for naturally sustainable practices, directly influencing innovation and business advancement (Kashif & Shaheen, 2023; UNDP, 2022).

2.3 Financial Development and Environmental Sustainability Development:

At the national level, research indicates a significant positive relationship between sustainable development initiatives and results (Pradhan et al., 2017). Financial development enables investments in green innovation by giving the necessary capital for environment-friendly projects. Moreover, Studies disclose that financial systems in South Asia are progressively brought into line with environmental goals over heightened accessibility to green funds and regulatory facility for sustainable development. Financial development and sustainable development are interrelated aspects of modern financial development growth. Financial development refers to the enhancement of financial institutes, markets, and instruments that enable the efficient distribution of resources. Environmental sustainability development emphasizes using natural resources reliably to meet current needs without negotiating future generations' capacity to meet theirs. This literature review discovers how financial development contributes to sustainable development, with a focus on instruments, challenges, and suggestions.

Financial development offers the tools and wealth necessary to encourage sustainable development practices. By supporting investments in green innovation technologies and renewable energy, financial development supports the transition to environmentally sustainable. For example, financial instruments like sustainability-linked loans, and green bonds, carbon trading systems encourage industries to adopt environmentally friendly practices (Rana & Sharma, 2020).

Instrument Associating financial development and sustainable development: Green Investments are defined as financial markets that simplify investments in renewable energy and environmentally-friendly structures, decreasing reliance on fossil fuels and encouraging cleaner energy substitutions (Hussain et al., 2021). Carbon Financing means Mechanisms like carbon credits and trading structures incentivize industries to decrease greenhouse gas emissions and assume sustainable development (Wang et al., 2019). Innovation Support is explained as financial development inspires

research and green innovation technologies, encouraging a transition to low-carbon sustainable economics (Nasreen & Anwar, 2022). Furthermore, Risk Mitigation defined as financial products, such as insurance and hedging products, helps industries manage environmental development risks, making it easier for them to capitalize on sustainability enterprises (Pereira et al., 2020).

2.4 In the Unique Context of South Asians:

Countries like Pakistan, India, and Bangladesh, face unique challenges, containing high carbon emissions, rapid urbanization, and restricted financial inclusion. The adoption of green innovation here is crucial for addressing these challenges while nurturing economic stability. The role of international contracts like the Paris Climate Accord and national strategies in encouraging green finance cannot be overlooked (Kashif & Shaheen, 2023; UNDP, 2022).

2.5 In Regional context Case Studies analysis:

India's renewable energy division focuses on the integration of green finance and green innovation. Enterprises such as the National Solar Task and public-private corporations have attracted positive important investment, and development large-scale adoption of solar and wind machineries (Sharma & Gupta, 2023). In Bangladesh country, Microfinance institutes have focused on green innovation in rural electrification through schemes like Grameen Shakti, which encourages solar home systems and clean stoves. These initiatives determine the connection between financial inclusion and sustainable development (Hossain et al., 2024). Additionally in Pakistan's economy Efforts in water preservation and energy efficiency highlight the importance of green finance in addressing resource shortages. The growth of green banking policies and energy-saving types of technology reflects Pakistan's commitment to sustainable activities (World Bank, 2023).

2.6 Challenges and opportunities:

While the prospective benefits of green innovation are well-documented, South Asia appearances challenges, containing limited financial inclusion, weak influential capacity, and inadequate investment in research and development. Addressing these obstacles requires a complex approach involving regional collaboration, international support, and the combination of digital financial tools to enlarge access to green financing. Limited Financial Inclusion states that a substantial portion of the populace remains omitted from formal financial development systems, restricting interaction with green finance. Moreover, according to institutional barriers Weak governance and regulatory structures hinder the actual execution of green policies. Furthermore, technological gaps explain that Limited investment in research and development restricts the scalability of green innovation technologies. Opportunities consist of leveraging fintech resolutions, nurturing regional collaboration, and bringing into line policies with international sustainability development goals. Block chain-based carbon transactions and digital policies for green financing represent developing tools for improving green innovation in the county (Mehroush et al., 2024; UNDP, 2022). Limited Financial Inclusion is explained as a significant percentage of the population's absence of contact with financial services, delaying investments in green projects. However, Institutional Barriers suggest that weak regulatory structures and governance issues obstruct the adoption of sustainable development activities. On the other hand, the economy faces multiple challenges such as insufficient Funding Many developing economies face challenges in rallying financial resources for environmental development activities (Sharma et al., 2020). Lack of Awareness also explains that incomplete awareness about green financial practices and their benefits baskets their adoption (Liu et al., 2021). Regulatory Gaps state that the absence of standardized structures for green financing leads to conflicts in implementation and observation (Zhang et al., 2020). Market Risks suggest that Investments in green projects are frequently perceived as risky due to ambiguous returns, preventing investors (Wang et al., 2019).

2.8 Hypothesis:

Based on the literature review, the subsequent hypotheses will be tested:

1. Green innovation has a positive impact on sustainable economic development practices in South Asia.
2. Financial development has a positive impact on green innovation in South Asia.
3. Green innovation mediates the relationship between financial development and sustainable economic practices in South Asian

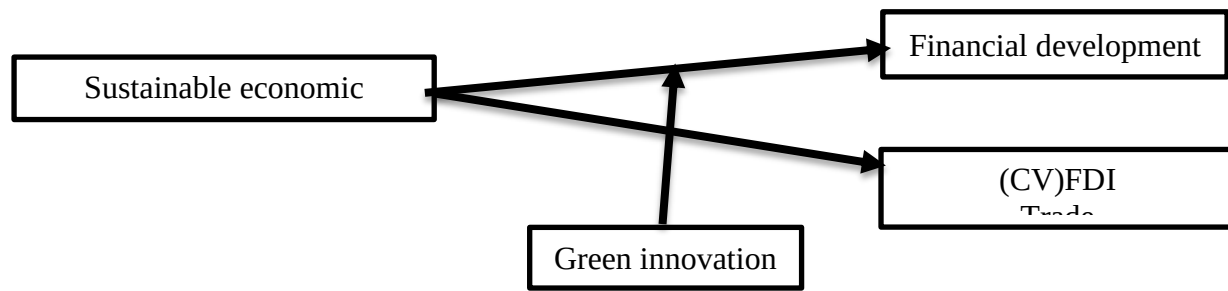


Figure-1 Conceptual Model

2.9 Operationalization of variables:

Variable	Dimension	Acronym	Operationalization	Source
Sustainable development (DV)	Environmental sustainability	SDG	Resource depletion rate	WDI
Financial development (IV)	Financial system depth	FD	Ratio of bank assets to GDP	WDI
Green innovation (Moderator)	Green innovation	GI	CO ₂ emissions	WDI
Control variables	Foreign direct investment; Trade	FDI; TR	FDI inflow (% of GDP); Trade (% of GDP)	WDI

Note. DV = dependent variable; IV = independent variable; WDI = World Development Indicators (World Bank).

3 | Research Methodology Research Design and Sample

This study created literature review by investigating data from WDI using the keywords “Sustainable Development (ENVS, Resource depilation rate)” and “Financial development (The ratio of bank assets to GDP).” The existing studies primarily focus on factors that improve sustainable development practices. For example, researchers explore accessible solutions through social entrepreneurship (Goyal et al., 2020), the part of ISO certifications (Khan et al., 2021; Toha et al., 2020), eco-friendly policies (Coscieme et al., 2021), the influence of sustainable development-focused sustainability practices (Calabrese et al., 2021), and offerings from public partnerships (Ordonez-Ponce et al., 2021), all presenting mostly positive results. Particular studies also founding the influence of the business revolution on digital technology, containing contributions to digital sustainability reporting (Ribeiro et al., 2021), digital combination (Onyango and Ondiek, 2021), Big Data (Hassani et al., 2021), and blockchain (Parmentola et al., 2021) in encouraging sustainable development among financial development, The research adopts quantitative techniques, which are appropriate for examining relationships between variables using statistical methods. The research explores the impact of financial development (independent variable) on sustainable economic development (dependent variable) and green innovation as the moderating variable. This investigation uses secondary data collected from reliable international databases to ensure reliability and accuracy. The foundations contain the World Development Indicators (WDI) data on green innovation (Moderator), with the help of indicators of CO₂ emissions, and financial development (independent variable) with the help of (the ratio of bank assets to GDP) and sustainable development (dependent variable) with indicator (Resource depilation rate). Foreign direct investment and trade are used as Control variables and data is collected with the help of indicators (inflow % of GDP, for FDI), and trade data with (trade% of GDP). The data covers South Asian countries (Pakistan, India, Sri Lanka, Bangladesh, Nepal) concluding the period 2000–2024. This period is intended to observe long-term developments and the growing relationship between financial development, sustainability development, and green innovation. A panel dataset will be formed, relating cross-sectional data from South Asian countries and time-series data (2000–2024). Missing values will be controlled using imputation techniques or excluded depending on their importance

3.1 Descriptive Analysis:

Statistical tools and software: The measurement item was established based on an inclusive review of the literature. The independent variable, demonstrating the firm's sustainable development, was derived from previous studies (Khan et al., 2021d) to evaluate the practices of financial development in South Asian countries. In the intervening period, the moderating variable, "green innovation," was selected by highlighting the most frequently repeated items in existing instruments. It includes innovations related to green products, procedures, and organizational activities. Statistical analysis (mean, median, standard deviation) for all variables will be calculated to understand data trends and validity. Pearson's Correlation will measure the linear relationships between the variables, finding any multi-collinearity issues. Panel Regression Analysis (PRA) is Appropriate for datasets with both cross-sectional and time-series measurements. It helps identify how financial development impacts sustainable economic development over time. To investigate the moderating influence of green innovation, a Moderated Regression Analysis will be executed. Interaction terms (Financial Development $\times$ Green Innovation) will be presented in the regression model. The variance Inflation Factor (VIF) test also ensures no multicollinearity between predictors. The Breusch-Pagan LM Test is used to check for heteroscedasticity in data. Moreover, the Durbin-Watson Test was utilized to identify autocorrelation in residuals.

E-views or R are used to test panel data and cross-sectional data regression and moderation analysis.

Excel: For initial data cleaning.

1.3 Model Equation:

$$D_SDG = \beta_0 + \beta_1 D_FDit + \beta_2 1FDit + \beta_3 D_Glit + \beta_4 D_Glit + \beta_5 (FD \times GI) + \beta_6 Xit + ut$$

Where:

β_0 = Intercept of the regression equation.

$\beta_1, \beta_2, \beta_3$ = all beta is the coefficient of dependent variable (Financial development)

FD= Financial development (independent variable)

SED= Sustainable Economic Development (Dependent Variable)

GI= Green Innovation (Moderator)

GI * FD= Interaction term analyzing how Green Innovation moderates the relationship between Financial Development and Sustainable Economic Development.

ϵ = Error term explaining unexplained variability

3.2 Hypothesis Testing:

Direct Effect H1: Financial development positively impacts sustainable economic growth.

Moderating Effect H2: Green innovation moderates the association between financial and sustainable economic development, strengthening the positive impact.

3.3 Estimation Methodology

Our empirical strategy is designed to: (1) Investigate the potential relationships between Financial development, sustainable development and Green innovation; (2) assess the impact of the interaction between financial development and green innovation (FD*GI) on sustainable development indicators (SD_GNI); and (3) evaluate the marginal effects at median, maximum, and minimum levels. The analysis was carried out in several steps. First, we employed the two-step System Generalized Method of Moments (SGMM) approach to estimate our models for SD_GNI. Both models were analyzed with and without interaction terms to explore potential moderating effects. In the second step, a static panel estimation was conducted for comparison purposes. This involved Ordinary Least Squares (OLS), OLS with Fixed Effects (OLS FE), and Least Squares Dummy Variable (LSDV) regression methods. These static estimations provided additional insights into the relationships among the variables. Finally, we estimated the marginal effects using the SGMM framework for both dependent variables. The entire analysis was performed using EVIEWS version 8, a widely recognized statistical software known for its advanced capabilities in data analysis. This software allowed us to conduct a robust and comprehensive evaluation, ensuring reliable estimation and interpretation of results. The dynamic panel SGMM method combines equations in first differences and levels, as suggested by Arellano and Bover, to address endogeneity. This method ensures accuracy and validity in the results, making it a preferred choice in empirical research.

4 |Results and Discussion

Table 1.3 presents the random correlation effect of Husman Test on the major variable adopted in the research, sustainable development as dependent variables, financial development as the independent variable, and green innovation, as moderating variables

1.3 Correlation Random Effect -Hausman Test:

Variable	Fixed	Random	Var(Diff.)	Prob.
D_FD	0.095009	0.106521	0.000020	0.0102*
D_GI×FD	−0.000482	−0.000355	0.000000	0.0984†
D_FDI	0.000410	0.001328	0.000006	0.7001
D_TR	1.317874	0.240712	4.268445	0.6021

Note. Test cross-section random effects: $\chi^2(4) = 9.165492$, $p = .0571$. † $p < .10$. * $p < .05$.

This test determines whether the fixed or random effects model is more appropriate.

Chi-Sq. Statistic (9.165492), $p = 0.0571$: The p-value is slightly above the 0.05 threshold, suggesting weak evidence to reject the null hypothesis. This means the random effects model might be appropriate, but the result is borderline, and caution is needed

Variable-specific comparison (Fixed vs. Random effects):

D_FD: The coefficient difference between fixed and random effects is statistically significant ($p = 0.0102$), indicating fixed effects better capture the impact of this variable.

D_GI*FD: The coefficient difference is marginally significant ($p = 0.0984$).

D_FDI and D_TR: The differences are not significant ($p > 0.05$), suggesting the random effects model captures these variables adequately.

1.4 Redundant Fixed Effects Tests and Fixed-Effects Regression Results

Effects Test	Statistic	d.f.	Prob.
Cross-section F	14.622483	(8, 113)	0.0000***
Cross-section Chi-square	89.536098	8	0.0000***

Variable	Coefficient	Std. Error	t	Prob.
C	0.999857	0.492996	2.028	0.0447*
D_FD	0.164794	0.041493	3.972	0.0001***
D_GI	−0.0000751	0.000110	−0.684	0.4952
D_FDI	0.015674	0.050776	0.309	0.7581
D_TR	0.019855	1.140934	0.017	0.9861

Note. Dependent variable: D_SDG. Total panel (balanced) observations = 126. * $p < .05$. *** $p < .001$.

Redundant Fixed Effects Tests and Fixed Effects Regression Results

This test assesses whether fixed effects significantly improve the model fit. **Cross-section F-statistic ($p = 0.0000$)** and **Chi-square ($p = 0.0000$)**: Both tests strongly reject the null hypothesis of no fixed effects. This implies that the fixed effects model is more appropriate than a pooled model.

Fixed Effects Model

Dependent Variable:

D_SD

The regression explains how independent variables influence SD growth, controlling for fixed effects across entities.

Significant variables:

D_FD (p = 0.0001): Financial development positively impacts SD growth.

Constant (p = 0.0447): The intercept is statistically significant.

Non-significant variables:

D_GI (p = 0.4952), D_FDI (p = 0.7581), and D_TR (p = 0.9861) do not have a statistically significant impact on SD growth in this model.

1.5 Panel Generalized Method of Moments Estimation Results (Dependent variable : Δ SDG)

Variable	Coefficient	Std. Error	t	Prob.
SDG(-1)	0.052860	0.146707	0.360	0.7194
FD	0.110311	0.032911	3.352	0.0011**
GI×FD	0.000385	0.000201	1.918	0.0579†
FDI	0.119158	0.061678	1.932	0.0561†
TR	32.37047	26.92597	1.202	0.2320

Note. Method: Panel GMM, first-difference transformation, White period instrument weighting. Total panel (balanced) observations = 108; cross-sections = 8; periods = 12. Instrument rank = 9; J-statistic = 4.254275, p = .3727 (instruments valid, not over-identified). †p < .10 **p < .01

The adoption of financial development practice has a significant impact on a company's sustainable development, as green innovation practices—as a core business strategy—allow initiatives to minimize production costs by lowering environmental hazards, according to the natural resource-based view and stakeholder theory, which also helps to gain a competitive advantage and, as a result, benefits the long-term financial health of businesses (Danso et al. 2019; Manrique and Martí-Ballester 2017). In line with the above discussion, the literature shows that firms in South Asian countries require a more significant adoption of environmental practices, and developed countries could move to advanced levels of environmental practices (Manrique and Martí-Ballester 2017). Dependent Variable: SDG This model accounts for endogeneity and first differences. Significant variables: FD (p = 0.0011): Financial development has a significant and positive impact on sustainable development goals (SDG). GI (p = 0.0579) and D_FDI (p = 0.0561) are borderline significant, suggesting potential effects on SDG. In-significant variables: SDG(-1) (p = 0.7194) and TR (p = 0.2320) are not statistically significant. Model diagnostics: J-statistic (p = 0.372686): The p-value indicates that the instruments are valid and the model is well-specified. In the short term, i.e., two years, these green innovation practices and investments generate eco-friendly products and processes that appeal to sustainable consumers and create a green culture or a strategy of performing operational and non-operational activities. However, the literature on green business practices provides evidence of improvement and attracting sustainable investment to enhance business operations and save resources for financial and non-financial activities in the long term (Song and Yu 2018; Weng et al. 2015). In the long term, green innovation techniques enable businesses to simultaneously meet legislative and industry regulations, reduce waste and pollution, protect the environment, boost competitiveness, and generate revenue (Huang and Li 2018; Khan et al. 2021c). Thus, H1a H2 are supported, lastly, model 1.4 also explains the moderating role of green innovation between SDs and FD. The direct relationship between financial development and the sustainable development is shown to be significant. In Table 1.4, the moderation of innovation shown to be significant; however, green innovation was insignificant. The interaction model parameters significantly impacted the return on sustainable development (GI*FD positively impacts SD), thus supporting H2. (Khan P. A., 2021d).

5 | CONCLUSION

The evidence theoretically supports the connection between financial development, green innovation, and sustainable development in South Asia. Endogenous Growth Theory states that financial development promotes capital allocation, technological advancement, and sustainable economic activity, all of which have a significant positive impact on sustainable development. The importance of nation-specific institutional components in shaping long-term outcomes is emphasized by institutional theory. The Natural Resource-Based View (NRBV) is supported by the positive and marginally significant interaction between green innovation and financial development, which implies that green innovation increases the sustainability benefits of financial development. Although there isn't much of a direct impact

of green innovation, its moderating influence suggests that investments in greener technology, resource efficiency, and environmental practices improve sustainability outcomes. The positive marginal benefit of FDI further implies that foreign resources can support sustainable development with the correct institutions and creativity. Overall, the findings extend current thinking by demonstrating that financial development combined with green innovation offers a more viable path toward sustainable economic development in South Asia.

6 | IMPLICATIONS

6.1 Theoretical and Practical Contribution:

Study makes a theoretical contribution by moving beyond the largely additive treatment of financial development and green innovation found in earlier South Asian literature and testing green innovation explicitly as a moderator within a dynamic panel framework. Much of the recent global literature continues to examine green finance and green innovation as parallel, independently acting drivers of sustainable development rather than as interacting mechanisms, a gap that recent systematic reviews have explicitly flagged as unresolved (Dhayal, 2025). By demonstrating that the interaction between green innovation and financial development, rather than either variable alone, is what most consistently predicts sustainable development outcomes in South Asia, this study extends ecological modernization theory and finance-led growth theory into a joint explanatory framework that has so far been under-tested outside of larger, more developed economies (Marín-Rodríguez, 2024). This also responds to a pattern identified in current cross-country evidence, that the positive relationship between green finance, green innovation, and sustainable development tends to be more robust in developed nations than in developing ones, by showing the specific conditions under which that relationship can be strengthened in a developing regional context (Epor, 2025). Practically, the findings offer direct guidance for South Asian financial regulators, development finance institutions, and firm-level decision-makers. Because financial development's effect on sustainable development strengthens once it is paired with green innovation, banks and regulators have a concrete lever- green credit lines, disclosure requirements, and innovation-linked lending criteria, for improving sustainability outcomes without waiting for slower-moving institutional reform. This mirrors practical implications drawn from recent mixed-methods evidence on green finance adoption in South Asia, where financial institutions were identified as central actors in translating green finance intentions into measurable environmental outcomes (Shahzad, 2025). At the firm level, the findings suggest that green finance, technological innovation, environmental innovation, and process innovation are more effective when treated as complementary elements of a single sustainability strategy. Rather than managing them as separate financing or compliance activities, firms can achieve stronger sustainability outcomes by coordinating these areas and using them together (Dhayal, 2025) (Kwilinski, 2025). For policymakers specifically, this reinforces the case, developed further in future research and policy recommendations sections of this supplementary material, that green innovation infrastructure should be treated as a companion investment to financial-sector deepening rather than an optional add-on.

6.2 Future Directions and Research Limitations:

This study has a few limitations. Firstly, the small number of observations ($n = 108$) creates a hurdle for generalizing the results. Secondly, this study did not cover green behaviour (employees) and green suppliers, green products in green innovation. Thirdly, the study adopted GMM methods to measure financial development and sustainability. Future research should adopt Tobin's Q to address market perspectives and non-financial performance parameters to measure business operational performance. Lastly, additional regression analyses (GMM, 2LS, and 3LS) should be adopted in future research in order to generalize the results. However, the current findings can be applied in South Asian countries in future research conducted around the world.

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