Open Access Library Journal
2026, Volume 13, e14430
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Investigating the Causal Relationship between Energy Consumption and Economic Growth in Nigeria

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How to cite this paper: Aleshinloye, M.F. (2026) Investigating the Causal Relationship between Energy Consumption and Economic Growth in Nigeria. *Open Access Library Journal*, **13**: e14430.
https://doi.org/10.4236/oalib.1114430

Received: October 11, 2025
Accepted: January 12, 2026
Published: January 15, 2026

Abstract

This study examines the link between Nigeria's economic growth and energy consumption from 1981 to 2024. The analysis validates a long-term equilibrium between consumption of energy, GDP, and associated variables using Granger causality tests, impulse response functions, the Vector Error Correction Model (VECM), and Johansen cointegration. The findings indicate that increase is largely driven by crude oil consumption, with coal playing a modest contribution and electricity having lag effects. Although growing CO_2 emissions draw attention to sustainability issues, economic growth and energy consumption show bi-directional causality, highlighting a feedback link. The study suggests increasing efficiency, bolstering capital formation, shifting Nigeria's energy mix towards renewable sources, and incorporating environmental regulations into growth plans.

Subject Areas

Economic Growth and Environmental Sustainability

Keywords

Energy Consumption, Economic Growth, Cointegration, VECM, Nigeria

1. Introduction

In development economics, the relationship between energy use and economic expansion has long been an ongoing debate, especially when discussing developing countries like Nigeria. In addition to being a vital component of manufacturing, energy also propels industrialisation, technical development, and general economic change. Almost every economic activity, from industry and services to agriculture, depends on accessible, reasonably priced, and dependable energy [1]-[3]. There are significant ramifications for public policy, investment planning, and the pursuit of sustainable development when it comes to the question of whether growth drives energy demand or energy consumption drives growth [4] [5].

The energy sector in Nigeria offers a fascinating context for this discussion. The nation still faces significant energy supply shortages even though it is abundantly endowed with water, natural gas, crude oil, and new potential for renewable energy. Performance has been limited by structural flaws such as inadequate infrastructure, ineffective distribution, and an excessive reliance on fossil fuels. Nearly 85 million Nigerians still do not have access to dependable electricity, a fact that continues to restrict productivity and competitiveness across industries, according to the [6]. Therefore, it is essential to comprehend the causal relationship between growth and energy consumption in order to inform policies that deal with these enduring limitations.

The outcomes of empirical research on this topic have been conflicting. Using an ARDL model, [7] discovered strong short- and long-term relationships between GDP and energy use that were mitigated by pricing and structural changes. According to [8], there is a long-term balance between energy output and consumption, but it is susceptible to fluctuations in energy prices. However, some research reveals no substantial association between growth and energy use, while others indicate unidirectional causality, highlighting methodological discrepancies and data limitations. Despite the fact that energy shortages are frequently mentioned as a binding limitation on Nigeria's growth trajectory, these contradictions have left policymakers with little clarity [9].

By re-examining the long-term relationship between energy consumption and economic growth in Nigeria from 1981 to 2024 and identifying the direction of causality between the two, this study aims to close that gap. This paper is organised into five sections: methodology, empirical analysis, literature review, introduction, and conclusion with suggestions.

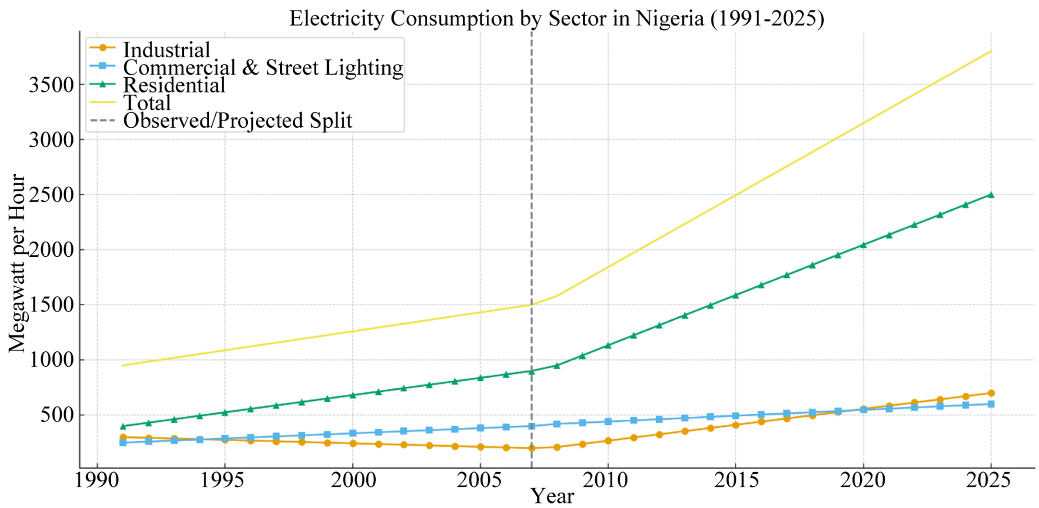
2. Literature Review

2.1. Stylized Facts on Electricity Consumption (Energy) and Economic Growth in Nigeria

The electricity consumption trends between 1991 and 2025 as depicted in **Figure 1**, reveal both the growing importance of energy demand in Nigeria's economy and the persistent structural challenges of the power sector. Residential consumption dominates throughout the period, rising steadily and projected to surpass 2,500 MW/hr by 2025. This growth reflects rapid urbanisation, population expansion to over 220 million, and rising household demand for basic and modern energy services. By contrast, industrial consumption declined through the 1990s and early 2000s due to supply unreliability, infrastructure decay, and economic stagnation. Its gradual recovery after 2010 is linked to policy reforms, such as the Power Sector Reform Act of 2005 and the privatisation of generation and distribution companies in 2013, which created opportunities for new industrial users, particularly in cement, steel, and agro-processing.

Commercial and street lighting have grown more modestly but show a post-2015 boost, partly driven by urban expansion and off-grid solar lighting initiatives. The total demand for electricity more than triples over the period, from about 1000 MW/hr in the early 1990s to nearly 3800 MW/hr by 2025 [10]. Yet, actual supply consistently lags behind demand, reflecting challenges in generation, transmission, and distribution.

These patterns underscore the energy–growth nexus: Nigeria's economic performance remains constrained by inadequate electricity supply, while rising demand signals both economic transformation and energy sector bottlenecks. The 2022 Energy Transition Plan further highlights the urgency of expanding renewable capacity and diversifying supply sources to meet demand sustainably while reducing reliance on fossil fuels.



Source: International Energy Agency (IEA) (2022) Nigeria Energy Profile. Paris: IEA.

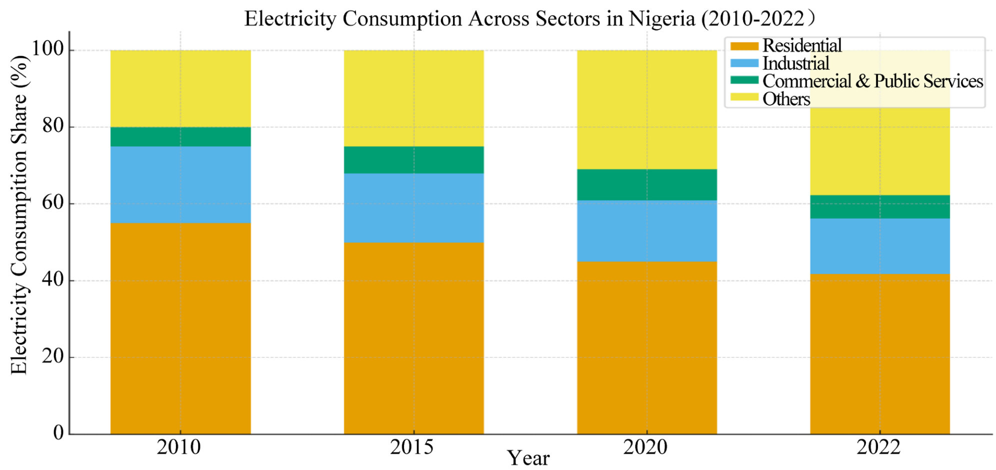
Figure 1. Consumption of electricity across sectors of the Nigerian economy.

The distribution of electricity consumption across sectors in Nigeria between 2010 and 2022 highlights both persistent structural challenges and evolving demand patterns. Residential consumption has consistently dominated, accounting for over half of total demand in 2010 before declining gradually to around 42% in 2022. This reflects rapid population growth and urbanisation, coupled with the rising use of electrical appliances. However, the decline in residential share is less about efficiency gains and more about the relative growth of other categories.

Industrial consumption fell from about 20% in 2010 to just under 15% in 2022 as depicted in Figure 2. This decline illustrates the vulnerability of Nigeria's manufacturing sector to unreliable electricity supply, high costs, and weak infrastructure. Despite reforms such as the Electric Power Sector Reform Act (2005) and privatisation in 2013, industries have often relied on self-generation through diesel and gas, which constrains productivity and competitiveness.

Commercial and public services remained stable, between 6% and 8%, while "other uses" (including agriculture, transmission losses, and unclassified demand) grew significantly, rising from 20% to nearly 38%. This surge underscores systemic inefficiencies and unaccounted-for consumption in Nigeria's grid [11].

Overall, the data reflects Nigeria's heavy reliance on residential demand, weak industrial utilisation, and rising system inefficiencies—issues that limit the energy sector's contribution to long-run economic growth.



Source: International Energy Agency (IEA) (2022) Nigeria Energy Profile. Paris: IEA.

Figure 2. Consumption of Electricity across Sectors of the Nigerian Economy.

2.2. Methodological Review

ARDL Bounds Testing, which is valued for its ability to accommodate mixed-order integrated series and efficiently estimate short- and long-run coefficients, is primarily used by researchers examining the energy-growth dynamics of Nigeria. The Lincoln University research (2024/2025) [7], [12] and [13] all use ARDL frameworks to capture dynamic inter-variable connections and adjustment processes.

The Toda-Yamamoto augmented Granger causality test, which has the advantage of being robust to pre-testing criteria, is used in numerous studies to determine causality. The works evaluating sectoral impacts and renewable versus non-renewable energy demonstrate this analytical approach, which permits reliable inference even in cases where data may be nonstationary.

According to [14], who model multivariate nexus and find equilibrium and causation interplays across energy kinds and GDP, also prominently utilise VECM with Johansen cointegration, demonstrating the method's strength in examining feedback loops.

More recent methods such as Bootstrap ARDL and Quantile ARDL provide more sophisticated insights in light of model sensitivity and data distribution issues [15]. These methods generally enable robust inference under non-normal residuals (bootstrap) or impacts across conditional GDP distribution (quantile), albeit specifics were not included in the sources collected here. For example, [16] quantile method accounts for the varying effects of policy uncertainty, institutional quality, and the distribution of the renewable transition.

Lastly, [7] and [17] demonstrate how regression-based price modelling, which has less dynamic insight than ARDL or VECM, highlights the usage of classical methods, such as multiple regression, to separate price effects [18].

These approaches work well together as a suite. Regression separates important policy-sensitive variables like energy price; bootstrap and quantile techniques improve robustness and depth; VECM structures multivariate equilibrium assessments; Toda-Yamamoto reinforces causal inference; and ARDL offers flexible modelling of dynamic linkages.

In conclusion, this research shows that Nigeria's energy consumption plays a major role in supporting economic growth, with the story being shaped by sectoral, temporal, and welfare considerations. The techniques used, particularly ARDL and its relatives, provide a comprehensive toolkit that can capture intricate dynamics. In order to find both aggregate and distributional insights, this 1981-2024 study would benefit from using a hybrid methodological framework that combines ARDL, causality testing, potentially VECM, and possibly quantile modelling.

2.3. Empirical Review

The critical role that energy consumption, especially that of gas and electricity, plays in supporting economic performance is a recurring theme in research on the relationship between energy and growth in Nigeria. While current-year electricity consumption has a negligible and even negative impact on GDP growth, the first lag of electricity consumption has a positive and significant impact, indicating that historical energy availability is crucial for today's economic output, according to [12] ARDL analysis covering 1990-2023. The Lincoln University study (2024/2025), which used ARDL and forecasting from 1980 to 2022, confirms both short- and long-run energy effects on growth, especially when taking population trends into consideration. This temporal dynamic is consistent with findings from more comprehensive analyses.

Divergent patterns appear when energy is broken down by source. According to studies like [13] and the "Exploring Renewable Energy & Oil Price" (2025) analysis, which uses ARDL with Toda-Yamamoto causality, oil prices significantly boost sectoral activity across a range of economic sectors, even though renewable energy makes a positive, albeit erratic, contribution to long-term growth. Using VECM and Granger causality for the years 1990-2022, [14] find a stable long-term relationship between energy and growth, but they do not find a significant causal link when separating renewable energy from non-renewable energy. This suggests that interactions between different types of energy are more complex than aggregate measures show.

In addition, broader analyses draw attention to the contextual and methodological complexity. A long-term bidirectional causal relationship between energy and growth is detected by [19] in panel ARDL/PMG across developing African economies (1980-2020); Nigeria reflects this pattern in the cross-national picture. The significance of environmental considerations also emerges: [16] ARDL analysis on economic growth, CO_2 emissions, and the renewable transition demonstrates the long-term interconnectedness of these variables, highlighting the importance of green energy in Nigeria's sustainable development goal.

The discussion is expanded to include pricing and welfare consequences in other studies. According to [7], energy prices—rather than just consumption—have an impact on GDP over the long run. While crude oil prices boost growth, electricity prices stifle it. Price sensitivity in policy design is further supported by [17] examination of energy pricing indices (coal, gas, and crude oil), which confirms that changes in energy prices have a major impact on economic output.

When human development results are taken into account, the story becomes much more complicated. According to research by [20], there is no discernible correlation between Nigeria's Human Development Index (HDI) and power usage. This shows that having access to energy does not always result in increased welfare, particularly if distribution or quality disparities continue.

The use of electricity has both short-term and long-term positive effects on economic expansion, according to [21]. Based on these findings, the study recommended the implementation of an effective energy policy that promotes sustainable consumption, which would help the economy quickly return to equilibrium after any economic disturbances. [22] comes to the conclusion that relevant environmentally friendly initiatives aimed at reducing carbon emissions include measures that enhance energy efficiency, price controls on carbon instruments in production and international-domestic trade activities, and nationwide social awareness programs to instruct about the detrimental effects of pollution.

According to [23], urbanisation exhibits a positive U-shaped trend in the middle region and an inverted U-shaped relationship with CO_2 emissions in the eastern part. In the western region, however, the nonlinear effect of urbanisation on CO_2 emissions is negligible. Therefore, in order to reduce China's CO_2 emissions, it is important to take into account the varied dynamic effects of industrialisation and urbanisation on CO_2 emissions in the three areas. Likewise. [24] discovered that energy use raises carbon emissions, with higher quantiles showing the most effects. Greater population growth and economic expansion seem to lower emissions in the high-emission nations. The study's findings also lend credence to the halo effect theory in nations with higher emissions. Using the cointegration approach, [25] identified a long-run equilibrium relationship among variables despite the presence of structural breaks. Economic growth leads to an increase in environmental carbon emissions. The findings suggest that adopting alternative energy sources is essential for achieving both environmental and economic sustainability.

Lastly, viewpoint studies provide nuanced caution. ARDL and Granger causality are used in [26] analysis, which finds a bidirectional link between energy use and growth and shows that while fuel (premium motor spirit) use raises GDP, electricity consumption has a negative impact on GDP. These results imply that choices on energy type and measurement have a significant impact on outcomes.

From sectoral and welfare analyses to [12], the empirical research all agrees that energy consumption boosts economic growth in Nigeria, albeit to differing degrees depending on the type of energy, price, time lags, and socioeconomic setting.

3. Methodology

3.1. Theoretical Framework

Following the theoretical framework and the work of [27], and considering the conventional production function (Y), where capital stock (K) and labor (L) are the main inputs. As presented in the theoretical background, energy as a factor of production, entered exogenously. By including energy consumption (EC) factors, the production function could be augmented as follows:

$$Y = f\left(K, EC, L,\right) \tag{1}$$

The Cobb-Douglas production function form of equation 1 is written as;

$$Y = A\left(K^{a}.EC^{b}.L^{c}\right) \tag{2}$$

where; a, b, c, are respectively output elasticity to changes in capital, energy consumption factors and labor. The above is "compositely" transformed thus to accommodate dynamism of growth process:

$$Y_{it} = A_{it} + X_{it}^{'}\beta + \mu_{it} \tag{3}$$

$$lny\left(t\right) = lnA + \alpha lnk\left(t\right) + clnL\left(t\right) + Aln\left(EC\right)^{1-\alpha-c} \tag{4}$$

For

$$EC\left(t\right) = T_{s}El\left(t\right)^{\delta} GPr\left(t\right)^{\vartheta} EcF\left(t\right)^{\pi} CC\left(t\right)^{\tau} \tag{5}$$

In order to incorporate therefore, the change in energy consumption (otherwise known as efficiency of energy consumption) given that subsequent values of A can be estimated alongside the latter coefficients, [28] specified in two separately observable parts thus:

$$\begin{aligned}\ln\left(A\right) = \delta_0 + \delta_1 \ln\left(El\right) + \delta_2 \ln\left(G\Pr\right) + \delta_3 \ln\left(EcF\right) \\ +\delta_4 \ln\left(CC\right) + \mu\end{aligned} \tag{6}$$

Model 3.6 treats electric power consumption, fuel pump price, energy capital formation and coal energy consumption as input factors augmenting the performance of economy (growth of GDP). If we therefore control for them in the country, then gross capital formation and income per capita would have been enhanced and thus in the logarithmic form:

$$\begin{aligned}\ln y\left(t\right) = \ln\theta + \alpha\ln k\left(t\right) + c\ln L\left(t\right) + \delta\ln El\left(t\right) + \vartheta\ln G\Pr\left(t\right) \\ +\sigma\ln EcF\left(t\right) + \gamma\ln CC\left(t\right) + \varepsilon\end{aligned} \tag{7}$$

where; log (*y*) represents gross domestic product (growth), log (*k*) represents capital stock *i.e.* gross capital formation driven by energy capital, Log (*EC*) represents energy consumption indicators to include: electricity power consumption, fuel pump price, energy capital formation, coal energy consumption, $Log(L)$ represents per capita income a measure of welfare or wellness of labour capital (HDI) and ε is the error term naturally assumed to be IID with zero mean and constant variance. As a result, Equation (6) will be estimated indirectly (ILS) on energy consumption ln (A^e).

3.2. Analytical Techniques

3.2.1. Unit Root Test

There are three normal techniques of unit root test such as the Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests, which are considered appropriate as a prior diagnostic test before the estimation of the model. This enables us to avoid the problems of spurious results that are associated with non-stationary time series models.

3.2.2. The Vector Error Correction Model (VECM)

The Vector Error Correction Model (VECM) is an econometric framework used to capture both the short-run dynamics and long-run equilibrium relationships among a set of non-stationary time series that are cointegrated. Cointegration implies that, despite being individually non-stationary, a linear combination of these variables is stationary, indicating a stable long-term relationship [16].

When variables are cointegrated, estimating a Vector Autoregression (VAR) in levels may lead to biased results due to omitted equilibrium conditions. Instead, the VECM corrects for this by incorporating an Error Correction Term (ECT) that measures deviations from long-run equilibrium and allows for short-term adjustments toward it [29] and [28].

3.2.3. VECM Specification

Suppose we have a vector of k non-stationary variables y_t that are integrated of order one, I (1), and cointegrated. The general form of the VECM is:

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{\rho-1} \Gamma_i \Delta y_{t-i} + \mu + \varepsilon_t \tag{8}$$

where:

- Δy_t is the first difference of the variables;
- Π is the long-run impact matrix (which contains information about cointegration);
- Γi are short-run coefficient matrices;
- μ is a vector of constants;
- ε_t is a vector of error terms.

The matrix Π can be decomposed as $\alpha\beta'$, where:

β contains the cointegrating vectors (long-run relationships);

α contains the adjustment coefficients (speed of adjustment to disequilibrium).

This implies that:

Short-run dynamics are captured through the lagged differences Δy_{t-i} and the Γi coefficients.

Long-run equilibrium is captured via $\beta' y_{t-i}$, with the matrix α showing how quickly each variable returns to equilibrium after a shock.

The significance of the Error Correction Term (ECT) indicates whether, and how fast, disequilibrium from the long-run path is corrected in each variable.

3.2.4. Granger Causality

The standard Granger causality testing [30] is used to identify the possibility of a causal relationship between the variables. The test approaches the question of whether past values of Y can predict future values of another variable E, for stationary series, I (0). Depending on the presence or lack of cointegrated relationships, the procedure takes place in a VAR or a VECM framework.

In the absence of cointegration, the linear Granger causality testing is constructed in a VAR. The mathematical representation of the model is given as follows:

$$Y_t = \sum_{i=1}^{l} a_i Y_{t-i} + u_t \tag{9}$$

where Y_t is the vector of all the endogenous variables, l is the selected number of lags, a_i are the matrices of coefficients to be estimated, and u_t is the error term that is assumed to be serially uncorrelated with zero mean and constant variance. Particularly, for a bivariate model, the following regression is taking place:

$$Y_t = a_0 + a_1 Y_{t-1} + \ldots + a_l Y_{t-1} + \beta_1 E_{t-1} + \ldots + \beta_l E_{t-1} + \varepsilon_t \tag{9}$$

$$E_t = a_0 + a_1 Y_{t-1} + \ldots + a_l Y_{t-1} + \beta_1 E_{t-1} + \ldots + \beta_l E_{t-1} + u_t \tag{10}$$

The test to find whether E Granger causes Y (or Y causes E) is a test of the joint hypothesis for the lagged coefficients:

$$\beta_1 = \beta_2 = \ldots = \beta_l = 0 \tag{11}$$

And the alternative is that at least one is different from zero. The null hypothesis of no Granger causality can be rejected if the alternative is proven. To sum up, the Granger causality test can lead to the following conclusions: 1) E causes Y, but Y does not cause E; 2) Y causes E, but E does not cause Y; 3) E causes Y and vice versa; and 4) neither Y causes E nor E causes Y. In cases 1) and 2) unidirectional causation is running, and in case; 3) the causality is bidirectional. Lastly, the last conclusion does not indicate a causal relationship between Y and E. The lag length, l, corresponds to the beliefs of the length of time over which one variable can help predict the other.

3.3. Empirical Model Specifications

Objective 1: Following [1] [7] [14] to achieve the Long-Run Relationship between energy consumption and economic growth, with Vector Error Correction Model (VECM) is as specified below:

$$RGDP_t = \alpha_0 + \alpha_1 ECON_t + \alpha_2 CCON_t + \alpha_3 CRUDE_t + \alpha_4 CO2_t + \alpha_4 GFCF_t + \varepsilon_t \quad (12)$$

where:

$RGDP_{it}$ represents economic activities at time t.

$ECON_t$ denotes electric consumption at time t.

$CCON_t$ represents coal consumption at time t.

$CRUDE_t$ represents amount of crude oil consumption at time t.

CO_{2t} represents amount of carbon dioxide emissions at time t.

$GFCF_t$ represents gross fixed capital at time t.

ε_{it} is the error term.

Objective 2: to determine the direction of causality between these variables, the Granger Causality was employed following [31] and [32].

$$Y = f\left(RGDP, ECON, CCON, CO_2, CRUDE, GFCF\right) \quad (13)$$

3.3. Nature and Sources of Data

This study employs time series data covering the period from 1981 to 2024 as shown in Table 1. Data on Gross Domestic Product (GDP), energy consumption measured in megawatt-hours, carbon dioxide emissions in million metric tons, crude oil production in barrels per day, and coal energy consumption, along with control variables such as gross capital formation and income per capita, were exclusively sourced from the World Development Indicators.

Table 1. Data descriptions and sources.

Variables	Description	Definition
ECON	Electric power consumption	kWh per capita
CCON	Coal Consumption	Coal rents (% of GDP)
CRUDE	Crude Oil Consumption	Oil rents (% of GDP)
GFCF	Gross capital formation	% of GDP
CO_2	Carbon dioxide emissions	Per capita (tCO_2e/capita)
RGDP	Real Gross Domestic Product	RGDP (Constant Price)

Source: Author's Compilation. **Note:** In order to stabilise variance, lessen skewness, and enable the VECM to interpret coefficients as long-run elasticities, the variables—which were initially measured in various units like percentage of GDP, kWh per capita, or barrels per day—were transformed using natural logarithms. This made comparisons between variables with various scales economically meaningful.

4. Results

4.1. Preliminary Analysis

4.1.1. Descriptive Summary

The macroeconomic and energy-related variables in Nigeria show significant volatility, according to the descriptive data from 1981 to 2024 (Table 2). With a wide range (std. dev. ₦157 billion), the average Real Gross Domestic Product (RGDP) was ₦288 billion, suggesting significant fluctuations in economic production. Its low kurtosis (1.585) and moderate right skew (0.461) indicate a generally steady distribution with sporadic years of high growth. The distribution of electric power consumption (ECON) was somewhat right-skewed and peaked (skewness 0.593; kurtosis 4.098), with a mean of 121.4 and a moderate spread (standard deviation of 33.13). With a near-symmetric distribution (skewness 0.195) and an average of 97.8, carbon dioxide (CO_2) emissions showed consistent trends throughout time.

Coal Consumption (CCON) showed low utilisation (mean 0.001) and strong skewness (1.347), which reflected rare but significant values across a few years. With a near-normal distribution and considerable fluctuation, crude oil production (CRUDE) averaged 11.1 percent. With a mean of 35.5 and significant variability (std. dev. 18.1), along with noticeable outliers (kurtosis 4.369), Gross Fixed Capital Formation (GFCF) suggested times of investment booms. With a modest left skewness (−0.436) and an average of 32.5, Trade Openness (TOPEN) suggested a few years of noticeably less trade integration.

Overall, the data exhibit different levels of kurtosis and skewness, with more tail risk and asymmetry seen in GFCF, CCON, and ECON. In time series analysis, these distributional characteristics highlight the necessity of proper model selection and pre-estimation diagnostics.

Table 2. Summary of descriptive statistics.

Variables	Obs	Mean	Std. Dev.	Min	Max	JB	Skew.	Kurt.
RGDP	44	2.88E + 11	1.57E + 11	1.15E + 11	5.70E + 11		0.461	1.585
ECON	44	121.372	33.132	50.481	219.234		0.593	4.098
CO_2	44	97.816	19.891	67.707	130.982		0.195	1.819
CCON	44	0.001	0.001	0	0.004		1.347	3.363
CRUDE	44	11.108	6.145	1.574	28.705		0.586	2.914
GFCF	44	35.537	18.094	14.904	89.381		1.22	4.369
TOPEN	44	32.475	11.671	9.136	53.278		−0.436	2.555

4.1.2. Correlation Analysis

With correlation values of 0.781 and 0.875, respectively, the correlation study (Table 3) demonstrates a strong and positive relationship between real GDP (RGDP) and electric power consumption (ECON) and CO_2 emissions. This suggests that energy use and emissions tend to increase in tandem with Nigeria's economic growth, thereby bolstering the well-established link between energy, growth, and the environment. The country's energy consumption is carbon-intensive, as evidenced by the significant positive correlation of 0.748 between ECON and CO_2. Conversely, there are significant negative correlations between Coal Consumption (CCON) and RGDP (−0.558), ECON (−0.536), and CO_2 (−0.669), indicating that coal's contribution to Nigeria's energy structure and economic growth is either minimal or diminishing. Crude oil production shows weaker and more mixed correlations, with slight negative associations with RGDP (−0.416) and CO_2 (−0.253), and virtually no meaningful link with CCON (0.059).

Interestingly, Gross Fixed Capital Formation (GFCF) has a positive association with coal consumption (0.613) but a high negative correlation with RGDP (−0.709), ECON (−0.796), and CO_2 (−0.701). This trend might be the result of investments in less energy-intensive or unproductive industries. Although there are subtle sectoral dynamics, the results generally show that energy consumption and environmental emissions are closely related to Nigeria's economic activity.

Table 3. Correlation matrix.

Variables	−1	−2	−3	−4	−5	−6
(1) RGDP	1					
(2) ECON	0.781	1				
(3) C02	0.875	0.748	1			
(4) CCON	−0.558	−0.536	−0.669	1		
(5) CRUDE	−0.416	−0.164	−0.253	0.059	1	
(6) GFCF	−0.709	−0.796	−0.701	0.613	−0.062	1

4.1.3. The Unit-Root Analysis

Three tests were used for the unit root analysis (**Table 4**): the KPSS test, the Phillips-Perron (PP) test, and the Augmented Dickey-Fuller (ADF) test. To ascertain the variables' stationarity characteristics, these were used at both levels and in first differences. The KPSS assumes that the series is stationary, whereas the ADF and PP tests assume that the null hypothesis is non-stationarity. The ADF and PP tests show non-stationarity at level but stationarity after first differencing for the majority of variables, including RGDP, ECON, CO_2, CCON, and CRUDE. Their test statistics become significant at the 1% level after differencing. The KPSS test further supported these conclusions by showing values above the critical threshold at level, which suggested non-stationarity, but decreasing below the threshold upon differencing, which supported stationarity.

Table 4. The unit root analysis.

Test	ADF		KPSS		P-PERRON	
Variables	**Level**	**1st Diff**	**Level**	**1st Diff**	**Level**	**1st Diff**
RGDP	2.553	−3.349***	0.259	0.15***	1.502	−3.189**
ECON	−2.478	−7.503***	0.076***	0.049***	−2.439	−7.63***
CO_2	−0.929	−7.462***	0.086***	0.052***	−0.677	−7.74***
CCON	−1.729	−5.491***	0.163***	0.061***	−1.743	−5.456***
CRUDE	−2.787*	−7.328***	0.212	0.068***	−2.60*	−8.01***
GFCF	−3.872***	−5.202***	0.227	0.087***	−4.05***	−5.16***

GFCF, however, is unique. It may be steady without differencing, according to the significance level shown by the ADF and PP tests. However, there appears to be some doubt as the KPSS result at level is not obviously below the 5% critical value. Overall, the findings indicate that all variables are integrated of order one (I (1)), with the possible exception of GFCF.

4.2. Empirical Results Analysis

4.2.1. Relationship between Energy Consumption and Economic Growth in Nigeria

The cointegration rank test (Table 5) offers compelling proof of a consistent, long-term correlation between Nigeria's economic growth and energy use. The null hypothesis of no cointegration is rejected at rank 0 because the trace statistic of 116.2 is greater than the 5% critical value of 94.15. The trace statistic (64.16), however, drops below the crucial value (68.52) at rank 1, and the following ranks likewise fall short of rejecting their null hypotheses. This result suggests that the variables being studied are connected by a single cointegrating vector.

It is implied that there is a single long-term equilibrium path for energy consumption, GDP, and associated variables including carbon emissions, the use of coal and crude oil, and capital formation. Therefore, shocks to one variable will spread to the others, guaranteeing that imbalances are finally fixed. Energy is not only an input but also a long-term determinant of output performance, which highlights the structural connection between energy consumption and economic growth for Nigeria. Additionally, the result supports the use of a Vector Error Correction Model (VECM), which accounts for both long-term correction mechanisms and short-term dynamics [9].

This interpretation is supported by empirical studies. While [7] demonstrates that the composition of energy matters, with renewable energy supporting sustainable growth in comparison to fossil fuels, [2] [14] and [29] emphasize that energy use considerably drives long-term growth in Sub-Saharan Africa. In a similar vein, [33] verifies the long-term, reciprocal causal relationship between GDP and energy use in emerging economies. Consistent with these conclusions, Nigerian data demonstrates that initiatives intended to diversify and modernise the energy industry would have a direct impact on the long-term growth trajectory of the nation.

Table 5. The Johansen cointegration test.

Cointegration Rank	Parameters	L-Likelihood	Eigenvalue	Trace Statistic	5% Critical Value
0	6	117.1		116.2	94.15
1	17	143.1	0.702	64.16	68.52
2	26	156.2	0.455	38.06	47.21
3	33	167.2	0.401	16.03	29.68
4	38	171.3	0.175	7.75	15.41
5	41	174.2	0.124	2.08	3.76
	42	175.2	0.047		

Clear indications of adjustment towards a long-term equilibrium between energy consumption and economic growth may be found in the VECM short-run dynamics data (**Table 6**). It is confirmed that the system's disequilibrium is addressed over time by the statistically significant and negative error correction terms. Specifically, the coefficient of −0.556 indicates a significant and steady convergence process, with over half of any divergence from the long-run path being rectified in a single period. This is in line with the primary goal of the study and confirms the presence of a long-term cointegrating relationship between energy use and economic growth.

The short-run coefficients provide crucial information on the relationship between energy and growth. Consumption of crude oil has a significant and favourable impact on economic growth in all categories, highlighting petroleum's ongoing economic supremacy in Nigeria. This outcome is consistent with Nigeria's significant reliance on oil earnings as well as previous research by [14], which highlighted how fossil fuels propel Sub-Saharan Africa's growth. However, the environmental trade-offs of energy-driven expansion are reflected in the positive and strong link between economic growth and CO_2 emissions. [1] and [7] who emphasised that fossil fuel-based energy raises emissions without ensuring sustainable growth, concur with this finding.

While gross fixed capital creation shows a negative and significant influence, other energy sources, including coal, seem unimportant in the short term and suggest a limited contribution to growth. This unexpected result could be the result of crowding-out effects, implementation delays, or inefficient capital use, which would support [34] and [35] findings about Nigeria's capital investment limitations. Overall, the findings support the long-term link between economic success and energy use, but they also emphasise how urgently cleaner energy sources and efficiency-focused investment methods must be diversified.

Meanwhile, according to the diagnostics, the Akaike Information Criterion (AIC) of −6.055 is a criterion for information, when choosing a model. This negative number indicates that your VECM fits the data quite well in comparison to alternative lag specifications, since lower AIC values indicate a better-fitting model. With a statistic of 25.46 and a p-value of 0.9047, the Vecmar test for serial correlation shows that the null hypothesis that there is no residual autocorrelation cannot be rejected. This indicates that the model effectively captures the dynamic interactions among the variables without leaving systematic patterns in the errors, as there is no indication of serial correlation in the residuals. The Breusch-Pagan test for heteroskedasticity yields a p-value of 0.4706 and a statistic of 0.52. The null hypothesis of homoskedastic residuals cannot be rejected because the p-value is significantly higher than standard significance thresholds. This suggests that the residuals' variance is constant across observations and that the dependability of the computed coefficients is unaffected by heteroskedasticity.

In conclusion, the model seems well-specified, with homoskedastic residuals, no serial correlation, and a strong overall fit (AIC), indicating that the VECM results are statistically reliable for predicting and interpretation.

Table 6. VECM estimating short-run dynamics.

Variable	ECT	Coef	Std. Error	z-value
D_LECON	1	−0.019***	0.02	−3.27
	2	−0.556***	0.134	−4.14
D_LCO₂	1	0.012**	0.013	0.91
	2	0.089	0.082	1.08
D_LCCON	1	0.064	0.104	0.54
	2	0.387*	0.674	0.57
D_LCRUDE	1	0.250***	0.072	3.48
	2	1.091***	0.47	2.34
D_LGFCF	1	−0.065***	0.019	−3.33
	2	−0.337***	0.127	−2.98
Diagnostics				
AIC		−6.055		
Vecmar (Serial Correlation)		25.46 (0.9047)		
Breusch-Pagan		0.52 (0.4706)		

Note: ***, **, and * values denote statistical significance at $p < 0.01$. $p < 0.05$, and $p < 0.1$.
Note: In order to stabilise variance, lessen skewness, and enable the VECM to interpret coefficients as long-run elasticities, the variables—which were initially measured in various units like percentage of GDP, kWh per capita, or barrels per day—were transformed using natural logarithms. This made comparisons between variables with various scales economically meaningful.

Table 7 presents long-run cointegrating relationships that shed light on the dynamics between economic growth and energy use. With real GDP as the dependent variable, electric power consumption (LECON) enters the first cointegrating equation with a negative coefficient of −2.65, indicating that collective energy use by itself does not, in the long run, directly translate into economic expansion. Rather, energy's efficiency and composition are important. Crude oil consumption (LCRUDE), on the other hand, has a significant and favourable impact (2.624***), reiterating the crucial role that petroleum plays in Nigeria's development. Additionally, coal consumption (LCCON) is positive and large (1.849**), suggesting that in the Nigerian context, fossil fuel-based energy sources continue to be important production drivers. Gross Fixed Capital Formation (GFCF) and energy consumption have a robust and statistically significant long-term positive relationship, as indicated by the EC1 coefficient of 2.624. Economically speaking, this link illustrates how capital investment is frequently energy-intensive: increasing industrial capacity, installing machinery, and constructing infrastructure all demand significant energy inputs. The link between economic growth through capital accumulation and energy use is thus highlighted by the fact that higher levels of investment immediately drive increased energy demand. However, CO_2 emissions (LCO_2) are negatively related to GDP (−0.063), consistent with the notion that environmental degradation can act as a drag on long-run sustainable growth.

The demand-pull effect of economic expansion is reflected in the second cointegrating vector, where energy consumption is the dependent variable. It shows that growing GDP is linked to higher energy use. There is some indication of efficiency gains or a shift away from carbon-intensive energy sources as CO_2 emissions enter negatively (−0.824**). Crude oil is especially robust (0.239***), indicating a continued reliance on conventional energy. Coal and crude oil also show a good sign. Despite being positive, gross fixed capital formation (LGFCF) is negligible (0.04), indicating that investment has not yet resulted in structural changes in energy demand.

When combined, these findings support a steady, long-term correlation between growth and energy use, but they also highlight how susceptible Nigeria's economy is to reliance on fossil fuels. The results support recent findings [7] [33] and [19] that reliance on fossil fuels increases environmental concerns while energy consumption propels growth. Growth strategies must combine energy expansion with cleaner technology and efficiency gains to decouple output from emissions. This is the clear policy implication for long-term sustainability.

Table 7. Cointegrating relationships (long-run equation coefficients).

Cointegrating	LRGDP	LECON	LCO_2	LCCON	LCRUDE	LGFCF	Constant
EC1	1		−2.65	−0.063	1.849**	2.624***	−19.21
EC2	0	1	−0.824**	−0.089*	0.239***	0.04	−2.413

Note: ***, **, and * values denote statistical significance at $p < 0.01$.$p < 0.05$, and $p < 0.1$.

The impact of an energy consumption shock (LECON) on real GDP (LRGDP) over the projected horizon is depicted in the Impulse Response Function (IRF) in Figure 3. The GDP response at step 0 starts at about 0.02. The line gradually increases to above 0.03 as the horizon moves closer to step 1. This upward-sloping, positive trajectory suggests that an innovation (shock) in energy use has a positive, long-lasting impact on economic growth. Put differently, there is a correlation between rising energy use and subsequent GDP increases.

There is no downward adjustment in the graph, indicating that, at least for the short horizon displayed, the relationship is both positive and stable. This supports the data from your cointegration and VECM results: Nigeria's long-term growth trajectory is significantly influenced by its energy use. This is in line with the energy-led growth hypothesis, which holds that increasing access to and use of energy drives economic growth by supplying energy for infrastructure, services, and industry. Recent empirical data (e.g., [14] [36] support the idea that energy shocks boost GDP in emerging nations, but frequently at the expense of the environment.)

Overall, the IRF indicates that governmental initiatives to improve Nigeria's consistent energy supply will boost growth, making energy sector changes essential to maintaining long-term economic success.

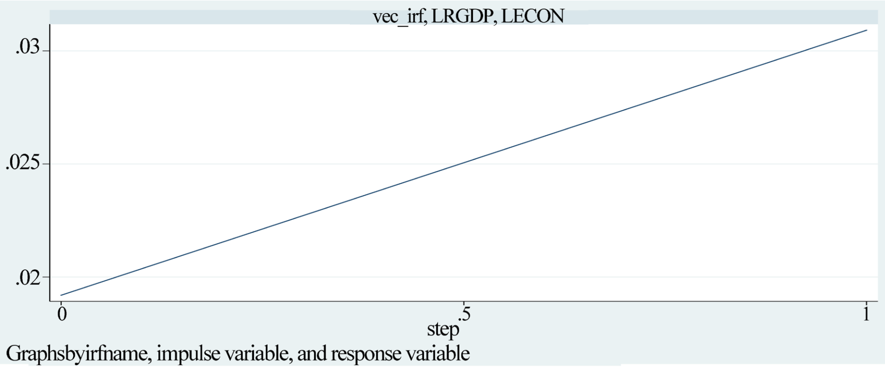


Figure 3. The Impulse Response Function (IRF).

4.2.2. Granger Causality to Determine the Direction of Causality between These Variables

Nigeria's economic development and the main energy and investment factors are strongly correlated, according to the findings of the block exogeneity Wald tests. Granger-cause analysis as shown in Table 8 reveals a feedback relationship between GDP and energy usage. This indicates that while GDP growth concurrently fuels energy demand, higher levels of energy consumption also contribute to production growth. This kind of reciprocal causality aligns with the feedback theory that has been extensively documented in the literature on energy and growth.

The relationship between GDP and carbon dioxide emissions shows a similar trend. According to the tests, economic growth is largely predicted by emissions, and rising GDP likewise causes emissions to rise. The environmental cost of Nigeria's growth trajectory is shown in this two-way causality, whereby energy-related and industrial activities raise carbon emissions, which in turn strengthen output dynamics. The relationship underlines how difficult it is to manage environmental concerns and achieve sustainable growth.

Additionally, there is a causal relationship between GDP and coal usage. Coal continues to be a significant energy source in Nigeria's development process despite its waning worldwide significance, both as an output driver and as a sector that grows in tandem with economic expansion. It should come as no surprise that crude oil consumption and GDP have a similar reciprocal relationship. This study emphasizes the economy's structural reliance on petroleum resources, which continue to be both a cause and an effect of economic performance given Nigeria's high reliance on oil.

Lastly, there is the strongest reciprocal relationship between GDP and gross fixed capital formation. Economic growth has a stronger impact on investment speed than capital formation, notwithstanding capital creation's positive GDP contribution. This is indicative of Nigeria's pro-cyclical investment climate. All of the included factors strongly explain GDP dynamics, according to the joint test.

Overall, these findings highlight how Nigeria's economy is intricately intertwined with energy, investment, emissions, and growth, underscoring the significance of environmental concerns and energy diversification in maintaining long-term prosperity.

Table 8. Granger causality results.

Equation	Excluded	chi2	df	Prob > Chi2
LRGDP	LECON	47.242	4	0.000
LECON	LRGDP	10.048	4	0.04
LRGDP	LCO2	13.514	4	0.009
LCO2	LRGDP	11.721	4	0.02
LRGDP	LCCON	19.476	4	0.001
LCCON	LRGDP	20.024	4	0.000
LRGDP	LCRUDE	16.844	4	0.002
LCRUDE	LRGDP	16.227	4	0.003
LRGDP	LGFCF	15.851	4	0.003
LGFCF	LRGDP	58.572	4	0.000
LRGDP	ALL	146.95	20	0.000

5. Conclusion

Examining the causal relationship between energy consumption and economic growth in Nigeria between 1981 and 2024 was the goal of this study. The findings demonstrate that energy consumption and economic growth are cointegrated, indicating the presence of a long-run equilibrium relationship, using the Granger causality, impulse response analysis, VECM framework, and Johansen cointegration test. The results demonstrate that while coal makes a minor contribution and electricity usage has long-term but substantial effects, crude oil consumption continues to be a major growth driver. Crucially, the feedback theory is supported by the mutual reinforcement of economic growth and energy use. The report also emphasises the environmental trade-off: GDP growth is closely linked to increased CO_2 emissions, which, if left unchecked, might jeopardise sustainability. Gross fixed capital formation, although vital, reveals inefficiencies in its short-run impact, suggesting institutional and structural challenges in translating investment into productive growth.

Overall, the results underscore that energy policy is central to Nigeria's growth agenda, but sustainability requires a careful balance between economic expansion, energy use, and environmental protection. In light of these findings, the study makes the following recommendations:

1) Nigeria must diversify its energy mix by scaling up renewable sources such as solar, wind, and hydro to reduce dependence on crude oil while ensuring sustainable growth.

2) Policies should prioritize energy efficiency through investment in modern technologies, grid infrastructure, and demand management to maximize output gains from available energy.

3) Strengthening capital formation effectiveness is critical; reforms that improve project implementation, transparency, and financing can ensure investment contributes positively to growth.

4) Finally, environmental considerations must be mainstreamed into energy and growth policies, with carbon mitigation strategies such as green financing and incentives for low-emission technologies.

Data Limitations

This study's dependence on nationally aggregated time-series data, which may obscure significant regional, sectoral, and distributional differences in energy use and growth dynamics, is a major drawback. Furthermore, the robustness of long-run estimates and causation patterns may be impacted by data gaps and measurement errors, especially for early-period power, coal, and CO_2 series. Additionally, firm-level behavioural reactions, efficiency heterogeneity, and structural fractures related to market shocks and governmental reforms are limited by the macro-level design. To further understand transition paths, future research should utilise structural or nonlinear modelling tools, integrate renewable-energy indicators, and use higher-frequency or sector-disaggregated datasets. Deeper understanding of Nigeria's changing energy-growth link might also result from extending the analysis to incorporate spatial impacts, micro-level surveys, and cross-country comparisons within West Africa.

Conflicts of Interest

The author declares no conflicts of interest.

References

[1] Abid, M. (2015) The Close Relationship between Informal Economic Growth and Carbon Emissions in Tunisia since 1980: The (Ir)relevance of Structural Breaks. *Sustainable Cities and Society*, **15**, 11-21. https://doi.org/10.1016/j.scs.2014.11.001

[2] Acheampong, A.O. (2018) Economic Growth, CO_2 Emissions and Energy Consumption: What Causes What and Where? *Energy Economics*, **74**, 677-692. https://doi.org/10.1016/j.eneco.2018.07.022

[3] Akbostancı, E., Türüt-Aşık, S. and Tunç, G.İ. (2009) The Relationship between Income and Environment in Turkey: Is There an Environmental Kuznets Curve? *Energy Policy*, **37**, 861-867. https://doi.org/10.1016/j.enpol.2008.09.088

[4] Antonakakis, N., Chatziantoniou, I. and Filis, G. (2017) Energy Consumption, CO_2 Emissions, and Economic Growth: An Ethical Dilemma. *Renewable and Sustainable Energy Reviews*, **68**, 808-824. https://doi.org/10.1016/j.rser.2016.09.105

[5] Bano, S., Zhao, Y., Ahmad, A., Wang, S. and Liu, Y. (2018) Identifying the Impacts of Human Capital on Carbon Emissions in Pakistan. *Journal of Cleaner Production*, **183**, 1082-1092. https://doi.org/10.1016/j.jclepro.2018.02.008

[6] World Bank (2023) Tracking SDG7: The Energy Progress Report 2023. https://trackingsdg7.esmap.org/

[7] Afaha, J.S. and Agbede, S.A. (2025) Energy Consumption, Prices and Economic Growth in Nigeria: Autoregressive Distributed Lag Model Analysis. *Annals of Management and Organization Research*, **6**, 385-404. https://doi.org/10.35912/amor.v6i4.2191

[8] Buzugbe, N.P. (2023) The Energy Consumption-Economic Growth Nexus in Nigeria: What Evidence Exists? *Futurity Economics & Law*, **3**, 209-222.

[9] Yusuf, L., Abdullahi, M.M. and Halliru, A.M. (2024) Impact of Economic Growth and Renewable Energy Consumption on CO_2 Emissions in Nigeria. *UMYUK Journal of Economics and Development* (*UJED*), **1**, 135-146.

[10] Usman, A.B., Usman, F.K., Sa'ad, S., Omaye, S.O. and Idris, M. (2025) The Relationship between Energy Transition, Economic Growth, and Carbon Emission in Nigeria. *International Journal of Research and Innovation in Social Science*, **IX**, 3871-3879. https://doi.org/10.47772/ijriss.2025.907000313

[11] Mirza, F.M. and Kanwal, A. (2017) Energy Consumption, Carbon Emissions and Economic Growth in Pakistan: Dynamic Causality Analysis. *Renewable and Sustainable Energy Reviews*, **72**, 1233-1240. https://doi.org/10.1016/j.rser.2016.10.081

[12] Ashakah, F.O. (2025) Impact of Energy Consumption on Economic Growth in Nigeria: An ARDL Estimation Approach. *Jalingo Journal of Social and Management Sciences*, **6**, 254-266.

[13] Goshit, G.G. (2022) Impact of Renewable Energy Consumption on Economic Growth in Nigeria. *International Journal of Economics & Development Policy*, **5**, 153-168.

[14] Ajah, N., Nzeribe, I., Okeyika, E. and Nwokoye, O. (2024) Energy Consumption and Economic Growth in Nigeria: VECM Analysis. *Nigerian Journal of Energy & Environmental Economics*, **15**, 16-33.

[15] Pao, H. and Chen, C. (2019) Decoupling Strategies: CO_2 Emissions, Energy Resources, and Economic Growth in the Group of Twenty. *Journal of Cleaner Production*, **206**, 907-919. https://doi.org/10.1016/j.jclepro.2018.09.190

[16] Engle, R.F. and Granger, C.W.J. (1987) Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica*, **55**, 251-276. https://doi.org/10.2307/1913236

[17] Le, T. and Quah, E. (2018) Income Level and the Emissions, Energy, and Growth Nexus: Evidence from Asia and the Pacific. *International Economics*, **156**, 193-205. https://doi.org/10.1016/j.inteco.2018.03.002

[18] Yang, G., Sun, T., Wang, J. and Li, X. (2015) Modeling the Nexus between Carbon Dioxide Emissions and Economic Growth. *Energy Policy*, **86**, 104-117. https://doi.org/10.1016/j.enpol.2015.06.031

[19] Efayena, O.O., Olele, E.H. and Buzugbe, N.P. (2022) Energy Consumption and Economic Growth Nexus in Africa: New Insights from Emerging Economies. *Theoretical and Applied Economics*, **29**, 185-196.

[20] Iormom, B.I., Jato, T.P., Ishola, A. and Diyoke, K. (2025) Economic Policy Uncertainty, Institutional Quality, and Renewable Energy Transitioning in Nigeria. *Energy Research Letters*, **7**, 1-6.

[21] Buzugbe, P.N. (2023) The Interconnectedness of Energy Consumption with Economic Growth in Nigeria. *Futurity in Economic Law*, **3**, 209-222.

[22] Mikayilov, J.I., Galeotti, M. and Hasanov, F.J. (2018) The Impact of Economic Growth on CO_2 Emissions in Azerbaijan. *Journal of Cleaner Production*, **197**, 1558-

1572. https://doi.org/10.1016/j.jclepro.2018.06.269

[23] Xu, B. and Lin, B. (2015) How Industrialization and Urbanization Process Impacts on CO_2 Emissions in China: Evidence from Nonparametric Additive Regression Models. *Energy Economics*, **48**, 188-202. https://doi.org/10.1016/j.eneco.2015.01.005

[24] Zhu, H., Duan, L., Guo, Y. and Yu, K. (2016) The Effects of FDI, Economic Growth and Energy Consumption on Carbon Emissions in ASEAN-5: Evidence from Panel Quantile Regression. *Economic Modelling*, **58**, 237-248. https://doi.org/10.1016/j.econmod.2016.05.003

[25] Das, T. and Chakraborty, D. (2024) Effect of Energy Consumption on Economic Growth and Sustainability: Panel Evidence from PCSE and FGLS. *Economics and Policy of Energy and the Environment*, **2**, 37-53. https://doi.org/10.3280/efe2024-002002

[26] Pal, D. and Mitra, S.K. (2017) The Environmental Kuznets Curve for Carbon Dioxide in India and China: Growth and Pollution at Crossroad. *Journal of Policy Modeling*, **39**, 371-385. https://doi.org/10.1016/j.jpolmod.2017.03.005

[27] Anwar, A., Sarwar, S., Amin, W. and Arshed, N. (2019) Agricultural Practices and Quality of Environment: Evidence for Global Perspective. *Environmental Science and Pollution Research*, **26**, 15617-15630. https://doi.org/10.1007/s11356-019-04957-x

[28] Hussian, A.E.M. (2018) The Role of Microalgae in Renewable Energy Production: Challenges and Opportunities. In: Türkoğlu, M., Önal, U. and Ismen, A., Eds., *Marine Ecology—Biotic and Abiotic Interactions*, InTech, 257. https://doi.org/10.5772/intechopen.73573

[29] Johansen, S. (1988) Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control*, **12**, 231-254. https://doi.org/10.1016/0165-1889(88)90041-3

[30] Granger, C.W.J. (1969) Investigating Causal Relations by Econometric Models and Cross-Spectral Methods. *Econometrica*, **37**, 424-438. https://doi.org/10.2307/1912791

[31] Ahmad, N., Du, L., Lu, J., Wang, J., Li, H. and Hashmi, M.Z. (2017) Modelling the CO_2 Emissions and Economic Growth in Croatia: Is There Any Environmental Kuznets Curve? *Energy*, **123**, 164-172. https://doi.org/10.1016/j.energy.2016.12.106

[32] Yeh, J. and Liao, C. (2017) Impact of Population and Economic Growth on Carbon Emissions in Taiwan Region Using an Analytic Tool Stirpat. *Sustainable Environment Research*, **27**, 41-48. https://doi.org/10.1016/j.serj.2016.10.001

[33] Demena, B.A. and Afesorgbor, S.K. (2020) The Effect of FDI on Environmental Emissions: Evidence from a Meta-Analysis. *Energy Policy*, **138**, Article ID: 111192. https://doi.org/10.1016/j.enpol.2019.111192

[34] Narayan, P.K., Saboori, B. and Soleymani, A. (2016) Economic Growth and Carbon Emissions. *Economic Modelling*, **53**, 388-397. https://doi.org/10.1016/j.econmod.2015.10.027

[35] Okorie, D.I. and Sylvester, M.A. (2016) Electricity Consumption and Economic Growth: The Nigerian Case. *International Journal of Current Research*, **8**, 12. https://ssrn.com/abstract=3003553

[36] Chen, P., Chen, S., Hsu, C. and Chen, C. (2016) Modeling the Global Relationships among Economic Growth, Energy Consumption and CO_2 Emissions. *Renewable and Sustainable Energy Reviews*, **65**, 420-431. https://doi.org/10.1016/j.rser.2016.06.074