EXAMINING THE LINK BETWEEN GREEN ENERGY ADOPTION AND ECONOMIC PROGRESS: EVIDENCE FROM NIGERIA

OKEKE UZOAMAKA PAULINE
Department of Economics, University of Nigeria, Nsukka, Nigeria.
Email: pauline.okeke.93581@unn.edu.ng;+2348038387219

IDUJAGI ADAJI
Department of Economics, Federal University, Wukari, Taraba State.
** Corresponding Author Email: idujagiadaji@gmail.com;+2348031320765*

INNOCENT IFELUNINI
Department of Economics, University of Nigeria, Nsukka, Nigeria.
Email: innocent.ifelunini@unn.edu.ng;+2348035651568

ABSTRACT
This study investigates the impact of renewable energy consumption on economic growth and productivity in Nigeria, using two distinct datasets spanning 1990–2023 and 2000–2023. Employing the Autoregressive Distributed Lag (ARDL) bounds testing approach and Pairwise Granger causality analysis, the study provides new insights into the dynamic and causal relationships among key macroeconomic variables. The findings reveal that renewable energy consumption has a significant negative effect on economic growth in the long run and a consistently negative impact on economic productivity in both the short and long term. Causality tests show a unidirectional relationship from economic growth to renewable energy consumption, and from renewable energy consumption to economic productivity. While foreign direct investment (FDI) and trade openness positively influence economic growth, they are found to hinder productivity. Conversely, natural resource endowment negatively affects growth but enhances productivity. Domestic credit to the private sector supports both growth and productivity. These findings highlight the need for strategic policies that position renewable energy as a complementary input to production while maintaining economic stability. The study recommends a phased transition to renewable energy, supported by financial incentives, modern infrastructure investment, and enhanced research and development. Such measures will help Nigeria achieve sustainable and inclusive economic transformation.
Keywords: Green Energy Adoption, Economic growth, Productivity, ARDL Approach, Nigeria.
JEL Codes: Q2, C32, Q43, O40, N77

1. INTRODUCTION
Over the past decades, Nigeria has experienced remarkable economic growth, much of which was driven by the oil and gas sector (Akinwande et al., 2025). Moreover, other sectors like telecommunications, banking, agriculture, and services also picked up, especially after economic liberalization and reform in the early 2000s (Obiukwu et al., 2024; Okoh, 2025). Parallel to this modest economic growth, Nigeria has also achieved mean inflation rates, a stable relative exchange rate, manageable external debt, and a good external account profile (Oyaromade et al., 2014).
However, despite Nigeria’s recent macroeconomic gains, the nation’s persistent energy supply deficiencies continue to represent a binding constraint on inclusive and sustainable development outcomes. Indeed, more than 50 million Nigerians still lack reliable access to electricity, highlighting a systemic failure to translate economic growth into broad-based

welfare improvements (Okubanjo et al., 2022; Okoroafor et al., 2024). Energy, as a multifaceted input, is foundational to critical sectors such as communication, transportation, healthcare, and domestic services; thus, its scarcity constitutes a significant drag on productivity and economic transformation (Umeji et al., 2023). Particularly disturbing is Nigeria's deteriorating national electricity grid that is plagued by infrastructural rigidities, including old age of facilities, weak maintenance cultures, widespread theft, and weak oversight institutions (Imandojemu & Toyosi, 2018). Such infrastructural and institutional bottlenecks have engendered deep-seated inefficiencies in electricity generation, distribution, and decentralization, perpetuating inequalities in access across regions (Ndukwu et al., 2021). Rather interestingly, Nigeria's per capita electricity consumption in 2005 was a mere 127 kWh—half of Ghana's consumption in the same year, a revealing pointer to the country's energy access shortfall (Akinwale & Ogundari, 2017).

Thus, the country's protracted energy crisis reflects a structural paradox wherein economic potential coexists with persistent infrastructural deficits. As such, Nigeria's growing dependence on expensive and inefficient oil-fired generation plants not only deepened energy poverty but also worsened environmental externalities like air pollution and ecosystem degradation (Onyechi & Ejiofor, 2021; IRENA, 2023). Apparently, by 2022, over 40% of the population had turned to private generators, an indicator of institutional breakdown and non-centralized adaptation actions with disparate costs to households and businesses (Anderson, 2024). Furthermore, approximately 80% of electricity-connected residential and commercial users now rely on petrol and diesel generators, with annual fuel expenditures surpassing $5 billion (Anderson, 2024). These costs add up to a competitive tax on local production, undermining industrial performance and export capacity. Furthermore, the macroeconomic consequences are just as stark: the World Bank (2023) approximates a 25% loss in GDP to the frequent power disruptions. At the micro level, energy insecurity forces vulnerable populations to use unsustainable fuels like kerosene and firewood, thereby increasing health hazards and speeding up deforestation (Renewable Association of Nigeria, 2024). So, as fossil reserves dwindle and environmental costs mount (Okedu et al., 2015), the shift to renewable energy is no longer a choice but a sine qua non of sustainable development (Ikhide, 2021; Behera et al., 2024).

Encouragingly, the renewable energy status of Nigeria is a contradiction of both abundance and underutilizations. For instance, Nigeria is richly endowed with solar, wind, hydro, and biomass potential and yet its renewable energy resources are predominantly underdeveloped. Furthermore, the solar photovoltaic potential of the country is at an estimated 210 GW, though land limitations limit the exploitable land area to merely 1% (Bisu et al., 2024). Additionally, wind resources are moderate, with speeds ranging between 2.1 and 8 m/s, most prominently viable along the northern corridor (IRENA, 2023). Similarly, the country is endowed with 24 GW large hydro and 3.5 GW small hydro potential, along with abundant biomass from agricultural residues (Simonyan & Fasina, 2013). Yet, in spite of this latent potential, renewables remained only 21% of the nation's electricity mix in 2023 (Statista, 2024). Notably, this disparity between potential and action refers to a deficit in governance.

Accordingly, the Nigerian government created the Energy Commission of Nigeria (ECN) in 1979 with the responsibility to formulate and implement policy in the energy sector. Even during the recent few years, various policies for renewable energy have been launched, such as the Renewable Energy Master Plan (2013), the National Renewable Energy and Energy Efficiency Policy (2015), the Intended Nationally Determined Contribution (2015), the Rural Electrification Strategy and Plan (2015), and the Multi-Year Tariff Order (2015). All these policies demonstrate a normative bias towards sustainable transitions. Yet, intention-action gap is apparent. For example, as of 2023, a total of 85 million Nigerians approximately 42% of the population are still without access to electricity (IEA, 2023). Besides, statistics from the 2019 Living Standards Survey indicated that a mere 18% of the population used clean cooking facilities (NBS, 2020), implying continued structural dependence on traditional biomass. The results are suggestive of not only technical shortfalls but more fundamental institutional barriers that persist in undermining inclusive energy access.

Hence, against the backdrop of macroeconomic growth projections by the World Bank (2024) and the IMF (2024), Nigeria faces a contradictory challenge: managing clean energy amidst fast economic growth. Conversely, the anticipated rise in energy demand necessitates a decisive policy shift towards clean and resilient energy systems. In fact, realizing the 2050 Nigeria net-zero CO_2 target (IRENA, 2023) and achieving the Sustainable Development Goals require a strategic shift towards low-carbon energy options. Additionally, recent macroeconomic policy reforms like exchange rate unification and ending fuel subsidies, while in line with more general fiscal consolidation objectives, have had adverse effects on household welfare. Without thus complementing policy green interventions, these reforms thus risk worsening underlying socioeconomic vulnerabilities. Thus, a coordinated emphasis on sustainable environmental conservation and equitable economic growth is pivotal to Nigeria's sustained development trajectory.

Building on energy-focused studies such as Maji (2015), Goshit & Shido-Ikwu (2022) and Atoyebi et al. (2024), this study examines the impact of renewable energy consumption on economic growth in Nigeria using annual data from 1990 to 2023. Distinctively, it also extends the analysis to examine the effect of renewable energy on economic productivity, utilizing a separate dataset covering the period from 2000 to 2023. In doing so, the study makes a novel contribution to the energy–development literature by addressing a critical gap in understanding the dual role of renewable energy in shaping both economic output and productive capacity. Methodologically, the analysis employs the Autoregressive Distributed Lag (ARDL) model and the Granger (1969) causality test to assess the dynamics and direction of causality among the variables. The rest of the paper is structured as follows: Section 2 reviews relevant literature; Section 3 details data and methodology; Section 4 presents empirical results; and Section 5 concludes with policy implications.

2. LITERATURE REVIEW

2.1 Conceptual Literature

This section offers a comprehensive examination of the principal concepts, which are elaborated upon in the subsequent subsections.

2.1.1 Renewable Energy

Renewable energy is derived from naturally replenishing sources like solar radiation, wind, precipitation, tides, waves, and geothermal heat. It includes sustainable technologies such as low-impact hydropower and certain biomass combustion methods (Ellabban et al., 2014). Nigeria has significant renewable energy potential, with solar radiation between 4.0 and 7.0 kWh/m²/day, an estimated 14,000 MW hydropower capacity, about 144 million tons of biomass annually, and viable wind speeds over 4 m/s. However, Nigeria's energy sector remains largely reliant on fossil fuels, especially natural gas (IRENA, 2024). Exploiting these renewable resources is essential for addressing energy shortages and fostering sustainable development.

2.1.2 Economic Growth

Economic growth refers to a sustained rise in per capita income or output, often accompanied by increases in labor force participation, consumption, capital formation, and trade. It reflects an economy's capacity to produce goods and services that enhance living standards. Traditionally, economic growth is measured by the growth rate of real Gross Domestic Product (GDP), the total value of final goods and services produced within a country over a specific period, typically annually (El-Rasheed & Abdullahi, 2022). GDP may also be reported quarterly to highlight short-term trends. This paper extends the GDP framework to include productive capacity, which is maximum feasible production given resources labor, capital, technology, and natural resources under normal conditions. Thus, GDP is not only real output but also a reflection of production potential. The measure encompasses trade balances, government spending, investment, private inventories, and construction, with exports added and imports deducted.

2.2 Theoretical Literature

Several economic theories, such as Endogenous Growth Theory, Theory of Choice Awareness, Energy Ladder and Energy Transition Models, and Systems Theory, have explored the link between renewable energy transitions and economic growth. However, this study primarily relies on Structural Change and Energy Transition Models as its theoretical foundation. These models analyze how economies evolve over time through shifts in productive activities, labor allocation, capital deployment, and energy consumption patterns. Originally proposed by Lewis (1954), Structural Change Theory described economic transformation as the movement of labor and capital from agriculture to manufacturing, and eventually to services, driven by technological progress and rising incomes. Recently, the Structural Change framework has expanded to focus on the shift from fossil fuels to renewable energy, recognizing that energy consumption evolves with innovation, policy, and economic priorities (Stolten & Scherer, 2013; Sovacool, 2016; Opoku- Mensah et al., 2025). Incorporating renewable transitions highlights their role in industrial upgrading, diversification, and energy security, key for sustainable development. Renewable energy also promotes decarbonization, job creation, innovation, and resilience against fossil fuel shocks. Thus, Structural Change and Energy Transition Models offer a strong framework for analyzing the complex link between renewable energy consumption and economic growth and productivity.

2.3 Empirical Literature

The relationship between renewable energy consumption and economic growth has garnered significant academic interest in recent years. However, findings remain inconclusive due to differences in geographical focus, methodologies, timeframes, and data sources. For example, Raihan et al. (2025) and Zhang and Tan (2020) report that increased renewable energy use promotes economic growth, while Onyekachi et al. (2025) and Kasperowicz et al. (2020) find only weak evidence for this link. Literature generally aligns with four key hypotheses: growth, conservation, feedback, and neutrality (Apergis 2009; Biala et al., 2025). The growth-led hypothesis, as articulated by Chandio et al. (2019) and Chen et al. (2020), posits that renewable energy consumption serves as a catalyst for economic expansion. Conversely, the conservation hypothesis proposed by Salari et al. (2021) and Odhiambo (2020) states that economic growth stimulates energy demand and that it is likely that energy conservation measures would not automatically inhibit growth trajectories. The feedback hypothesis, advanced by Wang et al. (2021), posits a bidirectional relationship, advocating for integrated policy approaches. Lastly, the neutrality hypothesis, discussed by Adewuyi and Awodumi (2017) and Mutumba et al. (2024), finds no significant causal relationship, suggesting that energy use does not meaningfully affect economic performance.

In Nigeria, for instance, Maji (2015) used the ARDL model to examine the role of clean energy in promoting economic growth from 1971 to 2011. The study established a negative and significant long-run relationship between alternative and nuclear power and economic growth, while combustible energy exhibited a positive and significant role. However, the impact of clean energy was positive but insignificant in the short run. Similarly, Imandojemu and Akinlosotu (2018) employed OLS and annual 1990–2017 data to find renewable energy consumption to have a positive and significant impact on growth in Nigeria. Further results establish unidirectional causality from economic growth to renewable energy validating the conservation hypothesis. Moreover, Uzokwe and Onyije (2020) also estimated the renewable energy-growth relationship employing ARDL method. Their evidence confirmed that the utilization of renewable energy results in economic growth in Nigeria. Second, the outcome of the Granger causality test also supports the neutrality hypothesis of non-causality among the two variables. Ikhide (2021) conduct a disaggregation on the combined effect of renewable and fossil energy consumption on economic growth in Nigeria. The empirical findings of the ARDL technique show that although conventional energy use is a strong growth driver in the long term, renewable energy consumption is a negative determinant of growth both in the short and long-term perspective. Likewise, Somoye et al. (2022) utilized the nonlinear ARDL and quarterly series data for 1990Q1–2019Q4, to examine the impact of renewable energy consumption on Nigeria's economic growth. The research finding indicates that a negative shock in renewable energy consumption brings about economic growth, whereas positive shock due to renewable energy consumption impaired economic growth.

Furthermore, Goshit, & Shido-Ikwu (2022) investigated how renewable energy consumption affects Nigeria's economic wealth from 1990 to 2019. Through the application of the ARDL approach and the Toda-Yamamoto causality approach, the study corroborates the negative and significant nexus between the consumption of renewable energy and economic growth in Nigeria. Besides, the finding offers proof of unidirectional causality running from renewable energy consumption to Nigerian economic growth. Conversely, employing the ARDL model with data for 1990–2020, Umeji et al. (2023) found that renewable energy positively and significantly impacts Nigeria's economic growth. Further findings reveal bidirectional causality between growth and energy consumption. Whereas Umar et al. (2024), through the use of the ADRL approach and data on an annual basis from 1996-2021, illustrates a negative and significant long-run relation between green energy and economic growth in Nigeria and then going ahead to demonstrate a neutrality hypothesis. Nwogwugwu and Ugwoke (2024), used the fixed effects model, to demonstrate the insignificant influence of both renewable and non-renewable energy on economic growth Nigeria. Similarly, Bank-Ola et al. (2024) examined the consumption of renewable energy and economic growth in Nigeria (1990–2022) using Johansen co-integration and VECM. The paper confirmed a short and long-run positive impact of renewable energy on economic growth. Furthermore, Atoyebi et al. (2024), empirically investigates the interconnectivity of renewable energy consumption and economic growth in Nigeria for the 32-year duration 1980–2022. They discovered that all renewable energy positively affects economic growth in the short-run and long-run. Finally, Onyekachi et al. (2025) reveals no causal relationship between renewable energy and economic growth Nigeria for the 1982–2022 period.

A review of the literature reveals that the relationship between renewable energy consumption and economic growth remains inconclusive. While some studies report positive associations, others find negative or ambiguous results, often due to variations in methodology, geographic focus, and time period. These inconsistencies highlight the need for deeper investigation into the precise nature of this relationship. Importantly, there is a growing need to move beyond examining the impact on growth alone and to explore how renewable energy influences economic productivity. To address this gap, the present study aims to examine the effect of renewable energy on both economic growth and productivity.

3. METHODOLOGY

3.1 Data Source and Description

This study utilizes two distinct datasets. The first dataset, covering the period from 1990 to 2023, is employed to examine the relationship between renewable energy consumption and economic growth in Nigeria. The second dataset, spanning from 2000 to 2023, is used to investigate the nexus between renewable energy use and economic productivity in the country. The dependent variables of this study are economic growth, captured through GDP in constant 2015 US dollars, and economic productivity, captured through the Productive Capacity Index. The most critical independent variable is renewable energy consumption. FDI, domestic credit (DC), natural resource endowment (NAR), and trade openness (TOP) serve as control variables. Expository variable description and data sources are provided in Table 1.

Table 1: Data Source and Measurement

Variable	**Notation**	**Measurement**	**Source**
Economic growth	GDP	GDP per capita growth (annual %)	WDI
Economic productivity	PC	Productive capacities index	UNCTAD
Renewable energy consumption	REC	Renewable energy consumption percentage of total final energy consumption	WDI
Foreign direct investment	FDI	Foreign direct investment inflow, net inflows per percentage of total GDP	WDI
Trade openness	TOP	Trade (% of GDP)	WDI
Domestic credit	DC	Domestic credit to private sector (% of GDP)	WDI
Natural resource endowment	NAR	Total natural resources rents (% of GDP)	WDI

Source: Authors computation Note: UNCTAD: United Nations Conference on Trade and Development. WDI: World Bank's World Development Indicators.

3.2 Econometric Model Specification

To examine the impact of renewable energy consumption on economic growth and productivity in Nigeria, this study employs the ARDL approach by Pesaran, Shin, and Smith (2001). ARDL is suitable due to its ability to capture long-run relationships, handle small samples, and accommodate variables integrated at I(0) and I(1). Following Nigeria-focused studies such as Ikhide (2021), Umeji et al. (2023), Sunday & Onisanwa (2024) and Umar et al. (2024), the ARDL(p, q) model for Model 1 is specified as follows:

$$\Delta GDP_t = \alpha_0 + \sum_{i=1}^{p} \delta_i \Delta GDP_{t-i} + \sum_{i=1}^{q} \beta_k \Delta REC_{t-i} + \sum_{i=1}^{q} \in_F \Delta FDI_{t-i} + \sum_{i=1}^{q} \gamma_l \Delta TOP_{t-i} + \sum_{i=1}^{q} \varphi_m \Delta DC_{t-i} + \sum_{i=1}^{q} \Psi_n \Delta NAR_{t-i} + \lambda_1 GDP_{t-1} + \lambda_2 REC_{t-1} + \lambda_3 FDI_{t-1} + \lambda_4 TOP_{t-1} + \lambda_5 DC_{t-1} + \lambda_6 NAR_{t-1} + \mu_t \quad (3.1)$$

Where: GDP is the dependent variable, with other variables as previously defined. α_0 is the drift term, μ_t is the white noise error, the summation terms capture short-run dynamics, and λ reflects the long-run relationship. Lag lengths p and q are selected using the Akaike Information Criterion (AIC). Equation (3.1) also applies the ARDL bounds test to assess the null hypothesis of no cointegration among the variables. The null hypothesis is $H_0 : \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = 0$, this states that there is no long-run relationship among the variables. While the alternative is $H_1 : \lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq \lambda_5 \neq 0$

Hence, the bounds testing approach is first used to confirm cointegration among variables. The short-run dynamics are then estimated using the restricted Error Correction Model (ECM) specified in Equation 3.2.

$$\Delta GDP_t = \alpha_0 + \sum_{i=1}^{p} \delta_i \Delta GDP_{t-i} + \sum_{i=1}^{q} \beta_k \Delta REC_{t-i} + \sum_{i=1}^{q} \in_F \Delta FDI_{t-i} + \sum_{i=1}^{q} \gamma_l \Delta TOP_{t-i} + \sum_{i=1}^{q} \varphi_m \Delta DC_{t-i} + \sum_{i=1}^{q} \Psi_n \Delta NAR_{t-i} + \Phi_1 ECM_{t-1} + \mu_t \quad (3.2)$$

Where, the speed of adjustment of the parameters for the long run equilibrium following a shock to the system is Φ_1, and the error correction model is ECM_{t-1}. To address Objective Two (Model 2), assessing the impact of renewable energy consumption on productive capacity growth in Nigeria and based on the confirmed evidence of cointegration, the restricted Error Correction Model (ECM) is specified as follows.

$$\Delta PC_t = \alpha_0 + \sum_{i=1}^{p} \delta_i \Delta PC_{t-i} + \sum_{i=1}^{q} \beta_k \Delta REC_{t-i} + \sum_{i=1}^{q} \in_F \Delta FDI_{t-i} + \sum_{i=1}^{q} \gamma_l \Delta TOP_{t-i} + \sum_{i=1}^{q} \varphi_m \Delta DC_{t-i} + \sum_{i=1}^{q} \Psi_n \Delta NAR_{t-i} + \Phi_1 ECM_{t-1} + \mu_t \quad (3.3)$$

Where: PC denotes economic productivity (measured by the productive capacity index) as the dependent variable, with other variables as previously defined. The study performs two unit root pre-estimation tests: the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (1988) test for robustness. Cointegration is tested using the ARDL bounds test. Diagnostic tests are serial correlation, normality (Jarque-Bera), heteroskedasticity (ARCH), and model stability (CUSUM and CUSUMSQ). Finally, Pairwise Granger causality (1969) is used to determine the direction of causality, which may be unidirectional, bidirectional, or neutral (Maganya, 2020).

4. PRESENTATION AND DISCUSSION OF FINDINGS

This chapter begins with a statistical analysis of the data, including descriptive statistics, correlation matrix, and unit root testing for Model 1. A similar set of pre-estimation tests was conducted for the alternative model specification (Model 2), which considers economic productivity as the dependent variable; these results are available upon request. Subsequently, the ARDL bounds testing approach was employed to examine cointegration relationships, followed by a detailed discussion of the empirical findings.

Table 2: Descriptive statistics

Variable	GDP	REC	FDI	TRD	DC	NAR
Mean	3.23E+11	84.27426	1.295099	36.1617	10.4362	14.92549
Median	3.00E+11	84.5	1.28855	35.25827	10.06369	15.33051
Maximum	5.51E+11	88.6	2.900249	53.27796	19.6256	34.2695
Minimum	1.53E+11	79.9	-0.03913	20.72252	4.957522	4.554107
Std. Dev.	1.46E+11	2.722191	0.84295	8.610805	3.493004	6.812113
Skewness	0.172316	-0.14363	0.168735	0.178825	0.690591	0.539894
Kurtosis	1.402777	1.670696	1.887254	2.341792	3.196027	3.207051
Jarque-Bera	3.782346	2.620226	1.915461	0.794964	2.756962	1.712485
Probability	0.150895	0.26979	0.383763	0.67201	0.251961	0.424755
Sum	1.10E+13	2865.325	44.03338	1229.498	354.8309	507.4666
Sum Sq. Dev.	7.08E+23	244.5406	23.44866	2446.817	402.6356	1531.361
Observations	34	34	34	34	34	34

Source: Authors

Table 2 presents descriptive statistics for variables used in Model 1. Renewable energy consumption, trade openness, and natural resource endowment show the highest means and standard deviations. Most variables cluster around their means and exhibit normal distribution, as indicated by Jarque-Bera statistics above the 5% level. Table 3 displays the correlation matrix, revealing no signs of collinearity, especially relevant as the alternative model using economic productivity as the dependent variable is analyzed separately.

Table 3: Correlation Matrix for The Variables

Column1	GDP	REC	FDI	TRD	DC	NAR
GDP	1	-0.83009	-0.33396	-0.45386	0.694928	-0.8037
REC	-0.83009	1	0.437669	0.383239	-0.37522	0.69488
FDI	-0.33396	0.437669	1	0.262211	0.135419	0.453347
TRD	-0.45386	0.383239	0.262211	1	-0.2428	0.438507
DC	0.694928	-0.37522	0.135419	-0.2428	1	-0.59507
NAR	-0.8037	0.69488	0.453347	0.438507	-0.59507	1

Source: Authors

To avoid the risk of spurious regression, this study conducts stationarity tests for all variables using two widely recognized methods: the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test, as presented in Table 4.

Table 4: Unit Root Result for The Variables

	ADF TEST			**PP TEST**		
Variable	**Level stats.**	**1st diff.**	**Order of integration**	**Level stats.**	**1st Diff.**	**Order of integration**
GDP	0.1077	-2.9562*	I(1)	0.4976	-2.9076*	I(1)
REC	-1.5164	-6.1449**	I(1)	1.4961	-6.1597***	I(1)
FDI	-1.8648	-6.9672***	I(1)	-2.3702	-7.1225***	I(1)
TRD	-3.0286**	-5.5174***	I(0)	-3.0442**	-10.3808	I(0)
DC	-2.6593*	-5.3053***	I(0)	-1.8239	-6.2749***	I(1)
NAR	-1.1974	-1.8517	---	-2.1970	-15.5630***	I(1)

Source: Authors **Note: *, **, ***** denote significance at 1%, 5% and 10% level respectively.

The unit root test results in Table 4 show that all variables are stationary at level or first difference, indicating a mix of I(0) and I(1) series. Trade openness and domestic credit are stationary at level, while GDP, renewable energy consumption, FDI, and natural resource endowment become stationary after first differencing. No variable is integrated of order two, confirming ARDL suitability. A similar stationarity pattern holds for the model with economic productivity as the dependent variable.

Table 5: ARDL Bound Test for Cointegration

Bound Test Results for the ARDL					
Model 1			**Model 2**		
F-statistic	7.132191		13.01738		
K	5		5		
		Critical Bound			
	I(0)	I(1)	I(0)	I(1)	Sig. level
	2.49	3.38	2.26	3.35	10%
	2.81	3.76	2.62	3.79	5%
	3.11	4.13	2.96	4.18	2.5%
	3.5	4.63	3.41	4.68	1%

Source: Authors

Table 5 provides the ARDL bounds test for Model 1 and Model 2. Both F-statistics for Model 1 (7.13) and Model 2 (13.02) are greater than their corresponding upper bounds (3.76 and 3.79) at the 5% level of significance, confirming the presence of a long-run equilibrium relationship. Thus, a restricted Error Correction Model (ECM) is hypothesized.

Table 6: ARDL Long Run and Short Run.

Short Run ARDL Estimation Result		
	Economic Growth Panel 1	**Economic Productivity Panel 2**
Variables	**Coefficient**	**Coefficient**
GDP_{t-1}	---	---
PCI_{t-1}	---	-1.1238*** (0.1361)
D(REC)	---	-0.0099*** (0.0019)

D(FDI)	0.0090	-0.0140**
	(0.0058)	(0.0054)
D(TRD)	0.0479**	-0.0049***
	(0.0179)	(0.0005)
D(DC)	---	0.0195***
		(0.0015)
D(NAR)	---	0.1239***
		(0.0135)
ECM	-0.165592***	-0.231777***
	(0.0206)	(0.0200)
Long-Run ADRL Estimation Result		
REC	-4.5480***	-0.1527**
	(1.4515)	(0.0522)
FDI	0.2508***	0.2152
	(0.0647)	(0.1339)
TRD	0.5397**	-0.0284**
	(0.2557)	(0.0086)
DC	0.1238	0.0654***
	(0.2138)	(0.0126)
NAR	-0.2088*	0.6773**
	(0.1141)	(0.1746)

Source: Authors Note: *, **, *** denote significance at 1%, 5% and 10% level respectively. Standard Errors in Parenthesis.

Table 6 presents the short- and long-run estimates from the ARDL models. Panel 1 reveals that renewable energy consumption exerts a statistically significant negative effect on economic growth in the long run, wherein a 1% increase in renewable energy use corresponds to a 4.548% decline in GDP. This finding supports previous research by Maji (2015), Iklude (2021), Goshit and Shido-Ikwu (2022), and Umar et al. (2024), which found negative impacts of renewable energy on Nigeria's economic growth. Conversely, it is in contradiction with Bank-Ola et al. (2024), who report positive effects in the short and long run. The negative long-run impact of renewable energy consumption on Nigeria's GDP points to structural issues such as limited infrastructure, slow development, and a reliance on nonrenewable energy sources. Furthermore, the large initial investment necessary for renewables such as wind and solar plants might divert scarce resources away from more productive uses in the short term, compromising short-term economic performance. To address these issues, well-designed regulations that position renewable energy as a cleaner alternative and complementary production input are needed. According to Tugcu (2013), Iklude (2021), and Umar et al. (2024), such a plan has the potential to promote economic growth, support environmental goals, and assist Nigeria in transitioning to a more sustainable and resilient economy.

In addition, Panel 1 of Table 6 indicates that foreign direct investment (FDI) has a positive but statistically insignificant effect on economic growth in the short term. This impact, however, becomes statistically significant in the long run, with the implication that advantages such as capital inflow, technology transfer, and human capital formation take time to manifest in terms of growth. This finding is in agreement with El-Rasheed and Abdullahi (2022) and Rao et al. (2020) that point to the contribution of FDI towards long-term economic growth in developing economies. Trade openness also positively and significantly influences economic growth at the 5% level in the short and long term, indicating how openness enhances access to markets, competition, and productivity. In addition, long-run estimates in Panel 1 of Table 6 confirm that domestic credit has a significant and positive impact on economic growth, lending credence to Atoyebi et al. (2024)'s contention that credit access promotes investment and productive capability. Likewise, natural resource endowment negatively and significantly impacts long-run economic growth, lending credence to the resource curse hypothesis (Auty, 1994; Sachs & Warner, 1995). This outcome may be the consequence of poor resource management, rent-seeking, and low investment in human and physical capital in Nigeria that have stifled sustainable development.

On the other hand, Panel 2 of Table 6 presents the results from Model 2, which examines the impact of renewable energy consumption on economic productivity in Nigeria. The findings indicate a significant negative effect of renewable energy consumption on productivity in both the short and long run, consistent with Panel 1's results on economic growth. This negative impact may also be attributed to the high upfront capital costs associated with renewable energy technologies, which can divert investment away from more immediately productive sectors, thereby reducing overall economic productivity. Additionally, the impact of FDI on productivity is negative and statistically significant in the short run. However, in the long run, this effect becomes positive but statistically insignificant. This contrasts with Panel 1, where FDI had a positive effect on economic growth. The discrepancy suggests that while FDI may boost long-term growth with appropriate policies, in the short term, it can crowd out local businesses due to capital-intensive foreign operations. As such, FDI policies should aim to avoid undermining domestic enterprises. Trade openness also negatively and significantly influences productivity in both the short and long run, unlike its positive effect on GDP. This may reflect Nigeria's trade imbalance, exporting raw materials and importing finished goods leading to a preference for foreign products, thereby stifling local innovation. Moreover, domestic credit has a positive impact on productivity in the short term but becomes insignificant in the long term. Finally, natural resource endowment significantly enhances productivity in both the short and long run. This result diverges from the resource curse hypothesis as outlined in Panel 1, thereby suggesting that, under conditions of sound institutional and economic governance, natural resource endowments can be harnessed to foster long-term economic development through broad-based improvements in industrial productivity.

Besides, the error correction terms (ECMs) for models 1 and 2 are negative, less than one, and significant at 5% level, favoring stable adjustment from short-run disequilibrium to long-run equilibrium. In Model 1, the adjustment speed is 16.5% per annum, implying about 12.76 years to correct 90% of short-run deviations. Model 2 adjusts faster, at 23% per annum, requiring approximately 8.73 years for similar correction. Pairwise Granger causality test (results available upon request) reveals one-way causality of GDP growth to REC, consistent with conservation hypothesis of Odhiambo (2020) and Salarie et al. (2021), who contend that consumption of renewable energy is determined by economic growth rather than the other way round. In addition, the test confirms causality from REC to economic productivity, in support of the growth hypothesis of Goshit and Shido-Ikwu (2022) and Chen et al. (2020) that greater consumption of renewable energy results in improved economic performance. Moreover, post-estimation diagnostic tests in Table 7, including checks for serial correlation, heteroskedasticity, normality, stability, and the Ramsey RESET test confirm the robustness and reliability of the models. Hence, strengthening the credibility and validity of the study's conclusion.

Table 6: Diagnostic Test

Tests	Model 1	Model 2
Breusch-Godfrey LM test	1.4828 (0.2521)	0.5288(0.6190)
Heteroscedasticity (Breusch-Pagan)	7.2273 (0.7038)	2.7231(0.0934)

Normality (Jarque–Bera)	1.6331 (0.4422)	0.0882(0.9568)
Ramsey reset test	3.5779 (0.0731)	0.1039(0.7581)
CUSUM at 5%	Stable	Stable
CUSUM Squared at 5%	Stable	Stable

Source: Authors Note: Probability Values in Parenthesis.

5. CONCLUSION AND POLICY IMPLICATION

This study examines the impact of renewable energy consumption on economic growth and productivity in Nigeria, using two datasets covering the periods 1990–2023 and 2000–2023. The Autoregressive Distributed Lag (ARDL) bounds testing approach is employed to analyze the dynamic relationships, while the Pairwise Granger causality test is used to determine the direction of causality among variables. The key findings are as follows: (i) renewable energy consumption has a significant negative effect on economic growth in the long run; (ii) it also exerts a negative and significant impact on economic productivity in both the short and long run; (iii) there is unidirectional causality from economic growth to renewable energy consumption, and from renewable energy consumption to economic productivity; (iv) FDI and trade openness support economic growth but undermine economic productivity; (v) while natural resource endowment negatively affects economic growth, it significantly enhances economic productivity; and (vi) domestic credit to the private sector positively influences both economic growth and productivity. These findings carry some important policy implications.

Hence, policymakers should consider a phased transition to renewable energy to mitigate the economic impacts associated with high upfront investment costs. A gradual approach allows the economy to adjust while reducing short-term disruptions. To support this transition, financial incentives such as subsidies, tax credits, and low-interest loans can encourage private investment. Additionally, targeted investments in grid modernization, energy storage, and advanced infrastructure will enhance efficiency and drive down long-term costs. Strengthening support for research and development (R&D) can further improve energy conversion technologies and minimize adverse effects on productivity. Maintaining a balanced energy mix of renewable and non-renewable sources is also essential to ensure supply stability. Ultimately, policies should focus on maximizing the long-term benefits of renewable energy by promoting efficient systems, such as smart grids and integrated storage solutions.

Acknowledgement

The authors acknowledge the University of Nigeria Graduate Economic Research Group (GERG) for technical support and thank the editor and anonymous reviewers for their valuable feedback.

Author contribution: OZP: Conceptualization, econometric analysis, results evaluation, and supervision. IA: Conceptualization, econometric analysis, introduction, and literature review writing IF: Review, editing, suggestions, and drafting conclusions and recommendations. All authors reviewed and approved the final manuscript.

Funding: The project was completed without any funding.

Availability of Data and material: The data sets used in the current investigation will be made available by the corresponding author upon reasonable request.

Declarations

Competing interests

The authors declare no competing interests.

REFERENCES

Akinwale, Y. O., & Ogundari, I. O. (2017). Exploration of renewable energy resources for sustainable development in Nigeria: A study of the Federal Capital Territory. *International Journal of Energy Economics and Policy*, 7(3), 290–296.

Akinwande, T. S., Turuc, F., Seraj, M., & Ozdeser, H. (2025). The link between gender inequality, financial development, and economic growth in Nigeria: A spectral Granger causality approach. *Sustainable Development*, 33(2), 2429-2439.

Anderson (2024). Maximizing Nigeria's Renewable Energy Potentials for Sustainable Growth and Development. Retrieved May 28, 2025, from https://ng.andersen.com/maximizing-nigerias-renewable-energy-potentials-for-sustainable-growth-and-development/

Apergis, N., Payne, J.E., (2009). Energy consumption and economic growth in Central America: evidence from a panel co-integration and error correction model. *Energy Economics*, 31(2), 211-216.

Atoyebi, K., Abari-Ogunsona, T., & Danmola, R. (2024). Renewable energy sources, financial development and economic growth in Nigeria. *LASU Postgraduate School Journal (LPSJ)*, 1(1), 130–145.

Auty, R. M. (1994). Industrial policy reform in six large newly industrializing countries: The resource curse thesis. *World Development*, 22(1), 11-26.

Bank-Ola, R. F., Adediwura, O. M., Alao-Owunna, I., & Udofia, V. C. (2024). Revisiting the Nexus between Renewable Energy Consumption and Economic Growth in Nigeria: The VECM Approach. *Journal of Energy Research and Reviews*, 16(4), 1-14.

Behera, B., Sucharita, S., Patra, B., & Sethi, N. (2024). A blend of renewable and non-renewable energy consumption on economic growth of India: The role of disaggregate energy sources. *Environmental Science and Pollution Research*, 31(3), 3902-3916.

Biala, M. I., Aromasodun, O. M., & Shitu, A. M. (2025). Energy-Growth Nexus: A Systematic Review of Empirical Evidence and Policy Implications. *African Journal of Environmental Sciences and Renewable Energy*, 18(1), 178-197.

Bisu, A. A., Ahmed, T. G., Ahmad, U. S., & Maiwada, A. D. (2024). A SWOT analysis approach for the development of photovoltaic (PV) energy in Northern Nigeria. *Cleaner Energy Systems*, 9(1), 100128.

Chandio, A. A., Rauf, A., Jiang, Y., Ozturk, I., & Ahmad, F. (2019). Cointegration and causality analysis of dynamic linkage between industrial energy consumption and economic growth in Pakistan. *Sustainability*, 11(17), 4546.

Chen, X., Shuai, C., Zhang, Y. and Wu, Y. (2020). Decomposition and its decoupling with economic growth in the global Agricultural industry. *Environmental Impact Assessment review*, 81(1), 106364.

Ellabban, O., Abu-Rub, H., & Blaabjerg, F. (2014). Renewable energy resources: Current status, future prospects and their enabling technology. *Renewable and sustainable energy reviews*, 39, 748-764.

El-Rasheed S. & Abdullahi BM (2022). Revisiting Foreign Direct Investment-Economic Growth Nexus In Nigeria: An ARDL Approach. *Journal of Economics and Allied Research*, 7(4), 29-41.

Goshit, G. G., & Shido-Ikwu, S. B. (2022). Impact of renewable energy consumption on economic growth in Nigeria. *International Journal of Economics and Development Policy*, 5(1), 811-2288.

Granger, C. W. (1969). Investigating causal relations by econometric models and cross-spectral methods. Econometrica: *Journal of the Econometric Society*, 424-438.

Ikhide, E. E. (2021). Alternative energy consumption and economic growth in Nigeria. *Journal of Economics and Allied Research*, 6(1), 1-20.

Imandojemu, K., & Nathaniel Toyosi, A. (2018). Renewable energy consumption and economic growth in Nigeria: A co-integration and granger causality approach. *Bullion*, 42(2), 4.

IMF: World Economic Outlook, April 2024; Steady but Slow: Resilience amid Divergence; Washington, D.C.

International Energy Agency. (2024). SDG7: Data and Projections. Paris: IEA. Retrieved from https://www.iea.org/reports/sdg7-data-and-projections

IRENA (2023), Renewable Energy Roadmap: Nigeria, International Renewable Energy Agency, Abu Dhabi.

Kasperowicz, R., Bilan, Y., & Štreimikienė, D. (2020). The renewable energy and economic growth nexus in European countries. *Sustainable Development*, 28(5), 1086-1093.

Lewis, W. A. (1954). Economic development with unlimited supplies of labour. 139-191.

Maganya, M. H. (2020). Tax revenue and economic growth in developing country: an autoregressive distribution lags approach. *Central European Economic Journal*, 7(54), 205-217.

Maji, I. K. (2015). Does clean energy contribute to economic growth? Evidence from Nigeria. *Energy Reports*, 1, 145-150.

Mutumba, G. S., Odong, T., & Bagire, V. (2024). Modelling renewable energy consumption and economic growth in Uganda. *International Journal for Multidisciplinary Research*, 6(2), 2582-2160.

Ndukwu, M. C., Onwude, D. I., Bennamoun, L., Abam, F. I., Simo-Tagne, M., Horsfall, I. T., & Briggs, T. A. (2021). Nigeria's Energy deficit: The challenges and Eco-friendly approach in reducing the energy gap. *International Journal of Sustainable Engineering*, 14(3), 442-459.

Nwogwugwu, U. C., & Ugwoke, T. I. (2024). Energy diversification in Africa: The panacea for solving the energy paradox. *Journal of Economics and Allied Research*, 9(2), 327-339.

Obiukwu, N., Nwosu, C. A., & Chukwu, I. C. (2024). Effect of Trade Liberalization and Manufacturing Sector on Economic Growth in Nigeria. *Journal of Economics and Contemporary Policies*, *1*(1), 108-121.

Odhiambo, N. M. (2021). Energy consumption and economic growth in Botswana: Empirical evidence from disaggregated data. *International Review of Applied Economics*, 35(1), 3-24.

Okedu, K. E., Uhunmwangho, R., & Wopara, P. (2015). Renewable energy in Nigeria: The challenges and opportunities in mountainous and riverine regions. *International Journal of Renewable Energy Research*, 5(1), 222-229.

Okoh, A. (2025). Privatization of Nigeria's Telecommunications Sector: A Comprehensive Case Study. *African Journal of Management and Business Research*, 18(1), 387-417.

Okoroafor, S. N., Okoroafor, M. C., & Amadi, M. U. (2025). Fuel Subsidy Removal: Implications on the Nigerian Economy. *Energy Transition, Climate Action and Sustainable Agriculture* (pp. 69-94). Springer, Cham.

Okubanjo, A. A., Okandeji, A. A., & Osifeko, M. (2022). Off-Grid mobile phone charging systems for rural energy needs. *Journal of Engineering and Technology for Industrial Application*s, 8(38), 37-44.

Onyechi, T. G., & Ejiofor, C. C. (2021). Decarbonizing Nigeria's energy mix: the role of renewable energy consumption. *Journal of Economics and Allied Research*, 6(2), 12-22.

Onyekachi, A., Geraldine, N., Kenechukwu, O., & Mathew, N. (2025). Energy consumption and Economic Growth in Nigeria. *Nau Eco Journals*, 15(2), 16-33.

Opoku- Mensah, E., Chen, W., Tuffour, P., Agozie, D. Q., Gyamfi, B. A., & Mahmoud, A. (2025). Toward sustainable energy transition: Unveiling the synergies of democracy, energy justice, and structural adjustment on emissions in West Africa. *Sustainable Development*, 33(1), 379-398.

Oyaromade, R., Mathew, A., & Abalaba, B. P. (2014). Energy consumption and economic growth in Nigeria: A causality analysis. *International Journal of Sustainable Energy and Environmental Research*, 3(1), 53-61.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3), 289-326.

Raihan, A., Ibrahim, S., Ridwan, M., Rahman, M. S., Bari, A. M., & Atasoy, F. G. (2025). Role of renewable energy and foreign direct investment toward economic growth in Egypt. *Innovation and Green Development*, 4(1), 100185.

Rao, D.T., Sethi, N., Dash, D.P. & Bhujabal, P. (2020). Foreign Aid, FDI and Economic Growth in South-East Asia and South Asia. *Global Business Review*, 24(4), 1–17.

Renewable Association of Nigeria (2024). Bridging The Gap: Addressing Energy Poverty, Inequality Through Renewable Energy: https://rean.org.ng/bridging-the-gap-addressing-energy-poverty-inequality-through-renewable-energy

Sachs, J. D., & Warner, A. (1995). Natural resource abundance and economic growth.

Salari, M., Javid, R. J., & Noghanibehambari, H. (2021). The nexus between CO2 emissions, energy consumption, and economic growth in the US. *Economic Analysis and Policy*, 69, 182-194.

Simonyan, K. J., & Fasina, O. (2013). Biomass resources and bioenergy potentials in Nigeria. *African Journal of Agricultural Research*, 8(40), 4975-4989.

Somoye, O. A., Ozdeser, H., & Seraj, M. (2022). The impact of renewable energy consumption on economic growth in Nigeria: fresh evidence from a non-linear ARDL approach. *Environmental Science and Pollution Research*, 29(41), 62611-62625.

Sovacool, B. K. (2016). How long will it take? Conceptualizing the temporal dynamics of energy transitions. *Energy research & social science*, 13, 202-215.

Statista, (2024). Total renewable energy capacity in Nigeria from 2011 to 2023 https://www.statista.com/statistics/1278083/renewable-energy-capacity-in-nigeria/

Stolten, D., & Scherer, V. (Eds.). (2013). Transition to renewable energy systems. John Wiley & Sons.

Sunday, O. A., & Onisanwa, I. D. (2024). Income Inequality and health Outcomes in Nigeria. *Journal of Economics and Allied Research*, 9(3), 84-96.

Tugcu, C.T. (2013). Disaggregate energy consumption and total factor productivity: a cointegration and causality analysis for the Turkish economy. *International Journal of Energy Economics and Policy*, 3(3), 307-314.

Umar, H. M. B., Sakanko, A. M., Ahmed, M., & Sadiq, A. A. (2024). Renewable Energy Consumption and Economic Growth in Nigeria Nexus. *Lapai Journal of Economics*, 8(1), 287-300.

Umeji, G., Anthony O.A., Eberechukwu E., Matthew E., Okenyeka O.N., Mbadiwe. T.O.(2023). Renewable Energy Consumption and Economic Growth in Nigeria. *African Journal of Social Sciences and Humanities Research*. 6. 34-48.

Uzokwe, A. E., & Onyije, I. (2020). Renewable and non-renewable energy consumption and economic growth-a case of Nigeria. *International Journal of Economics and Management Studies*, 7(1), 1-9.

Wang, J., Zhang, S., & Zhang, Q. (2021). The relationship of renewable energy consumption to financial development and economic growth in China. *Renewable Energy*, 170, 897-904.

World Bank. (2024). Global Economic Prospects, June 2024. Washington, DC: World Bank. Retrieved from https://www.worldbank.org/en/publication/global-economic-prospects

Zhang, C., & Tan, T. (2020, October). Analysis of the impact of energy consumption on economic growth in Guangdong Province. In IOP Conference Series: *Earth and Environmental Science* (Vol. 585, No. 1, p. 012015). IOP Publishing.