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Original Paper

Electricity Production, Consumption, and Manufacturing Sector Performance in Nigeria: A Multi-Decade Analysis

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Abstract. Electricity is a crucial factor in modern manufacturing processes, but erratic power supply hampers the efficiency of Nigeria's manufacturing sector. This research examines electricity production, consumption and its impact on Nigeria's industrial output, exploring the relationship between power availability and economic and industrial advancement. We hypothesise a significant long-term relationship exists between electricity production/consumption and manufacturing sector output in Nigeria. The time series data from 1985 to 2018 and the Autoregressive Distributed Lag (ARDL) bounds testing technique for cointegration were used. Our findings reveal long-term relationships between the variables, indicating that manufacturing output benefits from electricity in the short and long term. However, this effect only becomes statistically significant over time. A multiple regression model also shows that interest rate, inflation rate, electricity, and gross fixed capital formation variables are positively associated with economic development. These results have significant policy implications, demonstrating that increasing the electricity supply is essential for boosting productivity in the manufacturing sector. Moreover, to achieve Nigeria's economic goal of becoming one of the world's 20 largest industrialised economies, a consistent and sufficient increase in energy supply, particularly to the manufacturing sector, must be a steadfast policy. Economic growth appears to be closely linked to energy consumption. Therefore, to foster economic growth, it is recommended that industrial development and electricity generation issues be prioritised, especially in budget planning. A substantial allocation should be made to the electricity sector to permanently improve the state of the electricity supply, which in turn will support overall economic development.

Key words: electricity production; manufacturing sector; factors of production; output; Nigeria.

JEL C22, F43, O14

1. Introduction

Nigeria's economy is structured in a manner typical of developing countries. Agriculture is a vital component of the primary sector, contributing over half of the GDP. The oil and gas industry is a crucial driver of the economy. Despite the government's efforts over the past fifty years to expedite industrialisation, especially in recent years, the manufacturing-related industrial sector accounted for only 8 to 13 % of Nigeria's economic output in 2019 and 2020.

According to Afolabi & Laseinde [1], industrialisation is often seen as a vital instrument for promoting economic development and growth. For an economy to grow, it must produce a wide range of acceptable economic goods and services. Nigeria's manufacturing sector faces numerous challenges due to an excessive reliance on foreign technology, the inability to produce necessary equipment and technology domestically, and a lack of funding and infrastructure, such as power. This lack of research development and innovation funding risks Nigeria's technological foundation.

Nigeria needs to expand its industry as a developing country with abundant resources. Industrial strategy is crucial because it guides the achievement of economic objectives. The manufacturing subsector and industrialisation strategies are essential for utilising the economy's existing resources and realigning the state to improve living standards [2].

During the economic lockdown caused by the COVID-19 pandemic, many countries implemented investment decisions to support population growth and business prosperity. Surprisingly, Nigeria faced a dilemma of declining crude oil production and falling global prices during this period. Despite the country's vast energy resources, the growth in the industrial sector remains stagnant, impacting the sustainability of other economic sectors.

Kassim & Isik [3] noted that numerous existing literature explored the correlation between growth and energy, emphasising that energy is crucial to development. However, further research is required to address the equally important role of the industrial sector in economic growth. It is strongly advised that the industrial sector serves as the primary hub for the production and consumption of energy.

The unstable electricity supply has significantly hindered industrial progress, leading to the shutdown of machinery and the relocation of some operations to neighbouring countries. Consequently, Nigerian and foreign investors have moved to countries like Ghana and the Republic of Benin (e.g., Michelin). Onwe & King [4] observed that Nigeria's inconsistent electricity supply has adversely affected many productive sectors, particularly the industrial sector.

Electricity is crucial for any country's industrialisation. The modern world functions as a global village, relying on information access made possible by reliable and efficient electricity supplies. Industrial electricity has rapidly advanced worldwide due to large-scale electrification, which generates sufficient power for all the technology needed for production. With a steady and adequate supply of electricity, the output of goods and services will rise, unemployment and poverty rates will decline, and structural and technological challenges common in developing nations like Nigeria will be largely mitigated.

However, power outages significantly affect developing nations like Cameroon and Nigeria, with annual outages lasting at least 1,000 hours. This persistent Issue poses a major challenge to the efficient operation of enterprises that depend on a steady, adequate, and reliable electricity supply [5]. Consequently, more than 30 % of companies in developing countries own or share a generator; in South Asia and Africa, the ratios are closer to 50 % and 30 %, respectively [6]. These companies face numerous difficulties, including declining sales and earnings, rising production costs, and reduced productivity [7].

According to Amos et al. [8], one of the biggest infrastructure issues preventing Nigeria's business sector from growing faster is the country's inadequate electricity production and supply. Most Nigerian businesses and industries experience power outages due to erratic electricity supply, which raises production costs and results in lower output, damaged equipment, and higher material costs.

Despite government efforts to increase Nigeria's electricity production, significant challenges remain. Many industries have been relocating to neighbouring countries due to high production costs, impeding the nation's inclusive growth and development. This industrial exodus is attributed mainly to the persistent electricity crisis, which affects the expansion of the manufacturing sector and the overall economy. For instance, households are increasingly vulnerable to shocks due to a lack of affordable energy, which is essential for establishing backwards and forward linkages between the manufacturing and agricultural sectors [9].

Energy has a wide range of applications that could boost the Nigerian economy. Companies rely on electricity not only to light offices but also to power storage facilities for perishable goods. In addition, those dependent on computers and information communication technology (ICT) for business transactions suffer from unstable or insufficient power, which can frequently damage equipment.

Many industries collaborate to produce electricity, a crucial service for the industrial sector's production activities. Thus, the nation's ongoing electrical crisis may be affecting both the expansion of the manufacturing sector and the overall economy. Furthermore, current data shows that the industrial sector is growing slowly, with poor energy consumption being a significant factor behind this sluggish growth despite existing laws and incentives [10].

The scarcity of research in this field motivated the quest to study the effects of electricity production and consumption on Nigeria's manufacturing sector using annual data from 1985 to 2018 and the ARDL model.

The purpose of this study is to firstly determine whether there exists a correlation between the output performance of Nigerian manufacturing firms and electricity production and secondly to examine the relationship between Nigerian manufacturing firms' performance and electricity generation.

The main hypothesis to be tested is as follows:

Null Hypothesis (H0): There is no significant long-term relationship between electricity production/consumption and manufacturing sector output in Nigeria.

Alternative Hypothesis (H1): Nigeria has a significant long-term relationship between electricity production/consumption and manufacturing sector output.

Structure of the article. The remaining sections of this paper comprise the theoretical and literature review, methods, results presentation and discussions, and conclusions.

2. Review of Literature

2.1 Relevant theories

The production and consumption of energy are primarily explained through two main theories: the energy matrix model and the energy ladder model. These models offer different perspectives on how households and economies transition between various energy sources. The energy ladder model posits that as household economic activity increases, there is a shift towards more advanced fuels. Leach [11] argues that the primary barriers to this transition are the expensive appliances required for using modern fuels and their limited availability.

Heltberg [12] outlines three main steps in this model: forests, kerosene and coal, and natural gas. This concept provides a framework for estimating household energy use in developing economies.

Understanding fuel preferences, consumption patterns, and switching behaviours is crucial when developing transition support strategies. The energy ladder hypothesis forms the basis for conceptualising energy demand in emerging economies [11, 12]. In contrast, the energy matrix model focuses on how households allocate their disposable income to maximise utility.

Leach [11] explains that this model assumes household expenses primarily comprise food, clothing, and electricity, with energy costs further divided into various sources. While the energy ladder model emphasises the progression towards more advanced fuels based on economic growth, the energy matrix model highlights the economic decision-making process in energy consumption.

Both models contribute to understanding energy patterns, particularly in developing countries. These theoretical frameworks provide valuable insights into the complexities of energy transitions and consumption patterns in Nigeria's manufacturing sector. They can inform policy decisions and strategies to improve energy access and efficiency, especially in developing economies where the shift from traditional to modern energy sources is ongoing. By considering both models, researchers and policymakers can develop more comprehensive approaches to addressing energy challenges and promoting sustainable development [11, 12].

2.2. Empirical Literature Review

Quadri & Bukola [13] employed the ARDL model to analyse the relationship between Nigerian manufacturing output and electricity consumption from 1980 to 2021. Their study identified labour, capital, and electricity consumption as the primary factors influencing manufacturing output in Nigeria.

In contrast, Asaleye et al. [14] used Canonical Ordinary Least Squares (OLS) to examine Nigeria's manufacturing performance and electricity consumption from 1981 to 2019. Their analysis revealed that credit to the manufacturing sector and electricity consumption negatively impacted manufacturing output.

Majumder et al. [15] utilised quantile regression analysis to explore the effects of various power production sources on emissions in South Asian countries from 1972 to 2015. Their findings indicated a positive correlation between energy production and CO_2 emissions. However, they found that renewable energy sources did not significantly affect environmental degradation.

Laureti et al. [16] used a random effects model to examine the global impact of renewable electricity output on sustainability within a circular economy. Their study found that while renewable energy consumption negatively impacted cooling degree days and emission levels, renewable electricity output significantly improved adjusted savings-net forest depletion.

Chinedum & Nnadi [17] employed vector analysis to explore Nigeria's power supply and manufacturing output nexus from 1981 to 2013. Their findings indicated a relationship between the amount of manufacturing output and electricity production. However, they found no significant connection between the manufacturing sector and power supply during the study period.

Edet et al. [18] used the ARDL model to analyse Nigeria's manufacturing production and electrical supply from 1980 to 2022. Their study revealed that while technology enhances manufacturing output, power availability alone did not significantly increase manufacturing output in Nigeria.

Hao et al. [19] critically analysed the impact of the internet's growth on China's electricity intensity. Their research demonstrated that advancements in digitisation led to increased electricity intensity and highlighted a significant threshold effect. The inconsistent electricity supply in Nigeria has severely affected the manufacturing sector, leading to plant closures and relocations to neighbouring countries with more reliable electricity, such as Ghana and the Republic of Benin [4]. This unstable supply has negatively impacted various productive sectors, particularly the industrial sector.

Ghiani et al. [20] illustrated how the COVID-19 outbreak caused widespread socioeconomic disruptions affecting various sectors, including industry and education. They emphasised the critical role of adaptable energy sources, like electricity, in enhancing productivity across different industries [21]. Electricity is fundamental to economic growth, creating goods and services, improving efficiency and productivity, and fostering investment and entrepreneurship [22].

However, the impact of power supply on the Nigerian manufacturing sector has been minimal and complex to evaluate accurately, as shown in Table 1.

Table 1. **Matrix representation of the empirical study**

S/N	Author/Year	Objective	Methodology	Findings
1	Laureti et al. [16]	Examining the role of electricity output in ensuing sustainability at the global level	Panel estimation technique	The study suggests that output from electricity reduces the depletion of the forest net-saving.
2	Majumder et al. [15]	To investigate the sources of electricity production and emissions from 1972 to 2015	Quantile Regression Technique	The study shows that the generation of energy positively impacted CO_2 emissions. However, no relationship exists between renewable energy and environmental degradation
3	Edet et al. [18]	To examine electricity supply and manufacturing performance in Nigeria	ARDL	The study found that electricity supply does not spur manufacturing output, while technology impacts manufacturing sector output positively
4	Hao et al. [19]	To determine how internet improvement reduces electricity intensity	ARDL	The result shows that internet upgrading enhances electricity intensity
5	Quadri and Bukola [13]	To study the effect of energy consumption on the performance of manufacturing sectors in Nigeria from 1980 to 2021	ARDL	The study established that electricity, amongst other factors, is the country's major determinant of manufacturing output

End of table 1

S/N	Author/Year	Objective	Methodology	Findings
6	Asaleye et al. [14]	To examine the consumption of electricity and output of the manufacturing sector	OLS	The findings indicate that the manufacturing sectors' access to credit and energy consumption negatively affects output. Likewise, the impact of interest rates and electricity consumption on employment is significant
7	Chinedum and Nnadi [17]	To investigate the role of electricity supply in Nigeria's manufacturing sectors	VAR	The study reveals that electricity enhances manufacturing performance in Nigeria. Also, the electricity supply did not relate to the manufacturing sector during the study period

Therefore, further research is needed to gather new evidence and understand recent trends. This will assist the government in making informed decisions on reforms and policies to enhance the performance of Nigeria's manufacturing sector and improve the generation and distribution of electricity.

3. Methodology

3.1. Data and Sources

This analysis utilises time series data spanning 33 years, from 1985 to 2018, focusing on five key variables: Manufacturing output (explained variable), Electricity consumption (ELEC, explanatory variable), Gross fixed capital formation (GFCF), Interest rate (INT), Inflation rate (INF).

The study utilised data from multiple authoritative sources, including the World Bank Development Indicators, and from two key national institutions — the National Bureau of Statistics (NBS) and the Central Bank of Nigeria (CBN). This comprehensive dataset thoroughly examines the relationships between electricity, economic indicators, and manufacturing output over a significant period.

Using data from reputable national and international sources ensures the reliability and consistency of the analysis, enabling a robust investigation of electricity production and consumption effect on Nigeria's manufacturing sector.

3.2. Specification of Model and Methods of Estimation

This research aims to establish the impact of power production and consumption on Nigeria's manufacturing sector. The model specification is based on the relevant theories [11, 12] and an earlier empirical study by Sani et al. [23] which examined the connection between Nigeria's manufacturing output, power consumption, and financial development. Building on their approach, we employ multiple regression analyses to study the effect of electricity generation on Nigeria's manufacturing output.

The model uses manufacturing output (*MANQ*) as the dependent variable, with explanatory variables including interest rate (*INT*), inflation rate (*INF*), and electricity consumption (*ELECT*). To enhance our understanding of how electricity production and consumption affect the output of Nigeria's manufacturing sector, we added the Gross Fixed Capital Formation (*GFCF*) as an additional explanatory variable.

Hence, the model can be described as follows:

$$MANQ = f(ELEC, GFCF, INF, INT). \quad (1)$$

The random term "μ" is included in the model in equation (1). Therefore, transformed to:

$$MANQ_t = \beta_0 + \beta_1 ELEC + \beta_2 GFCF + \beta_3 INF + \beta_4 INT + \mu_t. \quad (2)$$

By linearisation, we have the equation thus:

$$\ln MANQ_t = \beta_0 + \beta_1 \ln ELEC + \beta_2 \ln GFCF + \beta_3 INF + \beta_4 INT + \mu_t. \quad (3)$$

Where *MANQ* — manufacturing sector output; *ELEC* — electricity; *GFCF* — Gross fixed capital formation; *INF* — inflation rate; *INT* — interest rate; *t* — time; *ln* — natural logarithm; μ_t — error term; β_o — intercept; β_1 — β_4 — slope parameters.

The apriori expectations are that electricity consumption (*ELEC*) and gross fixed capital formation (*GFCF*) are expected to positively influence manufacturing output (MO), indicated by coefficients β_1 and β_2, respectively.

Inflation (*INF*) is anticipated to have a positive relationship with MO, as reflected in coefficient β_3, due to the money illusion effect. Moreover, interest rates (*INT*) are expected to negatively impact MO (coefficient β_4) due to their influence on borrowing costs.

Furthermore, a battery of unit root tests (*ADF*, *PP*, *KPSS*, *LLC*) was used to determine the stationarity of the data; if stationary, OLS regression will be applied. Otherwise, cointegration analysis with the Kao test will be guided by an ARDL or error correction model.

4. Results

The estimated model results presented in this section include the descriptive statistic, the trend, pre-estimation tests, regression analysis, post-estimation tests and the discussions.

4.1. Trend Evaluation

Figure 1 shows that manufacturing production and *GFCF* have been trending upward consistently during the study period. On the other hand, the amount of electricity produced has an increasing and decreasing tendency. The inflation rate has steadily declined and stayed stagnant. The interest rates consistently increased until 2000, when it experienced a sudden fall. However, it rose immediately and has stayed stable ever since.

4.2. Summary Statistics

Table 2 presents descriptive statistics for the study variables. The average manufacturing output during the period was N2.85 trillion, with a standard deviation of N3.44 trillion. The lowest recorded output was N39.5 billion, while the highest was N12.5 trillion, highlighting the significant role and fluctuations in Nigeria's manufacturing sector and crucial economic growth.

The *GFCF* averaged N5.6 trillion over the period, with a substantial range from N87.1 billion to N24.6 trillion and a standard deviation of N6.07 trillion. This wide variation suggests significant fluctuations in capital investment, with the peak coinciding with periods of economic boom.

Electricity consumption, measured in kWh per capita, presents a different picture. With an average of 105.3 kWh, ranging from 74.5 kWh to 156.8 kWh, and a standard deviation of 25.19 kWh, the data indicates relatively little change in energy consumption over the study period. This stability, however, may point to constraints in energy infrastructure development rather than consistent adequacy.

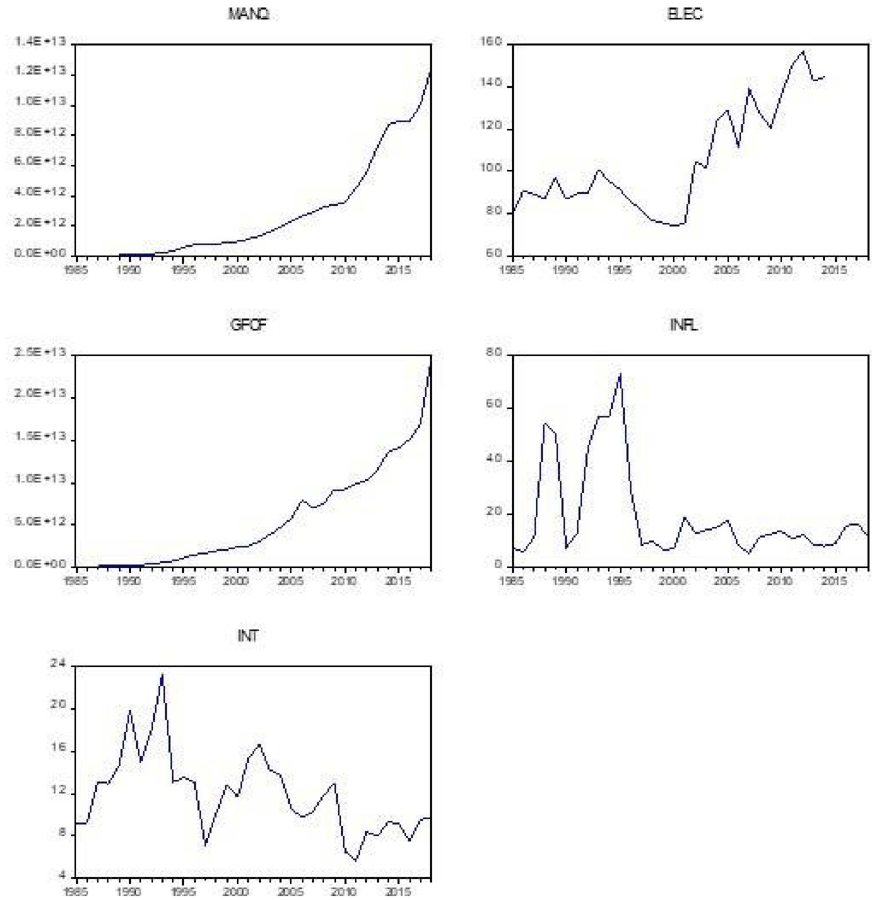

Figure 1. Trend Analysis of Variables

Source: Authors' Computation

Table 2. **Summary Statistics**

Variable	Mean	Std. Dev.	Minimum	Maximum
GFCF	N5.6trn	N6.07 trn	N87.1bn	N24.6trn
MANQ	N2.85trn	N3.44 trn	N39.5bn	N12.5 trn
ELEC	105.30kWh	25.19kWh	74.49kWh	156.79kWh
INF	19.58 %	18.12861	5.39 %	72.84 %
INT	11.93 %	3.839236	5.69 %	23.24 %

Source: Authors' Compilation.

The inflation rate during this period averaged 19.6 %, ranging from 5.39 % to 72.84 % and a standard deviation of 18.13 %. Notably, the average inflation rate has consistently remained in double digits, exceeding the CBN's target range of 6 % to 9 %. This persistent high inflation reflects ongoing economic challenges and potential instability in consumer prices. Interest rates also showed considerable variation, averaging 11.93 %, ranging from 5.69 % to 23.24 % and a standard deviation of 3.84 %. This average figure estimates Nigeria's cost of capital during the period, though it does not account for outliers.

4.3. Correlation Analysis

Table 3 presents the correlation coefficients and p-values for the explanatory variables, highlighting their relationships and potential multicollinearity issues.

The analysis shows a positive correlation between *MANQ*, *GFCF*, and *ELEC*, suggesting that increases in *GFCF* and *ELEC* are associated with higher manufacturing output. Conversely, inflation rates (*INF*) and interest rates (*INT*) negatively correlate with manufacturing output, indicating that higher inflation and interest rates tend to reduce production.

All explanatory variables, except *INF*, are statistically significant, with p-values less than 5 %. INF is significant at the 10 % level. The results further reveal that manufacturing output and *GFCF* move in the same direction, meaning that increases in *GFCF* are linked to higher manufacturing output. In contrast, rising interest rates are associated with decreased production.

Moreover, manufacturing production and electricity consumption are positively related, while inflation has an inverse effect. Notably, the results show no strong correlations among the variables, mitigating concerns about significant multicollinearity. This ensures that the variables can be included in regression models without issues.

4.4. Pre-Estimation Tests

4.4.1 Unit Root Test

To ensure the validity of our regression analysis, we employed the Augmented Dickey-Fuller (ADF) test [24] to examine the stationarity of each variable. The results in Table 4 reveal that only the interest rate (*INT*) exhibits stationarity at the 5 % significance level. The remaining variables — manufacturing output (*MANQ*), gross fixed capital formation (*GFCF*), electricity consumption (*ELEC*), and inflation rate (*INF*)— show p-values exceeding 0.05 and ADF test statistics below the 5 % critical value, indicating non-stationarity at level.

Following the decision rule, which states that the null hypothesis (Ho) of a unit root should not be rejected if the t-statistic falls below the 5 % critical value or if the p-value surpasses the significance level, we fail to reject Ho for *MANQ*, *GFCF*, *ELEC*, and *INF*. This implies these variables are not integrated of order zero [I(0)].

Table 3. **Correlation Matrix**

	ELEC	*MANQ*	*GFCF*	*INT*	*INF*
ELEC	1.0000				
MANQ	0.8409 (0.0000)	1.0000			
GFCF	0.8814 (0.0000)	0.9794 (0.0000)	1.0000		
INT	–0.4344 (0.0165)	–0.5183 (0.0017)	–0.5349 (0.0011)	1.0000	
INF	–0.2286 (0.2243)	–0.3224 (0.0629)	–0.3556 (0.0390)	0.4752 (0.0045)	1.0000

Source: Authors' Compilation.

All variables except the interest rate achieved stationarity upon applying the first differencing. The differenced variables displayed p-values below 0.05 and t-statistics surpassing the critical values, classifying them as integrated of order one [I(1)] series. Given the presence of both I(0) and I(1) variables in our study, it becomes crucial to test for cointegration to avoid potentially misleading results from OLS regression. To this end, we will utilise the ARDL bounds test procedure of Pesaran et al. [25] and Bertsatos et al. [26] to investigate potential long-term cointegration relationships among our model's stationary and non-stationary variables (Table 4).

4.4.2 Co-integration test

The cointegration test estimates, detailed in Table 5, were used to determine if long-term correlations exist between the studied variables.

The bounds test procedure was applied due to the differing orders of integration among the variables. The bounds test's null hypothesis (Ho) assumes no long-term cointegration among variables. We compare the calculated F-statistic with established critical boundaries to evaluate this hypothesis. A rejection of Ho, indicating a long-term association, occurs when the F-statistic surpasses the I(1) bound. Conversely, if the F-statistic falls below the I(0) critical bound, we accept Ho, suggesting no long-term relationship exists.

In our analysis, the computed F-statistic of 5.488 exceeds the I(1) critical value bound of 3.79 at the 5 % significance level. This result compels us to reject Ho, providing evidence for long-term relationships between our model's stationary and non-stationary series.

Table 4. **ADF Test**

Variables	t-statistic	Order of Integration
LNELEC	–6.429833**	I(1)
INT	–4.873051**	I(0)
LNINF	–3.883248**	I(1)
LNGFCF	–2.032862**	I(1)
LNMANQ	–3.687290**	I(1)

Source: Authors' Computation.

Note: ** implies significance at a 5 % significance level.

Table 5. **ARDL Bounds Test**

Test Statistic	Value	k
F-statistic	5.488	5
Critical Value Bounds		
Significance	I(0) Bound	I(1) Bound
10 %	2.26	3.35
5 %	2.62	3.79
2.5 %	2.69	4.18
1 %	3.41	4.68

Source: Authors' Computation.

Given this outcome, we can estimate our model's short-term and long-term parameters. This will be accomplished using long-run coefficients and the ARDL short-run error correction model, allowing us to capture our variables' immediate and enduring effects on the manufacturing sector.

4.5. Regression Analysis

The ARDL short and long-run regression analysis results, which examined the effects of power generation and consumption on Nigeria's manufacturing sector, are presented in Table 6.

5. Discussion

5.1. Verification of results

The model's R-squared indicates that 99.8 % of the fluctuations in Nigeria's manufacturing output can be explained by the variables used. The model is statistically significant, with a p-value of 0.0000 and an F-statistic of 3267.318, demonstrating a good fit and overall statistical significance. The error correction term's first-period lag (ECT (–1)) [27] has a negative coefficient and a p-value of less than 0.05, indicating significance. This suggests the model converges and returns to long-run equilibrium after a short-run disequilibrium [28].

For ease of interpretation, only the contemporaneous coefficients of the independent variables are shown in the short run, as specified by Banerjee et al. [27].

In the short run, the *INF* and *INT* coefficients are positive, at 0.003795 and 0.001639, respectively. Conversely, the coefficient for *LNELECT* is negative, at –0.076946. The p-values for electricity consumption and the inflation rate are below the 5 % significance level, at 0.0355 and 0.0124, respectively, indicating their significance. However, the interest rate's p-value is 0.0983>0.05, suggesting it is insignificant in the short run.

Table 6. **ARDL Estimates**

Variable	Coefficient	Prob.
Short-Run Coefficients		
D(INT)	0.001639	0.0983
D(LNELECT)	–0.076946	0.0355
D(INF)	0.003795	0.0124
ECT(–1)	–1.593172	0.0000
Long Run Coefficients		
D(INT)	5.496170	0.0497
D(LNELECT)	–258.100455	0.0402
D(INF)	12.729525	0.0398
Constant	1070.234873	0.9799
R-Squared	0.997862	
F-statistic	3267.318	
P-value of F-statistic	0.000000	

Source: Authors' Computation.

While the higher p-values of the interest rate indicate no statistically significant impact on the manufacturing sector's output, the lower p-values of the inflation rate and electricity consumption coefficients at 5 % significance levels demonstrate a statistically significant impact on economic growth. This negative electricity result contradicts Eke et al. [29] results and aligns with findings by Edet et al. [18], Quadri & Bukola [13], and Asaleye et al. [14] in Nigeria.

These findings could be broadly aligned with the energy ladder hypothesis. The interest rates have a significant positive short-term impact on Nigeria's manufacturing sector's production, as indicated by the positive interest rate coefficient. Effiong et al. [30] and Tadesse [31] findings on Nigeria's and Ethiopia's manufacturing productivity align with the results. Specifically, Nigeria's manufacturing sector will produce approximately 0.001639 percentage points more for a per cent increase in interest rates in the short term and vice versa. However, it contradicts the expected assumption and Tonye & Nwikina [32] findings on Nigeria.

Similarly, inflation in the short run positively impacts Nigeria's manufacturing sector output, as indicated by the noteworthy positive inflation coefficient. Nigeria's short-term economic growth will rise by approximately 0.003795 percentage points for every 1 % increase in the inflation rate, again not contradicting the a priori expectation despite its significance. The estimates indicate that inflation coexists with strong economic growth, driving up exports as manufacturers expand to meet domestic and international demand. The findings are in consonant with Odondo [33] on Kenya's manufacturing output and Masoga et al. [34] on South African energy prices but in divergence from Tonye & Nwikina [32] findings on Nigeria.

On the other hand, the substantial negative coefficient of electricity consumption implies a short-term detrimental impact on Nigeria's manufacturing sector output. Specifically, Nigeria's industrial sector output will decrease by approximately –0.077 percentage points in the short term for every percentage point increase in electricity consumption. The long-term results show positive coefficients for *INT* and *INF*, with values of 5.496170 and 12.729525, respectively. Conversely, the data show a negative correlation (–258.100) with electricity consumption. The significance of these variables is demonstrated by the p-values of 0.0497, 0.0402, and 0.0398 for interest rate, electricity consumption, and inflation rate, respectively, when compared to the 5 % significance level.

Considering the findings of this research, it would be more consistent to reject the null hypothesis (*H0*) and accept the alternative (*H1*), which states that there is a significant long-term relationship between electricity production/consumption and manufacturing sector output in Nigeria. It is worth mentioning that the discussion is premised on the analysis of the baseline variables, excluding the explanatory variables.

5.2. Post-Estimation Tests

The reliability and accuracy of our regression model were confirmed through a series of post-estimation tests, addressing potential issues of multicollinearity, autocorrelation, and heteroskedasticity following Mills [35]. Firstly, we employed the Variance Inflation Factor (VIF) to assess multicollinearity.

The results in Table 7 show low VIF values for all explanatory variables, well below the critical threshold of 10. This indicates the absence of serious multicollinearity problems, ensuring the stability and interpretability of our estimated coefficients.

Table 7. **Post-Estimation Results**

Variance Inflation Factor — VIF		
	Coefficient	Centred
Variable	Variance	VIF
INTR	201.0957	2.227486
LNELECT	0.004720	1.935306
INF	0.003489	1.650436
C	1602.235	NA
Breusch-Pagan-Godfrey Heteroskedasticity Test		
Model	F-statistic	P-value
MANQ	4.726577	0.5548
Breusch-Godfrey Serial Correlation LM Test		
MANQ	0.936745	0.4047

Source: Authors' Computation.

Next, we examined the presence of autocorrelation using the Breusch-Godfrey LM test. The test yielded an F-statistic of 0.936745 with a corresponding p-value of 0.4047. As this p-value exceeds the 0.05 significance level, we fail to reject the Ho of no serial correlation.

This result confirms that our regression model is free from autocorrelation issues, validating the independence of our observations. Lastly, we addressed the possibility of heteroskedasticity using the Breusch-Pagan-Godfrey test. The test produced an F-statistic of 4.726577 with a p-value of 0.5548. Again, as this p-value>0.05, we do not reject the Ho of constant variance. This outcome suggests that heteroskedasticity is not a concern in our regression results, ensuring the efficiency of our estimators.

The absence of multicollinearity, autocorrelation, and heteroskedasticity issues enhances our confidence in the reliability and interpretability of our findings regarding the impact of electricity production and consumption on Nigeria's manufacturing sector.

The residual distribution of the regression model is illustrated by the histogram in Figure 2.

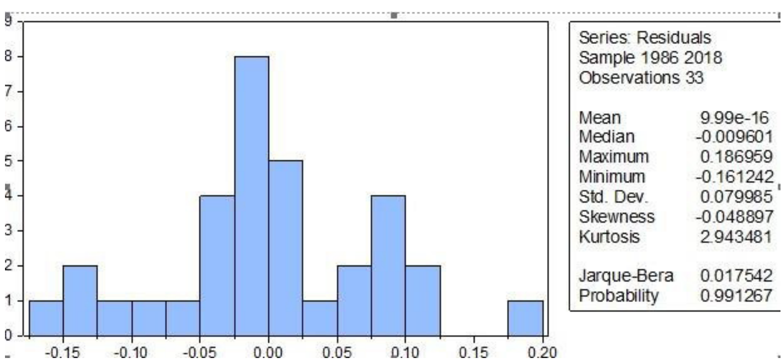

Figure 2. Histogram for Normality of Residual

Source: Authors' Computation.

This is necessary to ensure that the expected outcome adheres to the normality assumption of the conventional linear regression model. Alongside the histogram, the Jarque-Bera normality statistic is provided to determine whether the model's residuals are normally distributed, as visual inspection alone might not be sufficient.

The Jarque-Bera normality statistic value is 0.07542, with a p-value of 0.991267>5 % significance level. These values indicate that the statistic is insignificant at the 5 % level. Therefore, the analysis of the regression residuals confirms their normal distribution, thus satisfying a fundamental assumption of the classical linear regression model.

This finding supports the validity and reliability of our statistical inferences. Consequently, the Ho of the Jarque-Bera test, which states that the residual series has a normal distribution, cannot be rejected [36].

5.3. Limitations

Our study, while providing valuable insights into the relationship between electricity consumption and manufacturing output in Nigeria, has certain limitations that warrant consideration.

The analysis focuses on a specific time frame from 1985 to 2018, which may not capture the most recent developments in Nigeria's electricity sector and manufacturing industry. Also, using aggregate national data, though comprehensive, may overlook significant regional disparities in electricity supply and manufacturing performance across different parts of Nigeria. It's also worth noting that while we considered electricity consumption and key macroeconomic indicators, there may be other factors influencing manufacturing output that our study did not address.

These limitations open up several intriguing avenues for future research. Extending the study to include more recent data could provide insights into current trends and the impacts of recent policy changes. There's also potential to explore how the energy ladder model, typically applied to household energy consumption, could be adapted to industrial settings. This could offer new perspectives on energy use patterns in the manufacturing sector.

Further research could also investigate how manufacturing firms allocate energy sources, potentially connecting with the energy matrix model, to uncover more about decision-making processes within industrial energy consumption.

Another valuable direction would be to study the impact of improvements in electricity supply and policy reforms on the evolving "energy mix" in manufacturing over time, offering insights into how energy infrastructure development influences industrial practices.

Addressing these limitations and exploring new research directions can deepen an understanding of Nigeria's intricate relationship between energy infrastructure, economic factors, and industrial growth.

6. Conclusion and Recommendations

This research analyses electricity production, consumption and manufacturing sector performance in Nigeria from 1985 to 2018, utilising the ARDL approach. The analysis suggests that electricity consumption has a significant, albeit complex, relationship with manufacturing output in Nigeria.

While the overall trend indicates a positive correlation between increased electricity consumption and manufacturing growth, the relatively low and stable per capita electricity consumption over the study period indicates persistent infrastructure challenges hindering the sector's full potential.

Furthermore, the influence of macroeconomic factors such as inflation and interest rates on manufacturing output underscores the importance of a stable economic environment for industrial growth. The high volatility in these indicators over the study period likely contributed to uncertainties in the manufacturing sector, potentially dampening investment and expansion.

In conclusion, our findings highlight the critical role of reliable and sufficient electricity supply in driving Nigeria's manufacturing sector, aligning with the energy matrix and energy ladder theoretical framework, particularly in an oil-dependent economy like Nigeria.

Similarly, the practical significance of the findings shows that enhancing the electricity supply is vital for increasing productivity in the manufacturing sector. This research emphasises the importance of a consistent and adequate energy supply to support Nigeria's ambition of becoming one of the world's 20 largest industrialised economies. Also, the study reveals that energy infrastructure improvements alone may not sufficiently catalyse significant industrial growth. A holistic approach that addresses both energy sector development and broader macroeconomic stability is likely necessary to unlock the full potential of Nigeria's manufacturing sector.

These insights have important implications for policymakers and stakeholders in Nigeria's industrial development. Efforts to boost manufacturing output should focus on expanding and stabilising the electricity supply and creating a more favourable economic environment through prudent fiscal and monetary policies. Also, the Nigerian government should prioritise sustainable electricity supply for industries through good governance and encourage businesses to implement mitigating measures.

Lastly, the government should ensure the effective utilisation of allocated funds for the power subsector's development and maintain the ongoing deregulation to support industry competitiveness.

In light of this, future research could further explore how electricity availability impacts different manufacturing subsectors and investigate the potential for renewable energy sources to address Nigeria's persistent power challenges.

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Производство электроэнергии, ее потребление и производительность производственного сектора в Нигерии: долгосрочный анализ

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Аннотация. Электричество является важнейшим фактором в современных производственных процессах, но нестабильное энергоснабжение снижает эффективность производственного сектора Нигерии. В этом исследовании изучается производство электроэнергии, ее потребление и их влияние на промышленное производство в Нигерии, а также изучается взаимосвязь между доступностью электроэнергии и экономическим и промышленным прогрессом. Мы предполагаем, что существует значительная долгосрочная связь между производством/потреблением электроэнергии и выпуском продукции в производственном секторе Нигерии. Были использованы данные временных рядов с 1985 по 2018 г. и метод тестирования границ авторегрессионного распределенного лага (ARDL) для коинтеграции. Наши результаты показывают долгосрочные взаимосвязи между переменными, указывая на то, что производство продукции в производственном секторе выигрывает от электроэнергии в краткосрочной и долгосрочной перспективах. Однако этот эффект становится статистически значимым только со временем. Модель множественной регрессии также показывает, что переменные процентной ставки, уровня инфляции, электроэнергии и валового накопления основного капитала положительно связаны с экономическим развитием. Эти результаты содержать весомые выводы для формирования политики развития отрасли, так как демонстрируют, что увеличение поставок электроэнергии имеет важное значение для повышения производительности в промышленном секторе. Более того, для достижения экономической цели Нигерии по вхождению в число 20 крупнейших промышленно развитых экономик мира необходимо последовательное и достаточное увеличение поставок энергоносителей, особенно в производственный сектор. Экономический рост, по-видимому, тесно связан с потреблением энергии. Поэтому для стимулирования экономического роста рекомендуется уделять приоритетное внимание вопросам промышленного развития и производства электроэнергии, особенно при планировании бюджета. Значительные ассигнования должны быть выделены для отрасли электроэнергетики для постоянного улучшения электроснабжения, что, в свою очередь, будет способствовать общему экономическому развитию.

Ключевые слова: производство электроэнергии; обрабатывающий сектор; факторы производства; выпуск; Нигерия.

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