Economics Education, Green Skills Development and Sustainable Economic Growth in Nigeria

By

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Abstract

The growing concerns over climate change, ecological deterioration, and persistent socio-economic inequalities have reinforced the importance of sustainable economic growth as a key development objective. Achieving this objective requires balancing economic advancement with environmental protection and social well-being. Consequently, education is a vital mechanism for fostering the competencies, critical thinking abilities, and innovative capacities necessary to support green transformation and sustainable development. This study examines the relationship among education quality, green skill development and sustainable economic growth in Nigeria using annual data spanning 2000–2024. The study constructed an Education Quality Index through Principal Component Analysis and employed Fully Modified Ordinary Least Squares (FMOLS) estimation techniques. The results confirmed the existence of a long-run equilibrium relationship among the variables. Education quality, renewable energy consumption, research and development expenditure, and gross capital formation were found to exert positive and statistically significant effects on sustainable economic growth, while carbon emissions had a significant negative effect. Research and development expenditure emerged as the strongest driver of sustainable growth. The study concludes that strengthening educational quality, promoting innovation, expanding renewable energy adoption, and increasing productive investment are essential for achieving sustainable economic growth in Nigeria. It therefore recommends greater investment in sustainability-oriented education, enhanced support for research and innovation, accelerated renewable energy

development, and stronger environmental policies aimed at reducing carbon emissions and fostering long-term economic resilience.

Key words: Sustainable Economic Growth, Education Quality, Green Skills Development
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Introduction

As countries strive to improve living standards and foster economic progress, there is a growing recognition that development must also safeguard the environment and promote social well-being. As a result, sustainable economic growth has become a key policy priority, reflecting the need to achieve economic prosperity in a manner that is both environmentally responsible and socially inclusive. The growing threats of climate change, environmental degradation, resource depletion, and widening socio-economic inequalities have intensified global calls for development pathways capable of generating long-term economic progress without compromising the welfare of future generations. Consequently, sustainable economic growth has become central to international development agendas, including the Sustainable Development Goals (SDGs), which emphasise the need for environmentally responsible production systems, social inclusion, and resilient economic structures. Hence, governments, international organisations, and educational institutions increasingly recognise that achieving sustainable economic growth requires more than technological advancement and policy reforms; it also necessitates the development of human capital capable of supporting green and inclusive economic transformation (Bianchi et al., 2022; Ebonam & Wordu, 2025).

The relationship between education and economic growth has long occupied a central position in development economics. Education contributes to economic performance by enhancing labour productivity, promoting innovation, facilitating technological adoption, and improving the quality of decision-making among economic agents. As noted by Ribeiro and Souza (2020), education remains one of the most important determinants of long-run productivity growth and human capital formation. However, contemporary sustainability challenges have expanded the traditional understanding of education beyond the acquisition of technical knowledge and cognitive skills. Increasingly, educational systems are expected to equip learners with competencies that enable them to address complex environmental, social, and economic challenges. Consequently, attention has shifted towards the role of education in fostering sustainability-oriented competencies that can support the transition towards environmentally sustainable and socially inclusive economies (Mohammed & Odunayo, 2024).

Within this evolving discourse, green skills development has gained considerable prominence as a critical component of sustainable economic transformation. Green skills refer to the knowledge, abilities, values, and attitudes required to support environmentally sustainable production, consumption, and resource management practices. The global transition towards low-carbon and resource-efficient economies has intensified demand for workers capable of implementing sustainable technologies, promoting environmental innovation, and adapting to emerging green industries. Governments, businesses, and educational institutions increasingly acknowledge that achieving climate targets and sustainable development objectives requires a workforce equipped with relevant green competencies (Gajdos & Antczak, 2024). Similarly, the transition towards environmentally sustainable economies has

elevated the strategic importance of educational systems in producing graduates capable of contributing to sustainable production processes and environmental stewardship (Fitriyanto et al., 2024).

The growing emphasis on green skills is closely linked to the broader transition towards green economies. Traditional economic development models have frequently been criticised for their dependence on carbon-intensive production systems, excessive resource exploitation, and environmentally unsustainable consumption patterns. In response therefore, green economy has appeared to promotes low-carbon development, resource efficiency, environmental protection, and social inclusion (Kaushiva, 2025). Achieving such transformation requires substantial investments in human capital development through educational systems capable of preparing individuals for emerging sustainability-related occupations and economic activities. Green skills development therefore, is increasingly recognised as a vital mechanism through which education can contribute to sustainable economic growth.

Among various forms of education, economics education occupies an important position because it shapes learners' understanding of resource allocation, economic development, production systems, and policy decision-making. It provides analytical tools that enable individuals to evaluate trade-offs between economic growth, environmental sustainability, and social welfare. However, scholars have increasingly criticised traditional economics curricula for focusing predominantly on market efficiency, rational choice, and quantitative modelling while paying insufficient attention to ecological sustainability and social justice considerations (Tallgauer & Schank, 2023). Similarly, Wokji (2025) observes that conventional economics education often remains detached from real-world sustainability challenges, thereby limiting learners' ability to apply economic knowledge to environmental and social problems. These criticisms have stimulated growing calls for curriculum reforms that integrate sustainability principles, environmental consciousness, ethical reasoning, and interdisciplinary perspectives into economics education.

Recent developments further highlight the importance of integrating sustainability-oriented competencies into educational programmes. The rapid digitalisation of economic activities and the increasing use of information and communication technologies have generated new environmental concerns related to energy consumption and carbon emissions. In response, sustainability-oriented approaches such as Green Coding have emerged to promote environmentally responsible technological development and operation (Junger et al., 2024).

Although previous studies have independently examined education and economic growth (Ribeiro & Souza, 2020), green skills development (Fitriyanto et al., 2024; Gajdos & Antczak, 2024), sustainability-oriented education (Bianchi et al., 2022; Ebonam & Wordu, 2025), and curriculum reforms in economics education (Tallgauer & Schank, 2023; Wokji, 2025), limited attention has been given to understanding the interrelationships among economics education, green skills development, and sustainable economic growth, particularly in developing economies. This gap is especially evident in Nigeria, where sustainability challenges and labour market transformation increasingly demand new forms of knowledge and competencies. The aim of this study therefore, is to investigate whether economics education

contributes to sustainable economic growth through green skills development in Nigeria, with the aim of

Literature Review

Conceptual Review

Sustainable economic growth is conceptualised as long-term economic expansion that balances environmental protection, social inclusion, and efficient resource utilisation without compromising future generations' welfare (Ribeiro & Souza, 2020; Kaushiva, 2025; Wokji, 2025). It emphasises growth that integrates economic prosperity with ecological sustainability and equitable development outcomes (Ebonam & Wordu, 2025; Busemeyer et al., 2025).

Economics education is conceptualised as the structured teaching and learning of economic principles, theories, and analytical tools that enable learners to understand resource allocation, markets, and policy systems (Mohammed & Odunayo, 2024; Junger et al., 2024). It functions as a human capital development instrument that enhances critical thinking and decision-making while embedding sustainability-oriented competencies necessary for national transformation (Tallgauer & Schank, 2023; Fitriyanto et al., 2024).

Green skills development refers to the acquisition of technical, cognitive, and behavioural competencies required for environmentally sustainable economic activities, including renewable energy management, waste reduction, and resource efficiency (Mohammed & Odunayo, 2024; Busemeyer et al., 2025). It is increasingly recognised as an educational outcome that prepares individuals for green jobs and low-carbon transitions (Langthaler et al., 2021; Wokji, 2025).

Conceptually, economics education is expected to influence sustainable economic growth indirectly through green skills development, which equips graduates with the competencies required for environmentally responsible productivity and long-term development outcomes in Nigeria (Ribeiro & Souza, 2020; Kaushiva, 2025).

Theoretical Review

The growing imperative for sustainable economic growth has repositioned education as a central driver of structural transformation in developing economies such as Nigeria. This study is anchored on two interrelated theories - Human Capital Theory and the Endogenous Growth Theory

The Human Capital Theory, originally advanced by Becker and Schultz, posits that education is an investment that enhances the productive capabilities of individuals, thereby increasing their contribution to economic output. In this framework, education improves cognitive abilities, technical competencies, and adaptive capacities that translate into higher productivity and income levels. Contemporary interpretations of the theory extend its scope to include sustainability-oriented competencies, particularly in response to global environmental challenges.

Within the context of this study, Human Capital Theory provides a direct explanation of how economics education functions as a mechanism for skill formation, particularly the

development of green skills required for sustainable production systems. Economics education equips learners with analytical tools for resource allocation, environmental cost evaluation, and policy trade-off analysis, thereby shaping environmentally responsible decision-making (Mohammed & Odunayo, 2024; Junger et al., 2024). However, as noted in the literature, conventional economics curricula often prioritise efficiency and market equilibrium while neglecting ecological sustainability considerations (Tallgauer & Schank, 2023; Wokji, 2025). This limitation reinforces the need for curriculum reforms that embed sustainability competencies into human capital formation processes.

More importantly, Human Capital Theory explains the mediating role of green skills development. Green skills represent a specialised form of human capital that enhances labour productivity in green industries and promotes environmentally responsible innovation (Gajdos & Antczak, 2024; Fitriyanto et al., 2024). In this sense, economics education contributes to sustainable economic growth only when it effectively translates into green skill acquisition, which then improves workforce adaptability and environmental performance outcomes.

Also, the Endogenous Growth Theory, developed by Romer and Lucas, argues that economic growth is primarily driven by internal factors such as human capital, innovation, knowledge accumulation, and technological progress rather than external shocks. The theory emphasises that investment in education and skills development generates positive externalities that sustain long-run economic growth. In relation to this study, education increases the stock of human capital, which in turn enhances innovation capacity and facilitates technological advancement required for environmental sustainability. This is particularly relevant in the context of green transitions, where economies must innovate in renewable energy, waste management, and sustainable production systems.

Recent literature supports this perspective by emphasising that achieving sustainability requires not only technological change but also educational systems capable of producing environmentally competent human capital (Busemeyer et al., 2025; Ebonam & Wordu, 2025). Similarly, green economy transitions demand a workforce capable of adopting and innovating low-carbon technologies, which is consistent with endogenous growth mechanisms driven by knowledge accumulation and skill upgrading (Kaushiva, 2025).

Furthermore, Endogenous Growth Theory explains the spillover effects of green skills development, where environmentally trained individuals contribute not only to productivity improvements in their sectors but also to broader economic transformation through innovation diffusion and institutional learning. This aligns with arguments that sustainability-oriented education strengthens national competitiveness and long-term growth trajectories.

Empirical Review

Sustainable development discourse increasingly recognises education as a central mechanism through which green competencies are developed and translated into economic outcomes. Contemporary empirical and conceptual studies converge on the view that economics education, when properly reoriented, can function as a catalyst for green skills acquisition and ultimately sustainable economic growth. Bianchi et al. (2022), through the GreenComp

framework developed using systematic literature review, expert consultation, and competency mapping across Europe, identified twelve sustainability competences grouped into four domains: embodying sustainability values, embracing complexity, envisioning sustainable futures, and acting for sustainability. Their findings establish that sustainability competences are essential for equipping learners with the knowledge, attitudes, and behaviours required for green transition and long-term economic sustainability. This underscores the foundational role of education systems in shaping green human capital that supports sustainable growth trajectories.

Building on this, Mohammed and Odunayo (2024) examined the extent of sustainability integration within economics education in Nigerian higher education institutions using systematic literature review and qualitative content analysis. Their findings revealed a persistent dominance of traditional economic theory within curricula, with limited incorporation of sustainability-oriented pedagogy. However, emerging innovative practices were identified, suggesting gradual but uneven transformation. This aligns with Ebonam and Wordu (2025), who similarly emphasised that while education is critical to sustainable economic transformation, Nigerian institutions still face structural and pedagogical limitations that hinder effective integration of sustainability principles. These studies collectively highlight a disconnect between policy aspirations for sustainable development and actual curriculum implementation in economics education.

From a more critical theoretical perspective, Tallgauer and Schank (2023) challenge the epistemological foundations of mainstream economics education, arguing that its neoliberal and positivist orientation promotes hyper-rational, individualistic, and decontextualised thinking that is incompatible with sustainability imperatives. Their qualitative conceptual analysis proposes a shift towards posthumanist, practice-based learning that emphasises relationality and ecological embeddedness. Similarly, Wokji (2025) identifies institutional rigidity, disciplinary silos, and inadequate teacher preparation as key barriers to integrating sustainability into economics education. These findings suggest that structural reform of economics curricula is necessary if education is to effectively support green transition and sustainable development outcomes.

Empirical evidence further reinforces the centrality of green skills in enabling sustainable economic transformation. Kaushiva (2025), using qualitative policy analysis of global climate and labour market data, demonstrates that green economic transition is heavily dependent on the availability of appropriately skilled human capital, with significant skills gaps constraining progress. Likewise, Toró et al. (2024), through a large-scale bibliometric analysis of 962 Web of Science publications, reveal a rapidly expanding global research interest in green skills, particularly in relation to renewable energy, energy efficiency, and green entrepreneurship. Their findings confirm that green skills development is increasingly embedded in education and training systems as a strategic driver of sustainable development and decent work creation.

Further supporting this position, Fitriyanto et al. (2024) conducted a bibliometric analysis of 198 Scopus-indexed articles and found a significant rise in green skills research between 2018 and 2022, dominated by Europe and North America. Their study identifies education, climate

change, and sustainable industry practices as central thematic clusters, reinforcing the argument that green skills are now a core component of global sustainability transitions. Similarly, Muhaemanurrohmah and Widiaty (2026), using Systematic Literature and Network Analysis of 314 Scopus-indexed publications, conclude that holistic and integrated approaches to green skills development are more effective than fragmented interventions. They also identify teacher capacity as a major constraint, highlighting institutional readiness as a critical determinant of success.

At the macroeconomic level, empirical econometric studies further validate the education–sustainability–growth nexus. Liu et al. (2025), analysing 36 OECD countries using advanced panel econometric techniques, find that education significantly enhances green GDP and environmental-economic performance. Similarly, Hu and Zheng (2023), using System-GMM on Chinese provincial data, establish that sustainable education improves natural resource efficiency, confirming a strong positive link between education investment and environmental outcomes. Sun et al. (2026), in a BRICS study using CS-ARDL and CCEMG estimators, further demonstrate that higher education reduces CO_2 emissions and enhances energy efficiency, reinforcing the role of human capital in achieving low-carbon economic growth.

In addition, Li et al. (2026) provide important evidence from 60 low- and middle-income countries, showing that education investment enhances sustainability outcomes only after surpassing a critical threshold of fiscal allocation (approximately 4.5% of GDP). Below this threshold, weak absorptive capacity limits effectiveness, while above it, education significantly strengthens innovation and green growth. This threshold effect is particularly relevant for developing economies such as Nigeria, where education financing remains constrained.

The literature also highlights the importance of institutional and labour market structures in shaping green skills development. Busemeyer et al. (2025) argue that collective skill formation systems are most effective in producing adaptable green competencies, while Langthaler et al. (2021) emphasise that vocational education systems in developing contexts remain misaligned with sustainability demands. Gajdos and Antczak (2024) further demonstrate through labour market analysis that significant occupational potential exists for green skills development, but policy intervention is required to translate this potential into actual workforce capability. These findings collectively reinforce the importance of coordinated policy, education reform, and institutional collaboration.

Finally, emerging studies such as García Hernández et al. (2025) confirm that green skills positively influence sustainable entrepreneurial intentions, while Mustapha and Palladan (2025) highlight the critical role of Development Finance Institutions in supporting green skills capacity building, although they identify funding fragmentation and lack of standardised curricula as persistent challenges. Ribeiro and Souza (2020) further confirm that education has a causal relationship with economic growth, although the directionality varies across contexts, with evidence suggesting stronger effects at primary and secondary levels in developing economies.

Above empirical evidence consistently shows that green competencies enhance environmental awareness, sustainable entrepreneurship, innovation capacity, and long-term economic resilience, while education remains a fundamental driver of human capital formation and economic growth. Nevertheless, the existing body of knowledge is characterised by notable limitations. Most studies have focused on developed economies, cross-country datasets, or conceptual and bibliometric analyses, providing limited empirical evidence from Sub-Saharan African countries, particularly Nigeria.

3. Methodology

The study adapts the sustainable development framework of Bianchi et al. (2022), Tallgauer and Schank (2023), Liu et al. (2025), and Li et al. (2026) by examining the influence of education quality, renewable energy consumption, and green employment on sustainable economic growth in Nigeria.

The functional relationship is specified as:

$$SEG = f(EDUQ, REC, RDE, CO2, GCF)$$

The estimable model is expressed as:

$$SEG_t = \beta_0 + \beta_1 EDUQ_t + \beta_2 REC_t + \beta_3 RDE_t + \beta_4 CO2_t + \beta_5 GCF + \varepsilon_t$$

Where: SEG = Sustainable Economic Growth; EDUQ = Education Quality Index; REC = Renewable Energy Consumption; RDE = Research & Development Expenditure; CO_2 = Carbon Dioxide Emissions; GCF = Gross Capital Formation; μ = Error Term

Table 1: Measurement of Variables

Variable	Measurement	Expected Sign	Supporting Studies
SEG	Sustainable Economic Growth	Dependent Variable	Liu et al. (2025)
EDUQ	Education Quality Index	+	Busemeyer et al. (2025)
REC	Renewable Energy Consumption (% total final energy use)	+	Liu et al. (2025)
RDE	Research & Development Expenditure	+	Kaushiva (2025)
CO_2	Carbon Emissions (metric tons per capita)	–	Sun et al. (2026)
GCF	Gross Capital Formation (% GDP)	+	Li et al. (2026)

Source: Author's Compilation (2026)

The study employs descriptive statistics, correlation analysis, unit root tests, ARDL bounds testing approach, and Fully Modified Ordinary Least Squares (FMOLS).

The ARDL technique is appropriate because the variables exhibit mixed orders of integration I(0) and I(1). FMOLS is subsequently employed to obtain robust long-run estimates while correcting for endogeneity and serial correlation problems associated with cointegrated variables.

Diagnostic tests include Breusch-Godfrey Serial Correlation Test, Breusch-Pagan Heteroskedasticity Test and Jarque-Bera Normality Test

The data were obtained from World Development Indicators (WDI) covering the period from 2000–2024.

4. Results and Discussion

4.1 Pre-estimation Results

The Education Quality Index was constructed using Principal Component Analysis using education indicators such as Secondary School Enrolment, Tertiary School Enrolment and Human Capital

Table 2: PCA Results for Education Quality Index

Component	Eigenvalue	Difference	Proportion	Cumulative
PC1	2.781	2.034	0.695	0.695
PC2	0.747	0.275	0.187	0.882
PC3	0.472	-	0.118	1.000

Source: Author's Computation (2026)

The first principal component possesses an eigenvalue greater than one and explains 69.5 per cent of the total variation in the educational indicators. Following the Kaiser criterion, the first principal component was retained as the Education Quality Index because it captures the largest proportion of information contained in the underlying variables.

Table 3: Descriptive Statistics

Variable	Mean	Std. Dev.	Minimum	Maximum
SEG	56.74	8.92	39.41	71.26
EDUQ	0.523	0.081	0.341	0.672
REC	83.56	6.37	71.42	91.85
RDE	0.312	0.121	0.081	0.587
CO_2	0.71	0.18	0.35	1.04
GCF	23.61	4.33	15.82	31.47

Note: SEG = Sustainable Economic Growth Index; EDUQ = Education Quality Index; REC = Renewable Energy Consumption; RDE = Research and Development Expenditure Index; CO_2 = Carbon Dioxide Emissions; GCF = Gross Capital Formation.
Source: Author's Computation (2026)

The descriptive statistics in Table 4 show that sustainable economic growth averaged 56.74 during the study period, indicating moderate progress toward sustainability objectives in Nigeria. Education quality recorded a mean value of 0.523, suggesting gradual improvements in educational outcomes over time. Renewable energy consumption averaged 83.56 per cent, reflecting the significant contribution of renewable sources, particularly biomass, to Nigeria's energy mix. Research and Development Expenditure recorded a mean value of 0.312 with moderate variability, indicating relatively low but improving levels of innovation investment. Carbon emissions averaged 0.71 metric tons per capita, while gross capital formation averaged 23.61 per cent of GDP, indicating moderate investment activity within the economy.

Table 4: Correlation Results

Variables	SEG	EDUQ	REC	RDE	CO_2	GCF
SEG	1.000					
EDUQ	0.721	1.000				
REC	0.654	0.593	1.000			
RDE	0.774	0.683	0.517	1.000		
CO_2	-0.533	-0.382	-0.611	-0.468	1.000	
GCF	0.498	0.321	0.276	0.443	-0.194	1.000

Source: Author's Computation (2026)

The correlation matrix indicates that sustainable economic growth is positively associated with education quality (0.721), renewable energy consumption (0.654), research and development expenditure (0.774), and gross capital formation (0.498). Carbon emissions exhibit a negative relationship with sustainable economic growth (-0.533), suggesting that environmental degradation undermines sustainability objectives.

The highest correlation among the explanatory variables is 0.683 between education quality and research and development expenditure. Since none of the coefficients exceeds the conventional threshold of 0.80, there is no evidence of serious multicollinearity among the explanatory variables.

Table 5: Unit Root Test Results

Variable	Level	First Difference	Order of Integration
SEG	-2.28	-5.74***	I(1)
EDUQ	-2.16	-6.21***	I(1)
REC	-4.13***	-	I(0)
RDE	-2.01	-5.62***	I(1)

Variable	Level	First Difference	Order of Integration
CO_2	-3.84***	-	I(0)
GCF	-2.43	-5.17***	I(1)

*** denotes significance at 1%.
Source: Author's Computation (2026)

The Augmented Dickey-Fuller results reveal that sustainable economic growth, education quality, research and development expenditure, and gross capital formation are non-stationary at level but become stationary after first differencing. Renewable energy consumption and carbon emissions are stationary at level. The presence of both I(0) and I(1) variables justifies the application of the ARDL bounds testing approach.

Table 6: ARDL Bounds Cointegration Test

Test Statistic	Value
F-statistic	6.812
Lower Bound I(0)	2.62
Upper Bound I(1)	3.79

Source: Author's Computation (2026)

The ARDL bounds test indicates that the calculated F-statistic of 6.812 exceeds the upper critical bound value of 3.79. This result confirms the existence of a long-run equilibrium relationship among sustainable economic growth, education quality, renewable energy consumption, research and development expenditure, carbon emissions, and gross capital formation.

4.2 Regression Results

The FMOLS estimates indicate that education quality exerts a positive and statistically significant effect on sustainable economic growth. The coefficient of 0.384 implies that improvements in educational quality contribute significantly to sustainability outcomes through human capital development and knowledge creation.

Renewable energy consumption also records a positive and significant coefficient of 0.271. The result suggests that increased utilization of renewable energy sources contributes positively to sustainable economic growth by reducing dependence on environmentally harmful energy sources.

Research and development expenditure exhibits a positive and highly significant effect on sustainable economic growth. The coefficient of 0.452 indicates that increased investment in innovation, scientific research, and technological development promotes sustainable production processes and improves long-run economic performance.

Table 7: FMOLS Results

Variable	Coefficient	t-Statistic	Probability
EDUQ	0.384	3.941	0.001
REC	0.271	2.743	0.012
RDE	0.452	4.376	0.000
CO_2	-0.226	-2.616	0.016
GCF	0.183	2.304	0.031
Constant	18.563	2.784	0.011
R^2	0.87	Adjusted R^2	0.84
F-statistic	37.18 (0.000)		
Breusch-Godfrey	0.311		
Breusch-Pagan	0.428		
Jarque-Bera	0.551		

Source: Author's Computation (2026)

Carbon emissions exert a negative and statistically significant effect on sustainable economic growth. The coefficient of -0.226 implies that rising environmental pollution undermines sustainability objectives by imposing environmental and economic costs on society.

Gross capital formation records a positive and significant coefficient, suggesting that increased investment in productive infrastructure and capital assets contributes to sustainable economic expansion.

The coefficient of determination (R^2) indicates that approximately 87 per cent of variations in sustainable economic growth are explained by the explanatory variables included in the model. The diagnostic statistics further show that the model is free from serial correlation and heteroskedasticity, while the residuals are normally distributed.

4.3 Discussion of Findings

The results show that education quality exerts a positive and statistically significant effect on sustainable economic growth in Nigeria. This suggests that improvements in learning outcomes, knowledge acquisition, and skills development contribute to the achievement of sustainability objectives. The finding supports Busemeyer et al. (2025), who argued that educational institutions play a critical role in developing competencies required for the transition toward a green economy. The result is also consistent with Li et al. (2026), who

found that strategic human capital development contributes significantly to sustainability outcomes in developing economies.

Renewable energy consumption was found to have a positive and significant effect on sustainable economic growth. This implies that increasing the share of renewable energy in the national energy mix promotes environmental sustainability while supporting economic development. The finding agrees with Liu et al. (2025), who reported that energy transition contributes positively to green growth. The result also supports Sun et al. (2026), who found that improvements in energy efficiency and renewable energy utilization enhance sustainable development.

Research and development expenditure exerts the strongest positive influence on sustainable economic growth. This finding suggests that investment in innovation, scientific research, and technological advancement promotes the development of environmentally friendly production processes and sustainable economic activities. The result is consistent with García Hernández et al. (2025), who emphasized the importance of innovation and green competencies in achieving sustainability objectives. It also aligns with Li et al. (2026), who found that investments in research and knowledge creation significantly enhance sustainability performance in developing countries.

Carbon emissions exhibit a negative and significant relationship with sustainable economic growth. This indicates that environmental degradation weakens sustainability efforts and constrains long-run economic welfare. The finding supports the Environmental Kuznets Curve proposition and agrees with Sun et al. (2026), who found that environmental pollution adversely affects sustainable development outcomes.

Gross capital formation positively influences sustainable economic growth, suggesting that investment in productive infrastructure enhances economic productivity and supports sustainability objectives. This result is consistent with conventional growth theory, which identifies capital accumulation as a major driver of long-run economic development.

5. Conclusion and Recommendations

The empirical results established the existence of a positive long-run equilibrium relationship among sustainable economic growth, education quality, renewable energy consumption, research and development expenditure, and gross capital formation. Conversely, carbon emissions exert a negative and significant effect on sustainable economic growth

Based on the findings of the study, the following recommendations are advanced:

i. Government should strengthen the quality of education through curriculum reforms, improved learning facilities, teacher capacity development, and greater emphasis on science, technology, engineering, innovation, and sustainability-related competencies. This would enhance the quality of human capital required for sustainable development.
ii. Public and private investment in research and development activities should be substantially increased. Greater funding should be directed toward scientific research, technological innovation, university-industry collaboration, and knowledge-based

industries capable of generating sustainable solutions to economic and environmental challenges.

iii. Policymakers should accelerate the transition toward renewable energy through targeted incentives, investment support schemes, and regulatory frameworks that encourage the adoption of solar, wind, hydro, and other clean energy technologies across productive sectors of the economy.

iv. Environmental protection policies should be strengthened through stricter enforcement of environmental regulations, promotion of cleaner production technologies, and incentives for firms to reduce carbon emissions and adopt environmentally sustainable practices.

v. Government should promote greater gross capital formation by improving infrastructure, expanding access to finance, maintaining a stable investment climate, and encouraging both domestic and foreign investment in productive sectors that support sustainable economic growth.

vi. Stronger linkages should be established between educational institutions, research centres, industries, and government agencies to facilitate the commercialization of research outputs, enhance innovation capacity, and promote the diffusion of environmentally sustainable technologies throughout the economy.

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