IMPACT OF TELECOMMUNICATION INFRASTRUCTURE ON ECONOMIC GROWTH IN NIGERIA

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ABSTRACT

This study examines the impact of telecommunication infrastructure on economic growth in Nigeria from 2001 to 2022, grounded in the endogenous growth theory. Unlike previous studies that rely on monetary proxies, this research constructs a composite telecommunication infrastructure index with the aid of Principal Component Analysis (PCA)**,** incorporating key variables, which include fixed broadband subscriptions per 100 persons, mobile cellular subscriptions per 100 persons, and secure internet servers per one million persons. This multidimensional index offers a more accurate representation of infrastructure utilization and quality. The study utilizes the Autoregressive Distributed Lag (ARDL) bounds testing technique to explore both short-term and long-term relationships, given the mixed order of integration among variables. The empirical results indicate that, in the long run, telecommunication infrastructure has a marginally positive impact on the Nigeria economic growth, but its effect is statistically insignificant and below its potential , and it exerts a negative and statistically significant impact on economic growth in the short run. These findings suggest that operational inefficiencies occasioned by poor rural network service penetration and network infrastructure vandalism undermine the short-term benefits of telecom investments. However, with sustained long-term investment and policy reforms, the sector holds potential for growth-enhancing effects. Policy implications include; prioritizing telecom infrastructure as a critical national asset, expanding rural internet access, and enhancing regulatory frameworks by harmonizing the right-of-way federal and state charges to promote private sector participation and digital inclusiveness.

Keywords: Telecommunication Infrastructure, Economic Growth, ARDL, Nigeria, Principal Component Analysis

JEL Classification: L96, O47, C32, N17, C38

1. INTRODUCTION

The significance of infrastructure development spanning transportation, energy, ICT, and essential sanitation has long been established in academic discourse, notably following Aschauer's foundational work in 1989. In alignment with this, the United Nations underscores infrastructure as a cornerstone of its Sustainable Development Goals (SDGs). Specifically, SDG 9 highlights the importance of constructing high-quality, reliable, sustainable, and resilient infrastructure to drive economic progress and enhance human well-being (Mallek, Awad, Ozturk & Douissa, 2024). Telecommunication infrastructure plays a pivotal role in driving economic growth by facilitating communication, enhancing business operations, and promoting innovation (Maneejuk & Yamaka, 2020). Also, the availability of robust telecommunication infrastructure enables businesses to access global markets, improve operational efficiency, and adopt digital solutions (Asongu & Odhiambo, 2020). With the rise of mobile networks and internet penetration, sectors such as banking, agriculture, and education have benefited from innovations like mobile money and e-learning platforms (Englama & Bamidele, 2018). These advancements contribute to productivity and GDP growth by creating new economic opportunities and improving access to services in urban and rural areas (Usman & Mazadu, 2021).

Since the deregulation of Nigeria's telecommunications sector, the industry has undergone substantial changes in terms of regulation, service coverage, and investment. The adoption of Global System for Mobile Communications (GSM) technology paved the way for key operators such as Globacom, MTN, Visafone, and Etisalat to enter the market, contributing to the sector's expansion and modernization (Oyeniran & Onikosi-Alliyu, 2016). Data from World Development Indicator indicates that Nigeria had mobile lines subscriber strength of 18,587,000 lines in 2005 and increased to 195,128,265 lines in 2021 (WDI, 2022). Also, Nigeria secure internet server (per 1 million people) was 0.633 in 2010 and increased significantly to 73.163 in 2021 (WDI, 2022). Despite this progress, the growth potential of telecommunication infrastructure in Nigeria continues to be undermined by several challenges such as limited penetration in rural areas, high deployment and maintenance costs, inadequate supporting infrastructure such as electricity and frequent cases of cable vandalism which hinders service reliability and affordability (Usman & Mazadu, 2021). The digital divide between urban and rural populations exacerbates socio-economic disparities, restricting the ability of telecommunication services to foster broad-based economic development (Donou-Adonsou, Lim & Mathey, 2016).

Evidences in the literature have also shown that country specific and cross-country research tends to generate different result in the literature (Donou-Adonsou, Lim and Mathey, 2016; Pradhan, Mallik and Bagchi, 2018; Oladipo, 2019; Oladipo and Grobler, 2020; Maneejuk and Yamaka, 2020; Abeka, Andoh, Gatsi and Kawor, 2021; Pradhan et al., 2021; Abendin & Duan, 2021; Nchake & Shuaibu, 2022; Awad & Albaity, 2024). In Nigeria, few studies have investigated the link between telecommunication infrastructure and economic growth (Onakoya et al., 2012 and Oyeniran & Onikosi-Alliyu, 2016). The study of Onakoya et al. (2012) and Oyeniran and Onikosi-Alliyu (2016) measured telecommunication infrastructure using government spending on information and communication while the study of Usman and Mazadu (2021) measured telecommunication infrastructure by annual investment in telecommunication services and revenue from telecommunication services. However, using monetary unit to capture telecommunication infrastructure fails to account for the multi-dimensional nature and heterogeneity of telecommunication infrastructure over time and does not properly distinguish between quality/productivity and bulk of telecommunication infrastructure (Calderón & Servén, 2010; Kodongo & Ojah, 2016).

Unlike previous studies in Nigeria that employed single proxy or monetary aggregates to capture telecommunication infrastructure, this present study uses Principal Component Analysis (PCA) to construct a telecommunications infrastructure index that reflects not just access or investment levels, but actual service usage intensity and digital capacity from three indicators namely fixed broadband subscriptions per 100 people, Mobile cellular subscriptions per 100 people and Secure Internet servers per 1 million people to measure telecommunication infrastructure. By employing PCA to generate telecommunication infrastructure index from three indicators rather than singular measure or monetary unit, the study offers a more comprehensive understanding of the telecom-growth nexus in Nigeria by examining whether improvements in telecommunication infrastructure as measured by a usage and quality-weighted index translate into measurable gains in economic performance, and whether a causal relationship exists between the two. Additionally, the study utilizes the Autoregressive Distributed Lag (ARDL) bounds testing technique to estimate short- and long-run effects, accommodating small sample sizes and mixed data integration orders for more robust results. This represents the uniqueness of the present study on the telecommunication infrastructure-growth nexus in the literature.

The remainder of the paper is organized as follows: Section Two reviews the theoretical underpinnings and relevant empirical studies; Section Three outlines the study's theoretical framework and methodological approach. Section Four presents and interprets the empirical results, while Section Five concludes with key insights and policy recommendations.

2. LITERATURE REVIEW

2.1 Theoretical Literature

The relationship between telecommunication infrastructure and economic growth is explained through two core theoretical lenses: neoclassical growth theory and endogenous growth theory.

Neoclassical Growth Theory

The neoclassical growth model, originating from Ramsey (1928) and later refined by Solow (1956), attributes long-term economic growth to capital accumulation, population growth, and technological progress factors traditionally considered exogenous (Solow, 1994). This framework suggests that economic expansion can be achieved through the appropriate mix of labour, capital, and technology, including telecommunication infrastructure, which serve as the foundational drivers of growth. The model further emphasizes that output per worker is influenced by savings and population growth, while technological advancement such as improvements in telecommunications acts as a catalyst for knowledge diffusion, spillovers, and human capital enhancement across nations.

Building on this, scholars like Romer (1986) and Sala-i-Martin (1996) highlight the pivotal role of telecommunications in facilitating technological spillovers and knowledge transfers. These spillover effects strengthen the growth trajectory of countries that prioritize telecom-driven development. Consequently, investment in telecommunications not only boosts firm productivity and employment but also stimulates the emergence of digital industries. The expansion of ICT infrastructure, therefore, contributes meaningfully to job creation and broader economic growth (Pradhan *et al.*, 2024).

Endogenous Growth Theory

The endogenous growth theory, as articulated by Romer (1986, 1990), argues that economic growth results primarily from internal elements like the development of human capital, advancements in technology, and knowledge spillovers. Unlike the neoclassical model, technological progress in the endogenous model is not externally imposed but is the result of conscious investment decisions by economic agents. Telecommunication infrastructure fits squarely within this framework as a conduit for knowledge generation, dissemination, and innovation.

The theory suggests that telecommunication systems facilitate the generation and transmission of ideas, support research and development, and enhance the capacity for innovation in both the public and private sectors. For example, the increased use of mobile phones and internet connectivity allows firms to coordinate activities more effectively, access real-time market data, and adopt new technologies at a faster pace. It also facilitates the growth of digital entrepreneurship, e-commerce, and remote work, all of which are vital in a modern economy. Pradhan et al. (2020) emphasize that investments in telecommunication infrastructure produce network externalities benefits that extend beyond individual users thereby generating increasing returns to scale, a key premise of endogenous growth theory.

2.2 Empirical Review

Empirical evidence on the nexus between telecommunication infrastructure and economic growth has been widely explored, yet findings remain mixed, largely due to variations in measurement, regional focus, and econometric techniques. While some studies confirm a growth-enhancing role for telecom infrastructure, others uncover neutral or even adverse effects under specific conditions. For instance, Awad and Albaity (2024) applied the Dumitrescu–Hurlin causality approach across 42 African countries and found a unidirectional causality from economic growth to ICT investment. This reverse causality suggests that, in Africa, economic expansion often precedes and enables ICT infrastructure growth contrary to conventional assumptions of ICT as a growth driver. Similarly, Nchake and Shuaibu (2022), using S-GMM for 46 African countries, found that ICT infrastructure (proxied by mobile and internet users) contributes to inclusive growth.

In contrast, Abeka et al. (2021) identified that mobile and fixed broadband enhance economic performance by strengthening the finance-growth linkage in 44 SSA countries while internet connectivity component of telecommunication infrastructure hampers economic growth of SSA countries due to poor internet connection in the region. Adding a sustainability dimension, Fan *et al.* (2023), using Quantile ARDL in China, found that ICT progress not only boosts economic performance but also moderates environmental degradation. These findings highlight the potential for ICT to serve as a dual-purpose, yet such dynamics remain underexplored in African economies. Abendin and Duan (2021) took a broader digitalization perspective and showed that trade and digital infrastructure jointly inhibit growth in 53 African countries. an unexpected result possibly due to weak regulatory institutions and digital inequality.

Habibi and Zabardast (2020) confirmed positive growth effects of digitalization in OECD and MENA regions, emphasizing the importance of complementary factors such as education quality. Similarly, Kurniawati (2022) found that ICT development significantly spurred growth in high-income Asian countries but not in lower-income ones, suggesting heterogeneity in ICT effectiveness. These disparities raise concerns about applying global findings to Nigeria without considering regional economic, institutional, and digital divides. Empirical studies have employed various techniques to examine the telecom-growth nexus. Pradhan *et al.* (2018) used VECM on G-20 data from 2001 to 2012) and found that broadband and internet infrastructure significantly enhance growth. Similarly, Pradhan *et al.* (2021), using panel DOLS and VECM for 20 Indian states spanning 1991 and 2018, showed that investments in ICT and financial inclusion positively impact economic development. In Africa, Oladipo (2019) applied the Dumitrescu–Hurlin causality test to 46 countries and reported that improved telecom infrastructure boosts growth. Oladipo and Grobler (2020) confirmed these findings, highlighting the growth-enhancing role of mobile subscriptions across the region.

A more innovative approach was employed by Maneejuk and Yamaka (2020), who used panel kink regression across developing economies to reveal nonlinear effects of telecommunications and innovation on economic growth. Their findings suggest the existence of a threshold effect of telecommunications and innovation on economic growth. Specifically, telecommunications infrastructure exerts a significantly positive impact on economic growth only after reaching a critical mass, identified at approximately 25 fixed broadband subscriptions per 100 people, and beneath this threshold, telecommunications infrastructure inhibits growth.

Empirical contributions in the *Journal of Economics and Allied Research* have increasingly focused on how ICT infrastructure and adoption influence economic performance and financial development within the Sub-Saharan African context. For instance, the study of Nadabo (2023) examined the moderating role of institutional quality in the infrastructure–manufacturing nexus in Nigeria and found that infrastructure positively influences manufacturing performance, but poor institutional quality weakens this impact. Similarly, Leo and Abur (2022) assessed the effect of mobile broadband on Nigeria's economic growth and concluded that broadband enhances output and employment, especially when combined with supportive macroeconomic conditions. Nwala et al. (2020) found that investment in ICT significantly improves the financial performance of Nigerian insurance companies. Leo (2021), in a separate study, demonstrated that ICT contributes significantly to public sector efficiency, particularly in the long run. More recently, Okereke et al. (2025) investigated ICT adoption and stock market capitalization in eight Sub-Saharan African countries, revealing that while internet usage had a strong and significant positive effect, mobile and broadband use had mixed and mostly insignificant impacts. Collectively, these studies underscore the nuanced role of ICT and broader infrastructure in fostering development, stressing the need for complementary factors like institutional quality, financial depth, and macroeconomic stability to fully unlock their growth-enhancing potential.

A wide range of empirical studies has explored the relationship between infrastructure including telecommunication component and economic growth, producing mixed results. Kodongo and Ojah (2016) found that infrastructure had an insignificant impact on the growth of 45 Sub-Saharan African countries, largely due to infrastructural decay. Similarly, Azolibe and Okonkwo (2020) observed that while water, electricity, and transport infrastructure constrained industrial growth in SSA, the telecommunications component significantly enhanced productivity. In contrast, Jiya et al. (2020) and Donou-Adonsou et al. (2016) reported that mobile subscriptions and internet use significantly stimulated output and economic growth in COMESA and SSA regions, respectively. Muvawala *et al.* (2021), focusing on Uganda, found transport infrastructure harmful to short-run growth but beneficial in the long run.

Findings from other regions offer broader perspectives. Khan et al. (2020) demonstrated that infrastructure in South Asia positively influences growth by improving sector-wide productivity. Khanna and Sharma (2021) confirmed that infrastructure investment boosts total factor productivity in Indian industries. At the global level, Timilsina et al. (2024) found that infrastructure and human capital jointly drive growth across 87 economies. Asongu and Odhiambo (2020) emphasized the synergy between ICT and FDI in boosting SSA's economic progress, while Mallek et al. (2024) linked infrastructure development to poverty reduction and improved welfare in SSA.

While numerous studies highlight the growth-enhancing potential of ICT infrastructure, emerging evidence also points to its adverse effects in certain regional contexts. For instance, Alimi and Adediran (2020) applied a panel ARDL model with Pooled Mean Group (PMG) estimation across 13 ECOWAS countries spanning 2005 and 2016. They found that ICT diffusion measured through a composite index of mobile, internet, and fixed-line subscriptions has no significant short-run impact and, more critically, a significant negative long-run effect on economic growth when considered independently. However, the interaction between ICT and financial development yielded a positive long-run impact, suggesting that ICT infrastructure alone may not drive growth without complementary financial systems. Similarly, in the MENA region, Abu Alfoul, Khatatbeh, and Bazhair (2024) analyzed the moderating role of education in the ICT–growth relationship over the 2000–2020 period. Their findings revealed an overall negative effect of ICT usage on economic growth, with education failing to offset this decline primarily due to brain drain, which erodes the potential productivity benefits of digital investments. These studies collectively highlight that in the absence of supportive institutions such as robust financial systems or effective human capital retention policies ICT infrastructure can be ineffective or even detrimental to long-term economic performance.

Focusing specifically on Nigeria, numerous studies have attempted to assess the economic effect of telecommunications development, though the approaches and results vary. Onakoya et al. (2012) employed a three-stage least squares (3SLS) technique and reported that public investment in telecommunications significantly boosted economic output between 1970 and 2008. Oyeniran and Onikosi-Alliyu (2016), using an ARDL framework for the period 1980 to 2012, also found a significant positive long-run relationship between government ICT spending and GDP growth. Usman and Mazadu (2021), examining the period from 1981 to 2019, used ARDL to analyze the effects of annual telecom investment and sectoral revenues on economic performance. Their findings confirmed the positive role of telecommunication services over both the short-run and long-run dimensions of Nigeria's growth trajectory.

Although the empirical literature has advanced considerably, several critical gaps remain, particularly in relation to measurement approaches**,** methodological design, and context-specific analysis**.** The first major gap lies in the limited use of outcome-based or physical indicators to measure telecommunication infrastructure in Nigeria. Existing country-specific studies, such as those by Onakoya et al. (2012), Oyeniran and Onikosi-Alliyu (2016), and Usman and Mazadu (2021), primarily utilize monetary proxies**,** including government spending on ICT, telecommunications sector investment, and sectoral revenue. While useful for capturing financial trends, such monetary measures fail to account for infrastructure performance, access disparities, and actual service delivery outcomes. As Kodongo and Ojah (2016) argue, financial measures do not distinguish between the volume and quality of infrastructure, nor do they reflect heterogeneity in utilization or technological productivity across regions. Consequently, studies relying solely on financial proxies risk underestimating or misrepresenting the true performance of telecommunications infrastructure on economic development.

To fill the gaps identified in the literature, this study introduces key methodological and analytical innovations. It develops a composite telecommunication infrastructure index with the aid of Principal Component Analysis (PCA), combining fixed broadband, mobile subscriptions, and secure internet servers to better capture the scale and quality of telecom services while avoiding the limitations of monetary or single-dimensional indicators. Additionally, the study utilizes the Autoregressive Distributed Lag (ARDL) bounds testing technique to estimate short- and long-run effects, accommodating small sample sizes and mixed data integration orders for more robust results.

3. METHODOLOGY

3.1. Theoretical Framework

This study is grounded in the Endogenous Growth Theory, which highlights the pivotal role of technological innovation and human capital in sustaining long-term economic growth. Unlike exogenous models, it argues that investments in infrastructure, such as telecommunications, generate lasting productivity gains (Romer, 1990; Aghion & Howitt, 1992). Telecommunications enhance economic performance by lowering transaction costs, improving market and financial access, and fostering innovation. As a conduit for technological advancement, telecom infrastructure boosts the efficiency of economic agents by enabling information flow, reducing costs, and supporting resource allocation (Haftu, 2019).

The theory is commonly represented by a Cobb-Douglas production function as:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha} \quad [1]$$

where output is driven by labor (L), capital (K), comprising physical and human components, and total factor productivity (A), which reflects knowledge and technology. α and 1- α are the elasticities of output with respect to inputs. Since telecommunication infrastructure influences both capital accumulation and productivity, it plays a critical role in stimulating economic growth through these channels.

Equation [1] implies that economic growth depends on the level of capital stock (k), proxy by telecommunication infrastructure:

$$EG = f(TIN) \quad [2]$$

The theoretical linkage between economic growth and telecommunication infrastructure is employed to explain the channel through which telecommunication infrastructure transcend into economic growth.

3.2 Model Specification

Drawing from the theoretical foundation outlined above and following the approach of Oladipo (2019), the functional relationship between telecommunication infrastructure and economic growth in Nigeria is specified as follows:

$$EG = f(TIN) \quad [3]$$

From Eq. [3], EG is economic growth, while TIN is denoted as telecommunication infrastructure. In addition to telecommunications, other explanatory variables influencing growth include financial development, trade openness, and capital stock. These variables are included based on the frameworks of Habibi and Zabardast (2020) and Kurniawati (2022). Their inclusion is theoretically justified: financial development facilitates capital mobilization through the banking system to support private investment; trade openness promotes access to larger markets, technology transfer, and global integration (Alimi & Adediran, 2020); while capital stock reflects government investment in physical infrastructure and other growth-enabling assets consistent with Solow's (1956) emphasis on capital accumulation as a key driver of long-run growth. Incorporating these variables in Eq. [3] gives:

$$EG = f(TIN, FD, TOP, CAP) \quad [4]$$

The log-linear transformation of Equation [4] is presented as follows:

$$InEG_t = \beta_0 + \beta_1 InTIN_t + \beta_2 InFD_t + \beta_3 InTOP_t + \beta_4 InCAP_t + \varepsilon_t \quad [5]$$

From Eq. [5], EG is economic growth while TIN denote telecommunication infrastructure. In addition, FD is financial development, TOP is trade openness, while CAP denote capital stock at time t and ε_t is the stochastic error term. All variables are log-transformed to address potential non-stationarity and heteroscedasticity, allowing for elasticity-based interpretation of coefficients. To assess the impact of telecommunication infrastructure on economic growth in Nigeria, this study adopts the Autoregressive Distributed Lag (ARDL) bounds testing approach by Pesaran et al. (2001). The ARDL method is suitable for small samples and accommodates variables integrated at different levels (I(0) or I(1)) (Olamide & Maredza, 2023). It also handles possible endogeneity, produces reliable long-run estimates, and distinguishes between short-run and long-run dynamics (Aimola & Odhiambo, 2021; Islam et al., 2022; Mabula & Mutasa, 2019). "The general ARDL form of Equation [5] is specified as follows:

$$\Delta InEG_t = \beta_0 + \sum_{j=1}^{p} \beta_j \Delta EG_{t-j} + \sum_{j=0}^{q} \beta_{1j} \Delta InTIN_{t-j} + \sum_{j=0}^{q} \beta_{2j} \Delta InFD_{t-j} + \sum_{j=0}^{q} \beta_{3j} \Delta InTOP_{t-j}$$
$$+ \sum_{j=0}^{q} \beta_{4j} \Delta InCAP_{t-j} + \varphi_1 InEG_{t-1} + \varphi_2 InTIN_{t-1} + \varphi_3 InFD_{t-1} + \varphi_4 InTOP_{t-1} + \varphi_5 InCAP_{t-1} + \varepsilon_t \quad [6]$$

In the ARDL model, Δ denotes the first-difference operator; $\varphi_1 - \varphi_5$ are long-run multipliers, $\beta_1 - \beta_4$ are short-run dynamic coefficients, ε_t is white noise errors, α is an example of drift terms. The optimal lag lengths for the dependent and independent variables are denoted by *p* and *q*, respectively. To test for a long-run relationship, the study uses the F-test for the joint significance of lagged level variables, with the null hypothesis of no cointegration $H_0 : \varphi_f = 0$, against the alternative $H_a : \varphi_f \neq 0$. When multiple short-run coefficients exist for a variable, the Wald test is applied. If the F-statistic exceeds the upper critical bound, cointegration is confirmed; if it falls below the lower bound, no cointegration exists.

3.3 Source of Data.

This study relies on secondary data from 2001 to 2022 on trade openness (trade-to-GDP ratio), capital stock (gross fixed capital formation as a percentage of GDP), financial development (domestic credit to the private sector as a share of GDP), economic growth (GDP per capita), and telecommunication infrastructure (proxied by secure internet servers per million, fixed broadband, and mobile subscriptions per 100 people). All data were obtained from the World Bank's World Development Indicators (2023)."

4. RESULTS AND DISCUSSION OF FINDINGS

The findings on the linkage between Nigeria's economic growth and telecommunications infrastructure are presented and discussed in this section.

4.1 Principal Component Analysis

Table 4.1 presents the results of the Principal Component Analysis (PCA) conducted on three indicators of telecommunication infrastructure: secure internet servers (SER), fixed telephone subscriptions (FTS), and mobile cellular subscriptions (MTS). Each variable was log-transformed and standardized prior to analysis to ensure comparability. PCA, as a dimensionality reduction method, converts correlated variables into uncorrelated principal components, simplifying interpretation and addressing multicollinearity (Jolliffe & Cadima, 2016). Using the Kaiser criterion (eigenvalues > 1), only the first principal component (PC1) was retained, as it had an eigenvalue of 2.0912 and explained approximately 69.71% of the total variance. This suggests that PC1 effectively captures the common variance among the three indicators, making it suitable for constructing a Telecommunication Infrastructure Index (TII). The component loadings for SER (0.581), FTS (–0.622), and MTS (0.525) indicate that all three indicators contribute meaningfully to the index. The resulting index, derived from PC1, was used in the regression analysis as a more reliable and comprehensive measure of telecommunication infrastructure in Nigeria.

Table 4.1: Principal Components Analysis

Eigenvalues: (Sum = 3, Average = 1)					
Number	Value	Difference	Proportion	Value	CCP
1	2.0912	1.4793	0.6971	2.0912	0.6971
2	0.6118	0.3150	0.2040	2.7031	0.9010
3	0.2968	---	0.0990	3.0000	1.0000

Eigenvectors (loadings):			
Variable	PC 1	PC 2	PC 3
SER	0.580922	-0.556569	0.593937
FBT	-0.622057	0.167032	0.764948
MTS	0.524953	0.813837	0.249185

Note 1: SER, FBT and MTS denote secure internet service, fixed telephone subscription and mobile telephone subscription respectively.

Authors' Computation, 2025.

4.2 Summary Statistics

Table 4.2 presents the summary statistics of the study variables from 2001 to 2022, revealing that the mean values for all variables lie within their respective minimum and maximum values, indicating internal consistency. The skewness results show that the Telecommunication Infrastructure Index and Financial Development are positively skewed, while Economic Growth, Capital Stock, and Trade Openness are negatively skewed. Regarding kurtosis, Capital Stock, Financial Development, and Trade Openness exhibit leptokurtic distributions (kurtosis > 3), indicating peakedness, whereas Economic Growth and Telecommunication Infrastructure Index are platykurtic (kurtosis < 3), suggesting flatter distributions. The Jarque-Bera probability values for all variables exceed the 0.05 significance threshold, implying that the null hypothesis of normal distribution cannot be rejected and confirming that the series are approximately normally distributed.

Table 4.2: Descriptive Statistic of the Variable.

	GDP	TELI	CAP	FD	DOP
Mean	2274.529	0.00807	20.2839	12.0181	33.6451
Median	2415.384	-0.1997	19.5992	11.8325	33.5416
Maximum	2679.554	2.2309	33.1073	19.6256	53.2779
Minimum	1508.554	-2.3236	14.1687	8.0843	16.3521
Std. Dev.	338.1614	1.4801	7.4308	3.0668	12.4487
Skewness	-0.8003	0.2217	-0.5821	0.8492	-0.7525
Kurtosis	2.4771	1.7152	3.6519	3.5288	3.6340
Jarque-Bera	2.5990	1.6933	1.6321	2.9008	2.4449
Probability	0.2726	0.4288	0.4421	0.2344	0.2945
Observations	22	22	22	22	22

Note 1: GDP, TELI, CAP, FD, and DOP denote Gross Domestic Product Per Capita, Telecommunication infrastructure index, capital stock, financial development, and degree of openness, respectively.

Source: Authors' Computation, 2025.

4.3 Unit Root

To prevent spurious regression, it is necessary to assess the stationarity and integration order of the variables. While stationary series revert to their mean, nonstationary ones may produce misleading results. Accordingly, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were applied (Dickey & Fuller, 1981; Phillips & Perron, 1988). As shown in Table 4.3, all variables are integrated of order one, I(1), except financial development (LFD), which is stationary at level, I(0). With no variable integrated at I(2), the ARDL bounds testing method is appropriate due to its suitability for mixed integration levels.

Table 4.3: Unit Root Test Result

	ADF Test			PP Test		
Variables	**Level**	**First Diff**	**Status**	**Level**	**First Diff**	**Status**
LGDP	-2.0378	-3.2925	I(1)	-1.8629	-3.2925	I(1)
	[0.2697]	[0.0292]**		[0.3420]	[0.0292]**	
TELI	-1.5126	-3.7014	I(1)	-1.4833	-3.6973	I(1)
	[0.5078]	[0.0125]**		[0.5221]	[0.0127]**	
LCAP	-1.4958	-3.9423	I(1)	-1.1544	-3.9499	I(1)
	[0.5114]	[0.0291]**		[0.6725]	[0.0291]**	
LFD	-3.3314	-4.0142	I(0)	-4.6285	-6.3499	I(0)
	[0.0270]**	[0.0073]***		[0.0216]**	[0.0060]***	
LTOP	-2.0982	-5.1890	I(1)	-2.0464	-6.7999	I(1)
	[0.2472]	[0.0006]**		[0.2664]	[0.0000]***	

Note 1: GDP, TELI, CAP, FD and DOP denote Gross Domestic Product Per Capita, Telecommunication infrastructure index, capital stock, financial development and degree of openness respectively. Note 2: The values in the square bracket [ ] are the probability values; (*) indicates significant at 10% level, (**) indicates significant at 5% and (***) indicates significant at 1%.

Source: Authors' Computation, 2025.

The optimal lag length was selected based on multiple criteria: AIC, SC, HQ, FPE, and LR, as shown in Table 4.4. While most criteria favored lag two, SC and LR suggested lag one. To ensure model stability, the AR root test was applied, and Figure 1 confirms all roots lie within the unit circle at lag one. Thus, a lag of one was adopted to maintain robustness and prevent overfitting.

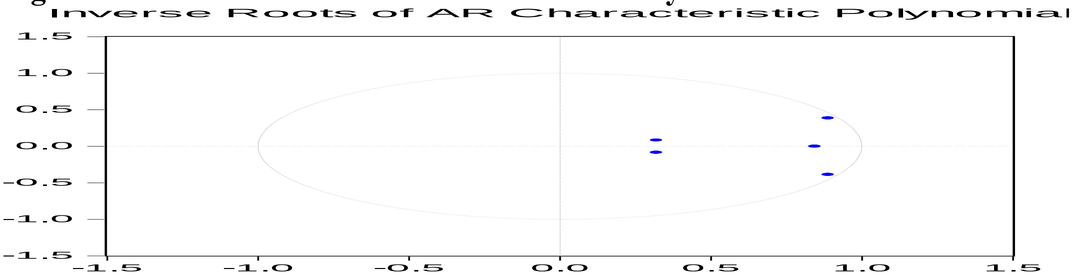
Table 4.4: VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-0.5557	NA	1.24e-06	0.5848	0.8333	0.6268
1	92.1941	126.9210*	1.10e-09	-6.5467	-5.0555*	-6.2943
2	125.3739	27.9407	9.47e-10*	-7.4077*	-4.6738	-6.9450*

*Note: * indicates lag order selected by the criterion; LR, FPE, AIC, SIC and HQ indicate sequential modified LR test statistic, Final Prediction Error, Akaike Information Criterion, Schwarzt Information Criterion and Hannan-Quinn respectively.*

Source: Authors' Computation, 2025.

Figure 1: Inverse Roots of AR Characteristic Polynomial



Source: Authors' Computation, 2025.

4.4 Bound Cointegration Test

Table 4.5 presents the ARDL bounds test results. At the 5% significance level, the F-statistic (12.4432) exceeds the upper critical bound (4.01), indicating rejection of the null hypothesis of no cointegration. This confirms the existence of a long-run relationship between economic growth and telecommunication infrastructure in Nigeria.

Table 4.5: Results from Bounds Tests

Variables	F-Statistics	Cointegration
	12.4432	Co-integration
Critical Value	Lower Bound	Upper Bound
1%	3.74	5.06
2.5%	3.25	4.49
5%	2.86	4.01
10%	2.45	3.52

Source: Authors' Computation, 2025."

4.6 Autoregressive Distributed Lag Estimates

Table 4.6 presents the long- and short-run estimates of the impact of telecommunication infrastructure on economic growth in Nigeria. In the long run, the Telecommunication Infrastructure Index (TELI), constructed using Principal Component Analysis (PCA), has a positive coefficient (0.0031) but is statistically insignificant. This indicates that a one standard deviation increase in the composite index, which captures broadband penetration, mobile subscriptions, and internet usage, does not translate into a significant long-term improvement in economic growth. The positive but insignificant effect may be attributed to persistent structural challenges in Nigeria's telecom sector, including poor service quality, rural-urban disparities in access, and regulatory inefficiencies. These issues likely constrain the productivity-enhancing potential of digital infrastructure, thereby limiting its contribution to sustained economic output. The finding aligns with the broader evidence from Kurniawati (2022) and Nchake and Shuaibu (2022), who reported that ICT infrastructure enhances growth in Asian and African countries. However, their results may differ due to broader regional integration, better policy execution, or more mature digital ecosystems in the countries examined. It also aligns with Jiya et al. (2020) and Donou-Adonsou et al. (2016), whose findings highlight significant long-run benefits of mobile and internet penetration in COMESA and SSA regions, respectively. However, it contrasts the study of Alimi and Adediran (2020), who reported a negative long-run impact of ICT diffusion in ECOWAS countries.

In contrast, in the short run, the Telecommunication Infrastructure Index (TELI), derived via PCA, exerts a negative and statistically significant effect on economic growth in Nigeria, suggesting that a one standard deviation increase in broadband penetration, mobile subscriptions, and internet usage is associated with a temporary decline in GDP. This counterintuitive result may reflect transitional costs associated with telecom expansion, such as high installation expenses and delays in network rollout. Additionally, short-run constraints like frequent power outages, fiber-optic cable vandalism, and inadequate complementary infrastructure (e.g., stable electricity and last-mile connectivity) may hinder service reliability. These inefficiencies can temporarily outweigh the productivity-enhancing benefits of telecommunications, resulting in a negative short-run impact on economic growth. This outcome aligns with Abu Alfoul *et al.* (2024), who found that ICT harm growth in the MENA region due to brain drain, which erodes the potential productivity benefits of digital investments. However, this finding contradicts the study by Usman and Mazadu (2021), who reported long-run and short-run positive effects of telecom investments on Nigeria's growth using monetary-based proxies.

Furthermore, Capital stock (LCAP) negatively affects growth in both the short and long run, indicating that public investment may not be efficiently allocated, likely due to corruption, cost overruns, and maintenance challenges. Financial development (LFD) shows a positive but insignificant long-run impact, suggesting underdeveloped financial intermediation systems, while its short-run coefficient is negative, possibly due to high lending costs. In addition, trade openness also reveals a positive but insignificant impact on growth in the long run, while negatively associated in the short run, likely driven by Nigeria's import-dependence and trade deficits. The significant error correction term (ECT = -0.2691) confirms the presence of a long-run equilibrium relationship, with about 27% of short-run deviations corrected each year. The model exhibits strong explanatory power (R^2 = 0.99), and the F-statistic confirms the joint significance of regressors.

Table 4.6: ARDL Result

Dependent Variable: LGDP				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Long run Estimate				
TELI	0.0031	0.0309	0.1016	0.9208
LCAP	-0.3501	0.0967	-3.6202	0.0040***
LFD	0.0718	0.0858	0.8368	0.4205
LDOP	0.0919	0.0995	0.9240	0.3753
C	8.3736	0.6318	13.2516	0.0000***
Short-run Estimate				
ΔTELI	-0.0440	0.0176	-2.4935	0.0298**
ΔLCAP	-0.0942	0.0458	-2.0573	0.0642*
ΔLFD	-0.0106	0.0257	-0.4138	0.6870
ΔLDOP	-0.0016	0.0207	-0.0817	0.9363
ECT(-1)	-0.2691	0.1012	-2.6573	0.0223**
R^2	0.9900			
Adjusted R^2	0.9828			
F-Stat	137.2547			0.0000***

Note 1: GDP, TELI, CAP, FD, and DOP denote Gross Domestic Product Per Capita, Telecommunication infrastructure index, capital stock, financial development, and degree of openness, respectively. Note 2: The values shown in the square bracket [ ] represent the probability values; (*) denotes significant at 10% level, (**) denotes significant at 5%, and (***) denotes significant at 1%.

Source: Authors' Computation, 2025.

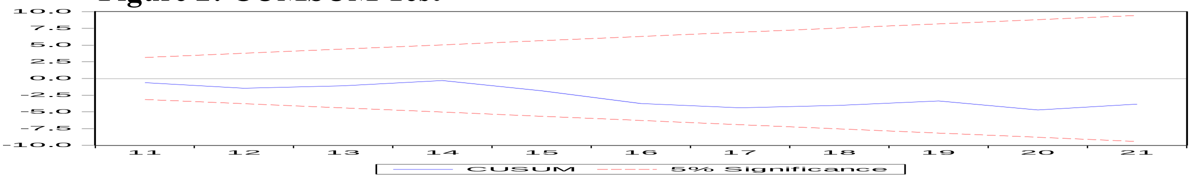
Diagnostic tests in Table 4.7 confirm the ARDL model's reliability. The Breusch-Godfrey test (p = 0.4417) shows no serial correlation, while the ARCH test (p = 0.9872) indicates homoscedasticity. The Ramsey RESET test (p = 0.1726) supports correct model specification. Additionally, the CUSUM and CUSUMSQ plots (Figures 2 and 3) fall within 5% confidence bounds, confirming parameter stability and absence of structural breaks.

Table 4.7: Diagnostic Tests based on the estimated ARDL models.

ARDL model	
Test	**F-statistic/P-Value**
Serial correlation LM test (Breusch-Godfrey)	1.6340[0.4417]
Heteroscedasticity test (ARCH)	1.7730[0.9872]
Ramsey RESET Test (specification form)	1.4690[0.1726]

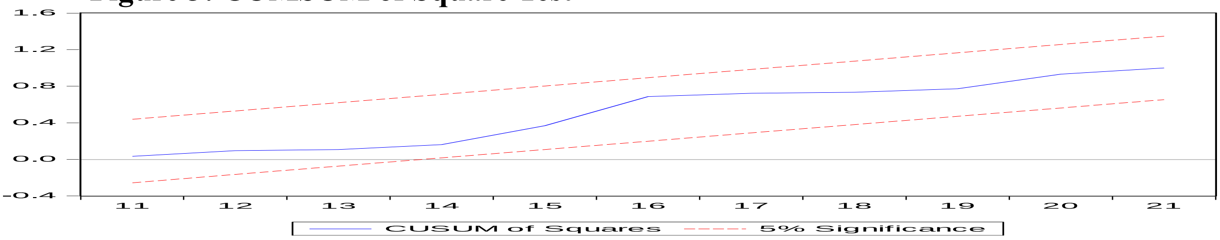
Note: Probability in parentheses
Source: Authors' Computation, 2025.

Figure 2: CUMSUM Test



Source: Authors' Computation, 2025.

Figure 3: CUMSUM of Square Test



Source: Authors' Computation, 2025.

5. CONCLUSION AND POLICY RECOMMENDATIONS

This study examined the impact of telecommunication infrastructure on economic growth in Nigeria using a composite index developed through Principal Component Analysis (PCA) and the ARDL bounds testing framework. The use of multidimensional infrastructure indicators such as mobile cellular subscriptions, fixed broadband subscriptions, and secure internet servers enhances the reliability of the analysis by capturing both access and quality dimensions. The outcome of the study reveals that telecommunications infrastructure exerts a positive and insignificant impact on economic growth in the long run, while the short-run impact was surprisingly negative and significant. These results suggest that while telecom infrastructure development holds promise for fostering long-term productivity gains, its short-term effects may be undermined by transitional inefficiencies such as unreliable electricity supply, poor digital literacy, fiber-optic cable vandalism, and multiple federal and state charges for right-of-way approvals create regulatory bottlenecks, and increasing fibre deployment cost.

To ensure telecommunication infrastructure contributes meaningfully to Nigeria's economic development, a set of coordinated, agency-specific policy actions are recommended. First, the Federal Ministry of Communications, Innovation and Digital Economy, in collaboration with the Nigeria Security and Civil Defence Corps (NSCDC) and the Transmission Company of Nigeria (TCN), should develop and implement a National Telecom Infrastructure Protection Strategy. This strategy should encompass enhanced surveillance along fiber-optic routes, stricter penalties for vandalism, and increased investments in off-grid energy solutions such as solar-powered base stations to reduce reliance on unstable grid electricity. Second, the NCC in conjunction with the National Economic Council (NEC) should streamline the regulatory landscape by harmonizing right-of-way charges, simplifying the approval processes for tower deployment, and implementing a unified national broadband plan to address interstate regulatory disparities that hinder network expansion and escalate costs.

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