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Electricity System Inefficiency and Agricultural Productivity in Nigeria: Empirical Evidence from Transmission and Distribution Losses, 1999 to 2023

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Abstract- ***This study examines the relationship that exists between electricity system inefficiency and agricultural productivity in Nigeria over the period 1999 to 2023. Electricity transmission and distribution losses serve as a proxy for electricity supply deficits, and the analysis is situated within an extended neoclassical production function framework. The Autoregressive Distributed Lag (ARDL) bounds testing approach is used to estimate both short-run and long-run effects on agricultural value added. The results reveal that transmission and distribution losses exert a statistically significant positive effect on agricultural value added in the short run; this outcome reflects generation throughput dynamics and producer adaptation through captive generation rather than any genuine productivity benefit from system deterioration. In the long run, the effect of electricity delivery losses on agricultural output is negative but statistically insignificant, which may reflect attenuation caused by labour-intensive farming structures and limited variation in the loss series across the sample period. The error correction coefficient of approximately 0.63 indicates that around 63 percent of deviations from long-run equilibrium are corrected within a single year. The cointegrating relationship among the variables and the directionally consistent long-run coefficient together support the conclusion that electricity system inefficiency constitutes a structural constraint on agricultural sector performance in Nigeria. The study recommends prioritising investment in transmission and distribution infrastructure alongside electricity-independent agricultural technologies, to close the gap between nominal generation capacity and effective electricity delivery.***

Keywords: Electricity System Inefficiency, Agricultural Value Added, Transmission and Distribution Losses, ARDL Bounds Testing, Nigeria

I. INTRODUCTION

Electricity is not simply a convenience of modern living. It is one of the most consequential inputs in any production system, shaping the scale and efficiency with which capital and labour are put to work. In developing economies, where infrastructural gaps remain wide and persistent, electricity supply quality tends to function as a binding constraint on productive activity well before other factors become limiting. Nigeria makes this point plainly: successive rounds of electricity sector reform have failed to translate increases in nominal generation capacity into reliable and efficient delivery for end users. The result is a power sector characterised by high transmission and distribution losses, persistent grid instability, and a growing dependence on costly self-generation alternatives among productive enterprises.

Agriculture sits at the heart of this problem in ways that are often underappreciated, both in research and in policy discussion. The sector contributes significantly to national output, remains the primary livelihood source for a large share of the Nigerian population, and is increasingly expected to support economic diversification as the country works to reduce its dependence on petroleum revenues. Modern agricultural production relies heavily on electricity: mechanised land preparation, irrigation systems, agro-processing facilities, cold storage units, and value-chain logistics all depend on a consistent energy supply. When that supply is unreliable, the productivity of the entire system suffers.

The empirical literature on electricity and economic performance in Nigeria has developed substantially in recent years. Researchers have demonstrated that electricity consumption is positively associated with aggregate economic growth and that outages impose measurable cost burdens on firms across manufacturing and services (Adenikinju, 2005; Sabiu, 2019). There is also a growing body of cross-country evidence suggesting that electricity infrastructure improvements support agricultural development in Africa more broadly (Manasseh et al., 2025). Yet the sector-specific productivity implications of electricity system inefficiency within Nigeria's agricultural sector have not been examined rigorously in a national time-series framework. Most existing work focuses either on aggregate macroeconomic outcomes or uses micro-level approaches that cannot capture the structural relationship between electricity delivery constraints and national agricultural output.

A particularly notable gap concerns how electricity supply conditions are actually measured. Many studies rely on generation capacity or aggregate electricity consumption as their primary electricity variable; neither captures whether generated power actually reaches productive users. Transmission and distribution losses are a far more direct indicator of effective supply deficits: they measure the gap between what is generated and what is delivered. High losses mean that even when the grid is producing electricity, a significant portion is lost before it ever reaches the farms, irrigation systems, and processing facilities that depend on it.

This study addresses these gaps by examining the effect of electricity transmission and distribution losses on agricultural value added in Nigeria from 1999 to 2023. This time horizon is particularly relevant because it covers the era of democratic governance during which Nigeria's electricity sector underwent a series of major structural reforms, including the unbundling of the national utility, the introduction of private sector participation, and repeated attempts to modernise the transmission and distribution infrastructure. The paper models electricity system inefficiency within a production function framework and employs the ARDL approach to distinguish short-run from long-run effects. The remainder of the paper is organised as follows: Section 2 reviews the relevant theoretical and empirical literature; Section 3 describes the methodology and data; Section 4 presents and interprets the results; Section 5 concludes with policy recommendations and directions for future research.

II. THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1 Theoretical Framework

The theoretical basis of this study draws on the neoclassical production function tradition, which expresses economic output as a function of capital and labour inputs in the form $Y = F(K, L)$, where Y represents output, K represents capital, and L represents labour. Contemporary production theory, however, recognises that infrastructure services, particularly energy, function as complementary inputs that condition the productivity of both capital and labour rather than merely facilitating production; this insight has been formalised in a number of contributions to the energy-growth literature and informs the analytical framework adopted here.

In settings where electricity delivery is imperfect, the relevant variable for productivity analysis is not nominal generation but effective supply: that is, the volume of electricity that actually reaches productive users. If E denotes total electricity generated and theta represents the transmission and distribution loss rate, then effective electricity supply can be written as $E^* = E(1-\Theta)$. Substituting this into the extended production function yields $Y = F(K, L, E(1-\Theta))$, which makes explicit that higher loss rates reduce effective electricity availability and therefore depress output, all else equal. Applied to the agricultural sector, this formulation implies that agricultural value added is a function of capital accumulation, labour input, and the efficiency of electricity delivery. Transmission and distribution losses thus enter the model as a negative productivity shifter.

Cost theory provides a complementary channel through which electricity system inefficiency affects agricultural output. When grid electricity is unreliable, agricultural producers and agro-processing firms face a choice: accept reduced operational capacity or substitute toward costlier alternatives such as diesel-powered generators. Either option is economically damaging; the first reduces output directly, while the second raises unit production costs and compresses profit margins. Both mechanisms reduce agricultural value added in the aggregate, and together they reinforce the production function result.

Because agricultural production systems do not adjust instantaneously to infrastructure shocks, the theoretical relationship between electricity inefficiency and agricultural productivity is inherently dynamic. Capital reallocation, technology adoption decisions, and farmer behavioural responses all take time to materialise. This temporal dimension motivates the use of a dynamic modelling framework capable of separately identifying short-run effects, which may involve adaptation and partial substitution, from long-run equilibrium relationships, which reveal the structural consequences of persistent delivery inefficiency.

2.2 Empirical Literature

The empirical relationship between electricity and economic performance in Nigeria has been examined from several angles. Sabiu (2019) employed the ARDL approach to investigate the link between electricity consumption and economic growth, establishing both short-run and long-run relationships and confirming that electricity functions as a productive input at the aggregate macroeconomic level. This study provides important methodological precedent for the present analysis. Adenikinju (2005) shifted the focus from aggregate growth to firm-level cost effects, documenting that electricity outages and supply instability impose substantial economic burdens on Nigerian manufacturing firms through forced reliance on self-generation; this seminal contribution established a framework for understanding electricity unreliability as a structural cost factor rather than a minor operational inconvenience. More recently, Bariki et al. (2025) extended this line of inquiry to small-scale enterprises and confirmed that electricity supply instability significantly constrains business viability and performance in Nigeria.

Understanding electricity system inefficiency in Nigeria requires placing it within the broader context of energy sector governance, which has been shaped by decades of policy decisions concerning oil subsidy regimes, pricing structures, and downstream sector regulation. Sani (2014) provided an analytical taxonomy of downstream oil market deregulation and subsidisation, classifying countries into four groups based on their resource endowments and refining capacity, and demonstrating that the economic consequences of deregulation depend critically on whether a country is a net oil exporter or importer and whether domestic refining capacity exists. This framework is directly relevant here because Nigeria's chronic grid unreliability has historically driven productive enterprises to substitute toward self-generation using petroleum products, embedding an energy cost structure conditioned by prevailing oil pricing policy. When petroleum subsidies are removed or reduced and domestic fuel prices rise, the cost burden on captive generators intensifies, amplifying the economic damage already imposed by grid electricity deficits. Sani (2014) further argued that subsidy removal in oil-exporting developing countries can simultaneously generate fiscal savings and impose production cost increases across energy-dependent sectors: a trade-off that is particularly acute in agriculture, where energy costs constitute a growing share of operational expenditure for irrigated farming and agro-processing activities.

At the macroeconomic level, Sani and Kouhy (2014) employed a Vector Autoregressive model with variance decomposition, impulse response functions, and Granger causality tests to assess the effect of downstream oil sector deregulation on gross domestic product and unemployment in Nigeria over the period 1980 to 2012. Their results demonstrated that changes in domestic petroleum prices were the dominant source of variation in both GDP and employment, with Granger causality running from petroleum prices to GDP and from petroleum prices to unemployment. The impulse response analysis revealed a positive short-run impact on GDP, reflecting increased government revenue and spending capacity as an oil exporter, but a negative short-run effect on unemployment that turned positive in the long run as structural cost pressures accumulated. These findings carry direct implications for the agricultural sector: rising petroleum prices resulting from subsidy withdrawal increase the operating costs of captive generators on which a substantial proportion of agro-processing enterprises depend, compressing margins and deterring productive investment. The amplification mechanism identified by Sani and Kouhy (2014), through which petroleum price changes propagate across sectors via both cost-push and demand-side channels, provides important context for the electricity system inefficiency effects examined here, since the two phenomena interact wherever agricultural producers are compelled to operate outside the grid.

Complementing this macroeconomic analysis, Abdullahi and Sani (2021) estimated the price and income elasticities of domestic petroleum consumption in Nigeria using the Johansen cointegration and Vector Error Correction Model approaches, covering the period 1985 to 2018. Both price and income elasticities proved inelastic in the long run, with estimated values of -0.212 for price and 0.293 for income. The short-run price elasticity was statistically insignificant, confirming that Nigerian consumers and producers do not substantially curtail petroleum use in response to price increases over the near term. This has significant implications for the electricity-agriculture relationship: because petroleum demand is largely price-insensitive, the costs that electricity system inefficiency imposes on agricultural producers through captive generation are not easily avoided through fuel conservation or rapid substitution. Producers facing grid supply deficits continue to demand petroleum-based generation inputs regardless of price movements, absorbing the cost increase into their operational budgets at the expense of productivity and investment. Abdullahi and Sani (2021) attributed this inelasticity to the inadequacy of grid electricity as a substitute, noting that more than eighty percent of small and medium businesses in Nigeria rely on petrol-powered generators; petroleum demand is structurally determined by electricity system conditions rather than by price signals alone.

The agricultural dimension of the electricity literature has developed along two broad methodological lines. At the cross-country level, Manasseh et al. (2025) used a system generalised method of moments approach across African countries and found a positive association between electricity generation capacity and agricultural development indicators; while this confirms the general direction of the relationship, the cross-country design cannot account for the institutional and structural specificities of Nigeria's electricity and agricultural systems. At the micro level, Ayeniyo and Binuyo (2023) examined the technological implications of electricity supply for agricultural producers in southwestern Nigeria using logistic regression and found that electricity availability significantly influenced technology adoption and production practices at the farm level. This regional evidence is valuable but does not speak to national-level agricultural productivity dynamics. Taken together, these studies establish that electricity matters for agricultural performance across multiple scales of analysis; neither, however, provides a national time-series examination of the specific mechanism through which delivery inefficiency, as distinct from generation capacity, constrains sectoral output in Nigeria.

Okorie et al. (2020) examined electricity consumption, public agricultural expenditure, and agricultural output in Nigeria using a time-series dynamic approach and found that electricity consumption exerts a positive influence on agricultural output over the long run, confirming the productive role of electricity throughout the agricultural value chain. They also highlighted public expenditure as a complementary driver of output growth, consistent with the view that infrastructure investment and direct productive subsidies interact to determine sectoral performance. However, by measuring electricity conditions through aggregate consumption rather than delivery efficiency, Okorie et al. (2020) left open the question of whether the output effects they documented were attenuated by transmission and distribution losses. The present study directly addresses this by incorporating delivery-side efficiency as the primary electricity variable: the volume of electricity entering the grid and the volume arriving at productive destinations are materially different quantities in the Nigerian context, and conflating the two misses the most important dimension of the supply problem.

A further limitation of existing work is the near-universal reliance on generation capacity or aggregate consumption as the electricity variable of interest. As Ugwu et al. (2025) noted in a related

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study of electricity losses and economic growth in Nigeria, transmission and distribution losses capture a dimension of system performance that generation statistics simply cannot reflect. Losses at the transmission and distribution stage constitute a persistent structural feature of Nigeria's electricity system rather than a transient technical problem, and their macroeconomic consequences operate over extended time horizons. The present study responds to this by placing transmission and distribution losses at the centre of the empirical model and extending the analysis to the agricultural sector specifically; here, electricity delivery gaps interact with labour intensity, captive generation costs, and energy pricing policy in ways that aggregate growth studies are unable to fully capture.

Surveying the literature as a whole, three gaps motivate the present study. First, while the macroeconomic and firm-level effects of electricity unreliability in Nigeria are reasonably well established, the sector-specific productivity consequences for agriculture have not been examined in a national time-series framework using delivery efficiency as the primary electricity variable. Second, existing studies that address the agriculture-energy nexus typically measure electricity conditions through generation capacity or consumption aggregates, neither of which captures how much electricity actually reaches productive users. Third, the interconnection between petroleum pricing policy, captive generation costs, and agricultural productivity, illuminated by Sani (2014), Sani and Kouhy (2014), and Abdullahi and Sani (2021), has not been examined alongside the electricity delivery constraint within a single analytical framework focused on the agricultural sector. This study addresses all three gaps by estimating the effect of transmission and distribution losses on agricultural value added in Nigeria from 1999 to 2023 within an ARDL bounds testing framework that separately identifies short-run and long-run dynamics.

III. METHODOLOGY

3.1 Model Specification

Building on the theoretical framework outlined in Section 2, the empirical model specifies agricultural value added as a function of capital accumulation, labour input, and electricity transmission and distribution losses. Formally:

$$AGVA = f(GFCF, LAB, TDL)$$

where AGVA is agricultural value added in constant prices, GFCF is gross fixed capital formation as a proxy for capital accumulation, LAB is the proportion of total employment engaged in agricultural activities, and TDL is electricity transmission and distribution losses expressed as a percentage of total electricity output. For econometric estimation, the model is transformed into a log-linear specification to stabilise variance, reduce potential heteroskedasticity, and allow coefficients to be interpreted as elasticities. TDL is retained in level form because it is already expressed as a percentage. The estimable equation is:

$$\ln(AGVA) = \beta0 + \beta1 \ln(GFCF) + \beta2 \ln(LAB) + \beta3 \, TDL + \varepsilon$$

Capital formation and labour are expected to exert positive effects on agricultural output. Transmission and distribution losses are expected to exert a negative effect in the long run, as persistent delivery inefficiency reduces effective electricity availability and raises production costs. As discussed in Section 2, the short-run sign on TDL may differ from this expectation due to throughput dynamics and producer adaptation, and is therefore treated empirically rather than constrained a priori.

3.2 Data

The study uses annual time-series data spanning 1999 to 2023; this period was chosen to coincide with the post-transition era of democratic governance in Nigeria, during which multiple rounds of electricity sector reform were implemented. Agricultural value added, agricultural labour as a share of total employment, and electricity transmission and distribution losses are sourced from the World Bank's World Development Indicators database. Gross fixed capital formation data are drawn from the Central Bank of Nigeria's Statistical Bulletin, from the national accounts table expressed at constant 2010 purchasers' prices. All sources are recognised institutional providers of Nigerian macroeconomic data, and the variables are consistent in measurement across the sample period.

3.3 Estimation Technique

The study employs the Autoregressive Distributed Lag (ARDL) bounds testing procedure developed by Pesaran et al. (2001). The ARDL approach is appropriate for several reasons. First, it accommodates regressors integrated of different orders, specifically a mix of I(0) and I(1) variables, which is precisely the case in this study as confirmed by Augmented Dickey-Fuller (ADF) unit root tests. Second, it is well suited to small sample estimation, an important practical consideration given the 25-year annual dataset. Third, the framework simultaneously estimates both the long-run equilibrium relationship and the short-run dynamic adjustment, which aligns directly with the theoretical expectations outlined in Section 2.

The estimation procedure proceeds in four stages. The ADF test is first applied to each variable to determine its order of integration. The ARDL F-bounds test then assesses whether a long-run cointegrating relationship exists among the variables. If cointegration is confirmed, the long-run coefficients and the short-run error correction model are estimated jointly. Finally, a suite of diagnostic tests is conducted to verify reliability and stability: the Breusch-Godfrey test for serial correlation, the Breusch-Pagan-Godfrey test for heteroskedasticity, the Ramsey RESET test for functional form misspecification, and the CUSUM stability test. All estimation is conducted using EViews 10.

IV. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

Table 1 reports the descriptive statistics for all variables in the study. Agricultural value added, gross fixed capital formation, and agricultural labour display distributions consistent with normality at the five percent level, as indicated by their Jarque-Bera probability values exceeding 0.05. Transmission and distribution losses, however, depart sharply from normality: the kurtosis value stands at 6.60, there is a pronounced left skew, and the Jarque-Bera probability value is approximately zero. This asymmetry reflects the episodic and politically conditioned trajectory of electricity loss rates in Nigeria, which have fluctuated widely across periods of infrastructure deterioration and reform-driven intervention. The non-normality of TDL does not compromise the ARDL estimation, as the bounds testing procedure does not impose normality on the regressors.

Table 1: Descriptive Statistics

Statistic	AGVA	GFCF	LAB	TDL
Mean	10.8955	3.9657	1.6380	15.1289
Median	10.9467	3.9662	1.6378	14.9981
Maximum	11.1095	4.0706	1.7229	20.0000
Minimum	10.4770	3.8364	1.5328	0.0000
Std. Dev.	0.1918	0.0622	0.0590	5.1221
Skewness	-0.9331	-0.3051	-0.1451	-1.8248
Kurtosis	2.8864	2.2114	1.8272	6.6048
Jarque-Bera	3.7868	1.0771	1.5813	28.5077
Prob.	0.1506	0.5836	0.4535	0.0000
Observations	26	26	26	26

Note: AGVA and GFCF and LAB are in natural logarithm form. TDL is expressed as a percentage of total electricity output. Source: Authors' computation.

4.2 Unit Root Tests

The ADF unit root test results indicate that AGVA, GFCF, and TDL are non-stationary at level but become stationary upon first differencing, confirming their status as I(1) processes. LAB, by contrast, is stationary at level and is therefore I(0). This mixed integration order rules out the classical Johansen cointegration procedure, which requires all variables to be uniformly I(1); it instead supports the ARDL bounds testing approach, designed to handle exactly this configuration. Importantly, none of the variables is integrated of order two, satisfying the prerequisite condition for valid ARDL estimation. Table 2 summarises these results.

Table 2: ADF Unit Root Test Results

Variable	Level (t-stat)	First Diff. (t-stat)	5% Critical Value	Order of Integration
AGVA	Non-stationary	-5.7647	-3.6122	I(1)
GFCF	Non-stationary	-7.7452	-3.6122	I(1)
LAB	-3.7987	—	-3.6329	I(0)
TDL	Non-stationary	-5.3661	-3.6122	I(1)

4.3 Bounds Test for Cointegration

The ARDL F-bounds test yields an F-statistic of 11.50, which comfortably exceeds the upper bound critical value at the one percent significance level (I(1) upper bound = 4.66 for an asymptotic sample and 5.816 for a finite sample of 35 observations). This provides strong evidence of a long-run cointegrating relationship among agricultural value added, gross fixed capital formation, agricultural labour, and electricity transmission and distribution losses. The confirmation of cointegration justifies proceeding to estimate the long-run equilibrium coefficients and the short-run error correction dynamics.

4.4 Long Run and Short Run ARDL Estimates

Table 3 presents the long-run and short-run coefficient estimates from the selected ARDL (4,4,2,3) model, chosen on the basis of the Akaike Information Criterion.

Table 3: ARDL Long Run and Short Run Estimates (Dependent Variable: ln AGVA)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
PANEL A: Long Run Estimates				
ln(GFCF)	-0.0889	0.3116	-0.2853	0.7868
ln(LAB)	-1.8501	0.3982	-4.6464	0.0056
TDL	-0.0016	0.0028	-0.5638	0.5972
Constant	14.4169	1.8382	7.8430	0.0005
PANEL B: Short Run Estimates				
D(GFCF(-1))	-0.1099	0.0360	-3.0539	0.0283
D(LAB(-1))	0.7884	0.1984	3.9734	0.0106
D(TDL(-1))	0.0030	0.0003	9.5801	0.0002
ECM(-1)	-0.6343	0.0624	-10.1738	0.0002

Note: Selected model is ARDL(4,4,2,3). Sample: 1999 to 2023. Source: Authors' computation using EViews 10.

4.5 Interpretation of Results

The long-run coefficient on transmission and distribution losses carries the theoretically expected negative sign, indicating that higher electricity delivery losses are associated with lower agricultural value added over the long run. However, the estimate does not attain statistical significance at conventional levels ($p = 0.597$). Several factors may account for this. The relatively small sample of 25 annual observations limits statistical precision; the predominantly labour-intensive character of Nigerian smallholder agriculture reduces the sector's dependence on grid electricity relative to more mechanised systems; and the adaptation strategies that producers employ, captive diesel generation above all, may partially sustain output even as grid delivery deteriorates, attenuating the estimated relationship. Despite the lack of statistical precision, the directional finding retains economic meaning and is consistent with the theoretical framework.

The short-run coefficient on the first lag of TDL is positive and highly statistically significant (beta = 0.003, $p < 0.001$). This result requires careful interpretation; it does not indicate that electricity system deterioration benefits agricultural productivity. Rather, it reflects two overlapping dynamics. Transmission and distribution losses tend to co-move with generation throughput: periods of higher electricity generation are also periods of higher absolute losses, even when the loss rate itself is elevated, and agricultural producers who benefit from higher throughput may record output gains even as system efficiency declines. In addition, producers operating agro-processing facilities and cold storage units tend to respond to deteriorating grid supply by intensifying captive generator use, thereby sustaining short-run output at the cost of higher operating expenditure. The positive short-run coefficient is therefore a product of adaptation and throughput dynamics, not genuine productivity improvement; the structural consequence of this adaptation is a compression of long-run agricultural productivity.

The long-run coefficient on agricultural labour is negative and highly statistically significant (beta = minus 1.850, p = 0.006). This reflects diminishing marginal returns to labour as the agricultural workforce continues to expand against binding infrastructure and capital constraints. In the short run, the first lag of labour exhibits a positive coefficient (beta = 0.788, p = 0.011), indicating that additional workers raise agricultural output in the immediate term through greater cultivation intensity and harvest activity. Over longer horizons, however, the absence of complementary capital deepening and reliable energy supply means that successive increments of labour generate progressively smaller output gains. This pattern is consistent with the structural condition of Nigerian smallholder agriculture, where labour absorption has continued without a commensurate expansion of mechanisation or electricity-supported agro-processing capacity.

The short-run coefficient on the first lag of gross fixed capital formation is negative and statistically significant (beta = minus 0.110, p = 0.028). This counterintuitive result most plausibly reflects the implementation lag between capital expenditure and productive deployment: investment in machinery, irrigation infrastructure, and processing facilities does not generate output returns immediately upon disbursement, as it requires installation, commissioning, and reliable energy supply before it can become productive. In an environment of persistent electricity delivery constraints, the short-run output contribution of new capital investment is further suppressed, since equipment cannot operate at designed capacity without stable power. The long-run coefficient on GFCF is also negative, though statistically insignificant, suggesting that the broader energy supply constraint has been persistent enough to prevent aggregate capital accumulation from reliably translating into sectoral output gains across the sample period.

The error correction coefficient of minus 0.634 is negative and statistically significant (p < 0.001), confirming the validity of the long-run cointegrating relationship and indicating that approximately 63 percent of any deviation from long-run equilibrium is corrected within one year. This adjustment speed is economically plausible in the context of agricultural production systems that can reallocate labour and modify operational intensity within annual crop cycles.

4.6 Diagnostic Tests

Table 4 reports the diagnostic test results applied to the estimated model. The Breusch-Godfrey LM test yields an F-statistic of 3.028 with a probability value of 0.191, indicating no evidence of serial correlation in the residuals. The Breusch-Pagan-Godfrey test produces an F-statistic of 0.338 and a probability value of 0.956, confirming that the residuals are homoscedastic. The Ramsey RESET test returns a probability value of 0.577, providing no evidence of functional form misspecification. Taken together, these results confirm that the estimated model is well-specified and that the reported coefficients and significance tests can be relied upon for inference and policy guidance.

Table 4: Residual Diagnostic Tests

Test	F-Statistic	Probability	Decision
Breusch-Godfrey Serial Correlation LM Test	3.0284	0.1906	No serial correlation
Breusch-Pagan-Godfrey Heteroskedasticity Test	0.3380	0.9555	Homoscedastic residuals
Ramsey RESET Test (Functional Form)	0.3670	0.5773	No misspecification

V. CONCLUSION AND RECOMMENDATIONS

5.1 Summary of Findings

This study set out to examine the relationship between electricity system inefficiency and agricultural productivity in Nigeria over the period 1999 to 2023, using transmission and distribution losses as the primary indicator of electricity supply deficits. The empirical evidence from the ARDL bounds testing framework can be summarised in three main findings.

First, a statistically robust long-run cointegrating relationship exists among agricultural value added, capital formation, agricultural labour, and electricity transmission and distribution losses. This confirms that electricity system conditions and agricultural productivity are structurally linked over time rather than simply co-moving by coincidence or short-run circumstance. The long-run coefficient on TDL carries the theoretically expected negative sign; persistent delivery inefficiency is associated with lower agricultural output, even if the estimate lacks statistical precision within the present sample.

Second, electricity system conditions exert a statistically significant short-run influence on agricultural value added, but through mechanisms that reflect producer adaptation rather than any direct productivity benefit from system deterioration. The positive short-run coefficient on transmission and distribution losses reflects the co-movement of losses with generation throughput and the tendency of agricultural producers to sustain output through captive generation when grid supply deteriorates. The economic cost of this adaptation, expressed through higher operating expenditure and reduced long-run productivity, is the relevant policy concern.

Third, the error correction mechanism operates at a speed of approximately 63 percent per year, indicating that deviations from long-run equilibrium are corrected relatively rapidly within agricultural production systems. This adjustment speed reflects the flexibility of labour reallocation and operational intensity adjustments within annual crop cycles; it also implies that persistent electricity supply constraints can impose recurring rather than once-off productivity costs on the sector.

5.2 Policy Recommendations

The findings carry several implications for electricity sector policy and agricultural development strategy in Nigeria.

The most direct implication concerns the composition of electricity sector reform. Policy discourse in Nigeria has historically emphasised generation expansion as the primary lever for improving electricity supply; but persistent transmission and distribution losses reveal that the delivery system is equally, if not more, consequential for productive sector performance. Reducing technical and non-technical losses in the transmission and distribution network would increase effective electricity availability without requiring proportional additions to generation capacity and would produce productivity gains in agriculture more quickly than capacity expansion alone.

Investment in agricultural technologies that are less vulnerable to grid instability constitutes a complementary priority. Solar-powered irrigation systems, battery-backed cold storage facilities, and low-energy processing equipment reduce the sector's dependence on grid electricity delivery and improve the returns to capital investment in environments where the grid remains unreliable. The failure of gross fixed capital formation to translate into significant long-run agricultural productivity gains in this study is at least partly a consequence of the energy supply environment in which that capital operates; addressing this constraint is therefore as important as increasing the volume of investment.

Public-private partnership arrangements offer a viable mechanism for mobilising the scale of investment that transmission and distribution infrastructure modernisation requires. The Nigerian government should create enabling conditions for private sector participation in distribution network rehabilitation and loss reduction, drawing on international experience with performance-based regulation and incentive frameworks for distribution utilities.

Finally, policymakers and agricultural development planners would benefit from improved data systems that capture electricity supply conditions at a more granular level. National annual transmission and distribution loss rates, while analytically useful, mask regional and seasonal variation that may be highly consequential for agricultural producers in specific locations and at specific points in the agricultural calendar. More detailed data would allow future research to identify the transmission mechanisms through which electricity constraints affect agricultural productivity with greater precision.

5.3 Limitations and Directions for Future Research

Several limitations of this study should be acknowledged. The analysis is restricted to national-level time-series data, which precludes any examination of regional disparities in electricity access and infrastructure quality. Agricultural production in Nigeria is geographically concentrated and regionally diverse; the national aggregate relationship estimated here may obscure important heterogeneity across states and agro-ecological zones. Future research employing state-level panel data would address this limitation and provide more actionable geographic targeting for infrastructure investment.

The study also does not disaggregate the agricultural sector into its constituent subsectors, such as crop production, livestock, agro-processing, and fisheries. These activities differ in their electricity intensity and in the specific ways that supply disruptions affect their operations; a subsector-level analysis would offer more targeted policy insights. Finally, future work might consider alternative or complementary econometric frameworks, including structural equation modelling or threshold regression, to test whether the relationship between electricity system inefficiency and agricultural productivity varies nonlinearly across different levels of infrastructure quality or agricultural development.

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