Digital Infrastructure Development and Economic Growth in Nigeria: The Role of Broadband Connectivity, Digital Identity, Data Centres, and Cybersecurity (2000-2025)

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ABSTRACT

This paper examines the relationship between digital infrastructure development and economic growth in Nigeria over the period 2000 to 2025, disaggregating digital infrastructure into four components: broadband connectivity, digital identity infrastructure, data centre capacity, and cybersecurity preparedness. Because official, continuous time series do not exist for all four components over the full study period, the paper constructs empirically defensible proxies for digital identity infrastructure, data centre capacity, and cybersecurity preparedness, drawing on internationally recognised indicators and documented policy milestones. The study is grounded in an augmented Solow-Swan growth framework in which digital infrastructure is treated as a distinct form of capital that complements physical and human capital in the aggregate production function. Using annual secondary data compiled from the World Bank, the International Telecommunication Union, the Central Bank of Nigeria, the National Bureau of Statistics, the Nigerian Communications Commission, and the National Identity Management Commission, the study applies the Autoregressive Distributed Lag (ARDL) bounds-testing approach to cointegration, which is well suited to a moderate annual sample with variables of mixed order of integration. The bounds test confirms a long-run equilibrium relationship among the variables. The results show that broadband connectivity and digital identity infrastructure exert positive and statistically significant long-run effects on real GDP growth, data centre capacity shows a positive but comparatively smaller effect consistent with its still-early stage of development in Nigeria, and cybersecurity preparedness exerts a positive effect that strengthens after the enactment of Nigeria's cybercrime legislation. The error correction term is negative and significant, confirming convergence to long-run equilibrium. The paper concludes that digital infrastructure has become a measurable driver of economic growth in Nigeria, but that growth dividends are constrained by the underdevelopment of data centre capacity and by the historically recent nature of formal cybersecurity governance, and it offers policy recommendations accordingly.

Keywords: Digital Infrastructure; Broadband Connectivity; Digital Identity; Data Centres; Cybersecurity; Economic Growth; Nigeria; ARDL

1. INTRODUCTION

Digital infrastructure has increasingly been recognised in the growth literature as a distinct factor of production that shapes the productivity of labour and capital, alongside its traditional role as a sector of economic activity in its own right (Vu, 2020; Bahia et al., 2020). For developing economies such as Nigeria, the promise of digital infrastructure lies not only in the direct output of the information and communication technology (ICT) sector, but in its capacity to lower transaction costs, widen market reach and access, deepen financial inclusion, and improve the efficiency of both public and private institutions (Asongu & Odhiambo, 2019; Ozili, 2018). Nigeria's digital infrastructure landscape has changed markedly since 2000, moving from a narrowband, largely state-monopolised telecommunications sector to a liberalised market characterised by extensive mobile broadband coverage, an expanding national digital identity system, a nascent but growing data centre industry, and an evolving cybersecurity governance architecture (Nigerian Communications Commission [NCC], 2023; National Identity Management Commission [NIMC], 2022).

The empirical growth literature has documented a broadly positive relationship between broadband penetration and economic growth, particularly once broadband diffusion crosses a critical threshold (Czernich, Falck, Kretschmer, & Woessner, 2011; Koutroumpis, 2009). In the African context, Asongu and Odhiambo (2019) find that ICT penetration is associated with higher inclusive growth, while Bahia et al. (2020) show that mobile broadband coverage raises household consumption and labour productivity in Sub-Saharan Africa. However, most of this literature concentrates on broadband and mobile telephony, with comparatively little empirical attention paid to the growth effects of digital identity systems, data centre infrastructure, and cybersecurity, despite these being explicitly identified as pillars of digital economy policy in Nigeria's National Digital Economy Policy and Strategy (Federal Ministry of Communications and Digital Economy, 2020).

This gap is partly a data problem. Unlike broadband subscriptions, which are tracked continuously by the International Telecommunication Union (ITU) and the World Bank, digital identity enrolment, data centre capacity, and cybersecurity preparedness are either not tracked at all in Nigeria over a long time series, or are tracked only from a recent base year. The present study addresses this gap by constructing theoretically grounded proxies for these three components, clearly documenting the rationale for each proxy, and using the resulting time series, spanning 2000 to 2025, to estimate the relationship between digital infrastructure and economic growth in Nigeria using the Autoregressive Distributed Lag (ARDL) bounds-testing approach of Pesaran, Shin, and Smith (2001), which is appropriate for a moderate annual sample in which variables may be a mixture of I(0) and I(1) processes.

The objectives of the study are threefold. First is to examine the individual and joint contribution of broadband connectivity, digital identity infrastructure, data centre capacity, and cybersecurity preparedness to real economic growth in Nigeria between 2000 and 2025. Second, to establish whether a stable long-run equilibrium relationship exists between digital infrastructure development and economic growth. And third is to identify which components of digital infrastructure remain underdeveloped relative to their growth-enhancing potential, so as to inform digital economy policy. The remainder of the paper is organised as follows. Section 2 reviews the theoretical and empirical literature. Section 3 sets out the methodology, including data sources and proxy construction. Section 4 presents and discusses the results and Section 5 concludes with policy implications.

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Theoretical Framework

The study is anchored on an augmented Solow-Swan growth model, in which digital infrastructure is introduced as a distinct input alongside physical capital, labour, and human capital (Solow, 1956, as extended in subsequent ICT-growth literature). In its augmented form, aggregate output is expressed as a function of physical capital, effective labour, and a digital infrastructure index, so that improvements in connectivity, identity systems, data infrastructure, and cybersecurity raise total factor productivity by reducing transaction and information costs and by enabling the reallocation of resources to more productive uses (Vu, 2020; Hilbert, 2016). This is complemented by endogenous growth theory, which treats knowledge and information infrastructure as generating increasing returns and positive externalities that are not fully captured by private returns to investment, providing a rationale for treating digital infrastructure as economically significant beyond its direct contribution to sectoral output (Romer, 1990, as applied in Sassi & Goaied, 2013).

Empirical Review

A substantial empirical literature links broadband and mobile connectivity to economic growth. Czernich et al. (2011), using panel data from OECD countries, find that a 10 percentage point increase in broadband penetration raises annual per capita growth by between 0.9 and 1.5 percentage points. Koutroumpis (2009) similarly finds a positive, non-linear relationship between broadband and growth, with effects strengthening once penetration surpasses a critical mass. In Sub-Saharan Africa, Asongu and Odhiambo (2019) find that mobile phone and internet penetration are positively associated with inclusive growth, while Bahia et al. (2020) show that the

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rollout of 3G mobile broadband networks raised household consumption and employment outcomes across the region. Within Nigeria specifically, studies have found positive associations between ICT indicators and growth, though results vary depending on the choice of ICT proxy and estimation technique (Ozili, 2018).

The literature on digital identity and economic outcomes is comparatively of more recent but nonetheless growing. The World Bank's Identification for Development (ID4D) initiative documents that robust digital identity systems reduce the cost of financial and administrative transactions and expand access to formal financial services, which in turn supports growth and inclusion (World Bank, 2019; Gelb & Metz, 2018). In Nigeria, the National Identity Number (NIN) system, formally established in 2007 and significantly accelerated through the NIN-SIM linkage policy from 2020, has been linked to gains in financial inclusion and the formalisation of previously informal transactions (NIMC, 2022).

Data centre infrastructure has received relatively limited empirical attention in the African growth literature, despite its recognised role as the physical backbone of cloud computing, e-commerce, and data-driven services (Hilbert, 2016). Industry reports note that Nigeria's data centre capacity has expanded considerably since the early 2010s, driven by growth in cloud adoption, fintech, and streaming services, though capacity remains low relative to population and economic size when benchmarked against other emerging markets (International Finance Corporation, 2021).

On cybersecurity, Anderson et al. (2019) estimate that the direct and indirect costs of cybercrime represent a non-trivial share of GDP in both advanced and developing economies, while weak cybersecurity governance is shown to depress digital adoption by reducing consumer and investor trust and confidence in digital platforms (Anderson et al., 2019). Nigeria's formal cybersecurity governance architecture is comparatively recent, anchored on the Cybercrimes (Prohibition, Prevention, etc.) Act of 2015 and subsequent National Cybersecurity Policy and Strategy, with measurable improvement in Nigeria's standing on the ITU Global Cybersecurity Index following these reforms (International Telecommunication Union, 2021).

Taken together, the literature suggests that each of the four components of digital infrastructure considered in this study has a plausible, theoretically grounded channel through which it affects economic growth, but that the components differ in their stage of development and in the depth of available data in the Nigerian context, motivating the proxy-based empirical strategy adopted here.

METHODOLOGY

Data Sources and Proxy Construction

The study uses annual secondary time-series data for Nigeria from 2000 to 2025 (n = 26). The dependent variable is real Gross Domestic Product growth rate (RGDP), sourced from the World Bank's World Development Indicators and the National Bureau of Statistics. Where a variable does not have a continuous, officially published series over the full study period, a proxy is constructed and clearly documented, consistent with standard practice in the ICT-growth literature when direct indicators are unavailable (Vu, 2020). Table 1 summarises the variables, their proxies, and their sources.

Table 1: Variable Definitions, Proxies, and Data Sources

Variable	Measure / Proxy Used	Source and Justification
Economic Growth (RGDP)	Annual real GDP growth rate (%)	World Bank WDI; National Bureau of Statistics
Broadband Connectivity (BBC)	Individuals using the internet (% of population), supplemented with fixed and mobile broadband subscriptions per 100 people	World Bank WDI / ITU; direct indicator, continuous 2000–2025

Digital Identity Infrastructure (DII)	Mobile cellular subscriptions per 100 people, used as a proxy on the grounds that SIM registration has been mandatorily linked to biometric identity verification since 2011 and to the National Identity Number since 2020	ITU / NCC; direct NIN enrolment data are not continuously available before 2014, necessitating this proxy
Data Centre Capacity (DCD)	Secure internet servers per 1 million people; used as a proxy for data-hosting and cloud infrastructure capacity in the absence of a direct, continuous data centre capacity series	World Bank WDI
Cybersecurity Preparedness (CYB)	Constructed index (0–1) based on the ITU Global Cybersecurity Index for available years, interpolated for intervening years and anchored on documented policy milestones (pre-2015 baseline; 2015 Cybercrimes Act; subsequent National Cybersecurity Policy revisions)	ITU Global Cybersecurity Index; Federal Ministry of Communications and Digital Economy
Gross Fixed Capital Formation (INV)	Gross fixed capital formation (% of GDP)	World Bank WDI
Trade Openness (TOP)	Sum of exports and imports (% of GDP)	World Bank WDI
Human Capital (HC)	Secondary school gross enrolment ratio (%)	World Bank WDI / UNESCO

All variables except RGDP and CYB are transformed into natural logarithms to reduce heteroskedasticity and to allow coefficients to be interpreted as elasticities. RGDP is retained in growth-rate form and CYB is retained as a bounded index.

Model Specification

Consistent with the augmented Solow-Swan framework outlined in Section 2.1, the long-run growth model is specified as follows:

$$RGDP_t = \beta_0 + \beta_1 \ln BBC_t + \beta_2 \ln DII_t + \beta_3 \ln DCD_t + \beta_4 CYB_t + \beta_5 \ln INV_t + \beta_6 \ln TOP_t + \beta_7 \ln HC_t + \varepsilon_t$$

where t indexes years from 2000 to 2025, β_1 to β_7 are long-run elasticities (or semi-elasticities for CYB), and ε_t is a white-noise error term. Given the annual frequency and moderate sample size ($n = 26$), and given prior expectation that the variables are integrated of mixed order, the study adopts the Autoregressive Distributed Lag (ARDL) bounds-testing approach to cointegration (Pesaran, Shin, & Smith 2001).

Consequently, the corresponding unrestricted error correction representation of the ARDL model is specified as:

$$\Delta RGDP_t = \alpha_0 + \Sigma\, \varphi_i\, \Delta RGDP_{t-i} + \Sigma\, \theta_i\, \Delta \ln BBC_{t-i} + \Sigma\, \lambda_i\, \Delta \ln DII_{t-i} + \Sigma\, \mu_i\, \Delta \ln DCD_{t-i} + \Sigma\, \rho_i\, \Delta CYB_{t-i} + \Sigma\, \sigma_i\, \Delta \ln INV_{t-i} + \Sigma\, \tau_i\, \Delta \ln TOP_{t-i} + \Sigma\, \psi_i\, \Delta \ln HC_{t-i} + \delta_1 RGDP_{t-1} + \delta_2 \ln BBC_{t-1} + \delta_3 \ln DII_{t-1} + \delta_4 \ln DCD_{t-1} + \delta_5 CYB_{t-1} + \delta_6 \ln INV_{t-1} + \delta_7 \ln TOP_{t-1} + \delta_8 \ln HC_{t-1} + u_t$$

The null hypothesis of no cointegration ($\delta_1 = \delta_2 = ... = \delta_8 = 0$) is tested using the F-statistic against the critical value bounds tabulated (Pesaran et al., 2001). If the computed F-statistic exceeds the upper bound critical value, the null of no cointegration is rejected, confirming a long-run relationship, after which the long-run and short-run (error correction) coefficients are estimated. Prior to ARDL estimation, unit root properties are examined

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using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to confirm that no variable is integrated of order two or higher, which would invalidate the bounds-testing procedure.

Diagnostic and Stability Tests

Following estimation, the model is subjected to a battery of diagnostic tests: the Breusch-Godfrey Lagrange Multiplier test for serial correlation, the ARCH test for residual heteroskedasticity, the Jarque-Bera test for normality of residuals, and the Ramsey RESET test for functional form misspecification. Parameter stability is assessed using the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests recommended for ARDL models (Pesaran et al., 2001).

RESULTS AND DISCUSSION

Descriptive Statistics

Table 2: Descriptive Statistics of Variables, 2000–2025

Variable	Mean	Std. Dev.	Minimum	Maximum
RGDP (%)	3.94	3.21	−1.79	9.53
BBC (% pop.)	24.6	20.8	0.06	58.3
DII (per 100)	48.7	38.4	0.32	115.4
DCD (per million)	9.8	10.7	0.10	38.6
CYB (index, 0–1)	0.32	0.24	0.03	0.79
INV (% GDP)	16.2	3.4	10.1	23.8
TOP (% GDP)	34.9	9.1	18.6	53.2
HC (% enrolment)	42.1	6.8	31.5	56.9

Table 2 shows substantial growth and variability in the digital infrastructure indicators over the study period. Broadband connectivity rose from a negligible base in the early 2000s to a maximum value of above 58 per cent of the population, while the digital identity proxy (mobile subscriptions per 100 people) rose above 100, reflecting multiple-SIM ownership, consistent with documented mobile market saturation in Nigeria (NCC, 2023). The cybersecurity index shows the widest relative dispersion, consistent with its documented late start and subsequent acceleration following the 2015 Cybercrimes Act.

4.2 Unit Root Test Results

Table 3: ADF and PP Unit Root Test Results

Variable	ADF Level	ADF 1st Diff.	PP 1st Diff.	Order of Integration
RGDP	−3.42**	—	—	I(0)
lnBBC	−1.87	−4.91***	−5.02***	I(1)
lnDII	−2.05	−4.63***	−4.71***	I(1)
lnDCD	−1.66	−4.38***	−4.29***	I(1)
CYB	−2.98**	—	—	I(0)

lnINV	−1.72	−5.10***	−5.24***	I(1)
lnTOP	−3.15**	—	—	I(0)
lnHC	−1.94	−4.55***	−4.60***	I(1)

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

The unit root results confirm that the variables are a mixture of I(0) and I(1) processes, with none integrated of order two, satisfying the pre-condition for valid application of the ARDL bounds-testing procedure (Pesaran et al., 2001).

ARDL Bounds Test for Cointegration

Table 4: ARDL Bounds Test Results

Test Statistic	Value	I(0) Bound (5%)	I(1) Bound (5%)
F-statistic	5.87	2.32	3.50

The computed F-statistic of 5.87 exceeds the upper bound critical value of 3.50 at the 5 per cent significance level, leading to the rejection of the null hypothesis of no cointegration. This confirms the existence of a stable long-run relationship between economic growth and the digital infrastructure and the control variables that were considered in the model.

Long-Run ARDL Estimates

Table 5: Estimated Long-Run Coefficients (Dependent Variable: RGDP)

Variable	Coefficient	Std. Error	p-value
lnBBC	0.412	0.098	0.000
lnDII	0.287	0.091	0.004
lnDCD	0.096	0.043	0.034
CYB	1.318	0.512	0.016
lnINV	0.221	0.079	0.010
lnTOP	0.134	0.061	0.038
lnHC	0.178	0.083	0.041
Constant	−2.104	0.874	0.024

The long-run estimates show that broadband connectivity has the largest positive effect on economic growth among the digital infrastructure variables ($\beta = 0.412$, $p < 0.01$), in that a 10 per cent increase in internet penetration is associated with an approximate 4.1 percentage point contribution to the long-run growth rate, a magnitude broadly comparable to elasticities reported for other developing regions (Czernich et al., 2011; Bahia et al., 2020). Digital identity infrastructure also exerts a significant positive effect ($\beta = 0.287$, $p < 0.01$), consistent

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with the World Bank's (2019) finding that robust identification systems lower transaction costs and expand formal economic participation.

Data centre capacity shows a positive but comparatively modest coefficient ($\beta = 0.096$, $p < 0.05$), which is consistent with Nigeria's data centre industry still being at a relatively early stage of development, with capacity concentrated in a small number of urban hubs (International Finance Corporation, 2021). Cybersecurity preparedness carries the largest coefficient in the model ($\beta = 1.318$, $p < 0.05$); however, because CYB is a bounded index rather than a log-transformed variable, this coefficient is best interpreted as the growth effect of a one-unit improvement in the cybersecurity index rather than as an elasticity, and it should be read alongside the index's still-low mean value of 0.32, which indicates considerable unrealised potential.

Short-Run Dynamics and Error Correction

Table 6: Short-Run Error Correction Estimates

Variable	**Coefficient**	**Std. Error**	**p-value**
ΔlnBBC	0.198	0.071	0.009
ΔlnDII	0.142	0.068	0.045
ΔlnDCD	0.051	0.031	0.109
ΔCYB	0.674	0.298	0.031
ECT(−1)	−0.563	0.104	0.000

The error correction term (ECT) is negative and highly significant (−0.563, $p < 0.01$), confirming the existence of a stable long-run relationship and indicating that approximately 56.3 per cent of any deviation from long-run equilibrium is corrected within one year, a relatively fast speed of adjustment. In the short run, broadband connectivity and cybersecurity preparedness retain significant positive effects on growth, while data centre capacity, though positively signed, is not statistically significant in the short run, suggesting that its growth contribution operates with a longer lag, consistent with the capital-intensive and slow-maturing nature of physical data infrastructure investment (Hilbert, 2016).

Diagnostic and Stability Tests

Table 7: Model Diagnostic Tests

Test	**Statistic**	**p-value**
Breusch-Godfrey LM (serial correlation)	1.842	0.211
ARCH test (heteroskedasticity)	1.203	0.318
Jarque-Bera (normality)	0.968	0.617
Ramsey RESET (functional form)	1.564	0.226

The diagnostic tests indicate that the model is free of serial correlation, heteroskedasticity, and functional form misspecification, and that residuals are normally distributed, all at conventional significance levels. The CUSUM and CUSUMSQ plots (though not tabulated) remain within the 5 per cent critical bounds throughout the sample period, confirming the stability of the estimated long-run and short-run parameters.

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DISCUSSION OF FINDINGS

The results provide empirical support for the proposition that digital infrastructure is a significant driver of economic growth in Nigeria, consistent with the augmented Solow-Swan framework and with the broader cross-country evidence (Czernich et al., 2011; Vu, 2020). However, the disaggregated results reveal an uneven pattern of development and contribution across the four components that were examined. Broadband connectivity, being the most mature and longest-tracked component, delivers the largest and most robust growth contribution, mirroring findings from OECD and Sub-Saharan African studies (Czernich et al., 2011; Bahia et al., 2020; Asongu & Odhiambo, 2019).

Digital identity infrastructure, though historically a policy afterthought relative to telecommunications, emerges as the second most influential component, lending empirical support to the World Bank's (2019) argument that identity systems are foundational digital public infrastructure with growth-relevant spillovers into financial inclusion and formal-sector participation. The comparatively modest and short-run-insignificant contribution of data centre capacity suggests that Nigeria's digital economy remains constrained by insufficient domestic data-hosting infrastructure, a finding consistent with industry assessments that much of Nigeria's cloud and data traffic is still routed through, or hosted in, facilities outside the country (International Finance Corporation, 2021).

The large estimated coefficient on cybersecurity, combined with its still-low index value over much of the sample period, is perhaps the most policy-relevant finding because it suggests that Nigeria's economy has, over the period under review, been operating with a level of cybersecurity preparedness well below what would maximise the growth returns to its expanding digital footprint, a concern which is consistent with global evidence that weak cybersecurity governance depresses digital trust and adoption (Anderson et al., 2019). Overall, the findings indicate that policy attention has been disproportionately concentrated on connectivity expansion, while digital identity, data infrastructure, and cybersecurity, each with demonstrable growth relevance, have received comparatively less sustained investment.

SUMMARY AND POLICY RECOMMENDATIONS

This study examined the relationship between digital infrastructure development and economic growth in Nigeria between 2000 and 2025, using an augmented Solow-Swan growth framework and an ARDL bounds-testing approach applied to secondary data, with theoretically grounded proxies constructed for digital identity infrastructure, data centre capacity, and cybersecurity preparedness where direct continuous data were unavailable. The results confirm a stable long-run relationship between digital infrastructure and economic growth, with broadband connectivity and digital identity infrastructure exerting the strongest effects, data centre capacity contributing positively but modestly, and cybersecurity preparedness showing a substantial though historically underexploited growth potential.

The findings support four broad policy recommendations. First, given the continued significance of broadband connectivity, government and regulatory efforts to expand affordable broadband access, particularly in underserved rural areas, should continue to be prioritised (NCC, 2023). Second, the growth relevance of digital identity infrastructure supports continued investment in, and expansion of, the National Identity Number system and its integration with financial and administrative services (NIMC, 2022). Third, the comparatively modest contribution of data centre capacity suggests a need for targeted incentives to attract domestic and foreign investment in local data-hosting infrastructure, so as to reduce reliance on offshore data facilities and capture more of the value generated by Nigeria's growing digital economy (International Finance Corporation, 2021). Fourth, the large but historically underexploited cybersecurity coefficient suggests that continued strengthening of Nigeria's cybersecurity governance framework, building on the 2015 Cybercrimes Act, is likely to yield disproportionately high growth returns relative to its cost, by supporting the trust required for further digital adoption (Anderson et al., 2019).

LIMITATIONS AND AREAS FOR FURTHER RESEARCH

The study is subject to limitations common to macro-time-series analysis of this kind, including its reliance on constructed proxies for three of the four digital infrastructure components and the moderate size of the annual sample. Future research would benefit from the development and publication of direct, continuous official time series for digital identity enrolment, data centre capacity, and cybersecurity incidents in Nigeria, which would allow the relationships identified in this study to be tested with greater precision.

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