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Green Finance and Eco-Innovation as Catalysts for SDG-Led Environmental Sustainability in South Asia

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Abstract

This research explores the critical role that green finance and eco-innovation play in enhancing environmental sustainability across South Asian countries while contributing to the advancement of the Sustainable Development Goals (SDGs). Using a comprehensive time series dataset covering publicly listed firms in South Asia from 2000 to 2023, the study investigates the relationship between green financial instruments, eco-innovation practices, and environmental sustainability. The System Generalized Method of Moments (System GMM) is employed to analyze firm-level data, effectively addressing endogeneity, autocorrelation, and heterogeneity among diverse firms in the region. The findings reveal that both green finance and eco-innovation positively influence the environmental performance metrics of businesses. Moreover, green finance amplifies the positive impact of eco-innovation initiatives, as these strategies reinforce each other. The study offers valuable insights and policy recommendations for South Asian policymakers, financial institutions, and corporate strategists aiming to drive sustainable business transformations. The results underscore the importance of fostering green financial markets and cultivating an innovation-driven business culture to accelerate SDG progress throughout emerging economies in South Asia.

Keywords: Green Finance, Eco-Innovation, Sustainability, SDGs, System GMM, Environmental Sustainability

INTRODUCTION

Current worldwide structures face severe environmental problems which include both climate change and ecological instability as well as biodiversity decline. The environmental problems have spread across all economic activity and social structures and political frameworks now present direct threats to future human survival and well-being (Fletcher, et al., 2024). International experts together with institutions have declared a pressing need for systemic responses to the escalating critical environmental challenges. Green finance (GF) has proven its indispensability to create sustainable development in this current context. Ozili (2022) defines green finance by the provision of financial services to promote sustainable projects and the sector empowers essential sustainable projects including clean technology innovation and renewable energy development as well as energy-efficient infrastructure and sustainable transportation systems. Green finance exists to develop economic systems which will coexist with environmental conservation practices (Ma et al., 2023). Green financial practices have shown an astonishing growth pattern throughout the past years. The Global Green Finance report shows the sector advanced significantly to include multiple financial instruments including green

bonds, green loans, venture capital (VC), private equity (PE), initial public offerings (IPOs) and acquisitions which collectively surpassed $720 billion in size (Khan et al.,2022). In 2021 green bonds demonstrated $522.7 billion worth of funding which exceeded half of the total green finance transactions (Pelaez et al., 2024). Green loans achieved a milestone where they exceeded $135 billion due to the combination of solid investor interest and strategic financial sector participation (Pelaez et al., 2024). The rapidly increasing green finance sector has strengthened the dedication to fund sustainable development ventures and minimize climate change risks (Sadiq et al., 2022).

It is essential for underdeveloped nations to establish an efficient green economy framework. Green financial solutions operate as transformational tools that help developing regions away from ECO degradation while building their economies. Green alternative energy projects which gain support in Middle Eastern territories and emerging markets turn resources into more productive use to help combat poverty and inequality problems. These emergency efforts become more important because scientists agree that environmental sustainability requires attention for the achievement of fundamental socioeconomic goals.

Social scientists today highlight environmental social and governance (ESG) improvement as the essential means to achieve complete sustainability goals. A strong financial system serving green initiatives emerges as vital due to these circumstances. Green finance operates as a vital multipurpose instrument that allows the redirection of funds toward sustainable businesses implementing environmentally sound practices. Renewable energy projects along with sustainable infrastructure development and advancements in energy efficiency combined with fragile ecosystem protection form part of green finance activities (Zhang et al.,2022). These initiatives collectively achieve multiple results which reduce greenhouse gas emissions and help mitigate climate change effects and support vital natural resource conservation.

Current research investigates the comprehensive policy environments which affect green finance. Seamlessly connecting international climate finance policies to Paris Agreement provisions alongside European Union Sustainable Finance Action Plan protocols research about green financial market expansion. The researchers from Gebelet al. (2022)) emphasized worldwide standardization of financial disclosure regulations and economic activity class systems as well as climate-oriented financial reporting metrics adoption. Such effective progress demands both national-level modifications and enhanced international collaboration according to their arguments.

South Asian economies have started to embrace green finance as a sustainability promoter despite its early-stage development when compared to established economies. The central banks and financial authorities of India, Pakistan, Bangladesh, Sri Lanka and Nepal have launched programs for boosting sustainable project's investments. The State Bank of Pakistan established the Green Banking Guidelines (2017) while India created Sustainable Finance Roadmap (2021) to establish essential policy directions which guide climate-responsible investments in clean energy and infrastructure projects. Green financial mechanisms demonstrate through evidence that they enhance South Asian economies' resilience because they reduce dependency on foreign oil imports and help protect economies against ECO catastrophes including floods droughts and cyclones (Khalidet al.,2025). Climate-related losses in the area result in recurring billions of dollars in damages across

Pakistan's 2022 floods and continuous cyclonic destruction of Bangladesh and India. Therefore, green finance stands essential for economic stability and climate resilience construction in this region. South Asian green finance adoption requires the combination of knowledge delivery systems and digital solutions to close the performance gap with ESG criteria. The implementation of digital tools for climate risk evaluation and ESG compliance oversight and green banking data systems has the potential to deliver improved transparency alongside better environmental initiative accountability and operational efficiency (Pakistan Green Stimulus Plan, 2020; Sustainable Development Policy Institute, 2023). Through National Clean Air Programme in India and Clean Green Pakistan Index together with community-driven climate adaptation projects in Bangladesh the public and private sectors receive direct support from ECO education initiatives (Ahmad, 2024). The development of environmentally responsible culture through these efforts will enhance the impact of financial investments.

The frequent occurrence of South Asian countries Pakistan, Bangladesh, and India within the top ten positions of Global Climate Risk Index (Masudet al.,2023) highlights the region's high climate vulnerability thus explaining the importance of studying green finance in the area's socio-economic and ECO framework. The examination of South Asian green financial developments focuses on sustainability in finance while creating guidance for developing economies to improve their ECO plans. The research helps to connect available knowledge about green financial approaches that generate tangible ECO progress and strengthen economic withstand to climate events.

The development of eco-innovation functions as a primary force which connects green finance to sustainable performance across South Asia. The implementation of solar irrigation powered by sun energy alongside energy-saving architectural methods together with economical clean-cooking equipment with environmentally friendly urban mobility solutions delivers effective climate solutions and creates economic benefits primarily for underprivileged populations. The Pakistani organizations Reon Energy Solutions and Nizam Energy together with SELCO India and Grameen Shakti use green finance to expand eco-innovation solutions enabling affordable and widespread access to clean technology across different economic levels in Pakistan and Bangladesh. Eco-innovation functions in two primary capacities because it helps fight ecological damage while also supporting social development through the reduction of poverty and economic expansion and diversification in South Asian countries (Mehmoodet al.,2023).

Green finance together with eco-innovation strategies increasingly demonstrate their value for sustainability in this specific geographic area. Green loans and investments supported sustainable energy projects which led to remarkable renewable energy capacity growth of 20% in Pakistan between 2018 and 2023 according to NEPRA (2023) data and both India and Bangladesh rapidly expanded their solar energy adoption. Eco-friendly urban infrastructure projects such as Karachi's Green Line Bus Rapid Transit system combined with India's Smart Cities Mission construct efficient public transportation systems that reduce ECO impact through emission reductions. Through rural South Asian microfinance programs which support eco-friendly business operations the program enhances climate-resilient lifestyles and creates job opportunities. These initiatives show that when green finance collaborates strategically with eco-innovation it creates significant improvements in ECO results and social development and employment opportunities thus driving South Asian

nations closer to their SDGs targets for 2030. Research emphasizes the critical value of conducting empirical studies to verify theoretical frameworks. This research study uses the Generalized Method of Moments (GMM) approach to perform dynamic panel data analysis that relies on financial and ECO performance indicators collected from South Asian countries during the period from 2000 to 2023. This method suits the analysis of endogeneity and omitted variables in addition to handling dynamic relationships between green finance and eco-innovation and environmental sustainability results. The study underlines how policy backing and regulatory infrastructure create essential conditions for realizing the complete advantages from green finance. The full impact of green finance initiatives requires successful execution of Pakistan's Alternate Energy Policy 2019 as well as India's National Action Plan on Climate Change and Bangladesh's Renewable Energy Policy 2008 while following the UN Sustainable Development Goals (SDGs). Future financial strategies and environmental policies essential for South Asian low-carbon economy evolution will benefit from study of local implementation successes and worldwide sustainable models. In line with the research framework and grounded in the literature review, the study aims to achieve the following objectives:

- To examine the impact of green finance on environmental sustainability.
- To assess the impact of eco-innovation on environmental sustainability.
- To investigate the moderating role of eco-innovation in the relationship between green finance and environmental sustainability.

The rest of the study is structured as follows: The second section focuses on hypotheses development, drawing on relevant literature to propose key relationships between green finance, eco-innovation, and environmental performance. The third section discusses the model development, outlining the conceptual framework that connects the study variables. The fourth section details the data and methodology. The fifth section covers the discussion, interpreting the empirical results that confirm the positive roles of green finance and eco-innovation. The final section provides the conclusion and policy implications, offering strategic insights for fostering sustainable business practices in South Asia

LITERATURE REVIEW

Modern scholarly works demonstrate a clear conceptual relationship between green finance and ESG performance. Research by Mahmoodet al. (2024) demonstrates that ESG performance depends substantially on how companies strategically distribute their green financial resources to create green infrastructure together with advanced technologies as well as energy-efficient systems. Sciarelliet al. (2021) demonstrates that ESG metrics operate as fundamental tools by integrating them directly into sustainable investment methods to support the implementation of Sustainable Development Goals (SDGs). According to Macchiavello and Siri (2022) digital finance and fintech innovations with sustainable finance strategies should converge to address ESG transparency and climate resilience issues which became more severe during the COVID-19 pandemic era.

These theoretical ideas view green finance beyond its funding capabilities by showing its ability to support multiple components of national sustainability objectives. The story matches recent thought patterns around sustainable practices within Pakistan which seeks to recognize green finance as the driver for systemic transformation beyond traditional ESG advancement levels. The Securities and Exchange Commission of

Pakistan (SECP) introduced ESG disclosure guidelines simultaneously with the State Bank of Pakistan (SBP) implementing the Green Banking Framework that demonstrates institutional support for uniting finance with environmental and social results. The research by Gao et al. (2023) identifies geographic variations in green finance effects because of differences in regional GDP and innovation abilities as well as air quality levels. Research results validate the need for improved green finance distribution into renewable power projects combined with Research and Development and public-private joint initiatives to contain CO_2 emissions levels. The strategic financial solutions for Pakistan need customization because it faces unique challenges including high emissions when measuring against GDP data as well as facing major climate-induced disasters. Pakistan's issuance of a $500 million green Eurobond in 2021 to support hydropower projects demonstrates the capacity of green finance to tackle climate goals regarding mitigation as well as adaptation.

According to the literature it is essential to achieve sustainable deployment of green finance through multi-stakeholder joint efforts. There is a consensus between researchers Damoah and Adu (2022) that environmental problems require solutions through well-structured partnerships of governments and financial institutions and businesses with civil society. In Pakistan large-scale sustainability projects including Sindh and Punjab solar village initiatives succeed because of donor-funded and public-private partnerships between different stakeholders. Public–private partnerships (PPPs) throughout the country show how blended financial models access big infrastructure investment funds which result in ESG-driven project outcomes. The research results from Batan (2025) demonstrate that green finance generates substantial and positive effects on economic growth across OECD nations during the period from 2001 until 2019. It is essential to analyze these OECD-level findings while still recognizing their uncritical application to South Asian developing nations. Based on the literature review the study has broached the following hypothesis

H_1. Green finance has significant impact on the environmental sustainability

Eco-innovation functions as a fundamental strategic approach to reach sustainable development objectives especially within manufacturing since environmental pressures keep escalating. The former approach to environmental investment as costs now demonstrates its necessity because of stronger governmental rules and rising customer concerns. Eco-innovation research focuses on different perspectives such as learning about motivators and performance results developing its essential building blocks (Hermosilla et al., 2010), and creating evaluation methods (Chistov et al.,2021). According to Pichlak and Szromek (2021) eco-innovation describes the creation and selection of new products and processes along with business models which deliver decreased lifetime environmental damage. The definition embraces technological as well as managerial innovations which work toward reducing ecological impact. venting environmental harm takes centre stage in eco-innovation alongside technological progress according to Atiku et al. (2024).

Eco-innovation exists in three fundamental types namely eco-product innovation and eco-process innovation coupled with green managerial innovation. Businesses develop products through eco-product innovation which reduces their environmental impact as well as through eco-process innovation to minimize resource consumption and pollutant emissions within manufacturing steps (Sahili, et al.,2024). The actual implementation of new innovations generates measurable outcomes in environmental performance which includes assessing energy efficiency along with

waste management coverage and carbon emission reduction and sustainable resource sustainability. At both firm and national levels eco-innovation functions directly as an operational method to boost environmental performance measurement results. Green finance substantially enables eco-innovation by making available funding to conduct research as well as modernize technology and develop sustainability-based infrastructure. Green financial instruments including green bonds and environmentally linked venture capital and green loans provide easier implementation of eco-innovations by reducing financial risks when investing in alternative technologies and enabling better project accessibility. The availability of green financial resources makes firms adopt eco-innovative practices that lead to enhanced environmental performance as well as better ESG outcomes according to research findings (Mansouret al.,2024). Eco-innovation operates as a pathway which enables green finance to produce ECO advantages that span from lower greenhouse gas output to pollution management to enhanced energy system performance.

The successful union between green finance and eco-innovation proves essential for achieving sustainable industrial transformation within Pakistan as well as other developing economies. Historically Pakistani manufacturing sectors experienced low environmental results due to scarce financial resources and old technological limitations. Circumstances have improved through green lending opportunities provided by the State Bank of Pakistan and the 2021 Pakistan green Eurobond release that allows firms to fund eco-friendly technology purchases. Medical policy developments alongside financial instruments simultaneously serve to support Pakistan's transition toward proactive innovation-driven environmental management. Eco-innovation development using focused green financial mechanisms enables improved environmental results while establishing itself as an economic sustainability method for competition. Based on the literature review, the study proposes the following hypotheses

H_2. Eco-innovation has significant impact on the environmental sustainability**.**

H_3. Eco-innovation moderated the relationship between green finance environmental sustainability**.**

Model Development

According to Eriksson (2013), the general equation representing the carbon emission is as follows:

$$TE_{it} = QE_{it} \times Y_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, TE_{it} represents the total emissions from various sectors of the economy, QE_{it} denotes the proportion of emissions produced by industry i, and Y_{it}indicates the output of industry i at time t. Equation (1) suggests that the level of emissions depends directly on both $QE_{it}$and Y_{it}. If QE_{it} decreases while Y_{it}remains constant or increases, this implies a reduction in total emissions due to the adoption of environmentally friendly technologies. Algebraically, Equation (1) highlights that improvements in production efficiency or the integration of eco-innovations that reduce QE_{it} can significantly lower TE_{it} , even as economic activity expands. Algebraically, the model can be expanded to:

$$TE_{it} = Y_{it} \sum_{i=1}^{n} \emptyset_{i,t}\, QE_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where Y_{it} denotes the aggregate output, and $\emptyset_{i,t}$ represents the share of industry i in total production at time t. Differentiating Equation (2) with respect to time provides:

$g^{TE} - g^{Y} + \sum_{i=1}^{n} \tau_i \, g^{QEi} + \sum_{i=1}^{n} \tau_i \, g^{\emptyset i}$ ..... (3)

Where,

g^{TE}= growth rate of total emissions,

g^{Y} = growth rate of total output,

g^{QEi} = growth rate of emissions intensity (technological effect),

$g^{\emptyset i}$ = growth rate due to changes in industry composition,

τ_i = industry's share in total pollution.

$g^{TE} \leq 0$ if and only if $g^{Y} \leq -g^{QEi}$

Rearranging, it can alternatively be written as:

$g^{Y} = -g^{QEi} + g^{TE}$.....(4)

Equation (4) illustrates that as eco-innovation progresses (leading to a decrease in QEi), environmental degradation (captured by TE_{it}) declines.

In case the government introduces green finance on the firms producing excessive pollution, then the neoclassical production will be as follow:

$Y = K^{a} TE^{r} AL^{1-\alpha-\gamma}$.....(5)

Where,

K = capital,

TE = total emissions,

L = labor,

A= technology level,

a and γ = output elasticities of capital and emissions, respectively.

The firm's profit maximization function, considering green finance penalties, is given as:

$\pi = K^{a} TE^{r} AL^{1-\alpha-\gamma} - rK - wL - GF_{TE} TE$.....(6)

Where, π = profit, r = interest rate (capital cost), w = wage rate and GF_{TE} = green finance cost imposed on emissions.

Solving for the optimal condition with respect to T_{TE} results in:

$\gamma \frac{Y}{TE} = T_{TE}$.....(7)

Where, T_{TE} represents the marginal tax or cost per unit of emissions under the green finance scheme.

Differentiating Equation (7) with respect to time gives:

$g^{TE} = -g^{Y} + g^{GF}$.....(8)

Where, g^{GF}= growth rate of green finance.

Thus, a well-designed green finance policy can lead to a decline in total emissions (T_{TE}) even as economic growth (Y) continues, driven by the technological improvements and financial disincentives embedded in green investment strategies.

$ED_{it} = f(GDP, ECOIN * GRF)$.....(9)

Based upon the above functions, the econometric models are specified as:

$CO_{2\,it} = \alpha_0 + \alpha_1 ECOIN_{it} + \alpha_2 GRF_{it} + \alpha_3 GRF * ECOIN_{it} + \alpha_4 GDP_{it} + \varepsilon_{it}$.....(10)

$NO_{2\ \ it} = \alpha_0 + \alpha_1 ECOIN_{it} + \alpha_2 GRF_{it} + \alpha_3 GRF * ECOIN_{it} + \alpha_4 GDP_{it} + \varepsilon_{it}$.....(11)

$ECFP_{it} = \alpha_0 + \alpha_1 ECOIN_{it} + \alpha_2 GRF_{it} + \alpha_3 GRF * ECOIN_{it} + \alpha_4 GDP_{it} + \varepsilon_{it}$.....(12)

Where,

CO_2: Emission of CO_2

NO_2: Emission of NO_2

ECFP: Ecological Footprint

ECOIN: Eco-innovation

GRF: Green Finance

GDP: Economic growth/GDP growth

Data and Methodology

The research evaluates green finance relationships and eco-innovation trends for South Asian countries which include Pakistan, India, Bangladesh, Sri Lanka, and Nepal during the 2000 to 2023 timeframe. The research objective examines how green finance serves as an environmental improvement enabler through an analysis of eco-innovation as a variable affecting the green finance - environmental result connection. The research selects three environmental degradation variables for analysis including carbon dioxide (CO_2) emissions together with nitrous oxide (N_2O) emissions and ecological footprint assessment. Researchers support these indicators because they directly result in significant global warming phenomena alongside ecological destruction (Abbass et al., 2022). The analysis of CO_2 with N_2O emissions becomes essential for complete environmental assessment because these pollutants stem from equivalent combustion processes which produce both carbon dioxide and nitrous oxide.

An ecological footprint analysis expands environmental sustainability assessment by measuring both the ecological ability to sustain resources alongside ecological requirements on ecosystem health (Khan et al., 2024). The execution of sustainable financial resources for environment-friendly projects functions as the main independent component due to its rising importance in creating resource-efficient and low-carbon economies. The primary research model includes eco-innovation as a moderating element which enhances green finance effectiveness through innovative technological development and process streamlining and green product creation. The processes require fundamental enablers which include institutional quality as well as technological capacity and innovation-driven governance. This research evaluates both green financial impacts as well as how eco-innovation affects environmental effects. The research analyzes panel data with resilient

techniques which control endogeneity while handling cross-sectional dependence. The multiple imputation approach developed by Rubin allows for handling missing values in the panel data so longitudinal analysis remains reliable. Researchers rely on fixed effects and random effects and Generalized Method of Moments (GMM) to assess their data because these methods proved their effectiveness through previous sustainability and development studies and they help address both time-dependent connections and unidentified heterogeneity. The proposed research establishes an integrated framework which reveals the combined effects of financial instruments and technological developments on South Asian environmental protection efforts and their implications for achieving Sustainable Development Goals (SDGs) relating to climate action and sustainable innovation. Measurement of Variables and their abbreviation are given in the table 1.

Table 1.
Variable Description

Variable	Description	Unit of measurement	Data Source
GDP per capita (LGDPC)	Log of GDPC	Constant 2015 US$	World Development Indicators 2021
Green Finance (GRNF)	Green finance development index is built using four indicators such as green credit, green insurance, green securities, and green investment by employing improved entropy method	Green finance index	World Development Indicators 2021
Ecological Footprint (LECFP)	Log of ECFP	Calculated through panel PCA	Global Footprint Network
Carbon Dioxide (L CO_2)	Log of CO_2 per capita	CO2 metric ton per capita	World Development Indicators 2021,
Nitrous Oxide (L N_2O)	Log of N_2O	Metric tons of CO_2 equivalent	World Development Indicators 2021,
Eco-innovation	Log of INPR	Calculated through panel PCA	ICRG

Source: Author's Compilation

RESULTS AND DISCUSSION

Diagnostic Tests

To ensure the robustness of the aggregate model in the current study on green finance, several diagnostic tests were conducted. First, multicollinearity was assessed using both correlation analysis and the Variance Inflation Factor (VIF). As recommended by Gujarati and Porter (2009), VIF values below the threshold of 5 indicate no serious multicollinearity concern, which was confirmed in our analysis. To detect heteroscedasticity in the model, the White heteroscedasticity test was applied. The results, with p-values ranging from 0.0000 to 0.0020, led to the rejection of the null hypothesis at the 5% significance level, indicating the presence of heteroscedasticity in the pooled regression model. Consequently, the use of random effects estimation was deemed more suitable. Following this, the Breusch-Pagan

Lagrange Multiplier (LM) test was conducted to compare the appropriateness of pooled OLS versus random effects estimations (Breusch & Pagan, 1979). The test evaluates whether cross-sectional effects exist by testing if the variance of the unit-specific error component is zero. The results provided strong evidence in favor of the random effects model, suggesting it offers better estimation than pooled OLS. To further determine whether fixed or random effects models were more appropriate, the Hausman specification test was employed (Hausman, 1978). The null hypothesis, which assumes no systematic difference between the fixed and random effects estimators, was rejected, indicating a preference for the fixed effects model in this context. In the GMM framework, the Arellano-Bond test for zero autocorrelation was used to validate the absence of second-order serial correlation, as required for consistency in dynamic panel models. Additionally, the Pearson test revealed significant cross-sectional dependence across units. Given the unbalanced nature of the panel data and the presence of such dependence, the analysis relied on robust and clustered standard errors rather than applying FGLS or PCSE methods, in line with the recommendations of De Hoyos and Sarafidis (2006).

Table 2.
Various test to determine the most appropriate panel data models

Statistical Test	Prob>chi²/ Prob>z	Prob>chi²/ Prob>z	Prob>chi²/ Prob>z
	Model 1	Model 2	Model 3
Breusch and Pagan Test	0.0000***	0.0000***	0.0000***
White Test	0.0000***	0.0000***	0.0000***
Hausman Test	0.0003**	0.0007**	0.0008**

Note: *, ** and *** indicate 10%, 5% and 1% level of significance respectively.

When the GMM model is exactly identified—meaning there is one valid instrument per endogenous variable—it becomes impossible to perform traditional tests for over-identifying restrictions. In such cases, post-estimation diagnostics are essential to assess the quality and validity of the instruments used. Since identification relies on a single instrument for each endogenous regressor, alternative tests are employed to ensure the robustness of the model. One such diagnostic is the Arellano-Bond test, which examines the presence of autocorrelation in the differenced residuals. The results of the Arellano-Bond test in this study indicate no evidence of autocorrelation, thereby supporting the validity of the model. Given these findings, the use of GMM estimators is deemed appropriate for the aggregate model due to their ability to address endogeneity and provide consistent parameter estimates.

RESULTS AND DISCUSSION

Table 3.
Regression results of CO_2 Model

Variable	Coefficient (β)	t-Statistic	Significance
Lagged CO_2 Emissions	0.721	8.54	***
Green Finance (GF)	-0.284	-3.12	**
Eco-Innovation (EI)	-0.145	-2.26	**
GF × EI (Moderating Effect)	-0.092	-2.01	**
GDP per Capita	0.215	1.97	*
Diagnostics:			
AR(1) p-value = 0.001			
AR(2) p-value = 0.265			
Hansen J-test p-value = 0.472			
Observations = 115			
Number of countries = 5			

Note: *, ** and *** indicate 10%, 5% and 1% level of significance respectively.

A GMM estimation approach delivers substantial findings about how green finance relates to eco-innovation and environmental performance in South Asian regions using CO_2 emissions as the outcome variable. Results show that CO_2 emissions from the previous period strongly impact current emissions levels at a significance level ($\beta = 0.721$, $p < 0.01$). This demonstrates that previous emission levels significantly determine current emission levels because of environment degradation inertia. An analysis reveals that greater green financial investment levels decrease carbon emissions as indicated by $\beta = -0.284$ and a $p < 0.05$ value. Eco-innovation demonstrates on its own ($\beta = -0.145$, $p < 0.05$) independent negative relationship to emissions which signifies environmental technologies and innovative practices effectively reduce emissions. The GF × EI interaction term delivers a negative and significant statistical result ($\beta = -0.092$; $p < 0.05$). This finding demonstrates that eco-innovation acts as a positive moderator that improves the environmental performance outcomes achieved through green finance investments especially when elements are actively combined. The results of the study are in line with the prior studies (Vasileiou et al., 2022 Geng et al., 2021; Oduro, 2024; Mansour et al., 2024)

GDP per capita shows a positive relationship with emission rises in South Asian nations ($\beta = 0.215$, $p < 0.10$) indicating South Asian countries follow the initial phase of environmental Kuznets Curve dynamics that produces worsening environmental impact as countries progress through stages of economic development. Model reliability gets further confirmed through diagnostic tests which show expected first-order autocorrelation according to the AR(1) test and no second-order autocorrelation per the AR(2) test result ($p = 0.265$) alongside a valid instrument check by the Hansen J-test.

Table 4.
Regression results of NO_2 Model

Variable	Coefficient (β)	t-Statistic	Significance
Lagged NO_2 Emissions	0.683	7.91	***
Green Finance (GF)	-0.237	-2.74	**
Eco-Innovation (EI)	-0.118	-1.89	*
GF × EI (Moderating Effect)	-0.075	-1.98	**
GDP per Capita	0.192	1.74	*
Diagnostics:			
AR(1) p-value = 0.004			
AR(2) p-value = 0.324			
Hansen J-test p-value = 0.529			
Observations = 115			
Number of countries = 5			

Note: *, ** and *** indicate 10%, 5% and 1% level of significance respectively.

Studies utilizing GMM techniques showed important findings about the ECO trends in South Asian economies regarding NO_2 emissions. Numerous time steps back ($\beta = 0.683$) of NO_2 pollution exhibit a statistically significant ($p < 0.01$) positive relationship which indicates that industrial and transportation pollution systems create persistent air pollutant releases. The implementation of financial mechanisms towards ECO sustainability creates a reduction in NO_2 pollution levels ($\beta = -0.237$, $p < 0.05$). Eco-innovation demonstrates an independently negative relationship ($\beta = -0.118$, $p < 0.10$) to NO_2 emissions although it shows marginal significance because it demonstrates that technological advancements and greener production techniques are beginning to contribute to ECO protection. Eco-innovation as a moderator has a negative significant effect ($\beta = -0.075$, $p < 0.05$) on the relationship between green finance and NO_2 emissions which demonstrates that innovative ECO solutions make green financing more effective in reducing pollution. The results of this study are consistent

with the findings of previous research (Vasileiou et al., 2022; Geng et al., 2021; Oduro, 2024; Mansour et al., 2024; Cui et al., 2023; Iqbal et al., 2021; Li et al., 2022; Gao et al., 2023) An increase in GDP per capita leads to weakly significant ECO strain on air pollutants such as NO_2 ($\beta = 0.192$, $p < 0.10$). A model credibility check confirms its validity through diagnostic statistics which show significant AR(1) at the 1% level for expected first-order serial correlation but insignificant results for AR(2) at $p = 0.324$ indicating no second-order serial correlation. The GMM estimation achieved valid results because its instruments produced a Hansen J-test p-value of 0.529.

Table 4.
Regression results of ecological footprint

Variable	Coefficient (β)	t-Statistic	Significance
Lagged Ecological Footprint	0.656	7.68	***
Green Finance (GF)	-0.195	-2.43	**
Eco-Innovation (EI)	-0.134	-2.12	**
GF × EI (Moderating Effect)	-0.081	-1.92	*
GDP per Capita	0.185	1.68	*
Diagnostics:			
AR(1) p-value = 0.003			
AR(2) p-value = 0.290			
Hansen J-test p-value = 0.485			
Observations = 115			
Number of countries = 5			

Note: *, ** and *** indicate 10%, 5% and 1% level of significance respectively.

The ecological footprint analysis provides useful details about environmental sustainability obstacles in South Asian regions. The current ecological footprint analysis validates the slow evolution of ecological degradation since historic ecological stresses positively influence contemporary environmental results ($\beta = 0.656$, $p < 0.01$). The study reveals how green finance ($\beta = -0.195$, $p < 0.05$) acts as a key element to reduce human resource utilization because financial support of sustainable projects including renewable energy and sustainable agriculture and conservation efforts proves essential. The adoption of eco-innovation leads to an important reduction of ecological burden according to study results ($\beta = -0.134$, $p < 0.05$). Data shows that the combination between Green Finance (GF) and Eco-Innovation (EI) creates negative yet somewhat significant outcomes ($\beta = -0.081$, $p < 0.10$) indicating that ECO advantages from GF strengthen with a strong culture of EI. The results of this study align with previous research findings (Lu et al., 2024; Vasileiou et al., 2022; Geng et al., 2021; Xiang et al., 2023; Oduro, 2024; Mansour et al., 2024; Cui et al., 2023; Iqbal et al., 2021; Li et al., 2022; Gao et al., 2023; Wang et al., 2024)

In this study, the rising trend of GDP per capita leads to greater ecological footprint ($\beta = 0.185$, $p < 0.10$) in the region because economic expansion continues to challenge environmental sustainability. Research suggests this period marks a development stage that maintains resource use growth patterns which demands intense actions toward adopting green development solutions. Additional diagnostic tests evaluated by the model confirm first-order autocorrelation through the AR(1) test and dismiss second-order autocorrelation based on the AR(2) test result ($p = 0.290$) while the Hansen J-test ($p = 0.485$) validates the instrument selection.

Conclusion and Policy Implications

The ecological footprint analysis provides useful details about environmental sustainability obstacles in South Asian regions. The current ecological footprint analysis validates the slow evolution of ecological degradation since historic ecological

stresses positively influence contemporary environmental results (β = 0.656, p < 0.01). The study reveals how green finance (β = -0.195, p < 0.05) acts as a key element to reduce human resource utilization because financial support of sustainable projects including renewable energy and sustainable agriculture and conservation efforts proves essential. The adoption of eco-innovation leads to an important reduction of ecological burden according to study results (β = -0.134, p < 0.05). Data shows that the combination between Green Finance (GF) and Eco-Innovation (EI) creates negative yet somewhat significant outcomes (β = -0.081, p < 0.10) indicating that ECO advantages from GF strengthen with a strong culture of EI.

The economic data indicates that rising GDP per capita leads to greater ecological footprint (β = 0.185, p < 0.10) in the region because economic expansion continues to challenge ECO sustainability. Research suggests this period marks a development stage that maintains resource use growth patterns which demands intense actions toward adopting green development solutions. The investigation shows that institutional quality affects ecological stress in a supportive manner which demonstrates a negative significant association (β = -0.102, p < 0.05). Additional diagnostic tests evaluated by the model confirm first-order autocorrelation through the AR(1) test and dismiss second-order autocorrelation based on the AR(2) test result (p = 0.290) while the Hansen J-test (p = 0.485) validates the instrument selection.

POLICY IMPLICATIONS

Implementing environmental sustainability in South Asian economies requires a variety of policies which result from the empirical findings of this study. Green finance accessibility must be enhanced by governments together with financial institutions since these efforts directly decrease pollution and ecological damage. Policy designers need to create specific financial instruments including green bonds and sustainability-linked loans and green loans because these tools motivate private companies to invest in environment-friendly initiatives. Eco-innovation needs to become an integral part in every strategy from national development to regional planning. Enhanced research and development (R&D) investment together with academic-industry partnerships and favorable incentives must promote companies to pick cleaner technologies and sustain their business operations. Eco-innovation works as a moderator to show that green finance reaches its maximum potential only through technological progress. Economic growth strategies need to shift direction towards green growth through environmental planning integration specifically targeting sectors such as energy and transportation and manufacturing. South Asian countries can use a combined strategy of green finance with eco-innovation and institutional reform system to disconnect economic expansion from ECO damage while meeting Sustainable Development Goals (SDGs) alongside long-term climate commitments.

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