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RENEWABLE ENERGY CONSUMPTION, ENVIRONMENTAL PRESSURE, AND ECONOMIC GROWTH IN NIGERIA: EVIDENCE FROM AN ARDL MODEL

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ABSTRACT

This study investigates how Renewable Energy Consumption (REC) and Environmental Pressure affect economic growth in Nigeria over the period 1990–2021, using the Autoregressive Distributed Lag (ARDL) modelling framework. The analysis focuses on REC, Carbon Dioxide emissions per capita (CO₂PC), Gross Fixed Capital Formation (GFCF), and Labour Force Participation Rate (LFPR) within a log-level specification in which real Gross Domestic Product (GDP) is expressed in logarithmic form. The bounds test confirms the existence of a stable long-run relationship among the variables. The long-run estimates reveal that REC exerts a significant negative effect on economic growth, indicating that increases in renewable energy consumption are associated with reductions in real GDP during the study period. CO₂PC and GFCF also exhibit significant negative long-run effects, suggesting that environmental pressures and inefficiencies in capital allocation may constrain long-term economic performance, while LFPR showed a weakly-significant positive effect on GDP. Short-run dynamics were examined using the error correction model (ECM). The error correction term is negative and highly significant (−0.3905), indicating that approximately 39 percent of short-run disequilibrium is corrected annually, confirming a stable adjustment process toward long-run equilibrium. The findings highlight the need for a transition toward modern renewable technologies, improved environmental management, and more efficient capital investment strategies to support sustainable economic growth in Nigeria.

Keywords: Renewable energy consumption; economic growth; carbon emissions; ARDL model; energy transition; Nigeria

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1. Introduction

Energy remains a fundamental driver of modern economic systems, powering production, transportation, communication, and household welfare. Among the various energy sources available, renewable energy (derived from solar, wind, hydro, and biomass resources) has increasingly gained prominence as a sustainable alternative to fossil fuels. Unlike conventional energy sources, renewable energy resources are naturally replenished and environmentally friendly, making them central to global strategies aimed at achieving climate stability and sustainable economic development (International Energy Agency [IEA], 2023; International Renewable Energy Agency [IRENA], 2023).

Globally, the transition toward renewable energy has accelerated over the past two decades, driven by concerns over climate change, energy security, and sustainable growth, alongside rapid technological advancements that have significantly reduced the costs of renewable technologies such as solar photovoltaic (PV) systems and wind power. Renewable energy accounted for nearly 30 percent of global electricity generation in 2021 and is projected to exceed 50 percent by 2040 (IEA, 2022). In developed regions such as Europe and North America, substantial investments in renewable infrastructure have been supported by international commitments under the Paris Climate Agreement (IRENA, 2022). Empirical evidence further suggests that renewable energy deployment contributes to employment generation, technological innovation, and long-run economic growth while simultaneously mitigating environmental externalities associated with fossil fuel dependence (Bhattacharya et al., 2016; Inglesi-Lotz, 2016; Sadorsky, 2009; Sebri & Ben-Salha, 2014).

In Africa, renewable energy plays a dual role as both a climate solution and a development strategy. The continent faces a persistent electricity deficit, with more than 600 million people lacking reliable access to electricity, thereby constraining industrial productivity and socio-economic development (World Bank, 2022). Nevertheless, several African countries have made notable progress in renewable energy deployment. Kenya has achieved an electricity mix comprising more than 90 percent renewable energy, largely driven by solar, hydro, and geothermal resources (The Guardian, 2024). Ethiopia has expanded electricity access significantly through hydropower development, while Morocco has invested heavily in large-scale solar projects such as the Noor Ouarzazate Solar Complex (ACWA Power, n.d.; Moroccan Agency for Sustainable Energy [MASEN], n.d.; World Bank, 2023). These developments demonstrate the feasibility of renewable energy expansion in the African context, although financing constraints, infrastructure gaps, and institutional limitations continue to hinder broader progress across the continent (Kouton, 2021; Konyeaso, Eregha, & Vo, 2022).

Nigeria presents a particularly compelling case within the renewable energy discourse. Despite possessing abundant renewable energy resources, including an estimated solar potential of about 427,000 MW and significant hydro, wind, and biomass reserves, the country remains heavily dependent

on fossil fuels. Natural gas alone accounted for approximately 75.5 percent of electricity generation in 2022 (IEA, 2022), while the country's installed solar capacity remains relatively modest. Although several policy initiatives have been introduced to promote renewable energy development, including the Renewable Energy Master Plan (2005), the National Renewable Energy and Energy Efficiency Policy (2015), and the Nigeria Energy Transition Plan (2022), progress has been constrained by weak policy implementation, limited financing mechanisms, and institutional challenges.

Consequently, Nigeria continues to face an energy paradox. On one hand, the country possesses vast renewable energy potential; on the other hand, electricity generation remains stagnant at about 4,000 MW for a population of over 200 million, leaving more than 80 million people without reliable electricity access (World Bank, 2022). This persistent reliance on fossil fuels not only constrains industrial productivity and household welfare but also contributes to rising carbon emissions and environmental degradation. The coexistence of high fossil fuel dependence and persistent environmental pressures raises important questions regarding the sustainability of Nigeria's economic growth trajectory and the extent to which renewable energy adoption has begun to influence the country's growth dynamics.

Empirical evidence on the renewable energy-growth nexus in Nigeria remains mixed. While some studies suggest that energy availability supports economic growth, others report weak, insignificant, or asymmetric effects of renewable energy consumption (Somoye et al., 2022; Menegaki, 2011). These inconsistencies highlight methodological differences in model specification and variable selection and suggest that the relationship between renewable energy consumption and economic growth in Nigeria remains an open empirical question. Furthermore, many existing studies rely on aggregated energy indicators without adequately examining the interaction between renewable energy consumption, environmental pressure, and core macroeconomic drivers of growth. It is against this background that the study seeks to provide more empirical evidence to the ongoing debate on the renewable energy-growth nexus in Nigeria.

Research Questions

- a) What is the long-run effect of renewable energy consumption on economic growth in Nigeria?
- b) What is the relationship between environmental pressure (CO₂ emissions) and economic growth in Nigeria within the ongoing renewable energy transition framework?
- c) What short-run adjustment mechanisms exist within the renewable energy-environment-growth framework, and how fast does the system converge to long-run equilibrium?

Objective of the Study

The overall objective of this study is to investigate how renewable energy consumption and environmental pressure shape economic growth in Nigeria.

The specific objectives are to:

- a) Examine the long-run effect of renewable energy consumption on economic growth in Nigeria.
- b) Evaluate the long-run relationship between environmental pressure (CO₂ emissions) and economic growth in Nigeria within the context of the ongoing renewable energy transition.
- c) Investigate the short-run adjustment mechanisms and the speed of convergence to long-run equilibrium within the renewable energy–environment–growth framework.

2. Literature Review

2.1 Conceptual Literature

Economic Growth

Economic growth refers to the sustained increase in an economy's productive capacity over time, commonly measured by changes in real gross domestic product (GDP). It reflects the expansion of goods and services produced within an economy and is closely associated with improvements in productivity, technological advancement, and efficient resource utilization (Barro, 2019; Todaro & Smith, 2020).

Within both neoclassical and endogenous growth frameworks, economic growth is driven by the accumulation of capital, labour, and technological progress (Solow, 1956; Lucas, 1988; Romer, 1990). In this context, energy constitutes a fundamental input in the production process, as it supports industrial activity, facilitates technological operations, and enhances overall productivity (Stern, 2011). Consequently, the availability, efficiency, and composition of energy sources play a crucial role in shaping growth outcomes, particularly in economies undergoing structural transformation.

Renewable Energy

Renewable energy refers to energy derived from naturally replenished resources such as solar radiation, wind, hydropower, geothermal heat, and biomass (IRENA, 2023). As an input in production, energy plays a fundamental role in supporting industrial activity, transportation, and technological operations. Renewable energy is often considered a sustainable alternative to fossil fuels due to its lower environmental impact and long-term availability. It is also central to global development frameworks such as Sustainable Development Goal 7 (SDG 7), which emphasises access to affordable, reliable, and sustainable energy (United Nations, 2015).

However, the economic implications of renewable energy depend largely on its composition and level of technological advancement. In many developing economies, renewable energy consumption is dominated by traditional biomass sources such as firewood and agricultural residues. Although these sources are classified as renewable, they typically exhibit low energy efficiency and contribute minimally to productivity growth (IEA, 2022). Consequently, the growth effects of renewable energy

may vary depending on whether consumption is driven by modern, technology-based sources or traditional biomass.

CO₂ Emissions

Carbon dioxide (CO₂) emissions are widely used as a proxy for environmental pressure arising from economic activities, particularly energy consumption. High levels of CO₂ emissions are typically associated with the intensive use of fossil fuels and environmentally inefficient production processes. Within the growth-environment literature, CO₂ emissions capture the environmental consequences of economic expansion and energy utilization (Stern, 2004).

From a theoretical perspective, environmental degradation may impose constraints on economic growth through multiple channels, including reduced productivity, health-related costs, and environmental damage (Nordhaus, 1992). As such, the relationship between economic growth and CO₂ emissions reflects a trade-off between economic expansion and environmental sustainability, particularly in developing economies where regulatory and technological constraints may limit the adoption of cleaner production methods.

2.2 Theoretical Literature

Sustainable Development Theory

Sustainable Development Theory provides a broad framework for understanding the relationship between economic growth and environmental sustainability. The concept gained prominence following the Brundtland Commission's report *Our Common Future* (1987), which defined sustainable development as development that meets present needs without compromising the ability of future generations to meet their own needs.

Within the energy–growth discourse, this framework emphasizes the need for cleaner energy systems that reduce environmental degradation while supporting economic progress. Renewable energy, therefore, plays a central role because it allows economic activities to expand while limiting greenhouse gas emissions and environmental degradation. In developing economies, expanding renewable energy access can also contribute to poverty reduction, improved health outcomes, and broader socio-economic development.

Neoclassical Growth Theory

The Neoclassical Growth Theory developed by Solow (1956) and Swan (1956) explains economic growth as a function of capital accumulation, labour supply, and technological progress. According to this framework, output growth occurs through increases in physical capital and labour inputs, while long-run growth depends primarily on technological advancement.

Within the renewable energy–growth nexus, renewable energy investment can be interpreted as a component of productive capital and technological progress. Investments in renewable energy infrastructure (such as solar photovoltaic systems, wind farms, and hydropower plants) expand the productive capacity of an economy and improve energy efficiency. By reducing reliance on fossil fuels and increasing energy security, renewable energy development can contribute to sustained economic growth.

However, the growth impact of renewable energy depends on the structure and efficiency of energy systems. In countries where renewable energy consists largely of low-productivity biomass, its contribution to economic growth may remain limited. This structural feature is particularly relevant in Nigeria’s energy system.

2.3 Empirical Literature

Empirical research on the renewable energy-growth nexus has produced mixed results across developed, emerging, African, and Nigeria-specific contexts, with findings depending on country characteristics, energy composition, and estimation techniques.

Early evidence from developed economies generally suggests a positive relationship between renewable energy consumption and economic growth. Apergis and Payne (2010), using panel cointegration and error-correction models for 20 OECD countries over the period 1985–2005, found bidirectional long-run causality between renewable energy consumption and GDP, implying mutual reinforcement between economic activity and renewable energy use. Similarly, Sadorsky (2009), focusing on G7 economies over 1980–2005 with time-series econometric techniques, reported that rising income stimulates greater renewable energy consumption, while renewable energy expansion also contributes to emissions reduction.

Evidence from Europe is more mixed. Menegaki (2011), applying a random-effects panel approach to 27 European countries for 1997–2007, found no significant causal relationship between renewable energy consumption and economic growth, thereby supporting the neutrality hypothesis. In contrast, Bhattacharya, Paramati, Ozturk, and Bhattacharya (2016), using panel DOLS and FGLS for high renewable-energy-consuming countries over 1991–2012, found that renewable energy consumption promotes both short-run and long-run economic growth, especially where governance quality and financial systems are stronger. Likewise, Inglesi-Lotz (2016), analysing OECD countries over 1990–2010 with panel methods, reported positive elasticities between renewable energy use and GDP, suggesting that sustained renewable energy expansion supports macroeconomic performance.

Other studies emphasize that the growth effects of renewable energy are often conditional on broader structural factors. Dogan and Seker (2016), using panel analysis for EU-15 countries over 1980–2012, found that both renewable and non-renewable energy support economic growth, although the

contribution of renewable energy becomes stronger at higher levels of development. Similarly, Balsalobre-Lorente and Leitão (2020), employing FMOLS and DOLS for EU-28 economies over 1995–2016, showed that tourism, trade openness, renewable energy use, and carbon emissions jointly influence long-run economic growth, highlighting the complementary role of renewable energy within broader economic structures. Tugcu, Ozturk, and Aslan (2012), applying ARDL bounds testing and Hatemi-J causality tests to G7 countries over 1980–2009, also found that both renewable and non-renewable energy significantly influence long-run growth, although the direction of causality varies across countries and model specifications.

Empirical evidence from Africa reveals even stronger heterogeneity. Acheampong (2018), using system-GMM for a large African panel over 1971–2013, found feedback relationships between energy use and economic growth, while also showing that the strength and direction of the effects vary substantially across countries. In a more focused African renewable energy study, Konyeaso, Eregha, and Vo (2022), covering 32 African countries from 1996 to 2018 and employing PMG, AMG, and DOLS estimators, found a positive long-run effect of renewable energy consumption on per-capita growth, with stronger results in countries exhibiting greater financial development. In a related study of African oil-producing countries, İnal et al. (2022), using bootstrap panel LM cointegration, AMG estimation, and Kónya causality tests for 1990–2014, reported that renewable energy consumption has a positive long-run effect on growth, although the magnitude differs across countries and depends on carbon-emission dynamics. Similarly, Yang, Namahoro, Wu, and Su (2022), focusing on nine Eastern Africa Power Pool countries over 1980–2017 and applying CCEMG, NARDL, and asymmetric causality techniques, found that the impact of renewable energy on growth is heterogeneous and asymmetric, varying according to shocks and the composition of the energy mix. Kouton (2021), using system-GMM for 44 African countries, further showed that renewable energy contributes positively to inclusive growth, implying that renewable energy can support broader development outcomes beyond aggregate GDP. At the country level, Al-Mulali, Solarin, and Ozturk (2016), using an ARDL approach for Kenya over 1980–2012, found that renewable energy consumption helps reduce environmental degradation and improves the environmental sustainability of growth.

The Nigeria-specific evidence remains comparatively cautious and conditional. Azeakpono and Lloyd (2020), using unit root tests, cointegration analysis, regression techniques, and Granger causality tests on annual Nigerian data from 1981 to 2018, found no causal relationship between renewable energy consumption and economic growth in either the short run or the long run. They attributed this result to the underdeveloped state of Nigeria's renewable energy sector and the dominance of traditional biomass. Somoye, Özdeser, and Seraj (2022), applying a nonlinear ARDL framework to quarterly data for 1990Q1–2019Q4, found asymmetric long-run effects of renewable energy consumption on growth: positive shocks to renewable energy consumption reduce output, whereas negative shocks increase output. The authors argued that this counterintuitive result reflects the biomass-dominated nature of renewable energy use in Nigeria, which may depress rather than enhance productivity.

Evidence from broader energy-growth studies in Nigeria also points to important environmental trade-offs. Musa and Maijama'a (2020), using the ARDL bounds testing approach, found a long-run relationship among energy consumption, economic growth, and environmental pollution, with energy consumption supporting growth but also increasing environmental degradation. Odugbesan and Rjoub (2020), examining the MINT countries with ARDL bounds and causality techniques, likewise found that economic growth and urbanization contribute to increased energy consumption and carbon emissions, suggesting that growth-driven environmental pressure is a common feature among emerging economies, including Nigeria.

A further strand of the Nigerian literature highlights the importance of financial and institutional conditions in shaping renewable energy outcomes. Fasheyitan, Omarkhanlen, and Okpalaoka (2022), using an ARDL framework, found that weak financial capacity and inadequate investment constrain renewable energy deployment in Nigeria. Similarly, Dimnwobi et al. (2022), employing ADF, Zivot–Andrews structural break tests, and ARDL estimation for Nigerian data over 1981–2019, concluded that financial development is an important determinant of renewable energy consumption.

The empirical literature, therefore, suggests that renewable energy can support growth, but the effect is far from uniform. Across countries, the relationship depends on the structure of the energy mix, institutional quality, financial development, and the dominance of either modern renewable technologies or traditional biomass. For Nigeria in particular, the evidence indicates that renewable energy has not yet generated strong growth dividends, largely because its current composition is still heavily biomass-based and embedded within wider structural and financial constraints.

3. Methodology

Data and Variables

This study uses annual time-series data for Nigeria covering the period 1990–2021. The variables included in the empirical model capture key economic and environmental factors associated with the renewable energy-growth nexus. Economic growth is proxied by real Gross Domestic Product (GDP). Renewable energy consumption is measured as the share of renewable energy in total final energy consumption. Environmental pressure is represented by carbon dioxide emissions per capita (CO₂PC, excluding Land Use, Land-Use Change, and Forestry - LULUCF), which captures the environmental implications of energy use. Gross fixed capital formation (GFCF) is included as a proxy for investment and capital accumulation, while the labour force participation rate (LFPR) reflects the contribution of labour supply to economic activity.

Data for renewable energy consumption, carbon emissions, labour force participation, and real GDP were obtained from the World Development Indicators (World Bank), while data on gross fixed capital formation were sourced from the Central Bank of Nigeria statistical bulletin.

Model Specification

To examine the relationship between renewable energy consumption, environmental pressure, and economic growth in Nigeria, this study specifies a parsimonious energy-growth framework in which economic growth is modelled as a function of renewable energy consumption, carbon dioxide emissions, gross fixed capital formation, and labour force participation rate.

The theoretical functional relationship is expressed as:

$$GDP_t = f(REC_t, CO_2PC_t, GFCF_t, LFPR_t) \dots \dots \dots (1)$$

For empirical estimation, the model is specified as:

$$GDP_t = \alpha + \beta_1 REC_t + \beta_2 CO_2PC_t + \beta_3 GFCF_t + \beta_4 LFPR_t + \varepsilon_t \dots \dots \dots (2)$$

Where:

GDP_t = Real Gross Domestic Product (constant 2015 US dollars)

REC_t = Renewable energy consumption (% of total final energy use)

CO₂PC_t = Carbon dioxide emissions per capita (proxy for environmental pressure)

GFCF_t = Gross fixed capital formation (% of GDP)

LFPR_t = Labour force participation rate (% of population aged 15+)

α = constant term

β₁–β₄ = parameters measuring the impact of the explanatory variables on economic growth

ε_t = stochastic error term

t = time period

For empirical estimation, the dependent variable, real gross domestic product, is expressed in natural logarithmic form, while renewable energy consumption, carbon dioxide emissions per capita, gross fixed capital formation, and labour force participation rate are retained in level form. The estimated specification is therefore a semi-log model.

Estimation Technique

The study employs the Autoregressive Distributed Lag (ARDL) modelling framework developed by M. Hashem Pesaran, Yongcheol Shin, and Richard J. Smith (2001) to examine both the long-run and short-run relationships among the variables.

The ARDL approach is particularly suitable for this study for several reasons. First, it can be applied when variables are integrated of order zero $I(0)$ or order one $I(1)$, provided none of the variables is integrated of order two $I(2)$. Second, the ARDL framework performs well with relatively small sample sizes, making it appropriate for time-series data covering limited periods. Third, it allows the simultaneous estimation of long-run equilibrium relationships and short-run dynamic adjustments within a single modelling structure.

The general ARDL dynamic specification employed in this study is presented as follows:

$$LGDP_t = \alpha + \sum_{i=1}^p \phi_i LGDP_{t-i} + \sum_{j=0}^{q_1} \beta_{1j} REC_{t-j} + \sum_{k=0}^{q_2} \beta_{2k} CO2PC_{t-k} \\ + \sum_{m=0}^{q_3} \beta_{3m} GFCF_{t-m} + \sum_{n=0}^{q_4} \beta_{4n} LFPR_{t-n} + \varepsilon_t$$

where p, q_1, q_2, q_3, q_4 represent optimal lag lengths selected using information criteria (AIC), and $\varepsilon_t \sim N(0, \sigma^2)$.

ϕ_i = coefficients of the lagged dependent variable

$\beta_{1j}, \beta_{2k}, \beta_{3m}, \beta_{4n}$ = distributed lag coefficients measuring the dynamic effects of the explanatory variables

i = lag order

$\varepsilon_t \sim N(0, \sigma^2)$ = stochastic error term assumed to be independently and identically distributed.

To test for the existence of a long-run relationship among the variables, the ARDL bounds testing approach is applied using the unrestricted error correction model (UECM) representation shown below:

$$\Delta LGDP_t = \alpha_0 + \sum_{i=1}^{p-1} \phi_i \Delta LGDP_{t-i} + \sum_{j=0}^{q_1-1} \beta_{1j} \Delta REC_{t-j} + \sum_{k=0}^{q_2-1} \beta_{2k} \Delta CO2PC_{t-k} \\ + \sum_{m=0}^{q_3-1} \beta_{3m} \Delta GFCF_{t-m} + \sum_{n=0}^{q_4-1} \beta_{4n} \Delta LFPR_{t-n} \\ + \lambda_1 LGDP_{t-1} + \lambda_2 REC_{t-1} + \lambda_3 CO2PC_{t-1} + \lambda_4 GFCF_{t-1} + \lambda_5 LFPR_{t-1} + \varepsilon_t$$

$H_0: \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = 0$ (No long-run relationship)
 $H_1: \text{At least one } \lambda_i \neq 0$ (Long-run relationship exists)

The null hypothesis of no long-run relationship is tested using the joint significance of the lagged level variables. Once cointegration is confirmed, the short-run dynamics and speed of adjustment toward long-run equilibrium are examined using the error correction model (ECM) representation given below:

$$\begin{aligned}\Delta LGDP_t = & \alpha + \sum_{i=1}^{p-1} \phi_i \Delta LGDP_{t-i} + \sum_{j=0}^{q_1-1} \beta_{1j} \Delta REC_{t-j} \\ & + \sum_{k=0}^{q_2-1} \beta_{2k} \Delta CO_2PC_{t-k} + \sum_{m=0}^{q_3-1} \beta_{3m} \Delta GFCF_{t-m} + \sum_{n=0}^{q_4-1} \beta_{4n} \Delta LFPR_{t-n} \\ & + \theta ECT_{t-1} + \varepsilon_t\end{aligned}$$

$$ECT_{t-1} = LGDP_{t-1} - \hat{\beta}_1 REC_{t-1} - \hat{\beta}_2 CO_2PC_{t-1} - \hat{\beta}_3 GFCF_{t-1} - \hat{\beta}_4 LFPR_{t-1}$$

θ represents the speed of adjustment toward long-run equilibrium

The coefficient of the error correction term captures the speed at which deviations from the long-run equilibrium are corrected following short-run shocks.

Diagnostic and Stability Tests

To ensure the reliability and robustness of the estimated ARDL model, several post-estimation diagnostic tests are conducted. These include tests for serial correlation, heteroskedasticity, normality of residuals, and functional form specification.

In addition, the stability of the estimated parameters is examined using the CUSUM and CUSUM of squares (CUSUMSQ) tests, which assess whether the estimated coefficients remain stable throughout the sample period.

4. Results and Discussion

4.1 Results Presentation

Table 1

Descriptive Statistics

Statistic	LGDP	REC	CO ₂ PC	GFCF	LFPR
Mean	26.35113	84.48750	0.692150	23.32846	82.07188
Median	26.36571	84.50000	0.685117	19.78226	81.88000
Maximum	26.97416	88.60000	0.911020	35.37855	84.09500
Minimum	25.75487	79.90000	0.499338	13.78732	79.31400
Std. Dev.	0.473457	2.662372	0.112057	8.576354	1.277330
Skewness	0.002274	-0.269064	0.203692	0.271471	-0.023562

Kurtosis	1.360880	1.812428	1.813423	1.339868	1.997248
Jarque-Bera	3.582313	2.266546	2.098569	4.067767	1.343643
Probability	0.166767	0.321978	0.350188	0.130826	0.510777
Observations	32	32	32	32	32

Source: Author's computation using EViews

From Table 1, real gross domestic product in logarithmic form (LGDP), which serves as the dependent variable, records a mean value of 26.35 and a relatively small standard deviation of 0.47, indicating moderate fluctuations in economic performance across the sample period. In the same vein, renewable energy consumption (REC) has an average value of 84.49 percent, which appears high but largely reflects the widespread use of traditional biomass in Nigeria, rather than modern renewable technologies. Carbon dioxide emissions per capita (CO₂PC) record a mean value of 0.69 metric tons, indicating relatively low emission intensity compared with many industrialised economies. Moreover, gross fixed capital formation (GFCF), averaging 23.33 percent of GDP, represents the level of investment activity in the Nigerian economy, while the labour force participation rate (LFPR) averages 82.07 percent, reflecting a relatively active labour market during the study period.

The Jarque–Bera statistics indicate that the variables do not significantly deviate from normality, suggesting that the data are suitable for subsequent econometric analysis. The descriptive statistics, therefore, suggest moderate variability across the variables and provide preliminary insight into the behaviour of the data.

Table 2
Correlation Matrix

	LGDP	REC	CO₂PC	GFCF	LFPR
LGDP	1.000000	-0.779806	-0.859125	-0.961414	-0.914958
REC	-0.779806	1.000000	0.393095	0.714339	0.712258
CO₂PC	-0.859125	0.393095	1.000000	0.851121	0.812417
GFCF	-0.961414	0.714339	0.851121	1.000000	0.888149
LFPR	-0.914958	0.712258	0.812417	0.888149	1.000000

Source: Author's computation using EViews

The correlation matrix in Table 2 provides preliminary insight into the relationships among the variables included in the model. In general, the correlations are mostly strong in magnitude, suggesting that the variables are related but not perfectly collinear. While pairwise correlations provide an initial indication of possible linear relationships among the variables, they do not constitute a formal test of multicollinearity. Therefore, the Variance Inflation Factor (VIF) test was subsequently conducted to provide a more rigorous assessment of multicollinearity in the model. The VIF test results are presented in Table 3.

Table 3

Variance Inflation Factor (VIF) Test

Variables	VIF	1/VIF
REC	4.04	0.248
CO ₂ PC	7.14	0.140
GFCF	9.76	0.102
LFPR	6.51	0.154
Mean VIF	6.86	

Source: Author's computation using EViews

The centred VIF values are all below the conventional threshold of 10, suggesting that multicollinearity is not a serious concern in the model. This indicates that the explanatory variables can be included simultaneously in the regression analysis without significantly inflating the variance of the estimated coefficients.

Table 4**Augmented Dickey–Fuller Unit Root Test**

Variable	Test at Level (ADF t-stat)	Prob.	Decision (Level)	Test at 1st Diff. (ADF t- stat)	Prob.	Decision (1st Diff.)	Order of Integration
LGDP	−1.789	0.6846	Fail to reject H ₀	−2.853	0.0630	Reject H ₀ (10%)	I(1)
REC	−1.401	0.5690	Fail to reject H ₀	−5.753	0.0000	Reject H ₀	I(1)
CO ₂ PC	−2.677	0.2523	Fail to reject H ₀	−6.129	0.0000	Reject H ₀	I(1)
GFCF	−1.631	0.7546	Fail to reject H ₀	−2.695	0.0874	Reject H ₀ (10%)	I(1)
LFPR	−4.194	0.0123	Reject H ₀	—	—	—	I(0)

Source: Author's computation using EViews

The results in Table 4 indicate that renewable energy consumption (REC), carbon dioxide emissions per capita (CO₂PC), and gross fixed capital formation (GFCF) are non-stationary at level but become stationary after first differencing, implying that they are integrated of order one, I(1). In contrast, the labour force participation rate (LFPR) is stationary at level and therefore integrated of order zero, I(0). The mixture of I(0) and I(1) variables justifies the use of the Autoregressive Distributed Lag (ARDL) modelling approach, which allows estimation of models containing variables integrated of different orders, provided none is integrated of order two.

Table 5**ARDL Bounds Test for Cointegration**

Panel A: Bounds Test Statistic

Test Statistic	Value	K	Decision
F-statistic	22.0441	4	Reject H ₀ (Cointegration exists)

Panel B: Critical Value Bounds

Significance Level	I(0) Lower Bound	I(1) Upper Bound
10%	2.525	3.560
5%	3.058	4.223
1%	4.280	5.840

Source: Author's computation using EViews

From Table 5, the computed F-statistic exceeds the upper bound critical value at a 5 percent significance level. Consequently, the null hypothesis of no long-run relationship is rejected. This confirms the existence of a stable long-run equilibrium relationship among renewable energy consumption, environmental pressure (CO₂ emissions), capital formation, labour force participation, and economic growth in Nigeria.

Table 6**Long-Run ARDL Estimates**

Variable	Coefficient	Std. Error	t-Statistic	Prob.	Decision
REC	-0.048307	0.009533	-5.067298	0.0001	Reject H ₀
CO ₂ PC	-1.719545	0.401562	-4.282145	0.0004	Reject H ₀
GFCF	-0.033721	0.005980	-5.639324	0.0000	Reject H ₀
LFPR	0.072469	0.037369	1.939310	0.0683	Reject H ₀ (10%)
C	26.53944	2.571827	10.31929	0.0000	Reject H ₀

Source: Author's computation using EViews

The results in Table 6 show that renewable energy consumption (REC), carbon dioxide emissions per capita (CO₂PC), and gross fixed capital formation (GFCF) exhibit negative and statistically significant long-run effects on economic growth. In contrast, the labour force participation rate (LFPR) shows a positive but weakly significant relationship with economic growth at the 10 percent level.

Table 7**Error Correction Model (Short-Run Estimates)**

Variable	Coefficient	Std. Error	t-Statistic	Prob.	Decision
D(CO ₂ PC)	-0.404152	0.059363	-6.808098	0.0000	Reject H ₀ (1%)
D(CO ₂ PC(-1))	0.206305	0.056458	3.654130	0.0018	Reject H ₀ (1%)
D(GFCF)	-0.004816	0.001039	-4.633758	0.0002	Reject H ₀ (1%)
D(GFCF(-1))	0.003710	0.001334	2.782126	0.0123	Reject H ₀ (1%)
D(LFPR)	0.006645	0.007784	0.853758	0.4045	Fail to reject H ₀
D(LFPR(-1))	-0.031224	0.007887	-3.959038	0.0009	Reject H ₀ (1%)
CointEq(-1)	-0.390510	0.030039	-13.00018	0.0000	Reject H ₀ (1%)

Source: Author's computation using EViews

The coefficient of the error correction term is negative and highly statistically significant (-0.3905), satisfying the theoretical requirement for a stable long-run relationship. The magnitude indicates that approximately 39 percent of short-run disequilibrium is corrected within one year, implying a relatively rapid adjustment toward long-run equilibrium following short-term shocks. In the short run, changes in carbon emissions and capital formation exert significant effects on economic growth. Labour force participation shows mixed short-run dynamics, while renewable energy consumption does not exhibit additional short-run lag effects under the optimal lag structure selected by the ARDL model.

Table 8
Diagnostic Test Results

Diagnostic Test	Test Statistic	Probability	Decision	Conclusion
Breusch–Godfrey Serial Correlation LM Test	F = 0.8197 Obs*R ² = 2.7882	0.4582 0.2481	Fail to reject H ₀	No serial correlation
Breusch–Pagan–Godfrey Heteroskedasticity Test	F = 0.2607 Obs*R ² = 4.1228	0.9864 0.9662	Fail to reject H ₀	Residuals are homoscedastic
Jarque–Bera Normality Test	JB = 2.6008	0.2724	Fail to reject H ₀	Residuals are normally distributed
Ramsey RESET Test	F = 0.1915	0.6672	Fail to reject H ₀	Model correctly specified

Source: Author's computation using EViews

The Breusch–Godfrey LM test confirms the absence of serial correlation, while the Breusch–Pagan–Godfrey test indicates that the residuals are homoskedastic. The Jarque–Bera statistic suggests that the residuals are normally distributed, and the Ramsey RESET test confirms the correct functional specification of the model. The stability of the model parameters was further examined using the CUSUM and CUSUMSQ tests.

Figure 1: CUSUM Stability Test

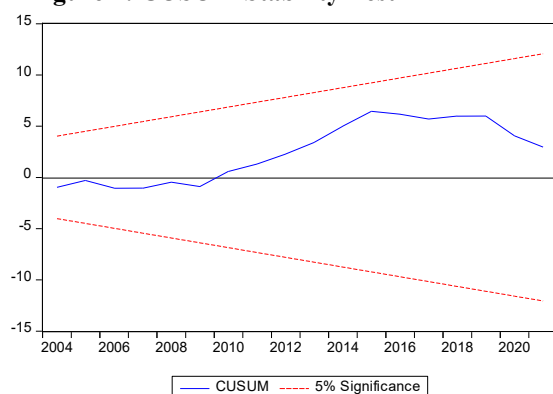
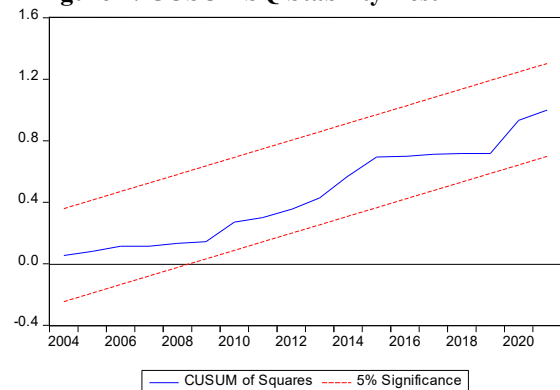


Figure 2: CUSUMSQ Stability Test



Source: Author's computation using EViews

The plots in Figure 1 and Figure 2 show that the cumulative sums remain within the 5 percent critical bounds, indicating that the estimated coefficients are stable over the sample period.

4.2 Discussion of Findings

The empirical findings of this study provide important insights into the relationship between renewable energy consumption, environmental pressure, and economic growth in Nigeria. The results indicate that renewable energy consumption exerts a negative and statistically significant long-run effect on economic growth. This outcome suggests that increases in renewable energy consumption during the study period were associated with reductions in real GDP. Although renewable energy is generally expected to support sustainable economic growth, this result can be explained by the current structural composition of renewable energy within Nigeria's energy system, whereby a substantial proportion of renewable energy consumption in Nigeria is derived from traditional biomass sources such as firewood and agricultural residues, which contribute little to productivity improvement and may even reflect energy poverty rather than technological progress. This finding is therefore consistent with the argument that the growth impact of renewable energy depends strongly on the technological sophistication of the energy mix. The result aligns with the findings of Somoye, Özdeser, and Seraj (2022), who reported asymmetric effects of renewable energy consumption on economic growth in Nigeria using a nonlinear ARDL framework. Their study also concluded that the dominance of biomass-based renewable energy could produce counterintuitive growth outcomes.

The results of the study further show that carbon dioxide emissions exert a negative and statistically significant long-run effect on economic growth, suggesting that increasing environmental pressure may constrain economic performance in Nigeria. Rather than reflecting productivity-enhancing industrial expansion, rising emissions may be associated with inefficient energy use, environmental degradation, and structural weaknesses within the production system. The result supports the argument that unsustainable energy use patterns can impose long-run economic costs through environmental damage, declining productivity, and increasing regulatory pressures. This is broadly consistent with the results of Musa and Majama'a (2020), who found that energy consumption in Nigeria contributes to environmental degradation even when it supports economic activity. It also aligns with broader empirical evidence suggesting that environmentally inefficient energy systems can undermine sustainable growth trajectories in developing economies.

Gross fixed capital formation also exhibits a negative and statistically significant relationship with economic growth in the long run. Although investment is theoretically expected to promote economic expansion within the neoclassical growth framework, the negative coefficient may reflect inefficiencies in capital allocation within the Nigerian economy. In particular, investments may have been directed toward low-productivity sectors or may have suffered from implementation constraints, weak infrastructure, and institutional inefficiencies. This interpretation is consistent with the argument that capital accumulation contributes to economic growth only when investments are efficiently allocated and supported by complementary institutional and structural conditions. Growth theory emphasizes that physical capital alone cannot sustain long-term economic expansion unless it is accompanied by

effective institutions, technological progress, and productive investment environments (Solow, 1956; Acemoglu, Johnson, & Robinson, 2005).

In contrast, the labour force participation rate exhibits a positive but weakly significant relationship with economic growth. This finding suggests that increases in labour participation contribute modestly to economic performance, although the magnitude of the effect appears limited. The weak significance may reflect structural challenges within the Nigerian labour market, including underemployment, skill mismatches, and low labour productivity. Existing literature emphasizes that the contribution of labour to economic growth depends not only on labour supply but also on the quality of human capital, technological capability, and labour market efficiency (Lucas, 1988; Barro & Sala-i-Martin, 2004).

Finally, the short-run adjustment dynamics, examined through the error correction model, further reinforce the existence of a stable long-run relationship among renewable energy consumption, environmental pressure, and economic growth in Nigeria. The significance and negative sign of the error correction mechanism indicate that deviations from the long-run equilibrium are corrected over time, suggesting that shocks to the energy-environment-growth system are not permanent. This adjustment process implies that although short-term fluctuations may occur in response to economic or environmental shocks, the economy gradually converges back to its long-run equilibrium path. Such behaviour is consistent with the theoretical expectation that energy consumption, environmental pressure, and economic performance are structurally linked within the production system, and that policy or structural changes affecting the energy mix may have lasting implications for long-run growth dynamics.

5. Conclusion and Recommendations

5.1 Conclusion

This study investigated the relationship between renewable energy consumption, environmental pressure, and economic growth in Nigeria using annual time-series data covering the period 1990-2021 within an Autoregressive Distributed Lag (ARDL) modelling framework. The results confirm the existence of a stable long-run equilibrium relationship among renewable energy consumption, carbon dioxide emissions, gross fixed capital formation, labour force participation, and economic growth.

The long-run estimates reveal that renewable energy consumption, carbon dioxide emissions per capita, and gross fixed capital formation exert statistically significant negative effects on economic growth, while labour force participation shows a positive but weakly significant relationship. These findings suggest that the current structure of renewable energy consumption in Nigeria, which remains heavily dominated by traditional biomass, has not yet translated into productivity-enhancing economic outcomes. In addition, environmental pressure and inefficiencies in capital allocation appear to constrain long-term economic performance.

The short-run dynamics further confirm a stable adjustment process toward long-run equilibrium, with approximately 39 percent of short-run disequilibrium corrected within one year following economic shocks. Overall, the findings highlight the importance of improving the structure of renewable energy deployment, strengthening environmental management, and enhancing the efficiency of capital investment to support sustainable economic growth in Nigeria.

5.2 Recommendations

Based on the findings of the study, several policy implications emerge. First, Nigeria's renewable energy strategy should prioritise the expansion of modern renewable energy technologies such as solar, wind, and small-scale hydropower rather than continued reliance on traditional biomass. Transitioning toward more efficient renewable energy systems could enhance productivity, improve energy security, and support sustainable economic growth. This policy direction aligns with global development priorities such as Sustainable Development Goal 7 (SDG 7), which emphasises access to affordable, reliable, sustainable, and modern energy for all (United Nations, 2015).

Second, policies aimed at reducing environmental pressure should focus on improving energy efficiency and promoting cleaner production technologies. Strengthening environmental regulations and encouraging low-carbon energy investments could help reduce emission intensity while maintaining economic growth. In this regard, integrating renewable energy expansion with environmental sustainability objectives remains critical for achieving long-term development outcomes.

Third, improving the efficiency of capital investment is essential for strengthening Nigeria's growth prospects. Policymakers should therefore focus on strengthening institutional frameworks for project selection, monitoring, and implementation to ensure that investment resources are directed toward productive sectors of the economy. Enhancing institutional quality in this regard will also support the effective deployment of modern energy infrastructure and reinforce sustainable development efforts.

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