**Does Energy Consumption Improve Economic Growth? An Empirical Evidence from Nigeria**

**Abstract**

The increasing quest for clean energy due to environment degredation and role of energy in the growth process in developing economies make it imperative to examine the effect of renewable (hydroelectric) and nonrenewable (petroleum oil and natural gas) energy consumption on economic growth in Nigeria. To acheive the purpose of the study data on petroleum oil, natural gas, hydroelectric and real economic growth were sourced from the Central Bank of Nigeria Statistical Bulletin, World Development Indicator (WDI) and the International Energy Association (IEA). The study utilised the econometric technique of cointegration and error correction mechanism (ECM) to investigate the relationship between the consumption of the types of energy and economic growth. Results from the study indicate that the utilisation of renewable energy sources, hydro power, had a substantial adverse effect on economic growth. Conversely, the use of nonrenewable energy sources, petroleum oil and natural gas, had a substantial contribution to boosting economic growth in Nigeria. This implies that non renewable energy source has serious positive implication on economic growth in Nigeria over the period of the study. Based on the findings, it was recommended among others that the players in the energy sector should increase investment in both downstream and upstream components in the energy sector in order to enhance efficiency, value chain and economic growth in Nigeria.

**Key words: Energy Consumption, renewable energy, non-renewable energy and economic growth**

1. **Introduction**

Recently, several countries have sought to attain enhanced economic growth by executing certain strategies that need elevated energy consumption for industrial production. Energy is crucial for the economic development of all countries (Kaygusuz, 2009). Mulugeta, Nondo, Schaeffer, and Gebremedhin (2010) contended that energy consumption is a vital accelerator for economic development, according to economic growth theory. This idea asserts that energy consumption directly or indirectly underpins labor and capital as essential components of the manufacturing process. Numerous countries augment their energy consumption to fulfill their productive capacity, motivated by the quest for expansion and progress. Energy has been a pivotal aspect that significantly boosts industrial productivity and economic advancement. Energy is a vital and necessary element in the economy. All facets of economic activities on Earth need energy for optimal functioning. Energy is an essential element of human society, and its importance has increased significantly during the last decade. It acts as a crucial element in advancing sustainable corporate, economic, and fiscal development, both globally and specifically for emerging countries such as Nigeria. According to Enu and Havi (2014) and Umeh, Ochuba, and Ugwo (2019), nations with lower energy consumption and per capita distribution are seen as less industrialized and economically weaker.

Economic development, technological advancement, healthcare, education, job creation, and the enhancement of the overall welfare of a nation's populace are all contingent upon dependable energy supplies. An economy requires a sufficient energy supply and its efficient use to attain comprehensive growth and development. The mere presence of energy does not resolve the social and economic challenges confronting developing economies, such as Nigeria; however, the lack of affordable and reliable energy services is recognized as a significant impediment to national development (Nkoro, Ikue-John & Joshua, 2019). Energy is a vital catalyst that significantly influences several aspects of economic and human development. Insufficient energy capacity, restricted access to affordable modern energy services, and inefficient energy use may impede macroeconomic performance and growth.   
Energy consumption is a vital driver of economic progress and growth, powering industry, transportation, and families worldwide. Nonetheless, reliance on fossil fuels and non-renewable energy sources has resulted in significant environmental consequences, exacerbating issues such as air and water pollution, deforestation, and climate change. As the global population grows and industrializes, the need for energy escalates, resulting in a heightened impact on the environment (Haliru, 2023).   
Energy consumption may be seen as a disparity statistic in developing countries. This mostly results from the widespread energy deficit in emerging countries, which obstructs advancements in education and healthcare, as well as the growth of enterprises and general national development. Access to contemporary energy services is essential for ongoing growth in industrialized economies. Nevertheless, several developing countries, such as Nigeria, have significant obstacles in ensuring energy accessibility. Over two-thirds of the Nigerian population lacks access to electricity, with most depending on hazardous and inefficient cooking techniques. The consequence of limited access is that energy availability and pricing are much worse compared to more industrialized nations. The ADB determined that the average per capita power consumption in Africa is 181 kWh, in contrast to 13,000 kWh in the United States and 6,500 kWh in Europe. Power outages and energy constraints exacerbate the issue. This situation is analogous to what is seen in Nigeria. Moreover, the average per capita power consumption is inadequate to support the uninterrupted functioning of a single 50-watt light bulb. Nigeria has a diverse energy portfolio and is among the leading crude oil producers globally; nonetheless, 70 percent of its population lives in poverty. Owing to issues within the energy sector, about 40% of Nigeria's population lacks access to electricity. The inadequate service has impacted all individuals, especially those in positions of authority.

A significant segment of the continent is devoid of access to the electricity grid. The restricted access to dependable and affordable energy supplies remains a significant barrier to personal, social, and economic development in Nigeria (Mmbaga, Kulindwa & Kazungu 2023). The environmental deterioration in Nigeria is a significant impediment exacerbated by the concurrent effects of energy consumption and economic growth. Nigeria relies significantly on fossil fuels, including coal, oil, and natural gas, to meet its energy needs. The extraction, production, and burning of these fuels generate pollutants that contaminate air and water, contributing to habitat destruction and the intensification of climate change. As energy demand rises with economic growth, there is a commensurate rush to use fossil fuel supplies, resulting in more environmental deterioration in Nigeria. Moreover, economic activities in Nigeria, such as agriculture, wood harvesting, mineral extraction, and infrastructure development, often result in deforestation and soil degradation. Igbru and Ifurueze (2021) contend that Nigeria has many challenges related to energy consumption and economic development, which together intensify unemployment, poverty, and inflation in the nation. Nigeria has difficulties in ensuring enough access to modern energy services, particularly in rural areas. A significant portion of the population relies on traditional biomass for cooking and heating, resulting in indoor air pollution and related health issues. Nigeria has an abundant array of energy resources, including oil, gas, coal, hydroelectric power, solar energy, and wind energy. However, the distribution of these resources is often unequal, resulting in variations in energy accessibility and macroeconomic development. Consequently, for Nigeria to advance towards a robust and sustainable macroeconomic environment and performance, it is essential to understand and predict energy consumption and its impact on sustained economic development. Consequently, the objective of this research is to scientifically assess the impact of energy consumption on economic development. The research aimed to ascertain the impact of hydroelectric power, petroleum oil, and natural gas on Nigeria's Real Gross Domestic Product.

1. **Literature Review**

**Energy-Growth Hypotheses**

Consistent with Yildrim and Aslan (2012), investigations on the relationship between energy use and economic development have been conducted since the 1970s, notably initiated by the foundational study of Kraft and Kraft (1978). The authors identified a unidirectional correlation between energy use and the rise of the United States' Gross National Product (GNP) from 1947 to 1974. A multitude of academics have recently performed additional experiments to ascertain a causal relationship between energy use and GDP development. Researchers have proposed four testable hypotheses to elucidate the relationship between energy consumption and economic development; nevertheless, they have failed to differentiate between qualitative and quantitative dimensions. Four theories in the energy-growth literature on the relationship between energy consumption and economic development are the Growth Hypothesis, the Conservation Hypothesis, the Feedback Hypothesis, and the Neutrality Hypothesis. Ekeocha, Penzin, and Ogbuabor (2020), Yildirim and Aslan (2012), and Ozturk (2010) assert that these ideas have significant policy implications.

**Growth Hypothesis:** The Growth Hypothesis posits that, after considering labor and capital, energy consumption directly influences economic development. According to the idea, there exists a unidirectional causal relationship between energy use and GDP growth. In this instance, conservative energy policies aimed at reducing consumption would adversely affect economic development (Emeka, Nenubari & Godsgrace, 2019).

**Conservation Hypothesis:** Ouedraogo (2013) Contends that the conservation hypothesis posits a less energy-dependent economy by asserting that economic progress is the primary driver of energy sector growth. The unidirectional relationship between economic growth and energy consumption supports the hypothesis's practical relevance. Investments in energy efficiency and demand management tactics, as exemplars of energy conservation measures, will not impede economic development in the long term.

**Feedback Hypothesis:** A reciprocal relationship exists between energy consumption and economic development, consistent with the Feedback Hypothesis, which posits that the relationship is bidirectional. According to Emeka, Nenubari, and Godsgrace (2019), attempts to reduce energy consumption via conservation regulations may adversely impact economic development, thus influencing energy consumption.

**Neutrality Hypothesis:**Energy use does not influence economic development, in agreement with the Neutrality Hypothesis. It asserts that energy use and economic growth are not directly correlated. If a link between energy use and GDP growth is absent, then this hypothesis is valid. If this is true, then initiatives aimed at decreasing energy use via conservation measures would not foster economic development (Emeka, Nenubari & Godsgrace, 2019). In accordance with the Neutrality Hypothesis, there is no association between the energy sector and GDP growth. The lack of a direct correlation between energy use and GDP growth supports the Neutrality Hypothesis. Economic development will remain unaltered by initiatives designed to enhance energy supply and consumption levels in this instance (Ouedraogo, 2013).

**Endogenous Growth Theory**

The notion of endogenous growth was proposed by economists Paul Romer and Robert Lucas in the mid-1980s. The idea arose from growing discontent with the neglect of sources of technical advancements in economies. This theory posits that internal factors, rather than external ones, are the principal catalysts of economic advancement, contrary to the claims of Neoclassical Theory. The Exogenous Growth Theory was supplanted by the Endogenous Growth Theory because of its constraints. The Endogenous development Theory posits that internal factors, rather than external influences, are the primary drivers of economic development (Romer, 1994). The aim of this theory is to provide a thorough explanation of long-term development by including the elements of productivity, growth, and technological innovation. The theory asserts the following fundamental principles: knowledge and technological advancements are commodities that can be disseminated without loss of value; private reserves related to innovation are essential for progress; human capital and the cultivation of new skills are critical for sustained economic growth; and the occurrence of increasing returns to scale results from advantageous external factors. The concept suggests that with an infinite supply of resources, such as energy and electricity, the economy may experience perpetual growth. Endogenous growth theory, similar to exogenous growth theory, posits that technology diffusion results in enhanced convergence across countries.

Romer presents a firm's production function in the following manner:

Y = A(R) *f*(Ri, Ki, Li,) (1)

Where:

A – Public stock of knowledge from research and development (R)

Ri – Stock of upshots from stock of expenditure on research and development

Ki – Capital stock of firm i

Li – Labour stock of firm i

The word "Ri" denotes the technology often used by business i at that era. The dissemination of novel research technologies is swift and pervasive across the whole country. Technological advancement involves the development of new ideas that resemble public goods owing to their non-rivalrous characteristics. The introduction of novel concepts as production variables often results in enhanced returns to scale.

In this framework, long-term growth is mostly determined by new technology, which is impacted by investment in research and development. Consequently, Romer regards investment in research technology as an endogenous factor, signifying that it is shaped by the rational profit-maximizing actions of firms aiming to get new knowledge. In accordance with the aforementioned facts, the aggregate production function of the Endogenous Theory may be formulated as follows:

Y = *f*(A, K, L) (2)

Where;

Y = Aggregate real output

K = Stock of capital

L = Stock of labour

A = Technology (or technological advancement)

The value of "A" is fundamentally influenced by the investment in research technologies (Egbichi, Abuh, Okafor, Godwin & Adedoyin, 2018).

Energy is crucial for achieving complete economic growth, with technology, as highlighted by the Endogenous development theory, serving as an internal factor linked to energy that may drive substantial economic progress. Diverse economic activities need the use of technology, whereas the majority of technologies, such as machinery, equipment, and computers, depend on the availability of usable energy for operation. Consequently, these systems are fundamentally ineffectual without an adequate energy source, either electricity or petroleum. Consequently, it is essential to allocate sufficient expenditures in energy, not alone for production, but also to attain energy efficiency. This may thus foster equitable economic development.

**Empirical Review**

Abdulkarim (2023) examined the dynamic effects of energy consumption, economic development, foreign finance, and urbanization on environmental deterioration in Nigeria. This study used the ARDL methodology, accounting for structural breaks, using yearly time series data from 1980 to 2020. The findings indicated that the environmental Kuznets curve hypothesis is valid for both the long-term and short-term in Nigeria. Total exports enhance environmental quality in both the short and long term, while energy consumption and total imports exacerbate environmental deterioration in both timeframes.

Mmbaga, Kulindwa, and Kazungu's (2023) study examined the relationship between energy use and economic growth in the East African Sub-Region. From 2012 to 2021, researchers in the East African subregion examined the relationship between energy and economic development via the perspectives of health and education, which serve as indicators of human capital. We used Pooled OLS, Fixed Effects, and the Generalized Method of Moments as analytical methods. The outcome illustrated the importance of historical context in shaping contemporary development plans. Maintaining constant energy prices is essential, since they adversely affect economic development. The use of energy seems to adversely affect GDP growth. This association, however, proves to be inverse when considering life expectancy as a proxy for human capital.

Okeoma, Nwachukwu, Ezeonye, and Osatemple (2023) evaluated the impact of energy consumption on economic development in Nigeria using data from 1981 to 2018. The primary objectives of the research were to investigate the short-term impact of energy consumption on GDP growth in Nigeria and to examine the long-term relationship between the two variables. Subsequently, the researchers used the Ordinary Least Squares (OLS) regression technique, the Johansen co-integration test, and the ex-post facto research methodology to reach their final decision. A long-term relationship exists between energy consumption and economic development in Nigeria, with findings indicating that crude oil consumption, gross fixed capital formation, and electricity consumption all positively and significantly influence the nation's economic progress. Conversely, coal usage positively but marginally influences economic development in Nigeria.

Ikpe and Oyedeji (2023) evaluated the intricate relationship among Nigeria's GDP growth, energy consumption, and several economic indicators. The research used a comprehensive methodology. The research used a stringent methodology to evaluate a 50-case observational dataset for connections between GDP and variables like population, unemployment, lending interest rates, import prices, and inflation rates. Analysis indicated that electricity consumption, population, and lending interest rates were the most significant predictors of Nigeria's GDP, whereas other factors had much lesser effects.

Haliru (2023) evaluated the impact of energy consumption on sustainable development in Nigeria, with a focus on renewable energy. To achieve this, we aggregated time series data from reputable domestic and international sources, including the International Energy Administration portal, the World Bank's World Development Indicators (WDI), and the National Bureau of Statistics' (NBS) annual statistical bulletin, spanning the years 1980–2021. This study used the ARDL Model to evaluate the influence of energy consumption and many other factors, including FDI, OPN, and CO2 tax, on Green Growth in Nigeria. This research demonstrated that green growth has a positive and statistically significant relationship with its initial latency and current value at the 1 percent level of significance. Nigerian researchers identified a significant and statistically robust association between energy use and sustainable development. However, foreign direct investment and green growth had a negative link that lacked statistical significance, in accordance with the study findings.

In their examination of Sub-Saharan Africa, Iyabo and Segun (2022) evaluated the relationship among energy consumption, foreign direct investment, and GDP growth. This study used the Generalized Method of Moments to assess the extent of the interrelationship among energy consumption, foreign direct investment (FDI), and economic development, in addition to examining the tripartite causal connection. Between 1991 and 2018, 42 countries in Sub-Saharan Africa contributed data for the study. The study revealed that for each percentage point increase in energy use, the GDP expands by 1.3 percent. Conversely, energy consumption increases by 0.004 percent as a result of economic growth. The relationship between FDI and GDP growth is mostly unidirectional. The association between energy usage and FDI was not statistically significant in direction nor magnitude.

Salisu and Moronkeji (2022) assessed the impact of Nigeria's electricity usage on industrial output using data from 1980 to 2021. Diagnostic tests conducted included descriptive statistics, correlation, the unit root test, and the ARDL.According to the ARDL limits testing process, the only determinants affecting Nigerian manufacturing output in the long term are labor, capital, and energy consumption. Nonetheless, inflation and interest rates have a little negative impact on industrial production in Nigeria. There exists a negative and statistically significant correlation between electricity production and manufacturing output in Nigeria, despite energy consumption, labor, gross fixed capital creation, and electricity generation being the determinants of manufacturing output in the near term.

In 2022, Mukhtar et al. evaluated the short-term dynamics and long-term relationship, including interruptions, between Nigeria's economic development and natural gas consumption. The used approaches include the ARDL model with breaks and the Shahbaz-Omay-Roubaud unit root test with both sudden and smooth breaks. Both short-term and long-term data demonstrated a favorable association between natural gas use and growth, with the latter exhibiting statistical significance. The relationship between natural gas consumption and growth seems to be unidirectional in the short term, however bidirectional in the long term.

Kehinde and Devi (2022) conducted an empirical analysis on the impact of fossil fuel use on energy efficiency and economic development. To ensure energy security, address climate change, and foster sustainable growth and development, the study focused on energy efficiency as a key consideration for policymakers. The study used a multivariate regression method to assess the impact of changes in the energy structure on total energy efficiency and GDP growth. The study revealed that although the escalation of fossil fuel use is vital to economic expansion, it hampers climate change mitigation efforts. The study revealed that both productivity enhancement and the assurance of a sustainable energy supply are influenced by the marginal efficiency of energy inputs.

Wang, Wang, and Li (2022) analyzed data from the BRICS countries from 1990 to 2019 to assess the impact of fossil fuel use on economic development. To assess the temporal impact of size, we used completely modified OLS with the quadratic function of coal, oil, and gas consumption. In agreement with the findings, coal consumption has a negative connection with HDI, whereas both natural gas and coal consumption have an inverted U-shaped relationship with HDI.

The authors of a recent research titled "A Lesson for Developing Nations," which examines the impact of renewable energy consumption and globalization on environmental deterioration, used a distinctive quantile on quantile regression (QQR) method and emphasized its non-linear advantages compared to conventional linear techniques. The writers are Oladipupo, Rjoub, Kirikkaleli, and Adebayo (2022). This study aims to address deficiencies in prior research and provide a comprehensive examination of the relationship between these characteristics and CO2 emissions. An analysis of data from 1970 to 2018 indicates that economic development, nonrenewable energy consumption, and globalization significantly contribute to environmental degradation across different quantiles, implying that these elements markedly undermine environmental sustainability in South Africa. The usage of renewable energy seems to have a little impact on CO₂ emissions across all quantiles, in agreement with their study.

Siyakudumisa, Kin, and Yiseyon-Sunday (2022) used the ARDL bounds test method to demonstrate a causal relationship between energy prices and economic performance in South Africa from 1994 to 2019. The study also used the ARDL model, which can identify concealed co-integration relationships and perform well with integrated series of differing orders. The study identified a long-term connection between the factors. The results indicated that crude oil prices have a robust positive link with economic growth in both the long and medium term, whereas energy costs had a significantly negative impact on both.

Employing the ECM, a multivariate framework from 2000Q1 to 2018Q4, the ARDL bounds test method, and the Clemente-Montanes-Reyes unit root to address structural breaks in the series, Abner, Izuchukwu, Eneoli, and Udo (2021) performed an empirical analysis of the causal relationship between energy consumption and economic development in Nigeria. Results indicated that the use of electricity, liquefied natural gas, and petroleum exhibits bidirectional relationships among them. The usage of energy enhances economic progress by increasing the value of goods and services. Conversely, a reduction in power use results in an increase in petroleum usage and a stagnation in economic progress owing to distribution inefficiencies, an approximated billing system, and an excessive dependence on generators as an alternative energy source. The mismatch between energy demand and supply is responsible for the non-causal relationship.

Udo, Idamoyibo, Victor, Akpan, and Victor (2021) examined the relationship between energy consumption and GDP development in Nigeria's agricultural, industrial, and service sectors. Utilizing a multivariate architecture and data gathered quarterly from the first quarter of 2000 to the fourth quarter of 2018. The study used the Clemente-Montanes-Reyes unit root technique for structural breakdowns in the series, as well as the ECM and ARDL bounds test methodology. The results indicated a strong correlation between economic development and value creation within sectors. The findings indicated that liquefied natural gas and energy consumption are mutually causally connected, but economic development and petroleum oil consumption exhibit a unidirectional causal relationship. Conversely, the study's findings indicated that the service and agricultural sectors are not causally linked.

In 2021, Łukasz identified a correlation between increasing energy use and GDP. This study focuses on the period from 2008 to 2019. Currently, 27 of Europe's 34 member states are members of the European Union, and the scope of evaluated subjects includes all of them. The study used dynamic panel models with the Arellano and Bond and Blundell and Bond estimators as research approaches. The study's findings indicated a correlation between energy use and GDP growth. The primary conclusion of the research indicates that, at least in the short term, a statistically significant increase in energy consumption correlates with elevated production levels.

Lawrence, Gideon, Uchechukwu, Johnson, Felix, Benjamin, and Alexander (2021) established that energy consumption and financial development influence economic progress in Nigeria. This study enhanced existing knowledge by measuring the contributions of the fiscal and energy sectors to Nigeria's GDP from 1981 to 2018. This study used the dynamic OLS (DOLS) estimation method, revealing that oil costs and gross fixed capital negatively predict growth, whereas electricity consumption, inflation, and fiscal development positively predict growth.

1. **Methodology**

Secondary data in the form of annual time series data were utilized for this study. The data were obtained from the World Development Indicators of the World Bank, the Africa Energy Portal (AEP), Central Bank Statistical Bulletin, and the International Energy Agency (IEA). Furthermore, the data spanned for thirty-three (33) years, i.e 1990 to 2022 and analysed using the Cointegration and Error Correction Method.

The objective of the study examined the effect of energy consumption (hydroelectricity, petroleum oil, and natural gas) on economic growth. The functional and estimation forms of the growth model are presented here. First, the functional form of the model for examining the impact of energy consumption (hydroelectricity, petroleum oil, and natural gas) on economic growth in Nigeria is as follows:

 3

The estimation form of the model for examining the impact of energy consumption on economic growth in Nigeria is as follows:

 4

Where, = Natural logarithm of Real GDP, = Natural logarithm of Hydroelectricity Consumption, = Natural logarithm of Petroleum Oil Consumption, = Natural logarithm of Natural Gas Consumption, = Natural logarithm of Total Government Expenditure,  = Natural logarithm of Credit to the Private Sector, = Natural logarithm of Trade Openness,  = Natural logarithm of Exchange Rate,  = Intercept of the model, = are the parameter estimates of the independent variables, A priori expectation = > 0, > 0, > 0, > 0, > 0, > 0, and > 0,  = error term (represents the omitted variables in the model)

**Model Estimation Technique: Error Correction Mechanism (ECM)**

Granger (1981) articulated a theorem to associate cointegration with error correction models. This theorem asserts that variables cointegrated of order (1,1) may be represented by an error correction model. This theorem is assumed to be self-evident, however its proof is documented in Granger (1981) and Engle and Granger (1987).

Error correction models (ECMs) facilitate the modeling of modifications that result in a long-term equilibrium state. These are dynamic models including both short-term and long-term variable evolutions.

Assuming and  are two cointegrated variables *CI*, (1, 1). The ECM can be written as:

 (5)

 (6)

Where:

* and are white noises,
* is the residual of the cointegration relationship between *and *
*  and  are (L) finite polynomial.

The error correction model describes an adjustment process. It includes two types of variables:

- Variables in first difference (stationary) which represents short-term movements.

- Variables in level (here) which are a stationary linear combination of non-stationary variables and assure the long-term movements.

1. **Results**

**Table 1: Results of Summary Statistics for Variables Selected for the study**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| S/N | Variables | Mean | Median | Std. Dev | Min | Max |
| 1 | Hydroelectricity Consumption (kWh) | 23.37 | 21.81 | 4.53 | 15.79 | 34.78 |
| 2 | Petroleum Oil Consumption Barrel per day (‘000) | 626.88 | 515.28 | 232.06 | 332.63 | 1005.84 |
| 3 | Natural Gas Consumption Cubic Metric tonnes (‘000) | 161.96 | 163.06 | 22.13 | 125.14 | 208.44 |
| 4 | Real GDP Naira (Trillion, at 2010 constant basic prices) | 44.745 | 41.127 | 20.237 | 21.680 | 74.752 |
| 5 | Government Expenditure Naira (Trillion) | 3.547 | 2.038 | 3.833 | 0.060 | 14.946 |
| 6 | Credit to the Private Sector Naira (Trillion) | 9.341 | 2.290 | 11.304 | 0.034 | 39.012 |
| 7 | Trade Openness (%) | 0.25 | 0.26 | 0.19 | 0.01 | 0.73 |
| 8 | Exchange Rate (Naira) | 146.55 | 129.22 | 116.64 | 8.04 | 425.97 |

Furthermore, the data in Table 1 indicates that the average petroleum oil consumption throughout this time is around 626.88. This provides a measure of central tendency for the data. The median number is around 515.28, signifying that fifty percent of the consumption levels fall below this threshold and fifty percent exceed it. The standard deviation is around 232.06, indicating considerable variability in the consumption figures relative to the mean. The least consumption amount is 332.63, while the highest is 1005.84. This range (673.21) indicates the disparity between the minimum and maximum consumption years. The data exhibits positive skewness, indicating a predominance of years with lower consumption numbers relative to higher ones. Historical data indicates a consistent increase in petroleum oil use. There are prominent peaks and considerable oscillations, particularly the abrupt increase to 1005.84. Finally, the data in Table 4.1 indicates that the mean natural gas consumption over this time is around 161.96, reflecting the central trend of the dataset. The median number is around 163.06, indicating that fifty percent of the consumption levels fall below this threshold while the remaining fifty percent exceed it. The standard deviation is around 22.13, indicating the variability or dispersion of the consumption levels relative to the mean. The least consumption amount is 125.14, while the highest is 208.44. This range (83.30) indicates the disparity between the minimum and maximum consumption years. The data indicates a consistent rising trajectory, marked by substantial increases over time. For instance, the increase from 125.14 in 1990 to 208.44 in 2022 indicates an increasing dependence on natural gas. Significant variations exist, although the overarching tendency persists positively. Stability and modest growth are seen, with some years exhibiting more pronounced surges, especially in recent times.

**(i) Unit Root Analysis**

Table 2 displays the results of the unit root testing. The "Status" column in each test specifies the sequence of integration. The ADF test indicates that real GDP has stationarity at order two, whereas the other seven variables are integrated at order one. The PP test reveals that real GDP is stationary at the second order, trade openness and exchange rate at the zeroth order, and the other five variables at the first order. Thus, with the exception of real GDP, which took two rounds of differencing to gain stationarity, all other variables achieved stationarity after a maximum of one differencing under both the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests.

**Table 2: The Results of Unit Root Test**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variables** | **Augmented Dickey-Fuller (ADF) Test** | | | |  |
|  | Constant  (p-value) | Constant & Trend  (p-value) | None  (p-value) | Status |
| LOG(RGDP) | -8.00\*\*\*  (0.000) | -7.87\*\*\*  (0.000) | 8.15  (0.000) | I (2) |
| LOG(HEC) | -6.55\*\*\*  (0.000) | 6.43\*\*\*  (0.000) | 6.54\*\*\*  (0.000) | I (1) |  |
| LOG(POC) | -6.65\*\*\*  (0.000) | -6.67\*\*\*  (0.000) | -6.65\*\*\*  (0.000) | I (1) |  |
| LOG(NGC) | -4.52\*\*\*  (0.000) | -4.31\*\*\*  (0.000) | -4.42\*\*\*  (0.007) | I (1) |  |
| LOG(GEXP) | -8.22\*\*\*  (0.000) | -9.65\*\*\*  (0.000) | -2.11\*\*  (0.036) | I (1) |  |
| LOG(CPS) | -4.13\*\*\*  (0.000) | -4.80\*\*\*  (0.000) | -2.32\*\*  (0.022) | I (1) |  |
| LOG(TOPEN) | -5.85\*\*\*  (0.000) | -6.19\*\*\*  (0.000) | -5.00\*\*  (0.022) | I (1) |  |
| LOG(EXCR) | -5.24\*\*\*  (0.000) | -5.34\*\*\*  (0.001) | -4.53\*\*  (0.022) | I (1) |  |

Table 3 presents the results of the Johansen cointegration test for the growth model, including both the Trace and Max-Eigen test data. The Trace test identifies four cointegrating equations at the 0.05 significance threshold. The Max-Eigen test similarly reveals three cointegrating equations at the same significance level. Notwithstanding slight variations between the two tests, each test surpasses the minimal criterion of at least one cointegration equation, so affirming the existence of a long-term link among the time series. Thus, it is determined that a long-term link exists among the variables in the growth model.

**Cointegration Analysis**

**Table 3: Results of the Johansen Cointegration Test**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Trace Test** **Maximum Eigenvalue Test** | | | | | | | |
| Hypothesized  No. of CE(s) | | Trace Statistic | 5% Critical  Value |  | Hypothesized  No. of CE(s) | Max-Eigen  Statistic | 5% Critical  Value |
| None \* | 277.1071 | | 159.5297 | None \* | 97.42998 | 52.36261 |
| At most 1 \* | 179.6772 | | 125.6154 |  | At most 1 \* | 55.03803 | 46.23142 |
| At most 2 \* | 124.6391 | | 95.75366 |  | At most 2 \* | 50.81277 | 40.07757 |
| At most 3 \* | 73.82635 | | 69.81889 |  | At most 3 | 30.21104 | 33.87687 |
| At most 4 | 43.61532 | | 47.85613 |  | At most 4 | 20.15603 | 27.58434 |
| At most 5 | 23.45928 | | 29.79707 |  | At most 5 | 12.91492 | 21.13162 |
| At most 6 | 10.54437 | | 15.49471 |  | At most 6 | 7.025129 | 14.26460 |
| At most 7 | 3.519239 | | 3.841465 |  | At most 7 | 3.519239 | 3.841465 |
| **Note 1**: \* denotes rejection of the hypothesis at the 0.05 level  **Source**: Author’s computation, 2024. | | | | | | | |

Table 4 presents the findings from the estimated error correction model, which analyzes the impact of energy consumption on economic growth in Nigeria from 1990 to 2022. The focus is on the sign, magnitude, and statistical significance of the coefficients. A coefficient is considered statistically significant if half of its value exceeds the standard error, the t-statistic surpasses the critical value of 2.00, and the p-value is below 0.05.

**Impact of Hydroelectricity Consumption on Economic Growth**

The coefficients for hydroelectricity consumption at levels, one-period lag, and two-period lag (-0.159515, -0.203672, and -0.030752) exhibit a negative sign. Analyzing the standard error statistics (0.042671, 0.035149, and 0.026985), t-statistics (-3.738247, -5.794453, and -1.139595), and probability values (0.0046, 0.0003, and 0.2839), the study finds that both levels and one-period lag of hydroelectricity consumption significantly affect economic growth during the period 1990-2022. This indicates that hydroelectricity consumption has a significantly adverse effect on economic growth in Nigeria during the review period.

**Impact of Petroleum Oil Consumption on Economic Growth**

The coefficients of petroleum oil consumption at levels (0.076935), one-period lag (-0.034298), and two-period lag (-0.016183) are positive, negative, and negative, respectively. Considering the standard error statistics (0.018987, 0.022088, and 0.021765), t-statistics (4.051946, -1.552827, and -0.743551), and probability values (0.0029, 0.1549, and 0.4761), the study concludes that petroleum oil consumption at levels significantly influences economic growth from 1990 to 2022. This implies that petroleum oil consumption has a substantial positive effect on long-term economic growth in Nigeria during the specified period.

**Impact of Natural Gas Consumption on Economic Growth**

The coefficients of natural gas consumption at the level (0.336431) and one-period lag (-0.257403) are positive and negative, respectively. Based on the standard error statistics (0.075027 and 0.097590), t-statistics (4.484125 and -2.637606), and probability values (0.0015 and 0.0270), the study concludes that natural gas consumption at levels significantly affects economic growth from 1990 to 2022. This indicates that natural gas consumption has a significant impact on economic growth in Nigeria during the review period: it reduces economic growth in the short run but increases it in the long run.

**Impact of Selected Control Variables on Economic Growth**

While government expenditure and credit to the private sector proved to reduce economic growth in the short run significantly, trade openness impacted positively and significantly in the long run.

**Error Correction Term [ECM(-1)]**

The error correction term coefficient (-0.76) exhibits the theoretically expected negative sign. Given the standard error (0.111118), t-statistic (6.86), and p-value (0.0001), the statistical significance of the error correction term is evident. This indicates that the model corrects short-run disequilibrium and converges to long-run equilibrium at a rate of 76%.

**Coefficient of Determination and Overall Significance of the Growth Model**

The final row in Table 4 presents the R-squared, Adjusted R-squared, and the probability of F-statistics. The R-squared value of 0.9609 indicates that 96.09% of the variation in economic growth in Nigeria during the period under review is accounted for by the explanatory variables, highlighting the high explanatory power of the model. The Adjusted R-squared of 87.39 is also notably close to the R-squared value, suggesting that increasing the degrees of freedom by incorporating more variables will likely result in a similar relationship between the explanatory variables and the dependent variable. Finally, the p-value of the F-statistics (0.00) demonstrates that the overall growth model is statistically significant, indicating that all independent variables collectively have a statistically significant impact on economic growth.

**Model Estimation**

**Table 4: Results of the Parsimonious Error Correction Model**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Dependent Variable = Natural log of Real GDP | | | |
| Variables | Coefficient | Std.Error | t-Statistic | Prob. |
| C | 0.035643\*\*\* | 0.009471 | 3.763258 | 0.0045 |
| DLOG(RGDP(-1)) | 0.820619\*\*\* | 0.131503 | 6.240286 | 0.0002 |
| DLOG(RGDP(-2)) | 0.270704\*\* | 0.118094 | 2.292276 | 0.0476 |
| DLOG(HEC) | -0.159515\*\*\* | 0.042671 | -3.738247 | 0.0046 |
| DLOG(HEC(-1)) | -0.203672\*\*\* | 0.035149 | -5.794453 | 0.0003 |
| DLOG(HEC(-2)) | -0.030752 | 0.026985 | -1.139595 | 0.2839 |
| DLOG(POC) | 0.076935\*\*\* | 0.018987 | 4.051946 | 0.0029 |
| DLOG(POC(-1)) | -0.034298 | 0.022088 | -1.552827 | 0.1549 |
| DLOG(POC(-2)) | -0.016183 | 0.021765 | -0.743551 | 0.4761 |
| DLOG(NGC) | 0.336431\*\*\* | 0.075027 | 4.484125 | 0.0015 |
| DLOG(NGC(-1)) | -0.257403\*\* | 0.097590 | -2.637606 | 0.0270 |
| DLOG(GEXP) | -0.049755\*\* | 0.021575 | -2.306152 | 0.0465 |
| DLOG(GEXP(-2)) | -0.118525\*\*\* | 0.021870 | -5.419632 | 0.0004 |
| DLOG(CPS) | 0.039432\* | 0.020578 | 1.916254 | 0.0876 |
| DLOG(CPS(-1)) | -0.070543\*\* | 0.027492 | -2.565936 | 0.0304 |
| DLOG(CPS(-2)) | -0.063150\*\* | 0.026771 | -2.358907 | 0.0427 |
| DLOG(TOPEN) | 0.071057\*\*\* | 0.016266 | 4.368579 | 0.0018 |
| DLOG(TOPEN(-1)) | -0.003688 | 0.012770 | -0.288831 | 0.7793 |
| DLOG(TOPEN(-2)) | 0.026999\*\* | 0.010281 | 2.625955 | 0.0275 |
| DLOG(EXCR) | -0.020504 | 0.015309 | -1.339380 | 0.2133 |
| ECM(-1) | -0.761931\*\*\* | 0.111118 | -6.856959 | 0.0001 |
| R-squared = 0.960872 | Adjusted R-squared = 0.873920 | | Prob (F-statistic) = 0.000421 | |
| Note: \*\* and \*\*\* implies significance at 5%, and 10% levels of significant errors respectively  **Source**: Author’s computation, 2024 | | | | |

**Table 5: Results of the Post-estimation Diagnostic Tests**

|  |  |  |  |
| --- | --- | --- | --- |
| **Tests** | **F-Statistic** | **Prob>|F|** | **Decision** |
| Breusch-Godfrey Serial  Correlation LM | 2.98 | 3.76 | Null hypothesis of no serial correlation cannot be rejected. |
| Breusch-Pagan-Godfrey Heteroskedasticity | 0.83 | 0.65 | Null hypothesis of homoscedasticity cannot be rejected |
| Ramsey RESET | 2.64 | 0.14 | Null hypothesis of misspecification of model can rejected |
| Note: \*\* and \*\*\* implies significance at 5%, and 10% levels of significant errors respectively  **Source**: Author’s computation, 2024 | | | |

**Serial Correlation** **Test**: The result of the Breusch-Godfrey Serial Correlation LM test is presented in Table 5. The null hypothesis of no serial correlation in the parsimonious ECM model is tested at 0.05 level of significance. The p-value (i.e., 3.76) of the computed F-statistics (i.e., 2.98) reveals that the parsimonious error correction growth model is free from serial autocorrelation problem.

**Heteroscedasticity Test**: The result of the Breusch-Pagan-Godfrey Heteroscedasticity test is presented in Table 4.5. The p-value (i.e., 0.65) of the computed F-statistics (i.e., 0.83) reveals that the parsimonious error correction growth model is free from the problem of heteroscedasticity.

**Specification Test**: The result of Ramsey Regression Specification Error Test (RESET) is presented in Table 5. The p-value (i.e., 0.14) of the computed F-statistics (i.e., 2.64) reveals that the parsimonious error correction growth model is well specified. The model is not misspecified.

**Stability Test:** The CUSUM (Cumulative Sum) plot presented below shows that plot stays within the critical bounds at 5% level. The growth model is therefore considered stable.



**Discussion**

Notable conclusions have arisen from the data analysis about the impact of energy consumption on macroeconomic performance indicators, including economic growth, price stability, and the unemployment rate. Consequently, analyzing the data subsequent to the literature study is a worthwhile pursuit. The research first examined the impact of renewable and non-renewable energy consumption on economic development, using real GDP as the indicator. Furthermore, hydro energy was designated as the renewable energy source, whereas petroleum oil and natural gas were identified as the non-renewable energy variables. Data study indicates that hydroelectricity use adversely impacts economic growth, but petroleum oil consumption positively influences long-term economic development. Furthermore, it was shown that whereas natural gas use markedly hampers economic development in the near term, it enhances economic growth in the long term. The results on the impact of renewable energy consumption align with the research conducted by Ikpe and Oyedeji (2023) and Salisu and Moronkeji (2022), which identified electricity consumption as a crucial factor in growth. Specifically, the results did not align with the research of Qudrat-Ullah and Chinedu (2021), which indicated that renewable energy consumption promotes development in both the short and long term. Furthermore, the results on the relationship between petroleum oil consumption and economic development align with Okeoma et al. (2023), who determined that crude oil consumption positively and significantly influences economic growth. Finally, the results on the influence of natural gas on long-term economic development align with the conclusions of Akokaike et al. (2021), Foye and Benjamin (2021), and Nwabueze et al. (2021), who determined that the use of natural gas is significantly correlated with real GDP over the long term. Finally, the research revealed conclusions about the influence of control variables on the chosen macroeconomic performance indicators. Initially, government spending and loans to the private sector substantially hindered short-term economic development, but trade openness markedly enhanced long-term economic growth.

1. **Conclusion and Recommendations**

The research indicates that the usage of renewable and non-renewable energy has varying effects on economic development in Nigeria. The use of renewable energy negatively impacts aggregate production, while the use of non-renewable energy significantly enhances long-term economic development. In light of the study's conclusion and findings, the following suggestions are proposed: Investment in clean energy and subsidies for low-income households should be prioritized, since this would enhance use among households, small companies, and manufacturing firms, therefore stimulating economic activity and improving overall economic performance. The government should promote the diversification of the energy industry from predominant fossil fuels to renewable energy to improve energy security and economic stability. The government need to promote investment in both conventional and renewable energy sources to establish a balanced energy portfolio. This may enhance employment opportunities and foster economic development in the nation.

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