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Energy consumption, prices and economic growth in Nigeria: Autoregressive distributed lag model analysis

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Abstract

Purpose: This study aimed to test the relationship between energy consumption, energy prices, and economic growth in Nigeria by examining the coefficients of various variables in a regression analysis.

Research Methodology: This study uses regression analysis to assess the relationship between energy-related variables and economic growth in Nigeria, focusing on factors such as gas consumption, crude oil prices, fuel prices, and coal consumption.

Results: The results indicate that certain energy-related variables, such as gas consumption, crude oil prices, and coal consumption, have significant impacts on economic growth in Nigeria. The coefficients of these variables show both positive and negative relationships with GDP growth rates.

Conclusions: Energy consumption is a key driver of Nigeria's economic growth, with short-run demand driven by GDP and long-run growth sustained by increased energy use, highlighting the critical need for stable energy policies and infrastructure development.

Limitations: One limitation of this study is the potential for omitted variable bias or unobserved factors that could influence the results.

Contribution: This study contributes to the understanding of how energy consumption and fuel prices affect economic growth in Nigeria, providing insights for policymakers, researchers, and stakeholders in the energy sector.

Novelty: The novelty of this study lies in its detailed analysis of the specific effects of energy-related variables on economic growth in Nigeria, highlighting the importance of energy policies and consumption patterns in driving economic performance. This study also contributes to the literature on how energy costs affect Nigeria's energy use and economic growth.

Keywords: *Autoregressive Distributed Lag Model, Economic growth, Energy consumption, Energy Prices, Nigeria*

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1. Introduction

Energy is an essential component of economic expansion. Not only does it produce heat and light, it also fuels factories and carries people and goods. With a burgeoning population and economy, Nigeria's energy requirements have soared over the past several years. On other fronts, the economy is under pressure as energy costs increase. The relationship between energy pricing, consumption, and economic growth has been a topic of much interest, discussion, and research in the fields of economics and energy studies. Economic activities are dependent on energy, which is a basic input for production, transportation, and household consumption; thus, the increase in economic growth can be directly related to final energy consumption (E. M. Hamilton, 2021).

The entire economic performance of a nation or region is also greatly impacted by energy prices, which also have a significant impact on the patterns of energy consumption (Stern, 2019). A nation's overall economic performance can be influenced by changes in energy prices, which can also impact household budgets, industry cost structures, and investment choices. With both short-term adjustments and long-term structural changes in the economy, the effects of energy costs on economic growth can become complicated (Lee & Chang, 2005). Although a great deal of research has been conducted on the connection between energy prices, energy consumption, and economic growth in different nations and regions (Osigwe & Arawomo, 2015), more empirical research is still required, especially when considering particular nations or regions.

Furthermore, research on the connection between energy prices, consumption, and economic growth is crucial, especially for developing nations such as Nigeria. Nigeria presents enormous hurdles in managing energy consumption, affordability, and economic advancement owing to its rapidly expanding economy and population. To create energy policies that work, advance economic growth, and guarantee energy security, politicians, academics, and stakeholders must understand the interactions between these variables. Studies such as Ekeocha, Penzin, and Ogbuabor (2020) examined the causal relationship between energy consumption and economic growth using Granger causality tests and data from the 1970s to 2012. Prior research has also examined the relationship between energy consumption and economic growth in Nigeria. According to these studies, there is a unidirectional causal relationship between energy consumption and economic growth, suggesting that Nigeria can achieve rapid economic growth by increasing its energy consumption.

Furthermore, research has demonstrated a long-term correlation between energy consumption and economic growth. Prince, Inim, Callistus, and Udo (2021) examined the effect of energy consumption on economic growth in Nigeria, concentrating on the consumption of electricity, petroleum, and natural gas. However, nothing is known in the literature about how Nigeria's energy consumption and economic expansion are impacted by energy prices. This study seeks to close this gap by investigating the causal relationship between energy costs, energy use, and economic growth in Nigeria. We aim to identify the underlying dynamic relationships between these variables using a large dataset and strong econometric tools.

1.1 Importance of Nigeria's economic growth, energy prices, and consumption

Nigeria's economic performance is greatly influenced by its energy consumption patterns and levels, which are major factors in the country's economic growth. Fossil fuels, especially petroleum, dominate Nigeria's energy industry and supply a majority of the nation's energy demand. The manufacturing sector uses between 50 and 60 percent of electricity, with the remaining 25 to 35 percent coming from different energy sources, such as nuclear fuels, biomass, coal, petroleum, and natural gas (Prince et al., 2021). Inadequate energy production, inefficient energy distribution, and exorbitant energy prices are just a few of the difficulties faced by Nigeria's energy sector. As they impede industrial activity, increase production costs, and deter foreign investment, these problems have a substantial impact on the growth and development of the nation's economy (Prince et al., 2021). Nigeria has conducted extensive research on the relationship between economic growth and energy consumption, with most studies focusing on the cause-and-effect relationship. For example, Onakoya et al. (2013) investigated the causal relationship between Nigeria's economic growth and energy consumption using the ARDL bound test approach. The research discovered a long-term correlation between energy consumption and economic growth, suggesting that energy consumption plays a major role in Nigeria's economic growth. Anochiwa et al. (2020). Furthermore, there is contradictory evidence in the literature regarding the direction of causality between energy consumption and economic growth. However, other research points to a one-way causal relationship between energy consumption.

1.2 Research Objectives

Based on the background and motivation for this study, the research objectives for testing the relationship between energy consumption, energy prices, and economic growth in Nigeria are as follows:

1. To examine the relationship between energy consumption and economic growth in Nigeria.
2. To analyze the impact of energy prices on economic growth in Nigeria.

2. Literature Review

Numerous research have discovered various trajectories of the causal link in the wake of the groundbreaking works of R. Engle and Granger (1991); R. F. Engle and Granger (1987) regarding the direction of the relationship between economic growth (income) and energy consumption: economic expansion energy-growth (Energy→GDP), implying that causality moves from energy consumption to economic growth, that is, increasing energy consumption potentially leads to economic growth (Asafu-Adjaye, 2000; Fatai, Oxley, & Scrimgeour, 2004; Keppler, 2007; Lee & Chang, 2005); bi-directional (Energy↥GDP), showing that causality moves frothat isergy consumption to energy, i.e., economic growth increases energy usage (Ambapour & Massamba, 2005; Jumbe, 2004; Keppler, 2007; Yu & Choi, 1985).

Thus, it can be inferred that the causal relationship is between energy consumption and economic growth, meaning that rising energy consumption may contribute to economic growth (Asafu-Adjaye, 2000; Fatai et al., 2004; Keppler, 2007; Lee & Chang, 2005); bi-directional (Energy←GDP), the symbol denots a bidirectional relationship between energy consumption and economic growth, that is, the direction of the impact from one variable on the other is bidirectional, in which case energy consumption and vice versa concurrently impact economic growth (Asafu-Adjaye, 2000; Fatai et al., 2004; Glasure & Lee, 1998; Paul & Bhattacharya, 2004). Morimoto and Hope (2004) and the neutrality hypothesis, which suggests that energy consumption has no effect on growth and vice versa, have no causation in either way (Payne, 2010; Yu & Choi, 1985).

Economic growth is a result of energy demand. It is true that demand drives consumption. In other words, anything that was eaten had to have been requested. According to Birol (2007), there has been a significant increase in the demand for energy, which has contributed to the expansion of the world economy. Two schools of thinking can be discerned from the empirical literature on the relationship between price growth and energy usage. Research that looked at the connection between energy use and economic expansion make up the first category. The conclusions of these studies, however, range from the bidirectional, unidirectional, and neutral relationship between energy consumption and economic growth to a variety of contradictory findings. Economic growth is a result of energy demand. It is true that demand drives consumption. In other words, anything that was eaten had to have been requested. According to Birol (2007), there has been a significant increase in the demand for energy, which has contributed to the expansion of the world economy. Two schools of thinking can be discerned from the empirical literature on the relationship between price growth and energy usage.

Research that looked at the connection between energy use and economic expansion make up the first category. The conclusions of these studies, however, range from the bidirectional, unidirectional, and neutral relationship between energy consumption and economic growth to a variety of contradictory findings. The causal relationship between energy consumption and economic growth was verified by Yu and Choi (1985), who discovered that causality was inverse, moving from economic growth to energy consumption. Research demonstrating bidirectional links suggests that higher levels of economic growth are necessary to assure adequate energy use, but higher levels of consumption are needed to promote economic growth. For example, Hou (2009) used cointegration and Hsiao's causality approach to evaluate the relationship between China's energy consumption and growth between 1953 and 2006. The long-term cointegration of the variables was not supported by the data. Nonetheless, there is evidence of a reciprocal causal relationship between China's economic expansion and energy use. In an investigation of Hungarian evidence of the energy-growth nexus, Ozturk and Acaravci (2010) discovered a reciprocal relationship.

On the other hand, employing cointegration and co-feature analysis, Akinlo (2008) examined the relationship between Nigeria's economic growth and electricity consumption from 1980 to 2006. The findings show that Nigeria's real GDP and electricity consumption are causally related in a unidirectional manner. Additionally, using Granger Causality and Cointegration approaches, Tang, Tan, and Ozturk (2016) investigated the relationship between energy consumption and growth in Vietnam from 1971 to 2011. Despite the cointegration of these variables, this study revealed that energy consumption drives economic growth, indicating a one-way relationship between energy consumption and growth. In a more recent study, Adewuyi (2020) used the nonlinear autoregressive distributed lag (NARDL) model to investigate the impact of the use of non-renewable energy (natural gas and petroleum) on economic growth and carbon emissions in African nations that produce oil between 1980 and 2015. The responses of different countries to variations in their nonrenewable energy usage were found to have different effects on economic growth. The second group focuses on the relationship between energy prices and economic growth. Energy costs are a key element in supporting economic expansion. Research on the relationship between energy costs and economic growth in Nigeria was scarce at the time of this study. Few academics have examined the relationship between energy prices and economic growth, despite the fact that many have concentrated on how they affect each other. Using the generalized least-squares approach, Gonese, Hompashe, and Sibanda (2019) investigated how South African sectoral production was affected by power costs between 1994 and 2015. The results demonstrate how severely production is affected by electricity prices.

Using the Johansen cointegration approach, VECM, Mazambani (2015) analyzed annual data from 1986 to 2013 in his study on the impact of electricity costs on the South African economy. This study discovered that the cost of power had a detrimental effect on economic expansion. The cost of producing energy, taxes or subsidies, weather, distribution and transmission infrastructure, and multi-tiered market management are some of the aspects that Legoete (2005) lists as having an impact on energy costs. If energy prices are relatively steady, economic growth can be positively affected; if they are unstable, prices can rise and have the opposite effect (Frimpong, Antwi, & Brew, 2018).

According to Inglesi-Lotz and Pouris (2016), there is disagreement in the energy economics literature about the relationship between energy prices and economic growth, with conflicting findings found in research conducted by Balcilar, Van Eyden, Uwilingiye, and Gupta (2017); Khobai, Mugano, and Le Roux (2017); Kumar, Shrivastava, and Untawale (2015); and Sodeyfi and Katircioglu (2016). Khobai et al. (2017) investigated the relationship between South Africa's economic expansion and energy prices between 1985 and 2014. The boundary test's findings point to a long-term correlation between growth and electricity prices, indicating that high prices are detrimental. WELISWA (2013) examined the impact of changes in oil prices on South Africa's economic growth from Q4 1994 to Q4 2020 using the VECM approach. The results showed that these variables had positive and negative long-term and short-term relationships.

Some academics have argued that there is a persistent positive association between energy prices and economic growth. The impact of energy prices on economic growth in 18 OECD countries was assessed in a recent study by Huntington and Liddle (2022), which focused on how energy prices shape the Organisation for Economic Co-operation and Development (OECD) Economic Growth: Panel Evidence from Multiple Decades. This study did so by controlling for other significant macroeconomic conditions that influence economic activity. According to the findings, economic growth slowed by roughly 0.15 percent for every 10% increase in energy prices. Economists have examined the connection between oil prices and economic activity since the early 1980s because of the vital role crude oil plays in the world economy.

Sitompul et al. (2022) explores Indonesia's Local Content Requirements (LCR) policy for power generation and turbine production, highlighting the challenges and opportunities for the country's domestic industry. It emphasizes the importance of LCR in reducing reliance on imports, boosting national industry, and achieving the government's goal of independence in electricity production, particularly in the context of Indonesia's 35,000 MW power plant program. However, the key challenges identified include limited technological capabilities, insufficient infrastructure, and institutional barriers, which hinder the development of large-scale turbines. The study recommends policy reforms, such as improving budget mechanisms, simplifying technology licensing processes, and developing industries that support turbine production. It also discusses the strategic role of coal-fired power plants in Indonesia's energy future while stressing the need to align LCR policies with the global shift toward cleaner energy sources.

According to J. D. Hamilton (1983), there is a causal relationship between oil prices and GDP in the United States because seven out of eight recessions from 1948 to 1980 were preceded by large increases in oil prices. These results were further verified by, (Burbidge and Harrison (1984), Gisser and Goodwin (1986), Mork (1989), Ferderer (1996), and other researchers. Studies conducted by Jiménez-Rodríguez* and Sánchez (2005); Lardic and Mignon (2006); Mork, Olsen, and Mysen (1994); Papapetrou (2001) and other corresponding researchers for other significant OECD nations demonstrated that almost all industrialised economies experience a negative correlation between oil prices and GDP. Moreover, research has demonstrated that oil price volatility significantly affects bilateral trade (Chen, Liu, & Hsu, 2013) and stock market returns (Filis, Degiannakis, & Floros, 2011). The results are surprisingly consistent among industrialized nations and apply to net oil importers as well as exporters (like the UK) (Mork et al., 1994). While acknowledging the economic vulnerability to oil shocks, Blanchard and Gali (2007) contend that industrialized nations have become less vulnerable to oil shocks since the 1970s for a variety of reasons, including a decline in their reliance on oil as an input in industrial production.

Rheynaldi, Endri, Minanari, Ferranti, and Karyatun (2023), in a study titled "Energy Price and Stock Return: Evidence of Energy Sector Companies in Indonesia" examines the impact of various factors, including exchange rates, interest rates, oil prices, coal prices, debt-to-equity ratio (DER), return on assets (ROA), and firm size, on stock returns of energy sector companies listed on the Indonesia Stock Exchange (IDX) from 2017 to 2021. This study uses panel data regression analysis and concludes that coal prices, DER, and firm size do not significantly affect stock returns. In contrast, oil prices and ROA have a positive impact, while exchange rates and interest rates negatively influence stock returns. The study suggests that investors should consider macroeconomic factors such as exchange rates, interest rates, and oil price fluctuations when investing in energy companies. This highlights the importance of these variables in determining the financial performance of energy sector companies in Indonesia.

2.1 Gaps in Previous Studies

The studies reviewed above highlight inconsistent findings regarding the relationship between energy consumption, economic growth, and energy price. Despite significant research, the direction of causality—whether energy consumption drives economic growth, vice versa, or both—remains unclear. Some studies suggest a bidirectional relationship, whereas others support unidirectional or neutral associations. Additionally, there is limited research specifically addressing the relationship between energy prices and economic growth in developing nations such as Nigeria and South Africa, where high energy costs have been shown to negatively impact production and economic expansion. These gaps highlight the need for more focused research on how varying energy prices influence economic growth in different contexts.

3. Methodology

3.1 Empirical Specification of the Model and Sources of Data

An Autoregressive Distributed lag (ARDL) regression was used to estimate secondary data from 1981 to 2019 during the estimation process. Information was obtained from Worldometers (online data archive), the World Bank (Worldbank, 2021), and the United States (US) Energy Information Administration (online, 2021 database).

3.2 ARDL Modelling Approach

During the estimation process, During the estimation process, ARDL modeling was used to analyze secondary data which ranges from 1981 through the year 2019. Data were collected from Worldometers (online database), 2021 statistics by The World Bank, and 2021 databases by the U.S. Energy

Information Administration Online. The ARDL approach is applied by utilizing the economic growth equation. This allows the systemic adjustment process from short-term dynamics to long-term equilibrium to be included in the author's estimate of the long- and short-term coefficients. The dynamic structure of the model improves the estimation efficiency and considers potential biases in the results. In contrast to Engle-Granger and Johansen's co-integration strategy, which does not seem to provide the best results in small-sample research, the literature suggests that the ARDL technique is crucial, especially for small-sample observations. (Narayan, 2005). In other words, ARDL provides a more reliable result for small samples compared to Johansen. Therefore, when applying ARDL, not all variables must be integrated in the same order. Variables of order zero or one, as well as a combination of both, can be integrated. It would be more ideal to apply ARDL to the mixture of I(0) and I(1), but not to grade one alone. When applying this technique, the first process involves examining the significance of the long-run lagged coefficient, which varies with the use of Fisher statistics. Second, the estimated parameters of the long- and short-term relationships of the variables were examined (Okorie, Osabuohien, & Oaikhenan, 2020).

3.1.1 Specification of the Model

The present study is anchored on Cobb-Douglas's production function of the form:

Y = A. f (L, K)…………………………………………………………………….… (1)

Where; Y is total economic growth (or real GDP?); L is the total labor force in the energy sector (total labor force, Nigeria); K is the total capital stock; and A is total factor productivity.

Here, the Cobb-Douglas model is expanded with the addition of energy as a factor that enhances productivity.

A=f (*Energy Consumption and prices*)…………………………………….……..……...(2)

When A is substituted in equation (1), we have

Y = f (L, K, Energy Consumption and prices)…………………………………………...(3)

Hence, the empirical model representing the impact of energy consumed on Real GDP is presented below:

Empirical Model

$$\Delta(RGDP) = \beta_0 + \sum_{i=1}^{p} f_{11}\Delta RGDP_{t-1} + \sum_{i=1}^{p} f_{12}\Delta ELECmwh_{t-1} + \sum_{i=1}^{p} f_{13}\Delta ELECkwh_{t-1} +$$
$$\sum_{i=1}^{p} f_{14}\Delta fuelCPMS_{t-1} + \sum_{i=1}^{p} f_{15}\Delta PMSPR_{t-1} + \sum_{i=1}^{p} f_{16}\Delta CrudeOilC_{t-1} + \sum_{i=1}^{p} f_{17}\Delta CRUDEPR_{t-1} +$$
$$\sum_{i=1}^{p} f_{18}\Delta LF_{t-1} + \sum_{i=1}^{p} f_{19}\Delta \log GASCons_{t-1} + \sum_{i=1}^{p} f_{20}\Delta \log energyuse_{t-1} + \sum_{i=1}^{p} f_{21}\Delta COALC_{t-1} + \sum_{i=1}^{p} \beta_1\Delta RGDP_{t-1} +$$
$$\sum_{i=1}^{p} \beta_2\Delta ELECmwh_{t-1} + \sum_{i=1}^{p} \beta_3\Delta ELECkwh_{t-1} + \sum_{i=1}^{p} \beta_4\Delta fuelCPMS_{t-1} + \sum_{i=1}^{p} \beta_5\Delta PMSPR_{t-1} + \sum_{i=1}^{p} \beta_6\Delta CrudeOilC_{t-1}$$
$$+ \sum_{i=1}^{p} \beta_7\Delta CRUDEPR_{t-1} + \sum_{i=1}^{p} \beta_8\Delta LF_{t-1} + \sum_{i=1}^{p} \beta_9\Delta GASCons_{t-1} + \sum_{i=1}^{p} f_{10}\Delta energyuse_{t-1} + \sum_{i=1}^{p} f_{11}\Delta COALC_{t-1} + \varepsilon_t$$
…(4)

Where;

Δ is the operator signifying the first difference, and μ_t is the error term.

3.1.2 Variable Description

The model is used to calculate how energy prices and consumption affect gross domestic product (GDP). where the influences of the independent variables on economic growth are measured as real gross domestic *product (RGDP)* output, which has been captured as the dependent variable. Electricity consumption is measured as electricity consumption in kilowatts per hour *(kwh)* and megawatts per hour *(mwh)*; that is, *(ELECkwh)* and *(ELECmwh),* fuel consumption *(fuelcpms)*, labor force *(LF),* coal consumption *(CoalC),* gas consumption *(logGASCons)*, crude oil consumption *(CRUDEoilC),* crude oil price *(CRUDEPR*), fuel price *(PMSPR)*, and energy use *(Logenergyuse)* are used as the exogenous variables.

The description of the variables and theoretical expectations is presented in the next section. (i) ELEC is one of the essential elements of production in the real subsector. It has been observed that electricity helps reduce the cost of production due to the high cost of generating energy, although it is expected to exert a negative influence on agricultural production due to low power supply and utilization in the agricultural sector. ELEC is measured in kilowatt-hours per capita. (ii) The LF labor force is considered an important variable in the GDPG model. Labor is expected to contribute positively to the output of the petroleum sector. In this study, we used the total LF as a proxy for labor. The total labor in the energy sector is measured in millions of people (Okorie et al., 2020).

4. Result and discussions

The previous section introduced the data and its sources, and the results and discussion based on the estimated results of the study model regarding the impact of energy prices and consumption are presented in this section. By interpreting the results in this section, we can make some recommendations and conclusions based on the empirical results of this paper as follows: The results of the study are presented and discussed appropriately.

4.1. Descriptive Analysis

Table 1. Unit Root Test

Variables	ADF_Augumented* Dicky-fuller Test		PP_Philip-Peron Test*		Decisions
	Level	1st Diff	Level	1st Diff	
RGDP	-5.173551 (0.0002)	Not Stationary	Not Stationary	Not Stationary	I(0)
PMSPR	Not Stationary	-4.810405 (0.0029)	Not Stationary	Not Stationary	I(1)
LF	Not Stationary	Not Stationary	Not Stationary	-5.221124 (0.0001)	I(1)
Loggascons	Not Stationary	-6.394741 (0.0000)*	Not Stationary	-9.302174 (0.0000)	I(1)
FuelCPMS	Not Stationary	-4.279104 (0.0020)	Not Stationary	-5.793650 (0.0000)	I(1)
Logenergyuse	Not Stationary	-5.221778 (0.0002)	Not Stationary	-5.889573 (0.0000)	I(1)
Elec (MegaWatt per hour)	Not Stationary	-6.836224 (0.0000)	Not Stationary	-14.93796 (0.0000)	I(1)

CrudePr	Not Stationary	-5.431801 (0.0001)	Not Stationary	-5.394483 (0.0001)	I(1)
CrudeOilC	Not Stationary	-10.38262 (0.0000)	Not Stationary	-9.790652 (0.0000)	I(1)
CoalC	Not Stationary	-5.688870 (0.0000)	Not Stationary	-5.702482 (0.0000)	I (1)
Elec_kwh	Not Stationary	-3.388649 (0.0702)	Not Stationary	-3.570585 (0.0482)	I (0)

Source: Author's computations, 2021. *variables are stationary at the 5 % level of significance

Table 1 presents the unit root statistics of the variables used in the model. Part of the justification for the autoregressive distributed lag model (ARDL) is the mixture of variables that are stationary at levels I (0) and at first difference I(1). The decision column, represented by the symbols I(0) and I(1), indicates whether the variable is stationary at level or after taking the first difference. The findings of the unit root test can be interpreted as follows: in terms of the Real Gross Domestic Product (RGDP), both the ADF and PP tests show that RGDP is stationary at the level, represented by the symbol I(0). This indicates that there is no unit root for RGDP and that stationarity can be achieved without additional differencing. With respect to the variable PMSPR, the results of the ADF and PP tests indicate that it is non-stationary at the level but becomes stationary upon taking the first difference, or I(1). This suggests that PMSPR has a unit root and that stationarity can only be attained by first differencing. Labor Force (LF) is not stationary at either the level or the first difference, according to the ADF test. After computing the first difference, the PP test indicates that the LF is stationary, indicating that it is I(1).

The ADF and PP tests show the following variables: loggascons, fuelCPMS, logenergyuse, Elec (MegaWatt per hour), crudePr, crudeOilC, and coalC. These variables are non-stationary at level but become stationary after taking the first difference, denoted as I(1). This means that these variables have a unit root, and first differencing is required to achieve stationarity. Concerning, Elec_kwh: The ADF test suggests that Elec_kwh is stationary at level, denoted as I(0). However, the PP test indicates that Elec_kwh is stationary after the first difference is considered, denoted as I(1). This conflicting result may require further investigation or additional tests to resolve ambiguity.

When nonstationary variables result in spurious regressions, where the statistical conclusions may be deceptive, the stationarity of a time series becomes crucial. Prior to performing additional analysis or modeling, stationarity can be achieved by applying proper transformations or differencing based on the order of integration (i.e., whether the variable is I(0) or I(1)). Notably, the test statistics and associated p-values should be considered when determining stationarity. However, there are limitations to these unit root tests, and in certain instances, additional testing or visual inspections of the time series may be required to verify the stationarity of the variables.

4.2 Results of the Estimated Model's Empirical Analysis

Table 2. Bounds Tests and Cointegrating Result

ARDL Bounds Test

Sample: 1982 2014

Included observations: 33

Null Hypothesis: No long-run relationships exist

Test Statistic	Value	K
F-statistic	5.570675	10

Critical Value Bounds

Significance	I0 Bound	I1 Bound
10%	1.83	2.94
5%	2.06	3.24
2.5%	2.28	3.5
1%	2.54	3.86

The results of the bound test indicate ARDL cointegration. The fundamental guideline states that the F statistics must exceed both the lower and upper bounds, I0 and I1. Thus, at a 5% significance level, the upper and lower limits coefficients have values of 3.24 and 2.06, respectively, while the F-statistic has a value of 5.57, which is larger than both the upper and lower bound coefficients. As a result, we accept the alternative, which suggests that the variables included in the study have a long-term link and reject the null hypothesis.

Table 3. Empirical Estimation of the Main Objectives (Combined Variables)
Relationship between Energy Consumption, Energy Prices, and Economic Growth in Nigeria.

Dependent Variable: GDP_GROWTH__ANNUAL___

Method: ARDL

Sample (adjusted): 1985 2019

Included observations: 35 after adjustments

Maximum dependent lags: 3 (Automatic selection)

Model selection method: Akaike info criterion (AIC)

Dynamic regressors (4 lags, automatic): LGAS_CONSUMPTION
LCRUDEOIL FUEL_PRICE___PRICE_IN_NA FUEL__CONSUMPTION
__PMS__ ELECTRIC_POWER_CONSUMPTI COAL_CONSUMPTION_
_THOUSA

Fixed regressors: C

Number of models evalulated: 46875

Selected Model: ARDL(3, 3, 4, 4, 4, 4, 3)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
GDP_GROWTH__ANNUAL___(-1)	-0.293244	0.213015	-1.376635	0.2624
GDP_GROWTH__ANNUAL___(-2)	1.396960	0.397956	3.510342	0.0392
GDP_GROWTH__ANNUAL___(-3)	-0.112699	0.147832	-0.762346	0.5013
LGAS_CONSUMPTION	28.48497	10.09028	2.823011	0.0666
LGAS_CONSUMPTION(-1)	-67.08150	19.25958	-3.483019	0.0400
LGAS_CONSUMPTION(-2)	4.243206	8.660434	0.489953	0.6578
LGAS_CONSUMPTION(-3)	-12.43992	4.257566	-2.921839	0.0614
LCRUDEOIL	-25.54188	8.131685	-3.141031	0.0516
LCRUDEOIL(-1)	-22.61756	8.753170	-2.583927	0.0815
LCRUDEOIL(-2)	33.85238	9.342885	3.623332	0.0362
LCRUDEOIL(-3)	51.51341	12.98701	3.966534	0.0286
LCRUDEOIL(-4)	-25.99340	11.80659	-2.201602	0.1150
FUEL_PRICE___PRICE_IN_NA	2.168545	0.596135	3.637672	0.0358
FUEL_PRICE___PRICE_IN_NA(-1)	0.023247	0.210597	0.110387	0.9191
FUEL_PRICE___PRICE_IN_NA(-2)	-0.420954	0.212115	-1.984550	0.1414
FUEL_PRICE___PRICE_IN_NA(-3)	1.027185	0.298196	3.444658	0.0411
FUEL_PRICE___PRICE_IN_NA(-4)	-1.746761	0.591990	-2.950661	0.0600
FUEL__CONSUMPTION__PMS__	0.107474	0.058101	1.849765	0.1615
FUEL__CONSUMPTION__PMS__(-1)	0.151656	0.059801	2.536018	0.0850
FUEL__CONSUMPTION__PMS__(-2)	0.000714	0.060811	0.011739	0.9914
FUEL__CONSUMPTION__PMS__(-3)	-1.084367	0.274602	-3.948863	0.0290
FUEL__CONSUMPTION__PMS__(-4)	0.294656	0.152123	1.936954	0.1482

ELECTRIC_POWER_CONSUMPTI	0.027700	0.059181	0.468051	0.6717
ELECTRIC_POWER_CONSUMPTI(-1)	-0.342976	0.102637	-3.341636	0.0443
ELECTRIC_POWER_CONSUMPTI(-2)	0.074945	0.063652	1.177403	0.3239
ELECTRIC_POWER_CONSUMPTI(-3)	-0.191208	0.131530	-1.453722	0.2420
ELECTRIC_POWER_CONSUMPTI(-4)	0.091882	0.096014	0.956963	0.4092
COAL_CONSUMPTION__THOUSA	-0.521023	0.139260	-3.741365	0.0333
COAL_CONSUMPTION__THOUSA(-1)	0.429140	0.099028	4.333532	0.0227
COAL_CONSUMPTION__THOUSA(-2)	-0.007103	0.061832	-0.114878	0.9158
COAL_CONSUMPTION__THOUSA(-3)	0.266791	0.069937	3.814742	0.0317
C	483.7075	179.7994	2.690263	0.0744

R-squared	0.977657	Mean dependent var	4.423378
Adjusted R-squared	0.746775	S.D. dependent var	3.830380
S.E. of regression	1.927504	Akaike info criterion	3.522165
Sum squared resid	11.14582	Schwarz criterion	4.944197
Log likelihood	-29.63788	Hannan-Quinn criter.	4.013050
F-statistic	4.234448	Durbin-Watson stat	3.109547
Prob(F-statistic)	0.129534		

*Note: p-values and any subsequent tests do not account for model selection.

4.2.1 Interpretations of Findings for Main Objectives

A regression analysis that examines the impact of various variables on economic growth, particularly focusing on energy consumption and fuel prices in Nigeria, is given above. The coefficients represent the estimated impact of each variable on economic growth. The t-statistics measure the significance of each coefficient. A higher t-statistic indicates a more significant impact. The coefficients for GDP growth lagged variables (-1, -2, and-3) show the impact of past GDP growth rates on current economic growth. A positive coefficient for lagged GDP growth (-2) suggests that a higher GDP growth rate two periods ago positively influences current economic growth.

The LGAS_CONSUMPTION and LCRUDEOIL variables represent the logarithm of gas and crude oil consumption, respectively. The positive coefficient of LGAS_CONSUMPTION(-1) indicates that an increase in gas consumption in the previous period positively affects economic growth.

FUEL_PRICE___PRICE_IN_NA and FUEL__CONSUMPTION__PMS__ represent fuel prices and consumption, respectively. The positive coefficient for FUEL_PRICE___PRICE_IN_NA(-3) suggests that higher fuel prices three periods ago had a positive impact on economic growth. The ELECTRIC_POWER_CONSUMPTI and COAL_CONSUMPTION__THOUSA variables represent electric power and coal consumption, respectively. The negative coefficient for COAL_CONSUMPTION__THOUSA(-1) indicates that an increase in coal consumption in the previous period negatively affects economic growth. The R-squared value (0.977657) indicates that the model explains approximately 97.77% of the variation in economic growth.

The Adjusted R-squared value (0.746775) adjusts for the number of predictors in the model, providing a more accurate measure of the model's goodness of fit. These analyses show that variables with statistically significant coefficients (p-value < 0.05) have a significant impact on economic growth. For instance, higher gas consumption and fuel prices in previous periods seem to positively influence economic growth, whereas coal consumption may have a negative impact. Therefore, the regression analysis suggests that energy consumption, fuel prices, and other energy-related variables play a significant role in influencing economic growth in Nigeria, highlighting the importance of energy policies and consumption patterns in driving economic performance.

4.2.3 Empirical Estimation of Objective 1

To examine the relationship between energy consumption and economic growth in Nigeria.

4.2.3.1: Co-integration and Long run coefficient of Variables used

Table 4. ARDL Cointegrating And Long Run Form

Dependent Variable: LOGRGDP

Selected Model: ARDL (2, 2, 2, 2, 2, 2, 2, 2, 0, 2)

Sample: 1981 2019

Included observations: 32

Cointegrating Form				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LOGRGDP(-1))	1.307364	0.260393	5.020729	0.0074
D(PMSPR)	-0.005703	0.001516	-3.762614	0.0197
D(PMSPR(-1))	0.004892	0.001369	3.573277	0.0233
D(LOGLF)	-2.935375	0.745488	-3.937523	0.0170
D(LOGLF(-1))	-4.905418	0.938073	-5.229248	0.0064
D(LOGGASCONS)	-0.049546	0.040688	-1.217717	0.2903
D(LOGGASCONS(-1))	0.115289	0.051230	2.250441	0.0876
D(FUELCPMS)	0.001195	0.000420	2.843360	0.0467
D(FUELCPMS(-1))	0.000552	0.000448	1.232386	0.2853
D(LOGENERGYUSE)	-2.236527	0.617997	-3.618993	0.0224
D(LOGENERGYUSE(-1))	-1.251830	0.432351	-2.895402	0.0443

D(ELEC)	0.000170	0.000055	3.071176	0.0373
D(ELEC(-1))	0.000145	0.000052	2.757222	0.0510
D(CRUDEPR)	0.008913	0.001259	7.081775	0.0021
D(CRUDEPR(-1))	-0.008253	0.001865	-4.424538	0.0115
D(CRUDEOILC)	0.000001	0.000000	3.051980	0.0380
D(COALC)	-0.003102	0.000635	-4.883972	0.0081
D(COALC(-1))	0.001612	0.000435	3.702542	0.0208
CointEq(-1)	-0.372572	0.163136	-2.283817	0.0844

Cointeq = LOGRGDP - (-0.0435*PMSPR + 2.8190*LOGLF + 0.2587
*LOGGASCONS + 0.0009*FUELCPMS -4.1736*LOGENERGYUSE +
0.0001*ELEC + 0.0376*CRUDEPR + 0.0000*CRUDEOILC -0.0091
*COALC -7.7036)

Long Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
PMSPR	-0.043511	0.022877	-1.901970	0.1299
LOGLF	2.818998	1.209334	2.331034	0.0802
LOGGASCONS	0.258718	0.155517	1.663596	0.1715
FUELCPMS	0.000854	0.001531	0.557684	0.6068
LOGENERGYUSE	-4.173564	3.146468	-1.326428	0.2554
ELEC	0.000126	0.000121	1.049045	0.3534
CRUDEPR	0.037622	0.018438	2.040447	0.1109
CRUDEOILC	0.000002	0.000001	1.753700	0.1543
COALC	-0.009118	0.004535	-2.010724	0.1147
C	-7.703555	13.194051	-0.583866	0.5907

4.2.3.2 Discussions of Findings for Objective One.

The error-correction coefficient was negative (-0.372572), as required, and significant. Importantly, the long-run coefficients of the cointegrating equation are reported, along with their standard errors, t-statistics, and p-values. So, what are we concluding about all of this? First, as might be expected, there is a long-term equilibrium relationship between economic growth (as measured by the real gross domestic product (RGDP)) and labor (as measured by the labor force). Second, there is a relatively fast adjustment of Real GDP growth when fuel price (as measured by PMSPR) and energy prices, among other variables, change.

Table 5. Empirical Estimation of Objectives 2
To analyze the impact of energy prices on
Economic growth in Nigeria.

Table 4 shows the findings of the Autoregressive Distributed Lag (ADRL) based on the empirical analysis of the relationship between energy consumption, energy prices, and economic growth in Nigeria. The dependent variable used is Real Gross Domestic Product growth (RGDP), while the independent variables are fuel price (PMSPR), labor force (LF), gas consumption (loggascons), fuel consumption (fuelCPMS), energy use (logenergyuse), electricity (Elec) Mwh, Crude oil price (CRUDEPr), Crude oil consumption, and coal consumption variable represented as (COALC).

Dependent Variable: LOGRGDP

Method: ARDL

Sample (adjusted): 1983 2014

Included observations: 32 after adjustments

Maximum dependent lags: 2 (Automatic selection)

Model selection method: Akaike info criterion (AIC)

Dynamic regressors (2 lags, automatic): PMSPR LOGLF
LOGGASCONS

FUELCPMS LOGENERGYUSE ELEC CRUDEPR CRUDEOILC
COALC

Fixed regressors: C

Number of models evalulated: 39366

Selected Model: ARDL(2, 2, 2, 2, 2, 2, 2, 2, 0, 2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LOGRGDP(-1)	1.934792	0.320797	6.031212	0.0038
LOGRGDP(-2)	-1.307364	0.260393	-5.020729	0.0074
PMSPR	-0.005703	0.001516	-3.762614	0.0197
PMSPR(-1)	-0.005616	0.001234	-4.552788	0.0104
PMSPR(-2)	-0.004892	0.001369	-3.573277	0.0233
LOGLF	-2.935375	0.745488	-3.937523	0.0170

LOGLF(-1)	-0.919764	0.639122	-1.439105	0.2235
LOGLF(-2)	4.905418	0.938073	5.229248	0.0064
LOGGASCONS	-0.049546	0.040688	-1.217717	0.2903
LOGGASCONS(-1)	0.261226	0.042796	6.103929	0.0036
LOGGASCONS(-2)	-0.115289	0.051230	-2.250441	0.0876
FUELCPMS	0.001195	0.000420	2.843360	0.0467
FUELCPMS(-1)	-0.000325	0.000444	-0.731138	0.5052
FUELCPMS(-2)	-0.000552	0.000448	-1.232386	0.2853
LOGENERGYUSE	-2.236527	0.617997	-3.618993	0.0224
LOGENERGYUSE(-1)	-0.570256	0.378254	-1.507600	0.2061
LOGENERGYUSE(-2)	1.251830	0.432351	2.895402	0.0443
ELEC	0.000170	5.55E-05	3.071176	0.0373
ELEC(-1)	2.14E-05	2.78E-05	0.770528	0.4840
ELEC(-2)	-0.000145	5.25E-05	-2.757222	0.0510
CRUDEPR	0.008913	0.001259	7.081775	0.0021
CRUDEPR(-1)	-0.003150	0.000782	-4.027988	0.0158
CRUDEPR(-2)	0.008253	0.001865	4.424538	0.0115
CRUDEOILC	6.48E-07	2.12E-07	3.051980	0.0380
COALC	-0.003102	0.000635	-4.883972	0.0081
COALC(-1)	0.001317	0.000350	3.766982	0.0197
COALC(-2)	-0.001612	0.000435	-3.702542	0.0208
C	-2.870127	5.102292	-0.562517	0.6038

R-squared	0.999876	Mean dependent var	17.10824
Adjusted R-squared	0.999038	S.D. dependent var	0.496475
S.E. of regression	0.015395	Akaike info criterion	-5.838934
Sum squared resid	0.000948	Schwarz criterion	-4.556415
Log likelihood	121.4229	Hannan-Quinn criter.	-5.413815
F-statistic	1193.863	Durbin-Watson stat	2.848639
Prob(F-statistic)	0.000002		

*Note: p-values and any subsequent tests do not account for model selection.

4.3.1 Discussions of Findings for Objective Two

The results of the ARDL regression show the results for the coefficients in the short run. Based on the results presented above, the price of petroleum is inversely related to the real GDP growth in the short run; that is, a 1%- percent rise in the price of fuel will contribute negatively to RGDP growth (showing a decreased demand or lack of income for consumption, or justifying the inverse relation of consumer demand). The labor force contributes positively, as the a priori expectations predicted. This means that a 1% rise in the labor force will bring about a 4% increase in the real GDP vis-à-vis contribution to economic growth in the short-run second period lag. (This indicates that more unemployed graduates should be mobilized to work. Through the government and the private sector providing jobs to boost economic growth). Fuel consumption contributes significantly to economic growth. (Through consumers' purchasing power). However, its contribution in the short run is minimal at 0.0012%. Energy use is inversely related in the initial and last period lags but positively related to economic growth in the second period lag. Contributing 1% to economic growth.

Electricity consumption is significant, but its contribution is infinitesimal at 0.000170% to the GDP- a sign that the industry is not operating at full capacity due to inefficiencies or mismanagement. Crude oil price contributes about 0.008253 % to the real GDP's growth in the short run second period, and crude oil consumption contributes about 6% to the gross domestic product. Coal consumption shows some prospects as its contribution is mixed in nature. In the initial period, its contribution is negatively related to GDP, even though it is significant based on its probability value. In the first period lag, it contributes positively to 0.00132% of economic growth as measured by GDP. These trends need to be reversed to enable consumers to contribute more to RGDP growth with improved income and technologies. We must obtain better infrastructure in place.

5. Conclusion

The results of this study clearly show that energy consumption plays an important role in Nigeria's economic growth. However, the results have been mixed. The Autoregressive distributed lag (ARDL) model, which was chosen based on the mixed nature of the unit root test and bound testing techniques, was applied to investigate the relationship between energy consumption, energy prices, and economic growth, as well as the relationship between energy consumption, electricity consumption, and economic growth and an additional variable (energy prices) for Nigeria for the period from 1981 to 2019. As far as the short-run dynamics of data are concerned, our analysis reveals that economic growth (as measured by Real GDP) has a positive and statistically significant effect on energy consumption in the short run in Nigeria and later in the long run. An increase in real GDP is likely to affect energy demand in several ways.

At the household level, as per capita income increases, people seeking to improve their comfort can spend the extra income earned on additional energy services. Second, economic growth can induce a demand for more energy, which is a major input in the production system. Thus, an increase in real GDP increases energy consumption in the short run, which in turn can increase production in the real sector. Conversely, in the long run, energy consumption causes Real GDP growth in Nigeria. Regarding the electricity consumption and real GDP, the relationship is significant, but its contribution is infinitesimal at 0.000170% to the GDP- a pointer that the industry is not operating at fully optimal capacity due to rip off by the management or some workers, or it can be attributed to the low access to electricity. However, in the long run, improving access to electricity in Nigeria is important for economic growth. These findings imply that high energy and electricity consumption drive economic growth. Changes in energy use patterns have a significant impact on changes in income in Nigeria. Energy is thus an important factor in economic development, and energy conservation may harm economic growth in these countries, regardless of being transitory or permanent.

Petroleum prices are inversely related to the real gross domestic product (RGDP). The findings of this study support signal theory, which states that the better the signal that has a positive impact on a company, the more attractive investors are to invest in that company. By implications, it means there is a decreased demand or lack of income for consumption, or justifying the inverse relation of consumer demand when energy price increases. However, this is not beneficial for the economy. Rather, government policies to maintain the current fuel price should be sacrosanct.

The analysis reveals that the labor force conforms to known theories that state that they are positively related to economic growth. Furthermore, we also discover that crude oil consumption, electricity consumption, and coal consumption are positively related to economic growth. However, the lagged values of electricity consumption and energy use are negatively related to economic growth. The reason for this could be that these two energy sources have a higher direct influence on the economy in the present period than in lagged periods. That is, energy consumption acts mainly as an intermediate good in past periods and then acts both as an intermediate and a final product of the present period. In other words, the effect of electricity in the past can only be seen in other factors or products that influence Gross Domestic Product today, but the effects of electricity in the current period will not only be seen in the same frame as in the lagged years, but in tune with its direct effect on economic growth. The promotion of clean cooking fuels and improved cooking stoves is required to improve households' energy access. Finally, based on the study findings, the following should be prioritized by policymakers and actors: turn around maintenance or building new refineries to lower the pump price of fuel, increase energy supply around the country, sustain and enhance energy infrastructure, increase research and development in the energy sector, diversify energy sources, promote energy efficiency and conservation, and maintain efficient pricing of energy supply.

5.1 Limitations

In the study, it is observed that changes in energy use patterns have a significant impact on changes in income in Nigeria, but the study does not fully explore the implications of these patterns on economic growth. Similarly, the study showed that there were positive relationships between crude oil consumption, electricity consumption, and coal consumption with economic growth, but does not fully explore the implications of these energy sources on economic development. Labor force, on the other hand, shows a positive relation to economic growth, but labor market dynamics are not fully captured in the output of findings. Therefore, it is imperative for researchers to study the areas highlighted as draw backs in this study.

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