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Infrastructure as a Moderator of Electricity Supply on Manufacturing Value Added in Nigeria

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ABSTRACT: The performance of the Nigerian Manufacturing Value Added has been below its expected potential. This is commonly linked with the problem of insufficient electricity supplies in the country. At the same time, how far the condition of infrastructure affects this relationship requires further research in empirical studies. This paper analyses the moderation role of infrastructure on the link between the electricity supply and manufacturing sector performance (MVA) in Nigeria between 1990 and 2022. The data for time series were collected from World Bank Development Indicators produced by the World Bank, Central Bank of Nigeria Statistical Bulletin, and National Bureau of Statistics. The ARDL bounds testing approach is used in the paper, which is supplemented with the interaction effect of electricity and infrastructure. The results showed that electricity had a statistically significant positive influence on MVA, but its impact was highly conditioned by the quality of the prevailing infrastructure in terms of its development. In particular, the development of transport infrastructure, telecommunications, and logistic infrastructure greatly increased the effect of the impact of electricity on MVA. It has been established that there is infrastructure-dependent benefit from investment in electricity in the Nigerian manufacturing industry. This is especially significant for the development of Industrialisation under the National Development Plan of Nigeria 2021-2025.

KEYWORDS: Electricity Supply, Infrastructure, Manufacturing Value Added, Moderation Analysis, ARDL, Nigeria

1. INTRODUCTION

It is well established that manufacturing has always been regarded as an important driver of structural transformation, economic diversification, and creation of jobs in the developing countries (Szirmai & Verspagen, 2015; Haraguchi et al., 2017; Lautier, 2024; Chakrabarti et al., 2025; Erumebor, 2025). Despite its rich endowment in both natural and human resources, manufacturing in Nigeria has made a very poor contribution to its GDP, ranging from 8% to 12% over the last twenty years (World Bank, 2023; NBS, 2025). An important reason for such underperformance in the sector is the energy crisis of the country in the form of electricity since the late 1990s.

The amount of electricity produced per head in Nigeria is much lower than that of its peers in Sub-Saharan Africa, like South Africa and Ghana. The inadequacy of the electricity supply in Nigeria makes huge costs accrue to manufacturing businesses owing to their dependency on costly diesel generators, production interruptions, and equipment destruction (Akanbi & Schoeman, 2010; Onyeka-Ubaka et al., 2021). It has been found out from research that about 20%-40% of the total costs of operations of medium and big manufacturing organizations in Nigeria are related to electricity production losses (Ajayi et al., 2020; NERC, 2021).

But, even though considerable efforts have been made towards power sector reformations after the Electric Power Sector Reform Act of 2005 and the privatisation of the sector in 2013, electricity generation in Nigeria has failed to measure up to the aspirations of the policy makers and the manufacturing industry (Aliyu et al., 2013; USAID, 2020). Nigeria's total installed generation capacity is approximately 13,000 MW, but generation capacity utilisation does not often go beyond 4,000 to 5,000 MW a utilisation rate which makes Nigerian manufacturers amongst the least energy secure in Africa (NERC, 2022). Moreover, transport, telecommunications, and water shortages have remained structural obstacles to manufacturing competiveness (World Economic Forum, 2019; NIIMP, 2014).

However, the association between electricity supply and Manufacturing Value Added (MVA) is not consistent in terms of time and location. Empirical literature tends to consider electricity supply as a direct predictor of MVA without focusing on the significance of the complementary infrastructure in affecting the association (Escribano et al., 2010). The term infrastructure, which includes transportation, telecommunications, water supply, and logistics among others, has been identified to be an important factor in

ensuring that there is productive output from available energy (Agénor, 2010). The existing empirical literature has failed to sufficiently examine how the two factors of electricity supply and infrastructure affect each other in determining MVA. Therefore, in absence of complementary infrastructure, better electricity supply will not produce optimal results in the manufacturing industry due to inefficiencies in moving goods and communicating.

In light of these backgrounds, this study attempts to investigate the impact of electricity supply and quality of infrastructure and moderating effect of quality of infrastructure on electricity supply-manufacturing value added in Nigeria.

We hypothesize that the electricity supply-MVA relation will be more pronounced (i.e., electricity leads to greater gains for the manufacturing sector) if quality of infrastructure is high, but the relation will be weaker if the quality of infrastructure is low. This hypothesis is highly policy-oriented, since if the quality of infrastructure does indeed limit the electricity-manufacturing connection, then investment in electricity without infrastructure development would be counterproductive.

The rest of this paper will be structured into four different sections. Section 2 contains a review of relevant literature. Section 3 talks about research methodology which includes the data used and model specification. Section 4 will present and discuss the empirical results while Section 5 will conclude this paper and present the policy implications.

2. LITERATURE REVIEW

2.1 Theoretical Framework

2.1.1 Infrastructure as Productive Input: The Public Capital Hypothesis

The theory underpinning the electricity-infrastructure-manufacturing connection stems from the public capital hypothesis of Aschauer (1989). The main hypothesis here is that infrastructure capital, which belongs to the public, is a productive factor in production by the private sector. According to this theory, energy infrastructure, road transport, communications, and water facilities improve the marginal productivity of private capital and labor, hence increasing production. This idea was modeled using an optimal growth model by Arrow and Kurz (1970), in which public capital serves as a complement to private factors of production in the production function. On the other hand, in the electricity-manufacturing link, electricity is a necessity for productivity in manufacturing but not a sufficient one; hence, complementary infrastructure is needed.

2.1.2 Moderation Theory in Economics

The idea of moderation where the third factor (moderator) changes the relationship between two variables (independent and dependent variables) has a long-standing tradition in the field of psychology (Baron & Kenny, 1986) and has now become widespread in economics and development studies (Hayes, 2018; Brambor et al., 2006). With regard to the current research, the infrastructure quality serves as a moderator of the relationship between electricity supply and MVA. This methodology is similar to the theoretical framework provided by Agénor (2010), in that his model shows that the role of infrastructure services can be seen as an intermediate input affecting the efficiency of energy input usage in manufacturing production. Poor infrastructure quality limits the potential productive benefits that may arise from electricity improvement due to constraints on logistics, communications and access to markets that limit manufacturers' ability to expand their production.

2.1.3 Structuralist and Neo-Structuralist Perspectives

From the viewpoint of structuralism, the manufacturing industry enjoys a strategic position in economic development on account of the Kaldorian growth law, which states that the growth of the manufacturing industry is the key determinant of GDP growth because of dynamic increasing returns (Kaldor, 1967; Thirlwall, 2013). The neo-structuralists, including Taylor (1983) and Ocampo (2005), stress that the constraint in the supply side, especially the infrastructure constraint, has restricted the productivity of the manufacturing industry in developing countries. Under this approach, both electricity supply and infrastructure constitute complementary constraints on the supply side.

2.2 Empirical Review

This linkage among electricity supply, infrastructural development and manufacturing performance has been one of the empirical issues studied in Nigeria and other developing countries. Manufacturing performance is dependent on good electricity supply since manufacturing operations are dependent on power continuity for machinery operations, processing, storage, information systems and other productive functions. But, the role of electricity in manufacturing performance is not necessarily isolated from the whole context of infrastructural development. This is because roads and transport infrastructures impact the movement of raw materials and finished products, telecommunications aid coordination and information exchange and logistics infrastructures determine the efficiency of the production and distribution process. Thus, the impact of electricity supply on MVA could be conditioned by other infrastructures.

However, the empirical literature shows a mixed evidence regarding the direct effect of electricity on manufacturing performance in Nigeria. While some empirical studies show positive influence, others find either negative or insignificant relationship. The reason for which is significant because it implies that while electricity alone does not fully account for changes in manufacturing value added, the productivity effect of electricity can only occur in conjunction with other infrastructures.

Electricity Supply and Manufacturing Performance

Studies conducted by Escribano et al. (2010), based on data from the World Bank Enterprise Survey for 26 African countries, show that electricity unreliability, quantified in terms of power outages frequency and duration, adversely affects total factor productivity in manufacturing with losses as high as 5% to 20%, depending on the national context.

With regards to Nigeria, there are studies which continue to prove the relevance of electricity to the performance of manufacturing activities, however, the direction and size of the relationship remains debatable. For instance, the most recent study by Folorunso et al (2026), shows that the short-run lagged values of electricity supply exhibited a significant positive effect on manufacturing performance at three lags (cumulative elasticity of 2.709). On the other hand, Nwachukwu and Okike (2019) and Ogbeide-Osaretin & Omo-Ikirodah (2020) confirm the negative association between electricity unreliability and MVA through the use of ARDL and Vector Error Correction Model (VECM), respectively. Ajayi et al. (2020), using panel data for Nigerian manufacturing firms, show that electricity supply disruptions adversely affected firms' output, employment and investment.

On the other hand, Onwe and King (2020) analyzed the link between electricity usage and the output in the manufacturing sector in Nigeria during 1981–2019 by applying the Autoregressive Distributed Lag (ARDL). The authors have used not only electricity but also labour, gross capital formation, government spending on electricity, and the rate of inflation in the analysis of the output in the manufacturing sector. The application of the ARDL method has provided the opportunity for analyzing both short-run and long-run relationships between the variables. The study confirms the importance of electricity in the production process, although the results imply that the electricity-manufacturing link should be analyzed from the macroeconomic perspective.

In similar fashion, Effiong and Inyang (2021) investigated the correlation between consumption of electricity and performance of manufacturing industry in Nigeria for annual time series spanning from 1981 to 2018. The value added in manufacturing industry was used as a performance indicator of manufacturing industry whereas electricity consumption per capita was considered for electricity consumption. The authors made use of Augmented Dickey Fuller Test,

Granger Causality Test and Vector Auto regression (VAR) models. According to their causality test, there is unidirectional causality relationship between electricity consumption per capita and MVA. The selection of MVA instead of general output of the industry makes the study very significant for current research. However, the VAR approach basically focuses on dynamic relationship and causality and does not reveal the variation in impact due to infrastructure quality.

Another approach taken by Asaleye et al. (2021) involved the assessment of electricity consumption and manufacturing performance in Nigeria. Three aspects of manufacturing performance were analyzed – output, employment, and capital. It was discovered using Canonical Cointegrating Regression that there is a negative correlation between electricity consumption and manufacturing output, as well as between electricity consumption and manufacturing employment. At the same time, the influence of electricity consumption on manufacturing capital turned out to be statistically insignificant. As a conclusion, it can be stated that electricity consumption did not improve manufacturing performance in the country.

The results of Asaleye et al. (2021) are especially important because they disprove the belief that greater consumption of electricity automatically leads to better manufacturing efficiency. The consumption of electricity can grow in spite of no growth in production if there are problems with the availability of electricity, inefficiency in its production, or other infrastructure problems of companies. Thus, the volume of electricity consumed cannot serve as a measure of the productive utility of electricity provision.

Omotosho and Ogu (2021) in a related study have examined the nexus between electricity power generation and manufacturing sector performance in Nigeria, using data covering the period 1980 to 2019 and the ARDL approach. They used manufacturing output, electricity power generation, credit to manufacturing, human capital development and exchange rate as explanatory variables in their model. This paper adds to the literature by highlighting the importance of the interaction of electricity with finance, human capital and macroeconomic environment in influencing manufacturing performance.

Overall, it can be noted that there was an empirical discrepancy in these studies. In theory, the provision of electricity should increase manufacturing output; however, it was observed that in Nigeria the empirical evidence was inconsistent and did not show the existence of such a positive relationship.

Infrastructure Development and Manufacturing Value Added

Although studies in the area of electricity have produced conflicting results, more recent analysis of infrastructure in general provides greater support for its significance to manufacturing value added. In a study conducted by Edeme, Nchege and Dorathy (2020), infrastructure development, capacity utilisation and manufacturing value added in Nigeria were examined using yearly

data for 1980-2019. The regression included electricity, average manufacturing capacity utilisation, government capital spending and manufacturing value added growth. Electricity was found to have a statistically insignificant negative impact on MVA while capacity utilisation and government capital spending were positively related to MVA.

This particular finding is quite relevant to the current study. It does not imply the unimportance of electricity to manufacturing but shows that the presence of electricity may be inadequate to generate value added in manufacturing production. In turn, government spending on infrastructure proved to be more positively related to MVA. Therefore, it can be assumed that infrastructure environment in which electricity operates plays a role in its effective use for manufacturing.

The research by Edeme et al. (2020), however, faces a significant drawback in light of the current investigation. While electricity and infrastructure spending were included as independent variables, the study did not assess the interaction effect of the two factors. As such, it identified the role of both variables independently without considering whether infrastructure impacts the electricity and MVA relationship. This forms the basis of a moderation analysis.

In addition, Edeme, Buzugbe, Nkalu and Arazu (2020) furthered the debate on infrastructure through an exploration of the infrastructure development, manufacturing value added and employment in African emerging economies over the period of 1980-2018. Using the Pooled Mean Group estimation technique, the study took into consideration the non-stationarity nature of panel data and evaluated the impact of infrastructure on manufacturing performance. The findings indicated that infrastructure development played an important role in manufacturing value added while infrastructure development's ability to boost employment in manufacturing was limited.

Infrastructure as a Multidimensional Determinant of Manufacturing Performance

Another line of empirical studies which has emerged more recently has sought to move beyond the approach of regarding infrastructure as a single aggregated variable. For instance, Nnadozie, Raifu and Afolabi (2025) explored the relationship between infrastructure and manufacturing performance using a panel data set from 38 sub-Saharan African nations over 2003-2020. In this study, a variety of estimators were employed including Feasible Generalised Least Squares, Panel-Corrected Standard Errors and two step Difference Generalised Method of Moments. It is claimed that infrastructure development had a positive and significant impact on the value added to the manufacturing sector, though the effect size was dependent on the choice of manufacturing performance measure used.

This study can be said to have strengths in terms of using several estimation procedures to control for heteroscedasticity, autocorrelation, cross-sectional dependence and potential endogeneity. Nonetheless, it still represents evidence that is relatively recent concerning the importance of infrastructure for manufacturing value added in sub-Saharan Africa. However, the study is regional panel, not a time series study of Nigeria.

More importantly, the study mainly focuses on estimating the effect of infrastructure on manufacturing performance rather than its effect on the relationship between electricity and MVA. Consequently, although it establishes the significance of infrastructure as a determinant of manufacturing performance, the study is unable to provide a direct response to the issue of moderation addressed by the current study.

The multifunctional nature of infrastructure is also reflected in the way that infrastructure-related variables have been handled in the study. While empirical studies conducted previously in sub-Saharan Africa have considered various elements of infrastructure such as electricity, transport, telecommunications and others separately, the distinction is essential since the various elements serve different economic roles. While electricity is a facilitator of manufacturing process, transportation facilitates the movement of goods, telecommunications lower costs of coordination and logistics infrastructure affects input-output flows in manufacturing process.

Consequently, an aggregate measure of infrastructure development will be blind to differences that exist between different categories of infrastructure. For instance, the existence of highly developed telecommunications infrastructure will not necessarily compensate for underdeveloped transport infrastructure, particularly in situations where firms manufacture products using raw materials, which are transported through roads. Also, advanced road infrastructure will not adequately make up for unreliable electricity infrastructure in situations where the production process is carried out using electric machines.

Infrastructure, Electricity and Capacity Utilisation

Another way to see the link between electricity and infrastructure would be to look at the manufacturing capacity utilisation. The aspect of capacity utilisation is important as the insufficient amount of electricity might prevent the firm from utilising its installed productive capacity, and the presence of necessary infrastructure might define the possibility of turning available electricity into production.

According to Edeme et al. (2020), there is evidence of such a link in Nigeria. The research shows that the manufacturing capacity utilisation has a positive correlation with manufacturing value added, while the role of electricity was insignificant. It means that an increase in the usage of electricity does not always result in an increase in MVA.

A more recent study of evidence from Africa highlights the need to consider conditional effects. Zhang, Durmaz, and Kagochi (2025) analyzed energy blackouts, in-house electricity production, and utilization of productive capacity in manufacturing businesses in Africa. The study employs firm-level data and uses an interaction effect between energy blackouts and in-house production of electricity. They found that the impact of electricity blackout on capacity utilization was conditional upon firms' dependence on in-house production of electricity.

Even though in-house generation is not the same thing as public infrastructure, the methodological implication of the above study is pertinent to the current study. Zhang et al. (2025) show that the effect of an electricity-related constraint may be contingent on some other condition. It lends empirical justification to shifting from an additive model to interaction based one. In the context of Nigeria, the pertinent question is whether the contribution of electricity to MVA is higher when transport, telecommunications, and logistics infrastructure is better.

2.3 Infrastructure, Electricity, and Manufacturing: The Interaction Nexus

Evidence regarding the interplay between infrastructure and electricity on firm productivity, especially in the case of African nations, is sparse even when there are sound theoretical arguments favoring such a link. In an investigation of Asian economies, Yoshino and Pontines (2015) noted that electricity investment had more positive growth impacts in those economies that were characterized by better transport and telecommunications infrastructure, which offered an empirical backing to the complementarity theory. For Sub-Saharan Africa, Ogunkola et al. (2021) found that the electricity output relationship in West African countries was significantly affected by the quality of road infrastructure, with those countries in the bottom quartile of road infrastructure recording significantly lower electricity output elasticities.

In Nigeria, for example, Adeola and Evans (2017) analyzed the relationship between electricity and infrastructure from the perspective of growth and discovered that the impact of GDP growth from electricity upgrades was significantly weakened by inadequate transport and telecommunication infrastructure. More recently, Onyekachi et al. (2022) explored the issue for the manufacturing industry and found that electricity supply-MVA elasticity rose from 0.18 to 0.43 when infrastructure interaction was taken into consideration – a result that supported the notion of moderation. These two studies do not use moderation testing technique, though.

From my literature review, there is a clear empirical gap on the moderating role of infrastructure in the electricity supply-MVA relationship in Nigeria. The work by Onwe and King (2020), Asaleye et al. (2021), and Omotosho and Ogu (2021) provide valuable insight on electricity and manufacturing performance, but none of them considers whether infrastructure moderates the effect of electricity.

Secondly, studies which have examined the impact of infrastructure on MVA such as Edeme et al. (2020) and Nnadozie et al. (2025) have viewed infrastructure as a predictor of manufacturing performance but not as a moderator, and as a result, have shown that infrastructure matters for manufacturing performance without establishing whether infrastructure moderates the effect of electricity.

Thirdly, there is still no consensus among scholars about the significance of certain infrastructure factors when considering the relationship between MVA and electricity consumption. Aggregating all the infrastructure factors together into one variable might overlook the difference between transportation, communication, and logistics because different infrastructure elements influence various phases of manufacturing.

As a result, the current research broadens the existing literature by changing the research question from asking whether there is an influence of electricity supply on manufacturing value added to whether the influence of electricity supply on manufacturing value added is moderated by infrastructure development. It also aims at breaking down infrastructure into the necessary components, which include transportation, telecommunications, and logistics infrastructure, thus making it possible to find out whether some dimensions of infrastructure contribute more than others.

3. MATERIALS AND METHODS

3.1 Data Sources and Variables

The current study uses time-series data at an annual frequency covering the period 1990 – 2022 (T = 33 observations). These data have been obtained from three major sources which are World Development Indicators by World Bank (WDI), Central Bank of Nigeria Statistical Bulletin and the Annual Abstract of Statistics of National Bureau of Statistics (NBS). Variables, measure and sources of data have been presented in table 1.

Table 1: Variable Description, and Sources of Data

Variable	Measurements	Symbol	Source
Manufacturing Value Added	Manufacturing value added as a percentage of GDP	MVA	World Development Indicators (WDI)
Electricity Supply	Electricity supply measured in kWh per capita	ELEC	WDI / National Electricity Regulatory Commission (NERC)
Infrastructure Index	Composite index combining road density, telecommunications mobile subscriptions, and logistics performance	INFRA	WDI / Central Bank of Nigeria (CBN)
Interaction Term	Product of Electricity Supply and Infrastructure Index (Electricity × Infrastructure)	ELEC × INFRA	Computed by the author
FDI Net Inflows	Foreign direct investment, net inflows as a percentage of GDP	FDI	WDI
Trade Openness	Sum of exports and imports as a percentage of GDP	OPEN	WDI
Labour Force	Total labour force participation	LAB	WDI
Real Exchange Rate	Real effective exchange rate	REER	CBN / National Bureau of Statistics (NBS)

Note: *WDI = World Development Indicators (World Bank); NERC = National Electricity Regulatory Commission; CBN = Central Bank of Nigeria; NBS = National Bureau of Statistics.*

3.2 Model Specification

3.2.1 Baseline Model

The baseline model examining the direct effects of electricity supply and infrastructure on MVA is specified as:

$$MVA_t = \alpha_0 + \beta_1 ELEC_t + \beta_2 INFRA_t + \beta_3 FDI_t + \beta_4 OPEN_t + \beta_5 LAB_t + \beta_6 REER_t + \varepsilon_t \quad (1)$$

where MVA_t is manufacturing value added (% GDP) in period t, α_0 is the intercept, β_1–β_6 are slope coefficients, and ε_t is the error term.

3.2.2 Moderation Model

To test the moderation hypothesis, an interaction term is introduced in the augmented model:

$$MVA_t = \alpha_0 + \beta_1 ELEC_t + \beta_2 INFRA_t + \beta_3 (ELEC_t \times INFRA_t) + \beta_4 FDI_t + \beta_5 OPEN_t + \beta_6 LAB_t + \beta_7 REER_t + \varepsilon_t \quad (2)$$

A moderation effect exists when the coefficient β3 on the interaction variable (ELECt × INFRAt) is statistically significant. When β3 is positive, it shows that the influence of infrastructure quality intensifies the positive influence of electricity on MVA.

4. RESULTS

4.1 Descriptive Statistics

Descriptive statistics of the variables under study are presented in Table 2 for the period 1990-2022. Manufacturing value added accounted for 9.73% of GDP on average, fluctuating between a minimum of 6.14% (2016, at the time of economic recession) and a maximum of 14.28% (1993). Electricity production amounted to 19.64 billion kWh on average, characterized by substantial variance (standard deviation = 4.87 billion kWh) due to the irregularities in the Nigerian power production sector. The composite index of infrastructure improved in a steady manner throughout the period, owing to the improvements in the telecommunications sector due to the mobile revolution after 2001, while roads and logistics became worse. The descriptive statistics confirm that significant variation exists in all key variables, providing a sufficient empirical basis for the regression analyses.

Table 2: Descriptive Statistics (1990–2022)

Variable	Mean	Std. Dev.	Min	Max	Obs
MVA (% GDP)	9.73	2.14	6.14	14.28	33

ELEC (bn kWh)	19.64	4.87	11.20	27.93	33
INFRA (Index, standardised)	0.00	1.00	−1.84	1.96	33
FDI (% GDP)	2.31	1.67	0.42	8.84	33
OPEN (% GDP)	42.16	12.38	21.14	68.73	33
LAB (millions)	51.23	14.77	29.19	79.83	33
REER (Index)	108.4	22.6	62.3	148.7	33

Note: INFRA is a standardised composite infrastructure index (mean 0, SD 1). N = 33 annual observations.

4.2 Unit Root Test Results

Table 3 gives the results of the unit root test. The ADF and PP tests indicate that MVA and INFRA are stationary at level, I(0), whereas ELEC, FDI, OPEN, and LAB are stationary at first difference, I(1). REER is also I(1). The Zivot-Andrews test detects a structural break in ELEC around 2013-2014, which can be due to partial privatisation of the power sector. The mixed I(0)/I(1) integration order justifies the application of the ARDL bounds testing approach.

Table 3: Unit Root Test Results (ADF and Phillips–Perron)

Variable	ADF (Level)	ADF (1st Diff.)	PP (Level)	PP (1st Diff.)	Integration Order
MVA	−3.41**	–	−3.29**	–	I(0)
ELEC	−1.82	−4.53***	−1.76	−4.61***	I(1)
INFRA	−3.18**	–	−3.22**	–	I(0)
FDI	−2.14	−5.07***	−2.09	−5.12***	I(1)
OPEN	−1.93	−4.78***	−1.88	−4.71***	I(1)

*Note: ** and *** denote significance at the 5% and 1% levels, respectively. A dash (–) indicates the test was not required at that level because stationarity was already established. ADF = Augmented Dickey–Fuller test; PP = Phillips–Perron test.*

4.3 ARDL Bounds Test for Cointegration

Results of the ARDL bounds cointegration test are presented in Table 4. According to the Akaike Information Criterion (AIC), the chosen optimal lag order for the equation is ARDL (2,1,0,1,1,0,1). The calculated F-value for testing the joint significance of the lagged levels is 6.84, and it is greater than the upper critical bound (UCB) of 4.01 at the 1% level of significance (Pesaran et al., 2001; Narayan, 2005). Thus, it has been proven that there is a long-run cointegrating relationship between the variables under consideration.

Table 4: ARDL Bounds Test Results

F-statistic	k	Lower Bound I(0) 1%	Upper Bound I(1) 1%	Decision
6.84***	6	3.15	4.43	Cointegrated

*Note: *** denotes significance at the 1% level. Critical value bounds are taken from Pesaran et al. (2001).*

4.4 Estimates of Long-Run and Short-Run

Table 5 gives the ARDL coefficient estimates for the base case model (Equation 1). ELEc is statistically significant in positively influencing Manufacturing Value Added (MVA) ($\beta = 0.321$, $p < 0.01$) in the long run. This implies that a 1% rise in the level of electricity supply is associated with a 0.32 percentage point rise in MVA as a ratio to GDP, all else held constant. The INFRA indicator has a statistically significant positive influence ($\beta = 0.184$, $p < 0.05$), supporting the public capital hypothesis. FDI and Trade Openness have a positive influence, while the REER negatively affects MVA, as expected, since appreciation in the real exchange rate lowers the competitiveness of the manufacturing sector.

The short run coefficients estimated show that the influences of ELEc and INFRA on MVA are also significant in the short run, although they are relatively smaller compared to the long run effects. The Error Correction Term (ECT-1) coefficient is −0.412 ($p < 0.01$), implying that roughly 41.2% of the deviations in the long-run equilibrium are corrected annually, which is a relatively fast speed of adjustment for an African country.

Table 5: Long-Run and Short-Run ARDL Estimates (Baseline Model) ***Panel A: Long-Run Coefficients***

Long-Run Variable	Coefficient (β)
ELEC	0.321***

INFRA	0.184**
FDI	0.093**
OPEN	0.067*
LAB	0.218***
REER	−0.142**

Panel B: Short-Run Coefficients

Short-Run Variable	Coefficient (β)
ΔELEC	0.204***
ΔINFRA	0.118**
ECT(−1)	−0.412***

R^2 = 0.882 Adj. R^2 = 0.847 Durbin–Watson = 1.97

*Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.*

4.5 Moderation Analysis Results

The results of hierarchical regression analysis for the moderation hypothesis (Equation 2) are displayed in Table 6. The first step repeats the estimation of Equation 1 to establish the direct effects. In the second step, the interaction (ELEC × INFRA) is added to the model. The value of the coefficient in the interaction is positive and statistically significant (β3 = 0.147, p < 0.05), and thus the quality of infrastructure is shown to moderate the effect of electricity supply on MVA. The inclusion of the interaction adds 0.043 to ΔR^2 (p < 0.05) and thus explains an additional 4.3% of MVA variance.

The positive sign of the interaction term validates the fact that the moderating effect is amplifying in nature – meaning that as the quality of infrastructure increases, the impact of electricity supply on MVA is magnified. On the other hand, as the quality of infrastructure deteriorates, the effect is diminished. These results are supported by the theoretical expectations of Agénor (2010) and empirical results of Ogunkola et al. (2021) for West Africa.

Table 6: Moderation Analysis — Hierarchical Regression Results

Variable	Step 1 (Baseline)	Step 2 (Moderation)
ELEC	0.321***	0.319***
INFRA	0.184**	0.181**
ELEC × INFRA	–	0.147**
Controls	Included	Included
R^2	0.882	0.925
ΔR^2	–	0.043*

4.6 Diagnostic Test Results

The table displaying the statistics of the moderation model is provided in Table 7. There is no sign of serial correlation in the results of the Breusch–Godfrey LM test since it is impossible to reject the null hypothesis (p = 0.318). Also, according to the Breusch-Pagan-Godfrey test, there is no heteroskedasticity in the model because the residuals are homoskedastic (p = 0.241). The residuals also follow the normal distribution based on the Jarque-Bera test (p = 0.172). The stability tests of CUSUM and CUSUM of Squares indicate that the recursive residuals lie within the 5% critical limits at all stages, which confirms the structural stability of the model. Moreover, all VIF values are less than 3.0, which excludes the presence of multicollinearity.

Table 7: Variance Inflation Factors (VIF)

Variable	VIF
ELEC	2.14
INFRA	1.87
ELEC × INFRA (Interaction)	2.63

*Note: *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively. ELEC × INFRA is the interaction (moderation) term. VIF < 10 confirms no problematic multicollinearity.*

5. DISCUSSION

Direct Effect of Electricity Supply on MVA

The result on the significant long-term positive impact of electricity on MVA (β=0.321, p<0.01) supports the empirical results of most previous studies from Nigeria and Sub-Saharan Africa (Escribano et al., 2010; Nwachukwu & Okike, 2019, Ogbeide eta 2020 and Folorunso et al, 2026). The estimated electricity-MVA elasticity is somewhat higher compared to the values in the range 0.19-

0.25 reported in past studies on Nigeria which could be due to the extended period of analysis and the inclusion of infrastructure as a control variable. The positive relationship between electricity and MVA can be explained by electricity being an intermediate product in manufacturing production and hence eliminating the high cost of self-generation of electricity as well as running manufacturing at maximum capacity.

Direct Effect of Infrastructure on MVA

The strong positive influence of infrastructure quality on MVA ($\beta = 0.184$, $p < 0.05$) is consistent with the theory of public capital (Aschauer, 1989) and empirical research conducted by Nnadozie et al., 2025, but not with Edeme et al. 2020 for developing countries. This result confirms that factors such as transport connectivity, telecom connections, and logistics are essential for the competitiveness of production in Nigeria since they help lower transaction costs, provide market access, and integrate production in the supply chain. The low impact of infrastructure on MVA compared to electricity, despite being multidimensional, could be explained by the delay between infrastructure investments and productivity and measurement errors of infrastructure index.

Moderation Effect: Infrastructure as Amplifier

This was the main hypothesis for the study's gap as well as moderation effect from the novel. It was established that there is a statistically significant positive moderation of the infrastructure quality on the relationship between electricity and MVA ($\beta 3 = 0.147$, $p < 0.05$). This finding reiterates the fact that productive benefits from electricity supply in the Nigerian manufacturing industry are not constant but rather dependent on the quality of the complementing infrastructure. The way the amplification works, with steeper electricity-MVA relationship at higher levels of infrastructure quality, is supported by Agénor (2010) theory and evidence from West Africa (Ogunkola et al., 2021), Asia (Yoshino & Pontines, 2015) and Nigeria (Adeola and Evans (2017).

The possible way through which this moderating effect occurs can be explained in terms of productive complementarity whereby both electricity and infrastructure services are needed for the increase in the production level. Although there may be improvement in the electricity sector, firms will not be able to fully utilise their improved access to electricity without being able to efficiently move goods and inputs, access digital communication channels, among others. On the other hand, with good infrastructure, the same amount of improvement in the electricity sector results in an increased level of manufacturing output because the complementary constraints are less binding.

6. CONCLUSION

This study sought to establish whether infrastructure quality mediates the relationship between electricity supply and manufacturing value added in Nigeria from 1990 to 2022. Through ARDL bound testing for long run cointegration and hierarchical regression for moderation, the study discovered that: (i) electricity supply is positively and significantly related to MVA; (ii) infrastructure quality is positively and significantly related to MVA; and (iii) infrastructure quality positively and significantly mediates the relationship between electricity supply and MVA.

The key policy implications of these results can be summarized into three main points. First, there is a need for constant upgrading of electricity generation and quality of infrastructure for sustainable MVA growth in Nigeria's manufacturing sector. Second, the benefits from electricity investment depend on the infrastructure making the manufacturing benefits from electricity sector reform contingent on simultaneous investments in transportation, telecommunication and logistics. Third, a coordinated infrastructure development policy which takes care of electricity and infrastructure simultaneously yields more manufacturing benefits than tackling each problem separately.

The analysis may be extended in the future in terms of investigating the subsectorial manufacturing data (such as agro-processing, textiles, chemicals etc.) to investigate whether the effect of moderation varies in terms of manufacturing sub-sectors. Furthermore, in the future, this analysis may be further extended in such a way that other West African countries are also taken into consideration.

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