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# Impact of Energy Consumption component and Industrial Output Dynamics in Nigeria

Iortyer Aondover Dominic<sup>1</sup> and Eyitayo Ewa Emmanuel<sup>1</sup>

<sup>1</sup>Department of Economics, Federal University Lokoja, Kogi State Nigeria.

#### Abstract

#### **Keywords:**

Energy components Industrial output Fossil energy consumption Renewable energy

#### JEL Classification:

*Corresponding author* Iortyer Aondover Dominic iortyer.dominic@fulokoja.edu.ng Tel: Energy consumption plays a crucial role in determining the performance of the real sector. This research examines how different components of energy consumption affect industrial productivity in Nigeria from 1981 to 2023. The components analyzed include electricity, gas, and petrol consumption, which serve as the explanatory variables in the model. Time series data for these variables were collected for the analysis. The study utilized advanced econometric methods, including unit root tests, cointegration analysis, and error correction mechanisms to estimate the model. Some diagnostics were conducted to test for normality, stability and serial correlation of the model. The results indicated that each component of energy consumption positively influences industrial output to varying extents. Based on these findings, the study recommends increasing energy supply to ensure sustainable performance in the industrial sector.

# 1. Introduction

economic growth and plays a significant role in job creation and enhancing production efficiency. The primary objective of an energy market is to bolster the economy across various sectors. In Nigeria, energy supply and demand are critical components of the economy, highlighting substantial research opportunities in this area.

An analysis of energy supply trends from 1981 to 2023 reveals a notable increase in renewable energy consumption, peaking at 62,000 kilowatt-hours (KWh) in 2022, indicating a shift towards renewable sources. In contrast, fossil fuel energy consumption (FFEC) showed fluctuations over the same period, with a peak of 22.84 million barrels of oil equivalent (MMBOE). Since 2000, FFEC has stabilized around 19.0 MMBOE, reflecting a more consistent consumption pattern.

Electricity consumption has also risen significantly, from 51.08 KWh in 1981 to 152.99 KWh in 2022, underscoring the growing demand

for electricity in line with Nigeria's economic development. The analysis of energy consumption trends between 2019 and 2022 indicates continued growth, driven primarily by sustained electricity demand and a gradual transition to renewable energy.

This research aims to explore how the increasing reliance on these energy sources—gas, petrol, and electricity—affects industrial output, which is vital for economic growth.

#### 2. Literature review

#### 2.1 Conceptual review

#### 2.1.1 Energy consumption

In this context, energy consumption refers to the total energy required for production processes or services, measured in kilowatt-hours (KWh). The energy components in Nigeria include electricity, gas, fuel, and biomass. Ahmad (2023) notes that energy consumption is essential for evaluating a country's standard of living, as it significantly impacts productivity.

#### 2.1.2 Industrial output dynamics

The term "industrial output dynamics" encompasses the range of productive activities across firms, from micro to macro levels. It involves the processes and technologies that drive production. Amadi (2019) argues that understanding these dynamics is crucial for assessing economic performance.

## 2.1.3 Overview of the Nigerian energy sector

Despite being a significant player in the global oil market, Nigeria's energy sector faces numerous challenges, including inefficiencies and systemic issues that jeopardize energy security (Orazulike, 2012). These challenges impact various energy resources, including diesel, which suffers from supply inefficiencies due to the Power Holding Company of Nigeria (PHCN) and the National Electric Power Authority (NEPA). This reliance on diesel as an alternative energy source has created issues related to availability and pricing. Petrol, another key energy resource, is influenced by a group of elites known as cabals, whose self-serving decisions complicate its management. Nigeria's economic structure heavily depends on oil and gas, with budgetary allocations closely tied to oil price fluctuations. Environmental pollution in energy-producing regions has sparked social unrest, resulting in vandalism, kidnapping, and other forms of political instability. The underutilization of refining capacity exacerbates these problems, leading to fuel shortages and rising prices. Adenikinju (2010) highlights that these factors contribute to a state of economic instability, with the energy sector playing a significant role.

Estimates by Emodi and Dauda (2015) and NERC (2017) indicate that Nigeria's grid supply potential is approximately 12,522 MW. However, operational inefficiencies hinder maintenance and fuel supply. Despite reaching a peak of 5,375 MW in February 2019, this capacity remains inadequate to meet the growing energy demands, which stand at 20,000 MW and have the potential to rise to 90,000 MW by 2021 (Mbah, 2019). Moreover, less than 50% of the population has access to the grid, with only 4% enjoying access to clean energy for domestic use (Anon, 2016).

#### 2.1.4 Energy Infrastructure in Nigeria

One of the leading energy producing country in Africa is Nigeria which has abundant energy resources in hydro-electric resources and biomass. Consequently, Nigeria has been able to generate substantial revenue from energy exports to neighbouring countries like Ghana and Niger.

Nigeria energy infrastructure consists of energy generation, transmission and distribution of electricity, the physical soil and natural gas pipelines that arises across the country as well as refineries and other energy transportation elements like marine and rail transportation.

Energy infrastructure according to Amadi (2019) posits that energy infrastructure implies facilities and equipment used for the generation

of electric energy or the production, processing and delivery of fossil fuel (fuel from petroleum or petrochemicals).

2.1.5 Implication of Energy on Nigeria Economy The growth and sustainability of modern industrial economy depends on availability of energy supply. Energy is considered as an essential ingredient for human activities. Barros (2018) conducted an analysis on the financial impact of power outages in Nigeria. According to Adenikinju (2018), the marginal cost of power outages ranges from \$0.94 to \$3.13 per kWh of lost electricity when using the revealed preference approach. The study found that businesses incurred large costs as a result of power outages, given Nigeria's inadequate electricity supply. It was discovered that smallscale operators were most severely impacted by the infrastructural breakdowns.

# 2.2 Theoretical framework

### Energy Consumption Theory

The Energy Consumption Theory, also referred to as the Energy Cost Theory, posits that the overall economic benefits of operations in the manufacturing and service sectors can outweigh the costs associated with energy use. This theory encompasses material acquisition and energy resource utilization, leading to broader economic advancements through a demand multiplier effect.

Advancements in energy efficiency and technology can reduce costs for businesses, ultimately benefiting consumers as well. This theory also suggests that while firms may not need to rely on a single energy source, a combination of technologies can enhance energy efficiency. comply with environmental regulations, and increase profitability. By diversifying energy sources-including fossil fuels, hydrogen fuel cells, and renewable technologies-companies engaged in energyintensive operations can achieve sustainable growth.

In conclusion, the implications of energy consumption extend beyond mere availability; they encompass affordability and the interplay of various energy sources in driving industrial output and economic development.

#### 2.3 Empirical review

This section integrates findings from various studies to explore the relationship between energy consumption and economic performance in Nigeria, guided by co-integration estimates from Engel and Granger as well as unit root tests.

To assess the causal relationships between service output and energy consumption, a bivariate VAR Granger causality approach was employed. The analysis revealed a unidirectional causation from aggregate energy consumption to service output, while a bidirectional relationship was identified between agricultural output and energy consumption.

Enang (2017) investigated the interplay between Nigeria's industrialization, energy supply, and economic development from 1970 to 2016, illustrating how these variables influence industrial growth. Similarly, Ekpo (2019) utilized ARDL bound testing to analyze the connections among industrial output, population, real GDP per capita, and energy consumption from 1970 to 2018. Many studies have focused primarily on the correlation between electricity supply and economic growth, often neglecting the impact of energy on various economic sectors. This oversight can lead to misleading conclusions, as economic growth is influenced by multiple sectors with differing energy needs.

According to Okafor (2018), insufficient electricity generation poses a significant barrier to Nigeria's industrial advancement. George and Oseni (2020) pointed out that the less productive residential sector consumes nearly four times more electricity than the commercial and industrial sectors, which they argue hampers industrial sector growth. Emovon (2016) emphasized that a reliable power supply is essential for rapid industrial and economic development. In their analysis, Ayodele and Falokun (2019) highlighted the importance of industrialization for economic growth, noting that Nigeria's abundant labor resources could be effectively utilized through industrial processes.

The general state of infrastructure greatly influences economic development, with inadequate energy generation identified as a key issue in Nigeria's infrastructural decline (Asaolu and Oladele, 2016). For over four decades, Nigeria has struggled with challenges related to energy access, availability, and quality, which if addressed could enhance economic performance and reduce social issues (Rabiu, 2019). Small and medium-sized enterprises (SMEs), which are crucial for employment, require reliable power supplies to operate efficiently.

Moreover, Adeyeye (2014) pointed out that the high cost of electricity from private providers exacerbates challenges for SMEs due to the intermittent supply from the national grid. Many small businesses, such as barber shops and repair services, struggle to thrive without reliable power, particularly in Nigeria's competitive market.

The reliance on generators as the primary electricity source for homes and businesses has become prevalent. This situation arises from governmental inefficiencies that have caused these backup systems to become more common than primary energy sources (Okereke, 2021). However, the costs associated with using private generators—such as fuel expenses, noise pollution, and fire hazards—are significant.

Alaba (2012) investigated the link between energy consumption and the performance of Nigeria's manufacturing sector, revealing a correlation between energy price and availability with productivity. While energy resources are vital, the study also noted that merely having these resources is not sufficient to enhance manufacturing performance. A key conclusion was that the industrial sector heavily relies on outdated technologies, underscoring the need for more advanced, energy-efficient processes. This indicates that changes in energy pricing alone will not substantially impact industrial success; rather, simultaneous reforms in the energy sector and technological advancements are necessary for maximizing benefits from energy resources.

Research indicates that energy demand directly influences economic growth. Birol (2017) highlighted the dramatic increase in energy demand, which has spurred global economic expansion. Yu and Choi (2015) found a positive correlation between energy consumption and economic growth in the Philippines, characterizing it as a unidirectional relationship where energy consumption drives growth.

Similar findings were reported by Asafu (2016) for Singapore and Indonesia, where a unidirectional link between economic growth and energy consumption was observed. Ukpong (2016) also noted this relationship, suggesting that the energy sector's growth significantly contributes to the industrial sector's expansion. However, alternative studies have presented conflicting views on the causal relationship between GDP and energy consumption.

Yu and Choi (2015) identified an inverse relationship, suggesting energy consumption is driven by economic growth rather than the other way around. Some scholars maintain that there is a persistent positive relationship between economic growth and electricity consumption. The consensus among economists points to a direct link between energy use and economic growth.

Using the Pearson correlation coefficient, Morimoto and Hope (2011) demonstrated a strong association between energy use and economic growth in Sri Lanka. Ndebbio (2006) asserted that energy consumption, measured in megawatts, is a crucial indicator of a nation's level of industrialization, emphasizing a direct correlation between per capita energy consumption and industrial growth. Breshin (2014) concluded that the energy, manufacturing, and social sectors are interdependent and cannot thrive without electricity, noting a concurrent increase in GDP and energy demand. Simpson (1969) stated that "developing industries in modern Africa are driven by electricity rather than steam engines," implying that economic growth is fundamentally linked to electricity usage.

Ageel (2020) found that increased electricity consumption significantly fuels economic growth in Pakistan, mirroring Nigeria's circumstances. Through a co-integration model, Ageel explored the relationship between energy consumption and economic growth. Sanchis (2017) noted that the electricity sector contributes substantially to output, emphasizing its role in capital accumulation and production inputs.

Alam (2016) posited that neoclassical economics, which traditionally recognized only labor, capital, and technology as production factors, must now include energy as a key component, as it powers the processes transforming raw materials into finished goods. In addition, Adeleke and Oyebisi, (2021) exposed the role of public-private partnerships in boosting energy security in Nigeria. The study argued that such partnerships could leverage the strengths of both sectors to address major challenges facing the energy sector and improve access to energy and utilization.

#### 3. Methodology

### 3.1 Model Specification

This study builds on the work of Payne (2020) by substituting coal consumption with petrol and adjusting manufacturing to industrial output. The functional model can be expressed as follows:

$$INDP = f(ELC, PEC, GAC)$$
 1

This model indicates that industrial output (INDP) is influenced by electricity consumption (ELC), petrol consumption (PEC), and gas

consumption (GAC). Although the economic relationships represented in these models do not establish precise interactions, they suggest inexact influences. Therefore, the econometric model is specified as:

$$INDP_{t} = \beta_{0} + \beta_{1}ELC_{t} + \beta_{2}PEC_{t} + \beta_{3}GAC + \mu_{t}$$

$$2$$

INDP<sub>t</sub> = Industrial output at time t ELC<sub>t</sub> = Electricity consumption at time t PEC<sub>t</sub> = Petrol consumption at time t GAC<sub>t</sub>= Gas consumption at time t  $\mu_t$  = stochastic error term

 $\beta_0$  = constant and  $\beta_1$ ,  $\beta_2$  and  $\beta_3$  = slopes of explanatory variables; t = time. A priori expectations are;  $\beta_1$ ,  $\beta_2$  and  $\beta_3 > 0$  The ECM version of the model

$$INDP = \beta_0 + \sum_{t=1}^{k-1} \beta_1 \Delta ELC_t + \sum_{t=1}^{k-1} \beta_2 \Delta PEC_t$$
$$+ \sum_{t=1}^{k-1} \beta_3 \Delta GAC_t + \lambda ECT + \mu \cdot$$
3

From the model specified, the a priori expectations are written as;  $\beta_1$ ,  $\beta_2$ , and  $\beta_3_{>0}$ 

#### 3.2 Unit root test

Stationarity tests are conducted to prevent the selection of inappropriate methods that could lead to spurious regression and consequently yield misleading policy recommendations. To determine the order of stationarity for the variables, the Augmented Dickey-Fuller (ADF) test was applied at both the level and first difference. The results indicate that all variables (INDP, ELC, PEC, and GAC) were non-stationarity ar level but became stationary at the first difference, as evidenced by their P-values being below the 5% significant threshold.

Variables	ADF Statistic	ADF Statistic	Critical values	Critical values of	P-values at level	P-values at first	Order
	at level	at first difference	of 5% at level	5% at first difference	ut level	difference	integration
INDP	-0.192364	-7.453713**	-3.098654	-4.521925	0.8364	0.0000	I(1)
ELC	1.133543	-6.820853**	-3.098675	-2.967767	0.8565	0.0000	I(1)
PEC	-1.223124	5.974522**	-3.221654	-2.786318	0.7058	0.0015	I(1)
GAC	0.045215	-13.2273**	-3.098675	-2.986225	0.8237	0.0000	I(1)

Table 1 Augmented Dickey Fuller (ADF) Unit Root Test Results at First difference

3.3 Cointegration test

The Johansen cointegration result indicate I cointegration equation in both the trace and maximum Eigen statistics at 5 percent level.

Since there is at least one cointegration equation, it indicates a stable long – run relationship among the variables. The result is presented in table 2.

HypothesizedTrace0.05No. of CE(s)EigenvalueStatisticCritical ValueProb.**						
None *	0.849634	109.5713	47.85613	0.0000		
At most 1	0.386042	28.09985	29.79707	0.0775		
At most 2	0.152662	7.123218	15.49471	0.5634		
At most 3	7.89E-07	3.39E-05	3.841466	0.9973		

**Table 2: Unrestricted Cointegration Rank Test (Trace)** 

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

\* denotes rejection of the hypothesis at the 0.05 level

\*\*MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.849634	81.47148	27.58434	0.0000
At most 1	0.386042	20.97664	21.13162	0.0525
At most 2	0.152662	7.123184	14.26460	0.4747
At most 3	7.89E-07	3.39E-05	3.841466	0.9973

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

\* denotes rejection of the hypothesis at the 0.05 level

\*\*MacKinnon-Haug-Michelis (1999) p-values

Variables	Coefficient	Std. Error	t-statistic	Prob.
С	-145635.	5.63432.	-0.308334	0.0023
$\Delta(ELC)$	4.56226	2.27446	1.304563	0.0041
$\Delta(\text{PEC})$	471.2222	5427.719	-0.086818	0.0316
$\Delta(GAC)$	3.155911	0.060679	52.00954	0.0000
ECT(-1)	-0.550428	0.054440	1.926304	0.0443
R-squared	0.899921			
F-statistic	69815.91			0.000000

Source:	Author	s,s computat	ion 2024	using e	-view	10
Table 3	Error	Correction	Mechan	ism Re	sult	

Source: Author's computation, 2024 using E-view 10

The ECM results indicate that the model is wellspecified statistically and significant, demonstrating a convergence to equilibrium with 55% of short-run deviations corrected over time, as suggested by the negative ECT coefficient (-0.55). The changes in ELC, GAC, and PEC all exhibit significant positive effects at the 5% level. Specifically, a 1% increase in ELC, holding other factors constant, leads to a 3.58% increase in industrial output. Furthermore, a rise in GAC results in a 3.16% increase in industrial output, while PEC contributes a 4.71% increase. The R-squared value of 0.899921 indicates that approximately 90% of the variation in industrial output is explained by the energy consumption variables.

## 3.1 Post-Estimation Results

# Ramsey Test for Stability

The Ramsey test was conducted to evaluate the stability of the variables. The null hypothesis, stating that the variables are unstable, is rejected if the probability value exceeds the statistical threshold. The results below support the conclusion that the variables are stable.

Table 4. Ramsey	v test for	stability	Result
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	Value	Df	Probability
t-statistic	0.201	24	0.0747
F-statistic	0.085	(1, 24)	0.2307
Likelihood ratio	0.031	1	0.8119

Source: Author's computation, using E-view 10

The result as revealed in the table established the stability of the model as all the probability values of both t-statistics and f-statistics are more than 5%.

#### 3.2 Normality Test

To assess normality, the Histogram Normality Test was utilized, revealing a normal distribution of variables. The Jarque-Bera probability value was below 0.05, affirming the normality of the model.



**Table 5: Serial Autocorrelation Result** 

F-statistic	4.748649	Prob. F(2,23)	0.0188
Obs*R-squared	8.475217	Prob. Chi-Square(2)	0.0144

## 3.3 Serial Autocorrelation

The LM test indicated no presence of autocorrelation, as shown by the F-statistic probability values below 0.05. The serial autocorrelation results indicate that the model exhibits significant autocorrelation. The Fstatistic is 4.748649 with a probability of 0.0188, suggesting that at least one lagged value significantly correlates with the current values. Additionally, the Obs\*R-squared value is 8.475217 with a Chi-Square probability of 0.0144, further confirming the absence of autocorrelation. Both statistics indicate that the null hypothesis of no autocorrelation can be accepted at a 5% significance level. This suggests that the model require adjustments to account for the absence of serial correlation in the residuals.

## 4. Conclusion and recommendation

This study explored the impact of various energy consumption components on the dynamics of industrial output in Nigeria, focusing on the effects of electricity, petrol, and gas consumption. Time series data for industrial output (dependent variable) and electricity consumption (ELC), petrol consumption (PEC), and gas consumption (GAC) as independent variables were analyzed using econometric methods, including ADF tests for unit roots and the Johansen technique for co-integration.

The findings indicate varying impacts of energy consumption components on industrial output levels in Nigeria, highlighting that these components play a crucial role in the short-term improvement and sustainability of industrial performance. The analysis confirms that electricity, petrol, and gas consumption significantly affect industrial output. With approximately 90% of the variability in industrial output explained by the independent variables, the study strongly asserts that energy components—specifically electricity, petrol, and gas consumption—have a meaningful impact on industrial output in Nigeria. Based on the study's findings, the following recommendations are made:

1. The government should enhance electricity generation and distribution to industries to elevate output levels. Possible methods include investing in renewable energy sources, improving grid infrastructure, and incentivizing private sector involvement in energy generation.

2. Industries dependent on petrol as their primary energy source should seek alternatives, as its positive impact on industrial output is limited. Transitioning to more sustainable energy options can improve efficiency and output.

3. Industries are encouraged to increase their use of gas energy for production processes, given its significant positive impact on industrial output in Nigeria. Implementing gas infrastructure improvements can facilitate this transition.

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