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# THE INTERACTIVE EFFECTS OF INFRASTRUCTURAL AND HUMAN CAPITAL DEVELOPMENT ON ECONOMIC GROWTH IN NIGERIA

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**ABSTRACT**

*The study examines the interactive effects of infrastructural and human capital development on economic growth in Nigeria over the period 1990 to 2023. Anchored on the New Growth Theory, the study adopts a Simultaneous Equation Model (SEM) framework and employs the Two-Stage Least Squares (2SLS) technique to account for endogeneity and feedback effects among the key variables. The results indicated that infrastructural development had a negative and statistically significant impact on growth when evaluated independently, highlighting inefficiencies, inadequate project execution, and underutilization in Nigeria's infrastructure sector. Also, human capital development showed a negative and significant effect when considered in isolation, implying that quality deficiencies, skills mismatches, and limited absorption in the labour market hinder its contribution to growth. However, the interaction term between infrastructure and human capital had a positive and significant impact on economic growth, suggesting a strong complementarity. This indicated that infrastructure and human capital enhance one another, and their joint development resulted to economic growth that neither can achieve on isolation. Among the control variables, labour force and population growth positively and significantly influenced growth, highlighting the role of demographic expansion. Inflation, government expenditure, and domestic credit to the private sector were statistically insignificant, reflecting structural and institutional inefficiencies. The study concludes that Nigeria's growth is driven mainly by the synergy between infrastructural and human capital development. Infrastructure policy should emphasize projects that directly enhance access to education and healthcare, such as electricity for schools and hospitals, reliable transport to reduce travel barriers, and ICT networks that expand learning opportunities. Also, Transparent procurement, strong monitoring systems, and timely maintenance are essential to ensure that infrastructure spending translates into productive outcomes rather than becoming a drain on public resources.*

**KEYWORDS**: *Infrastructural Development; Human Capital Development; Economic Growth; Interaction Effect*
**JEL Classification**: H54, I25, O40, C32

## 1. INTRODUCTION

Economic growth represents a sustained increase in an economy's productive capacity, driving prosperity, technological advancement, and improvements in human welfare. Beyond mere expansion in output, growth encompasses social stability, national security, and enhanced quality of life. In developing economies such as Nigeria, economic growth functions as a critical mechanism for improving living standards, generating employment, and alleviating poverty. With a youthful population and a high dependency ratio of 73.3%, significantly above the global average of 47%, Nigeria faces mounting pressure to implement policies capable of translating demographic potential into inclusive and sustainable growth (World Economics, 2024). Projections that the population may reach 400 million by 2050 further underscore the urgency of strengthening the structural foundations of growth (Nwanze, 2019).

Despite abundant natural resources, particularly oil and gas, Nigeria's growth trajectory has been volatile and insufficiently inclusive. The economy recorded average growth rates of 6–7% during the mid-2000s oil boom but contracted to –1.8% in 2020 before recovering modestly to 3.1% in 2022 (World Bank, 2023). Real GDP growth declined to 3.3% in 2022 from 3.6% in 2021 due to falling oil production (African Development Bank, 2023), and further slowed to 2.51% year-on-year in the second quarter of 2023 (National Bureau of Statistics, 2023). Growth in income per capita remains weak, reflecting limited welfare gains. Regional disparities persist, with rural areas

facing poor road networks, unreliable electricity, and limited access to quality education and healthcare (World Bank, 2022). These structural constraints highlight the importance of examining the underlying drivers of sustained economic performance.

Among the determinants of growth, physical capital, human capital, technological progress, natural resources, and institutional quality, physical capital, particularly infrastructure, serves as a fundamental enabler of economic activity. Infrastructure enhances productivity by reducing transaction costs, facilitating trade, and supporting service delivery. However, Nigeria's infrastructure landscape remains deficient. Inadequate transport systems, unreliable power supply, and limited digital connectivity constrain business operations and deter investment (Agwu & Ukakwu, 2019). Nigeria's infrastructure stock is estimated at only 30% of GDP, far below the 70% international benchmark (World Bank, 2020). The country ranked 24th out of 54 in the Africa Infrastructure Development Index (AIDI, 2021) and 130th out of 141 globally in infrastructure quality (GCI, 2019), reflecting persistent gaps in electricity, transport, and digital systems.

Parallel to infrastructure, human capital development (HCD) constitutes a central pillar of long-term economic transformation. Investments in education, health, and workforce skills enhance labour productivity, stimulate innovation, and strengthen competitiveness (Faggian et al., 2019; Tran & Vo, 2020; Okunade et al., 2022). Theoretical foundations from Becker (1964) and Lucas (1988) emphasize that sustained investment in human capital generates cumulative growth benefits. Empirical evidence further shows that economies with strong human capital systems are more resilient to external shocks and better positioned for structural transformation (Marimuthu et al., 2009; Talan & Tyagi, 2020).

In Nigeria, however, progress in human capital accumulation has been constrained by chronic underinvestment and institutional weaknesses. Public spending on education consistently falls below the 15–20% benchmark recommended by UNESCO (2023), while households finance 70–75% of total health expenditure through out-of-pocket payments, with government health spending at only 0.63% of GDP (Jia et al., 2025). These deficiencies are reflected in Nigeria's Human Capital Index (HCI) score of 0.36, implying that a child born today will achieve only 36% of potential productivity under prevailing conditions (World Bank, 2020). Such weaknesses limit the economy's ability to harness its demographic dividend and sustain productivity growth.

Crucially, infrastructure and human capital are not independent drivers of growth; rather, they interact in mutually reinforcing ways. Infrastructure improves access to education and healthcare, thereby strengthening human capital formation. Conversely, a skilled and healthy workforce enhances the efficient utilization and innovation potential of infrastructure investments (Romer, 1990). Endogenous growth theory further underscores that coordinated investments in physical and human capital can generate self-reinforcing growth dynamics and technological diffusion (Aghion & Howitt, 1998). In Nigeria's context, where deficits in both domains persist, understanding their interactive effect is essential for designing coherent development strategies.

Although existing studies have examined the individual impact of infrastructural development (Ogbebor & Ashakah, 2022; Benne et al., 2021; Siyan & Adegoriola, 2017) and human capital (Khan et al., 2023; Ogunjobi et al., 2021; Effiom & Okoli, 2018; Anochiwa & Maduka, 2014) on economic growth in Nigeria, most have treated these variables in isolation. Panel-based analyses across countries (Nkembga et al., 2023; Acheampong et al., 2022) may not fully capture Nigeria's unique structural dynamics. The limited exploration of the joint and interactive effects of infrastructure and human capital constrains a comprehensive understanding of their combined influence on growth.

Against this backdrop, this study investigates the interactive effect of infrastructural development and human capital development on economic growth in Nigeria. By adopting a Two-Stage Least Squares (2SLS) estimation approach to address potential endogeneity and employing Principal Component Analysis (PCA) to construct composite indices, the study provides a more integrated and methodologically robust examination of the infrastructure–human capital–growth nexus. This approach contributes to policy discourse by highlighting how coordinated investments in infrastructure and human capital can enhance productivity, promote structural transformation, and foster inclusive and sustainable economic growth in Nigeria.

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## 2.LITERATURE REVIEW

### 2.1. Conceptual Literature

#### 2.1.1. Economic Growth

Economic growth represents the sustained expansion of a country's productive capacity and is commonly measured by increases in real Gross Domestic Product (GDP). It reflects improvements in the production and consumption of goods and services over time and serves as a key indicator of economic performance and rising living standards (Mankiw, 2016). Although GDP growth signals positive economic progress, it does not fully capture income distribution or the sustainability of growth outcomes. Nevertheless, within macroeconomic analysis, economic growth remains the central benchmark for evaluating development performance and structural transformation.

In the context of this study, economic growth is conceptualized as the ultimate outcome variable influenced by infrastructural development and human capital development. It reflects not merely expansion in output, but also improvements in productivity and efficiency arising from enhanced physical and human capacities.

#### 2.1.2 Infrastructural Development

Infrastructural development is widely recognized as a fundamental driver of economic growth, particularly in developing economies (Calderón & Servén, 2004). It entails the deliberate creation, expansion, and maintenance of physical and organizational systems that enable economic and social activities. These systems include transportation networks, energy supply chains, communication infrastructure, and essential utilities such as water and sanitation (World Bank, 2016). By reducing transaction costs, facilitating market access, and improving production efficiency, infrastructure forms the backbone of economic activity.

Transportation infrastructure plays a critical role in integrating domestic and international markets. Efficient roads, railways, ports, and airports enhance the mobility of goods and labour, reduce logistical bottlenecks, and promote industrial competitiveness. However, deficiencies in transportation systems can constrain productivity and regional integration, particularly in developing contexts (Onokala & Olajide, 2020; Theresa, Gloria & Frank, 2025).

Energy infrastructure is equally vital, as reliable electricity and fuel supply underpin industrial production, technological adoption, and economic diversification. Persistent energy deficits, characterized by unreliable generation and distribution, raise operational costs and deter investment (OECD, 2010; Emovon, Samuel, Mgbemena & Adeyeri, 2018). Addressing such constraints requires modernization of energy systems and expansion of access to underserved areas (Adebayo & Ainah, 2024).

Communication infrastructure, including broadband internet and telecommunications, has emerged as a key enabler of knowledge-based economic activities. Robust digital networks facilitate innovation diffusion, entrepreneurship, and participation in global markets (Sindakis, Depeige & Anoyrkati, 2015). However, digital divides may limit inclusive growth and reduce the potential benefits of technological transformation (Adeleke, 2021).

Importantly, infrastructure components operate synergistically. The integration of transportation, energy, and communication systems enhances supply chain coordination, fosters innovation spillovers, and accelerates structural transformation (World Bank, 2016). Thus, infrastructural development constitutes the physical foundation upon which productive activities and long-term growth depend.

#### 2.1.3 Human Capital Development

Human capital development (HCD) refers to the process of enhancing individuals' skills, knowledge, competencies, and health to improve productivity and societal well-being. Early conceptualizations define human capital as investment in people as productive agents capable of contributing to economic progress (Harbison, 1962). Similarly, the United Nations Development Programme (UNDP, 1990) emphasizes enlarging people's choices, particularly in terms of health, education, and access to resources necessary for a decent standard of living.

Human capital encompasses formal education, vocational training, healthcare, and skill acquisition (Becker, 1993). Schultz (1993) argues that investments in education and health increase workers' cognitive abilities, productivity, and efficiency, thereby enhancing both firm-level competitiveness and national growth prospects.

This perspective underscores the transformative nature of human capital as an asset embedded in individuals but developed through deliberate investment.

Empirical and theoretical literature consistently affirms the centrality of human capital to economic growth (Barro, 1991; World Bank, 1995; Adedeji & Bamidele, 2003; Nwokoye et al., 2020). In the absence of sustained investment in education and health, productivity gains remain limited, and long-term growth becomes unsustainable. As economies become increasingly knowledge-driven, the importance of a skilled and healthy workforce intensifies, making human capital development a strategic imperative for competitiveness and structural transformation.

**2.1.4 Interaction between Infrastructure and Human Capital**

While infrastructural development and human capital development are individually important, they are conceptually interdependent. Infrastructure enhances access to education and healthcare by improving connectivity and service delivery, thereby facilitating human capital formation. Conversely, a skilled and healthy workforce improves the efficient utilization, maintenance, and innovation potential of infrastructure.

This mutual reinforcement implies that the growth impact of infrastructure may depend on the level of human capital, and vice versa. In other words, infrastructure without adequate human capacity may yield suboptimal returns, while human capital without supportive physical systems may remain underutilized. Therefore, understanding their interactive effect provides a more comprehensive framework for explaining economic growth dynamics.

**2.2 Empirical Literature review**

Sapkota (2014), using dynamic panel estimation for 91 developing countries (1995–2010), found that access to electricity, clean water, and road density significantly improved the Human Development Index (HDI), underscoring the role of infrastructure in enhancing human capital outcomes. Similarly, Mohanty et al. (2016) employed panel data analysis across districts in India and reported a strong linkage between infrastructure and human development, particularly in less developed regions. In Nigeria, Olagunju et al. (2017) applied Probit regression and poverty indices to household data and found that access to roads, electricity, schools, and health facilities significantly influenced welfare outcomes, reinforcing the human capital–infrastructure connection. Enilolobo and Sodeinde (2019), using OLS (1991–2014), revealed that human capital significantly improved industrial productivity, while infrastructure had a positive but insignificant effect, suggesting asymmetry in their contributions. At the continental level, Nchofoung et al. (2022) applied system GMM and found that infrastructure positively influenced inclusive human development in Africa, though ICT infrastructure showed weak effects. Nkemgha et al. (2023) also used system GMM for 33 African countries and observed that infrastructure promoted industrialization, but its interaction with human capital produced mixed outcomes, indicating threshold effects. Foster et al. (2023), through a systematic review of over 300 studies, confirmed that digital, energy, and transport infrastructure significantly enhance human capital formation and productivity, although impacts are context-specific.

Nedozi et al. (2014) employed OLS within a simultaneous equation framework and concluded that infrastructure is essential for growth, functioning both as an intermediate and final good. Ekpung (2014), using VEC methodology (1970–2010), found that public infrastructure expenditure was insufficient and weakly linked to growth outcomes. Owolabi-Merus (2015), applying OLS and Granger causality (1983–2013), reported a positive and significant effect of infrastructure on GDP, although causality was weak. Fatai et al. (2016), using cointegration and ECM techniques, found that infrastructure components positively contributed to growth, but domestic investment and labour force showed negative associations, implying that infrastructure alone may be insufficient without complementary human capital improvements. Ogbaro and Omotoso (2017), employing a Cobb-Douglas production function, demonstrated that air transport, communication, power, and rail infrastructure exerted significant positive elasticities on growth. Kodongo and Ojah (2016), through system GMM for Sub-Saharan Africa, identified strong positive effects of infrastructure spending and access on growth, especially in less developed economies. Bennee et al. (2021), using longitudinal data (2000–2020), found a statistically significant positive relationship between infrastructure expenditure and real GDP in Nigeria.

Empirical attention to the joint or interactive effects remains limited but revealing. Anochiwa and Maduka (2014), using cointegration and ECM (1970–2010), found that human capital significantly influenced growth, while electricity infrastructure had a positive but insignificant effect, recommending simultaneous policy focus. Tsaurai and Ndou (2019), employing dynamic GMM for transitional economies, demonstrated that the interaction

between infrastructure and human capital significantly enhanced economic growth, supporting theoretical complementarity. In Nigeria, Ogunjobi et al. (2021), using ARDL (1981–2018), found that education quality, transport, communication, and energy infrastructure significantly influenced growth, though with lagged effects in some cases. Most notably, Ogbebor and Ashakah (2022), using ARDL (1990–2020), reported that infrastructure and human capital were individually insignificant, but their interaction produced a modest positive effect at the 10% level. This finding underscores the potential importance of examining their combined rather than isolated impacts.

The empirical literature demonstrated substantial evidence on the individual effects of infrastructural development and human capital development on economic growth in Nigeria and other developing economies. However, most studies examine these variables in isolation, focusing either on infrastructure–growth or human capital–growth linkages. Although a few studies, such as Tsaurai and Ndou (2019) and Ogbebor and Ashakah (2022), consider interaction effects, evidence for Nigeria remains limited, inconclusive, and methodologically constrained. Moreover, existing Nigerian studies often rely on single indicators of infrastructure or human capital, which may not adequately capture their multidimensional nature. Consequently, there is insufficient empirical understanding of how infrastructural development and human capital development jointly and interactively influence economic growth in Nigeria. This gap necessitates a more integrated analysis of their interactive effects, which this study seeks to address.

## 3. METHODOLOGY

### 3.1 Theoretical Framework

This study is anchored on the **New Growth Theory**, as advanced by Paul Romer (1986) and Robert E. Lucas Jr. (1988). The theory emphasizes that long-term economic growth is driven not only by physical capital accumulation but also by endogenous factors such as human capital development, innovation, and knowledge spillovers. Central to this framework is the proposition that investments in education, healthcare, and skill acquisition enhance labour productivity, stimulate technological progress, and generate sustained economic growth.

Within this theoretical perspective, infrastructural development plays a complementary and enabling role. Infrastructure provides the physical systems, such as transportation, energy, and communication networks that facilitate access to education, healthcare, and other human capital-enhancing services. Consequently, the interaction between infrastructural development and human capital development becomes critical in determining economic performance. Infrastructure strengthens the productivity of human capital, while a skilled and healthy workforce enhances the efficiency and utilization of infrastructure. This mutual reinforcement forms the theoretical basis for examining their interactive effect on economic growth in Nigeria.

The analytical foundation of the study is derived from an extended Cobb–Douglas production function specified as:

$$Y = AK^{\alpha}H^{\beta}L^{(1-\alpha-\beta)} \qquad 1$$

Where Y represents economic output, A denotes total factor productivity (TFP), K is physical capital, and H represents human capital. Also, L denotes labour, while α and β are the output elasticities of physical and human capital, respectively.

In this model, total factor productivity (A) captures technological progress, innovation, and institutional influences that enhance overall economic efficiency. The inclusion of human capital (H) reflects the theoretical assertion that a more educated and skilled workforce improves productivity and output. Infrastructure, as part of the broader capital accumulation process, enhances the effectiveness of both physical and human capital by reducing transaction costs and improving productive efficiency.

Thus, supports the proposition that infrastructural development and human capital development jointly and interactively influence economic growth. By embedding these variables within the extended production function, the study provides a structured basis for empirically assessing their combined impact on economic growth in Nigeria.

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### 3.2. Data and Data Sources

The data is an annual frequency timeseries data, sourced from World Bank Development Indicators (WDI), Africa Infrastructure Development Index (AIDI), Humanitarian Data Exchange (HDX), and the Central Bank of Nigeria (CBN). The data covered the periods from 1990 to 2023.

### 3.3 Model Specification

In line with the theoretical underpinning of the study, the model examining the interactive effect of infrastructural development and human capital development on economic growth in Nigeria is specified in its functional form as follows:

$$RGDPGt = f(AIDIt, HCDIt, AIDIt * HCDIt, INFLt, GEXPt, \text{LABFt}, \text{DCPSt}, \text{POPGt}) \quad 2$$

Where RGDPG is real GDP growth, $AIDI$ is aggregate infrastructural development index (transportation, energy, telecommunications), $HCDIt$ is human capital development index (life expectancy, education index and Gross National Income – GNI index), while $AIDIt * HCDIt$ is the interaction of aggregate infrastructural development index and human capital development index. $INFL$ is defined as inflation, consumer prices (annual %), $GEXP$ is defined as federal government recurrent expenditure (education), LABF is labour force participation rate, DCPS is domestic credit to private sector, and POPG is population growth.
The econometric form of Equation (2) is expressed as:

$$RGDPGt = \delta_0 + \delta_1 AIDIt + \delta_2 HCDIt + \delta_3(AIDIt * HCDIt) + \delta_4 INFLt + \delta_5 GEXPt + \delta_6 \text{LABFt} + \delta_7 \text{DCPSt} + \delta_8 \text{POPGt} + \varepsilon_1 \quad 3$$

Taken the logs, we re-specify the equation as:

$$RGDPGt = \delta_0 + \delta_1 AIDIt + \delta_2 HCDIt + \delta_3(AIDIt * HCDIt) + \delta_4 INFLt + \delta_5 logGEXPt + \delta_6 \text{logLABFt} + \delta_7 \text{logDCPSt} + \delta_8 \text{POPGt} + \varepsilon_t \quad 4$$

Where $\delta_0$ is the intercept, $\delta_1$ to $\delta_8$ are the regression coefficients, $\varepsilon_t$ is the error term, while $t$ represents time. The a priori expectation is that the coefficient of the interaction term between infrastructural development (AIDI) and human capital development (HCDI) will be positive. This implies that the combined effect of infrastructural development and human capital development is expected to enhance economic growth more than their individual effects (Eniekezimene et al., 2023).

This study employs the Simultaneous Equation Model (SEM) framework and applies the Two-Stage Least Squares (2SLS) estimation technique to analyse the specified models. The SEM approach is suitable given the interdependent relationship among infrastructural development, human capital development, and economic growth, where feedback effects may exist among the endogenous variables. Such mutual causality violates the exogeneity assumption underlying the Ordinary Least Squares (OLS) method. The 2SLS technique, originally developed by Henri Theil (1953) and David A. Basmann (1957), addresses this challenge by incorporating instrumental variables that are correlated with the endogenous regressors but uncorrelated with the error term. This approach ensures unbiased and consistent parameter estimates while capturing the direct and indirect effects of infrastructural and human capital development on economic growth, alongside relevant macroeconomic and institutional factors.

## 4. RESULT

### 4.1 Unit Root Test

A unit root test was conducted using the Augmented Dick-Fuller and Philips Perron unit root tests were conducted and the result is reported in Table 1.

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**Table 1: Augmented Dick-Fuller and Philips Perron unit root test results**

| Variable | ADF | $ADF_{1st}$ | $ADF_{2nd}$ | Order | PP | $PP_{1st}$ | $PP_{2nd}$ | Order |
|---|---|---|---|---|---|---|---|---|
| RGDPG | -2.7565*** (0.0676) | - | - | I(0) | -2.6436* (0.0869) | - | - | I(0) |
| AIDI | -2.1109 (0.5316) | -2.6928*** (0.0798) | - | I(1) | -0.0115 (0.9542) | -2.8238*** (0.0595) | - | I(1) |
| HCDI | -1.5555 (0.5021) | -1.6199 (0.4693) | -8.8580* (0.0000) | I(2) | -0.5156 (0.8833) | -2.8076*** (0.0601) | - | I(1) |
| INFL | -3.8167** (0.0222) | - | - | I(0) | -2.1849 (0.2128) | -3.5616* (0.0079) | - | I(1) |
| GEXP | -0.5209 (0.8816) | -3.7097* (0.0053) | - | I(1) | -0.1004 (0.9644) | -3.4022* (0.0131) | - | I(1) |
| LABF | 0.09065 (0.9639) | -3.0682** (0.0316) | - | I(1) | 8.8194 (1.0000) | -0.4782 (0.8906) | -11.8605* (0.0000) | I(2) |
| DCPS | -2.7504* (0.0685) | - | - | I(0) | -2.0785 (0.2537) | -3.9317* (0.0024) | - | I(1) |
| POPG | -1.3282 (0.6151) | -1.9397 (0.3133) | -11.32996* (0.0000) | I(2) | 1.0012 (0.9965) | -2.0988 (0.2456) | -11.3435* (0.0000) | I(2) |

Notes: *, ** and *** denote significant at 1%, 5% and 10% levels respectively. Figures in ( ) denote *p*-values.

*Source: Researchers' computation*

The results from the Augmented Dick–Fuller (ADF) and Phillips–Perron (PP) tests showed a mixed order of integration among the variables. Real GDP growth (RGDPG) was stationary at level, with both ADF and PP statistics significance at conventional levels, which means it is integrated of order zero, or I(0). On the other hand, DCPS is also stationary at level according to the ADF test, but the PP test suggested it only became stationary after first differencing, highlighting some inconsistency between the two tests. When we looked at infrastructural development (AIDI), it was non-stationary at level but turns stationary at first difference in both ADF and PP tests, indicating that it is I(1). Government expenditure (GEXP) follows a similar I(1) pattern under both tests. Human capital development (HCDI) presents a bit of a puzzle: the ADF test suggested it is I(2), becoming stationary at the second difference, while the PP test showed that it was stationary at first difference (I(1)). Inflation (INFL) was stationary at level under ADF but only at first difference under PP, which points to its sensitivity to the testing method used. Both the labour force (LABF) and population growth (POPG) were integrated of order two, I(2), especially according to the PP test. These findings revealed a mix of I(0), I(1), and I(2) variables.

### 4.2 Impact of Interaction between Infrastructure Development and Human Capital Development on Economic Growth

In line with the study's objective, the impact of interaction between infrastructure development and human capital development on economic growth was estimated using the Instrumental Variables (2SLS) technique and the result is presented on Table 2.

**Table 2: Instrumental Variables (2SLS) estimates of the impact of** interaction between infrastructure development and human capital development on economic growth

| Variable | Coefficient (B) | Std. Error | z | p-value |
|---|---|---|---|---|
| Infrastructural Development (AIDI) | -8.966679*** | 2.54902 | -3.52 | 0.000 |
| Human Capital Index (HCDI) | -53.9488*** | 12.32754 | -4.38 | 0.000 |
| Interaction Term (AIDI*HCDI) | 4.991137*** | 1.195537 | 4.17 | 0.000 |
| Inflation (INF) | 0.0737755 | 0.1278746 | 0.58 | 0.564 |
| Government Expenditure (LNGEXP) | -0.7338333 | 2.4952 | -0.29 | 0.769 |
| Labour Force (LNLABF) | 126.4877*** | 31.00403 | 4.08 | 0.000 |
| Domestic Credit (LNDCPS) | 0.6632826 | 0.7431227 | 0.89 | 0.372 |
| Population Growth (POPG) | 132.876*** | 21.08887 | 6.30 | 0.000 |
| Constant | -2516.093*** | 585.7976 | -4.30 | 0.000 |
| **Model Statistics** | | | | |
| R-squared | 0.9219 | | | |
| Wald $chi^2(8)$ | 629.45 ($p < 0.001$) | | | |
| Root MSE | 0.61612 | | | |
| Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$ | | | | |

*Source: Researchers' computation*

The coefficient of infrastructural development (AIDI) is negative and highly significant (–8.9667, $p < 0.001$). This indicates that infrastructure, when considered in isolation, imposes a net drag on growth. This finding reflects the reality that much of Nigeria's infrastructure is characterized by inefficiency, high maintenance costs, and frequent underutilization. Poor execution, corruption in project delivery, and the fiscal burden of debt-financed projects may cause infrastructure to weigh on growth when not complemented by other supportive factors. The result implies that infrastructure on its own does not automatically translate into economic expansion and can even become a liability if it fails to stimulate productivity.

Similarly, human capital development (HCDI) has a negative and significant coefficient (–53.9488, $p < 0.001$). This suggests that, in isolation, human capital improvements have not independently translated into higher economic growth. A plausible explanation is that Nigeria's education and health systems, while expanding in quantity, often underperform in quality, producing skills that are mismatched with labour market needs. High unemployment among graduates and limited absorption capacity in the economy reduce the growth impact of human capital. This underscores that human capital accumulation, when not paired with enabling infrastructure and productive opportunities, may generate underutilized or idle capacity.

By contrast, the interaction term between infrastructure and human capital (AIDI*HCDI) is positive and highly significant (4.9911, $p < 0.001$). This is the central finding of the model, demonstrating that infrastructure and human capital are complementary rather than independent drivers of growth. When both are developed together, the positive synergies outweigh their individual weaknesses. For instance, quality roads and electricity make health and education services more accessible and effective, while a skilled workforce enhances the productivity returns from infrastructure investments. The result highlights that the growth payoff in Nigeria is unlocked not by single investment but by integrated development strategies that combine physical and human capital.

Among the control variables, inflation (INF) is positive but insignificant (0.0738, $p = 0.564$), implying that inflationary variations during the period did not exert a direct growth effect once structural factors were controlled for. Government expenditure (LNGEXP) is negative and insignificant (–0.7338, $p = 0.769$), suggesting that public spending has not consistently translated into productive outcomes, likely due to inefficiencies, leakages, and a bias toward recurrent over capital expenditure.

The labour force (LNLABF) exerts a strong, positive, and significant effect (126.4877, $p < 0.001$), confirming that the size of Nigeria's working-age population is a major contributor to growth. However, this effect may reflect sheer demographic expansion rather than productivity-driven employment, raising questions about the sustainability of growth without quality jobs. Domestic credit to the private sector (LNDCPS) is positive but insignificant (0.6633, $p = 0.372$), indicating that financial sector deepening has not effectively translated into productive investment capable of stimulating growth.

Population growth (POPG) is positive and highly significant (132.876, $p < 0.001$). This suggests that demographic expansion has boosted growth, primarily through increased labour supply and aggregate demand. While this highlights the potential of Nigeria's demographic dividend, the long-term sustainability of this effect depends on whether the expanding population is matched with adequate infrastructure, employment opportunities, and human capital investments.

The constant term is negative and highly significant (–2516.093, $p < 0.001$), implying that in the absence of the included explanatory variables, the economy would be on a declining trajectory. This captures the structural weaknesses inherent in Nigeria's economy, where growth is heavily reliant on the interaction of key drivers rather than occurring autonomously.

These results emphasize that Nigeria's growth trajectory is shaped less by single drivers than by the interaction of multiple inputs and the institutional efficiency with which they are mobilized. Infrastructure and human capital, while individually constrained, reinforce each other strongly when combined, and this complementarity provides the most reliable pathway for long-term economic expansion

The model achieves a strong explanatory power, with an R-squared of 0.9219, indicating that the included regressors jointly explain about 92.2 percent of the variation in economic growth. The Wald chi-square statistic of 629.45 ($p < 0.001$) confirms the collective statistical significance of the explanatory variables, while the relatively low root mean square error of 0.6161 demonstrates a good model fit. Taken together, these diagnostics suggest that the model is both statistically robust and well specified.

### 4.3.Discussion of Findings

One of the study's most revealing insights is that infrastructure and human capital, when considered separately, had negative effects on growth, yet their interaction produced a strong positive effect. This suggested that neither infrastructure nor human capital alone is sufficient to drive growth; rather, their complementarities are decisive. Similar findings are reached by Tsaurai and Ndou (2019), who argued that infrastructure and human capital reinforce each other in transitional economies, and by Nchofoung et al. (2022), who showed that infrastructural development requires complementary thresholds in human capital to be effective.

For Nigeria, this means fragmented investments are unlikely to produce growth dividends. The evidence resonated with Foster et al. (2023), who highlighted that infrastructure generated uneven outcomes across Africa unless accompanied by supportive human capital. Thus, this study contributed to the debate by providing Nigerian-specific evidence that integrated, not isolated, investment strategies hold the greatest potential for sustainable growth.

## 5.CONCLUSION AND RECOMMENDATIONS

This study examined the interactive effect of the impact of infrastructural development and human capital development on economic growth in Nigeria from 1990 to 2023 using the two stage least squares estimation framework. Based on the findings, it is concluded that the interaction between infrastructural development and human capital produces a strong and significant positive effect on growth. This synergy indicates that infrastructure and human capacity reinforce one another to generate productivity gains that neither can achieve alone. Infrastructure is most productive when there is a skilled, healthy, and adaptable labour force to use and maintain it, and human capital investments yield larger returns when supported by reliable physical and digital networks. Also, infrastructural development considered in isolation is associated with negative effects on growth in the Nigerian context. This paradox reflects implementation weaknesses in the infrastructure sector such as governance failures, cost overruns, poor maintenance practices, and weak project selection and oversight. Human capital on its own exerted a positive effect but its magnitude was moderated by supply side constraints and quality gaps in education and health provision. Labour force expansion supported human capital formation but sometimes insignificant in growth regressions because of skills mismatch and unemployment.

Macroeconomic and fiscal conditions further shape these relationships. Inflation and inefficient government expenditure were found to depress growth, while population growth displayed a positive association with growth, signaling an untapped demographic dividend that can be realized only through job creation and effective human capital policies. The weak or insignificant role of domestic credit and some fiscal channels in promoting human capital points to structural bottlenecks in financial intermediation and public sector absorptive capacity.

Since the study found a positive and significant relationship between infrastructural development and human capital, infrastructure policy should emphasize projects that directly enhance access to education and healthcare, such as electricity for schools and hospitals, reliable transport to reduce travel barriers, and ICT networks that expand learning opportunities. Policymakers should move beyond headline infrastructure projects and instead prioritize investments with clear spillover benefits for human capital development. Also, given the negative standalone effect of infrastructure on growth, reforms must focus on quality, efficiency, and governance rather than on the sheer volume of projects. All infrastructure investments should undergo rigorous cost–benefit analysis and long-term sustainability assessments. Transparent procurement, strong monitoring systems, and timely maintenance are essential to ensure that infrastructure spending translates into productive outcomes rather than becoming a drain on public resources.

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