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INVESTIGATING THE ECONOMIC EFFECTS OF THE SUPPLY AND DEMAND FOR INFRASTRUCTURE IN WEST AFRICA: EMERGING INSIGHTS FROM A SIMULTANEOUS ANALYSIS

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Abstract: The study investigates how infrastructure affects the economic growth of West Africa while considering the issues of endogeneity and simultaneity. Data was collected from 2005 to 2022 and nonlinear three-stage least squares GMM methods were used to make the infrastructure variable endogenous, while examining different kinds of infrastructure models. It was revealed that aggregate infrastructure supports and enhances economic growth. The transportation, energy, ICT, and water and sanitation components of infrastructure give unique support to economic growth. The study showed that the amount of industrial activity and fiscal balance in the West African region was not adequate to influence the trajectory of

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the demand and supply of infrastructure. It is suggested in the study that West African nations should invest in infrastructure that promotes and speeds up their economic growth. This study gives important information for shaping growth strategies and creating a base for making and carrying out economic policies.

Keywords: infrastructure; growth; electricity; ICT; transport.

JEL CODES: H54, O18.

1. Introduction

Strong infrastructure plays a key role in the economy by stimulating factors of production and influencing how fast the economy develops. For this reason, governments are putting greater efforts and resources into developing the infrastructure in different economic sectors. Endowed with human and natural resources, West Africa needs to use its infrastructure to help with sustainable development. West Africa, despite improving in the three key areas of infrastructure – telecommunication, transport, and energy – has lagged behind in terms of quantity and quality of infrastructure. Although the demand for and supply of infrastructure vary from one country to another in West Africa, there is a huge gap across key infrastructural facilities, especially given the growing infrastructural needs of its teeming population. For instance, the region requires between $130 and $170 billion in annual investment to address infrastructure gaps (Puye, 2024). Over the years, this has been the case in West Africa, a region with relative infrastructural deficiency. West African countries have experienced economic challenges that a viable infrastructure framework would have averted. Most countries have experienced economic recessions through the years (Efayena & Olele, 2024). While some economies have technically exited these recessions at different times, these economies have remained in a stagflation phase that is characterized by soaring unemployment and inflation rates and sluggish economic growth. The West African region has undergone phases of the business cycle – boom (peak), decline, recession, and recovery. In most cases, the peak periods are not linked with the real sector of these economies, possibly due to infrastructure development. Infrastructural development in the region also faces security challenges (Efayena et al., 2024).

Theoretical and empirical evidence has demonstrated the indispensability of infrastructure for economic performance at both country and regional levels (see Timilsina et al., 2023; Du et al., 2022; Asher & Novosad, 2020; Canning & Pedroni, 1999). Theoretically, three broad perspectives explain the growth-stimulating effect

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of infrastructure. The Keynesian approach views infrastructure as growth-stimulating because of its ability to increase aggregate demand. Infrastructure is assumed to have a multiplier effect on growth through aggregate demand. In addition, the Keynesian approach considers infrastructure as a self-sustaining instrument capable of managing the oscillations of business cycles (Young & Sobel, 2013), which can potentially stimulate employment in the economy. In the Ricardian approach, infrastructure is considered a tool for improving an economy's comparative advantage in trade through cost reduction in distributing goods and services. Therefore, the Ricardian approach views infrastructure as a trade facilitator that fosters long-term growth. Whereas the neoclassical approach postulates that infrastructure spurs economic growth by stimulating productivity through innovation. Technology diffusion enhances the communication, distribution, and transportation processes, thereby boosting economic growth (Canning & Pedroni, 2008; Kahrl & Roland-Holst, 2009).

Irrespective of the theoretical approach, investment in infrastructure can potentially spur economic growth (Burke et al., 2018; Chakamera & Alagidede, 2018; Kodongo & Ojah, 2016; Ajakaiye & Ncube, 2010). This can be achieved, particularly through the diffusion of technology, which enhances economic productivity. Improved infrastructure can create demand for raw materials and labour, and this will increase the demand for and supply of other goods and services. In addition, infrastructure improvements can potentially stimulate local and foreign trade. Because infrastructure is very important, both rich and developing countries now invest in it by starting programmes and projects to support sustainable future growth. Most research carried out in West African nations studying infrastructure's influence on economic development suggested a positive relationship (see Usman et al., 2024; Ojo, 2022; Obiri et al., 2020; Owusu-Manu et al., 2019; and Nedozi et al., 2014). Even so, the results of the investigations indicate that the countries' infrastructure is still very underdeveloped. For this reason, infrastructure has not been as contributing to GDP as it could be. Still, one serious flaw of these studies is that they ignore the possibility that economic growth could adversely impact infrastructure. Most existing studies revealed that reverse causality affected policy relevance. Most of the research conducted in West African countries is also vulnerable to problems caused by simultaneity. For this reason, this study has contributed to existing knowledge in two important ways. First, a nonlinear 3-stage least squares generalized method of movements (N-3SLS-GMM) analysis was adopted to unravel the association between infrastructure and economic growth. At the same time, the study accounts

for reverse causality and simultaneity. Most studies on West Africa that look at infrastructure and economic growth tend to investigate only part of the relationship and neglect the possibility of a feedback between these stages. If these effects are disregarded, it leads to issues in policymaking. Economic growth in West Africa and infrastructure development are interrelated.

These identified research gaps were aptly bridged in this study. This enhances the policy relevance of the study's findings. The results showed that the infrastructure's impact on growth differs in terms of magnitude and significance. Hence, the impact is a factor of the infrastructure component. Second, the study not only estimated the effect of the aggregated infrastructure index but also analyzed the effects of disaggregated infrastructure components. The study jointly estimated the demand for and supply of infrastructure in West Africa by endogenizing the infrastructure variable. This simultaneous approach presents a holistic perspective of the effects of infrastructure on growth, which is grossly absent in previous studies. This approach is novel among studies that have investigated the infrastructure-economic growth nexus in West Africa. The importance of utilizing panel data for empirical analysis is highlighted in previous studies (Efayena & Olele, 2024a; Ekeocha et al., 2022).

Although there are numerous studies on the infrastructure-economic nexus in Africa (see Kouladoum, 2023; Ekeocha et al., 2022; Kodongo & Ojah, 2016; Calderón & Servén, 2010), a pooled African study may not identify the specific social and economic characteristics of West Africa that may significantly influence the infrastructure-economic growth nexus. This study will potentially result in more region-specific policies that are more relevant, effective, and efficient. Following the introduction, sections 2 and 3 cover the literature review and methods employed in the study, respectively. Sections 4 and 5 present the results and discussion of the findings of the study, respectively. Section 5 concludes the study with policy implications and recommendations.

2. Literature review

There is a plethora of studies that investigated the infrastructure-economic growth nexus in both industrialized and developing nations, employing various econometric methods and frameworks. This research classified the literature review into panel studies and country studies.

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2.1. Panel studies

Numerous panel studies have investigated the association between infrastructure and economic growth, producing diverse outcomes. Edeme et al. (2020) investigated the influence of infrastructure on economic growth, measured by employment and manufacturing value added, in emerging economies in Africa from 1980 to 2018, employing the pooled mean group (PMG) technique. The research indicates that infrastructure positively influences manufacturing value added (MVA) and can create employment opportunities in African nations.

Nnyanzi et al. (2022) x-rayed the impact of infrastructure on MVA among 30 sub-Saharan African (SSA) economies between 2003 and 2018, and found that infrastructure spurs MVA positively. The study specifically focused on electricity and transport infrastructure, and it used the panel-corrected standard error estimation technique.

Azolibe and Okonkwo (2020) focused their study on selected SSA economies between 2003 and 2018, using the panel least squares technique. The study focused on telecommunications infrastructure, examining both the quantity and quality levels. The research indicated that inadequate infrastructure led to diminished industrial output in Sub-Saharan Africa. There was a similar outcome for transport and electricity infrastructure. Anyanwu (2018) applied the IV-SLS approach to study the link between infrastructure and African countries' economic growth from 1990 to 2011. The study revealed that infrastructure affects the economy in a variety of ways. Manufacturing output depends on education and other parts of social infrastructure. Education's effect on manufacturing output follows an inverted U shape, and secondary education decreases output, but tertiary education increases output. According to Anyanwu (2018), the infrastructure for ICT does not have a large effect on the economy, and corroborates the findings of Ahmed (2016).

Timilsina et al. (2023) studied telecommunication, electricity, and transport using the PMG method to check how these factors affected 87 countries between 1992 and 2017. The study found that positive results lasted for long periods. Infrastructure components are necessary for long-term growth, but not much for short-term growth. Ekeocha et al. (2022) analyzed how the development in Africa changed based on the progress in water and sanitation, transportation, electricity, and ICT. It emerged from the study that infrastructure plays a role in spurring the economy. In addition, Abdullahi and Sieng (2023) found that electricity, water, and sanitation sectors contributed to the increase in 10 African countries' economies, whereas ICT sectors were a hindrance to economic growth. Etensa et al. (2022) used the panel

autoregressive distributed lag (PARDL) method to investigate East African economies. The study found a positive nexus between infrastructure and economic growth. Palei (2015) reached a similar conclusion.

Wang et al. (2020) undertook a comparative analysis between Asia, Africa, and Europe using data between 2007 and 2016 to analyze the infrastructure-economic growth relationship. The study found that infrastructure impacted growth positively at the national level. At the regional level, however, infrastructure had a negative impact on growth in East, Central, and South Asia but was positive in Central and Eastern Europe. Pradhan et al. (2018) x-rayed the long-term nexus between ICT infrastructure and growth in G-20 nations from 2001 to 2012, using the VECM method. A positive nexus was observed between the variables.

Irshad et al. (2023) utilized the dynamic ordinary least squares (DOLS) and the fully modified ordinary least squares (FMOLS) techniques among 18 lower and middle-income economies between 1995 and 2017. The study found that investments in electricity consumption, telecommunications, and transportation contributed to growth in these countries. Chin et al. (2021) arrived at a comparable conclusion through an analysis of the impact of infrastructure on growth across 59 countries.

Slesman et al. (2015) investigated the nexus between various institutional infrastructure components and economic growth among a panel of 39 Organization of Islamic Cooperation (OIC) member nations. The empirical findings support the axiom that improved institutions can boost economic growth. The nonlinear model showed that the most important parts of an institutional matrix are the quality of political institutions that ensure stable government, low expropriation, and low external conflict. This is because these factors have a significant impact on the growth benefits of economic institutions. The study also reveals that, when considering political and economic institutions, those that mitigate internal conflict and tensions arising from ethnic and religious disputes do not significantly (positively) impact growth. Badalyan et al. (2014) carried out a panel study using data from Georgia, Armenia, and Turkey between 1982 and 2010, utilizing the VECM technique. The study identified a beneficial effect of infrastructure on economic growth. Furthermore, bi-directional causality exists between the variables in both the short and long terms.

Khan et al. (2020) investigated the role in South Asia's economic performance. The study used a composite infrastructure index with over thirty components and the PMG estimation technique. The study demonstrated that infrastructure has a positive impact on economic growth. Sahoo and Dash (2011) examined infrastructure output

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elasticity in four South Asian economies—Sri Lanka, India, Bangladesh, and Pakistan—using data from 1980 to 2005. The study identified a long-term equilibrium relationship and a beneficial effect of infrastructure on economic growth. Farhadi (2015) employed the GMM technique to assess the impact of infrastructure on growth across 18 OECD economies from 1870 to 2009. The study demonstrated a beneficial impact.

Several panel studies exist on the nexus between infrastructure and economic growth in Europe. For example, Batrancea et al. (2023) analyzed the infrastructure-economic growth relationship in 212 Western, Central, and Eastern European regions between 2001 and 2020, utilizing first-difference GMM. The study found a positive nexus between the variables. Maciulyte-Sniukiene and Butkus (2022) investigated the impact of different categories of infrastructure (ICT, transport, water and sanitation, and energy) on growth outcomes among 28 European countries between 2000 and 2019. Specifically, the study found positive but insignificant correlations between the infrastructure categories and economic growth. The study found that only ICT, energy, and transport infrastructure significantly impact growth. The study by Ng et al. (2019) was based on the neoclassical paradigm, and it examined 60 economies between 1980 and 2010 using the fixed effects model. The study found a positive nexus between the variables.

Vlahinić Lenz et al. (2018) x-rayed the influence of transport infrastructure, represented by rail and road systems, on growth in Central and Eastern European Member States from 1995 to 2016, employing fixed, random, and pooled OLS methodologies. The study found that while road infrastructure positively impacted economic growth, rail infrastructure negatively impacted it. In addition, Toader et al. (2018) x-rayed the impact of ICT infrastructure on growth (proxied GDP per capita) in the EU between 2000 and 2017. As in Vlahinić Lenz et al. (2018), the study found a positive impact, especially considering the level and type of technologies utilized in the EU.

2.2. Country-specific studies

There are several studies on countries designed to examine the impact of infrastructure on growth. These studies resulted in differing outcomes. For instance, there are several studies undertaken in Nigeria. Olayiwola (2022) analyzed the nexus between economic growth and infrastructure from 1986 to 2020, employing the ARDL technique. The study identified a nexus only in the short term. Balogun (2021) x-rayed the association between infrastructure and economic growth in Nigeria, leveraging data from 1990 to 2020. The study employed the ARDL

methodology alongside infrastructure elements, including communication technology, electricity, and road transport. The study identified a positive association between electricity and growth, whereas it revealed a negative association concerning telecommunications and road transport. Oyeniran and Onikosi-Alliyu (2016) identified a long-term nexus between infrastructure and growth. The study employed the ARDL technique on data spanning from 1980 to 2012, incorporating the telecommunication infrastructure index. Nedozi et al. (2014) conducted a simultaneous analysis demonstrating a positive impact of infrastructure on economic growth. Aworinde and Akintoye (2019) identified a long-term relationship using the bound test technique. The study also found that infrastructure harms economic growth. Babatunde (2018), using data from Nigeria between 1980 and 2016, reached a similar conclusion.

There are several studies carried out in China. Several studies have been conducted on the relationship between infrastructure and economic growth. Zhou (2022) found a positive correlation between digital infrastructure and economic growth. Du et al. (2022) analysed provincial panel data on the infrastructure-economic growth nexus and concluded that infrastructure investment enhances economic growth. Magazzino and Mele (2021) investigated the relationship between transport and growth across 28 provinces from 1990 to 2017, and Shin et al. (2017) used the VEC technique to x-ray the nexus between the variables between 1990 and 2013. The study utilized electricity, telecommunication, railway, and roadway infrastructure, and found an inverse U-shaped nexus between growth and infrastructure.

Owusu-Manu et al. (2019) investigated the infrastructure-economic growth nexus in Ghana using the ARDL technique between 1980 and 2016. Among other findings, the study established that electricity positively impacted growth. Abokyi et al. (2018) previously found the same conclusion, covering Ghanaian data from 1971 to 2014. Using the ARDL technique, Nenavath (2023) investigated the impact of transport infrastructure on growth in India between 1990 and 2020. The study found a positive impact on growth, as well as a unidirectional causality running from infrastructure to growth. Pradhan and Bagchi (2013) investigated the impact of transport on economic growth in India from 1970 to 2010, employing the VECM methodology. The research identified a bidirectional causality between road infrastructure and economic growth, alongside a unidirectional causality between rail infrastructure and economic growth.

Mohmand et al. (2017) identified an absence of causality between infrastructure and economic growth at the national level; however, they observed a long-term

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unidirectional causality from economic growth to infrastructure. At the provincial level, there were different causalities, ranging from no causality, bidirectional causality, and unidirectional causality. In addition, Haider et al. (2012) found that infrastructure (proxied by the electricity index) stimulated growth in Pakistan, utilizing data ranging from 1972 to 2009. Using the VECM technique, Zhang and Cheng (2023) x-rayed the infrastructure-economic growth nexus in the UK between 1970 and 2017. The study found a positive long-term and negative short-term nexus. Other studies (Sarangi & Pradhan, 2020; Ramadhan, 2019; Nguyen et al., 2021; Meersman & Nazemzadeh, 2017) reached a similar conclusion.

Table 1 provides an overview of the reviewed empirical literature, including the focus of the studies, the methods employed, key findings, and identified gaps.

Table 1. Literature synthesis matrix

Author(s) & Year	Focus & Methodology	Key Findings	Identified Gaps
Edeme et al. (2020)	Infrastructure-growth link in Africa, 1980 and 2018; panel estimation	Infrastructure positively affects growth	No simultaneous estimation; regional heterogeneity not addressed
Nnyanzi et al. (2022)	30 sub-Saharan African (SSA) economies between 2003 and 2018; panel analysis	Positive nexus	Only focuses on electricity and transport infrastructure, limiting its policy scope
Azolibe and Okonkwo (2020)	SSA economies between 2003 and 2018; panel least squares technique	Poor infrastructure resulted in low industrial output in SSA	Focuses only on telecommunications, transport, and electricity infrastructure, limiting its policy scope
Anyanwu (2018)	African economies from 1990 to 201; IV-SLS method	Primary, secondary, and tertiary education have an inverted U-shaped, negative, and positive impact on	Regional heterogeneity is not addressed

		manufacturing output, respectively. The ICT infrastructure has no significant impact on economic growth	
Timilsina et al. (2023)	87 countries between 1992 and 2017; the PMG estimation technique	positive long-term impact	Focuses only on the telecommunication, electricity, and transport; regional heterogeneity is not addressed
Ekeocha et al. (2022)	Infrastructure-growth nexus in Africa	Positive nexus	Insufficient aggregation of infrastructural types
Abdullahi and Sieng (2023)	10 African economies between 2010 and 2020; panel analysis	Electricity, water and sanitation infrastructure positively impacted economic growth, while ICT infrastructure negatively impacted economic growth.	Missing simultaneous analysis
Etensa et al. (2022)	East Africa; panel autoregressive distributed lag	Positive nexus	Regional heterogeneity is not addressed
Wang et al. (2020)	Asia, Africa, and Europe, using data between 2007 and 2016; panel analysis	Infrastructure had a negative impact on growth in East, Central, and South Asia, but was positive in Central and Eastern Europe.	Integration with the external sector was not addressed
Pradhan et al. (2018)	G-20 economies between 2001 and 2012; vector error correction (VECM) technique.	Positive relationship between the variables.	Short-run effects are not captured.

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Irshad et al. (2023)	18 lower and middle-income economies between 1995 and 2017; dynamic ordinary least squares (DOLS) and the fully modified ordinary least squares (FMOLS) techniques among	Investment in electricity power consumption, telecommunication, and transportation stimulated economic growth among these countries.	No simultaneous modeling
Slesman et al. (2015)	39 Organization of Islamic Cooperation (OIC) member nations; panel analysis	Improved institutional infrastructure can boost economic growth	Limited application scope
Badalyan et al. (2014)	Georgia, Armenia, and Turkey between 1982 and 2010; VECM estimation technique	Positive influence of infrastructure on economic growth; bi-directional causality between the variables	No consensus on causality
Khan et al. (2020)	Sri Lanka, India, Bangladesh, and Pakistan; the PMG estimation technique	Infrastructure positively influenced economic growth	No simultaneous modeling; Short-run effects not captured
Batrancea et al. (2023)	212 Western, Central, and Eastern Europe regions between 2001 and 2020; first-difference GMM.	Positive nexus	No disaggregation by sector
Maciulyte-Sniukiene and Butkus (2022)	28 European countries between 2000 and 2019; panel analysis.	Positive but insignificant correlations between the infrastructure categories and economic growth. Only ICT, energy, and transport infrastructure significantly impact growth	No dynamic models were considered
Ng et al. (2019)	60 economies between 1980 and 2010; fixed effects model.	Positive nexus	No dynamic models were considered

Vlahinić Lenz et al. (2018)	Central and Eastern European Member States between 1995 and 2016; fixed, random, and pooled OLS techniques	Road and rail infrastructure positively and negatively impact economic growth, respectively	No link to demand-side drivers
Olayiwola (2022)	Nigeria between 1986 and 2020; ARDL technique.	Short-run nexus identified	Missing simultaneous analysis
Balogun (2021)	Nigeria between 1990 and 2020; ARDL technique	Positive nexus between electricity and growth; negative relationship in the case of telecommunication and road transportation.	Missing simultaneous analysis
Oyeniran and Onikosi-Alliyu (2016)	Nigeria between 1980 and 2012; ARDL technique	Long-run nexus identified	Missing simultaneous analysis
Aworinde and Akintoye (2019)	Nigeria, bound test technique	Long-run relationship	Missing simultaneous analysis
Shin et al. (2017)	Nigeria between 1990 and 2013; vector error correction technique	Inverse U-shaped nexus between growth and infrastructure.	Regional heterogeneity is not addressed
Owusu-Manu et al. (2019)	Ghana technique between 1980 and 2016; ARDL	Electricity positively impacted growth	
Nenavath (2023)	India between 1990 and 2020; ARDL technique	Positive impact on growth, as well as a unidirectional causality running from infrastructure to growth.	No consensus on causality

Pradhan and Bagchi (2013)	India between 1970 and 2010; VECM technique	Bidirectional causality between road infrastructure and growth, and a unidirectional causality between rail infrastructure and growth	No consensus on causality
Zhang and Cheng (2023)	UK between 1970 and 2017; VECM technique.	Infrastructure stimulated growth in the long term; infrastructure adversely impacted growth in the short term	Regional heterogeneity is not addressed

Source: Authors' computation.

A review of related literature shows that there is a dearth of studies x-raying the infrastructure-economic growth relationship in West Africa. Many prior studies have not sufficiently addressed the simultaneous relationship among the variables. A panel study encompassing countries with homogenous characteristics presents significant policy implications (Efayena & Olele, 2024b), and it is thus suitable for analyzing the relationship between infrastructure and economic growth in West Africa.

Given the above review, we, therefore, proposed the following hypotheses:

H1: Demand for infrastructure significantly impacts economic growth in West Africa.

H2: Supply for infrastructure significantly impacts economic growth in West Africa.

H3: Infrastructure significantly impacts economic growth in West Africa.

3. Research methodology

3.1. Model specification

In accounting for the causal effects of infrastructure on economic growth, the study employs a structural equation model that adequately estimates not only an aggregate infrastructure model but also the demand and supply of infrastructure. This framework will help avoid the endogeneity and simultaneity issues present in most previous studies (Chuku et al., 2021; Roller & Waverman, 2001). In addition, such a model helps capture structural characteristics important to the components of a

unit, such as infrastructure. The study adopts a modified model of Chuku et al. (2021) in specifying the following structural system with three equations:

Aggregate Production Equation:

$$GDPPCG_{it} = \alpha_{0i} + \alpha_1 log(PK_{it}) + \alpha_2 log(HK_{it}) + \alpha_3 PINFRAS_{it} + \alpha_4 X_{it} + \alpha_5 t + \epsilon^{1}_{it} \quad (1)$$

Infrastructure Demand Equation:

$$INFRAS_{it} = \beta_0 + \beta_1 (GDPPCG_{it}) + \beta_2 log(PINFRAS_{it}) + \beta_3 log(Y_{it}) + \epsilon^{2}_{it} \quad (2)$$

Infrastructure Supply Equation:

$$log(WINFRAS_{it}) = \delta_0 + \delta_1 log(PINFRAS_{it}) + \delta_2 Z_{it} + \epsilon^{3}_{it} \quad (3)$$

Where *GDPPCG* denotes GDP per capita growth, *PK* denotes physical capital stock, *HK* denotes human capital stock, and *INFRAS* represents the composite measure of infrastructure. This variable is derived from four infrastructure components, namely, transport, electricity, ICT, and water and sanitation. The variable *X* denotes growth determinants, while *t* represents the exogenously determined time trend. The price an average infrastructure user is willing to pay for infrastructure is denoted as *PINFRAS*; *Y* refers to a vector of infrastructure demand determinants; *WINFRAS* refers to infrastructure investment; and *Z* is the vector of infrastructure supply determinants. Eq. 1 refers to the aggregate production equation that incorporates infrastructure and other explanatory variables affecting economic growth. Eq. 2 and Eq. 3 are the infrastructure demand and supply equations and their determinants, respectively.

The variable *INFRA* captures the direct impact of infrastructure on economic growth. In Eq. 1, the relationship is a one-way relationship. It should be noted that the income elasticity of infrastructure captures the two-way nexus, showing the effect of economic growth on infrastructure. To achieve this feat, the infrastructure variable is endogenized in Eq. 2 and Eq. 3.

3.2. Scope and data

To estimate the structural model, we source data for each of the variables. The study employs data from 2005 to 2022. In the aggregate production model, primary enrollment rates capture human capital (*HK*). Physical capital (*PK*) is captured by gross capital formation, and trade openness (*TRAD*) is derived from the total trade-

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to-GDP ratio. We also included financial development (*FIN*), proxied as credit to the private sector as a percent of GDP.

In the infrastructure demand model, it is imperative to state that there is no established measure for users' infrastructure pricing (*PINFRAS*). The study, therefore, employs government tax revenue as a variable, based on the axiom that citizens pay taxes for the use of infrastructural amenities (Chuku et al., 2021; Edeme et al., 2020). The vector of infrastructure demand determinants includes the structural characteristics of the economy. We therefore assume that the structural characteristics of the economy are a major factor that determines the demand for infrastructural amenities. For instance, a typical agrarian or crude economy will demand less infrastructure when compared to an industrialized economy. We, therefore, used the industry value-added/GDP ratio as a proxy for this variable. The variable was adopted in previous studies such as Ekeocha et al. (2020), Edeme et al. (2020). We also include the level of government revenue, captured as the government revenue-GDP ratio. This variable is imperative given that government revenue influences infrastructure level, which will affect the demand level (Chuku et al., 2021).

In the infrastructure supply model, public gross capital investment captures *WINFRAS* (infrastructure investments), while the fiscal balance share of GDP is the most accessible determinant of infrastructure supply for West African countries. We also included other factors that can potentially influence infrastructure supply, including the government revenue-GDP ratio. We assume that infrastructure supply across West Africa is affected by geographical, political, and economic factors. Geographically related factors (*GEO*) are controlled by utilizing a dummy (assumes the value of 1 for a resource-rich country, and zero otherwise). Following Efayena and Olele (2024b), we controlled for political factor by employing the principal component analysis to generate an institutional quality variable (*INST*) from institutional variables (*governance effectiveness*, *regulatory quality*, *rule of law*, *voice & accountability*, *political stability & absence of violence/terrorism*, and *control of corruption*). It should be noted that our choice of variables is constrained by the availability of appropriate proxies.

The study used data from 16 West African countries. These countries include Cabo Verde, Gambia, Cote d'Ivoire, Senegal, Burkina Faso, Ghana, Nigeria, Guinea, Benin, Liberia, Togo, Guinea-Bissau, Mauritania, Sierra Leone, Mali, and Niger. The Africa Infrastructure Development Index (AIDI) captures the composite infrastructure. We present the various infrastructure components as indices, designed

to assess and track the progress and status of infrastructure development in Africa. We extract this data from the African Development Bank database. We source the data for the other variables from the World Bank (WDI) database.

4. Empirical results

4.1. Descriptive statistics

Table 2 presents the descriptive statistics for these variables. A consideration of these statistics shows that the level of infrastructure indicators varies across West African countries. For example, the electricity infrastructure index's mean is 5.15 across West Africa, with a standard deviation of 12.99 (over twice the mean) and a maximum value of 86.21.

Table 2. Descriptive statistics

Variable	Mean	Std. dev.	Min.	Max.	Obs.
African Infrastructure Development Index	15.24	12.81	0.19	87.33	304
Electricity Infrastructure Index	5.15	12.99	0.00	86.21	304
Fiscal Balance-GDP ratio	0.28	6.18	-19.35	105.09	294
GDP per capita growth	1.75	5.09	-41.98	35.61	304
Government Revenue-GDP ratio	19.08	9.75	2.82	53.07	304
ICT Infrastructure Index	3.93	5.06	0.00	68.43	304
Transport Infrastructure Index	6.38	7.40	0.17	61.06	292
Trade openness	37.84	11.07	6.42	13.02	292
Capital stock	20.58	14.80	-2.92	110.43	304
Financial development	23.05	10.72	4.36	72.81	262
Water and Sanitation Infrastructure Index	31.86	15.19	0.00	89.15	304

Source: Author's computation.

Other infrastructure indicators follow a similar pattern. A country-by-country analysis confirms this trend, with the AIDI value for 2022 ranging from 6.79 for Niger to 49.80 for Cabo Verde (AIDI, 2022).

4.2. Analytical statistics

We attempted to take a look at the infrastructure-growth nexus among the sampled countries. Figure 1 graphically illustrates the nexus between trade and the Africa infrastructure index. Generally, there is a positive nexus. Countries are generally

clustered around the line prediction, with most of the countries showing homogenous characteristics as seen in the clustering pattern except Niger and Cabo Verde.

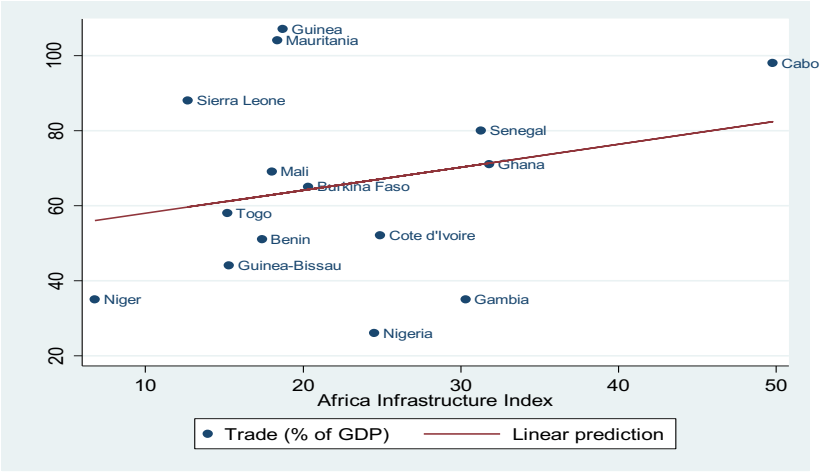

Figure 1. The trade-infrastructure relationship
Source: Authors' computation from AfDB Indicators Database.

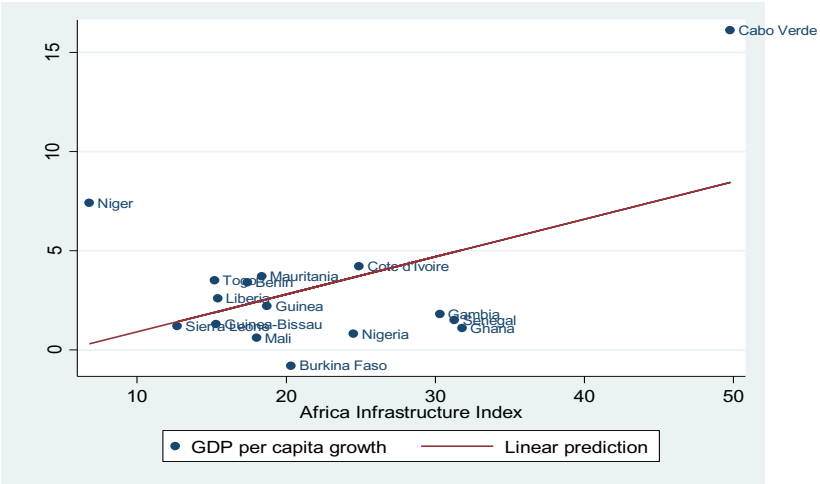

Figure 2. GDP per capita growth and infrastructure relationship
Source: Authors' computation from AfDB Indicators Database.

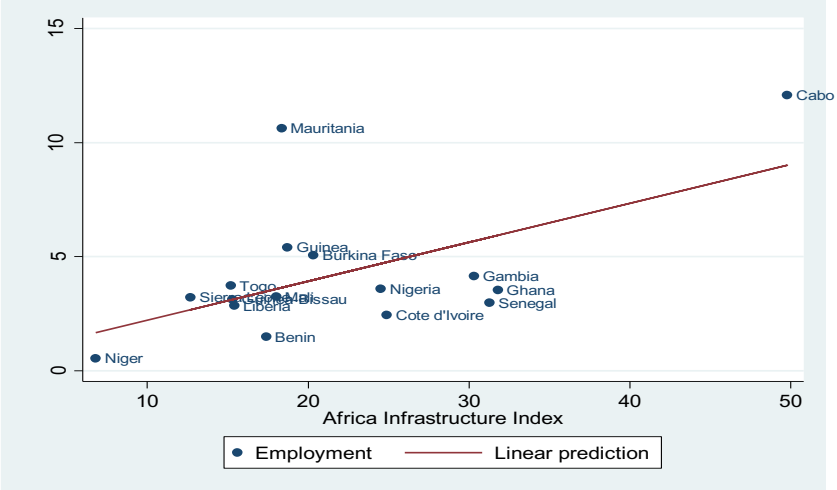

Figure 3. Employment and infrastructure relationship
Source: Authors' computation from AfDB Indicators Database.

We also observed that the countries showed a positive GDP per capita growth-infrastructure and employment-infrastructure nexus (see Figure 2 and Figure 3). Specifically, Figure 2 shows that infrastructure stimulates growth through an increase in GDP per capita. We observed a positive nexus among the economies. Whereas Figure 3 depicts a positive infrastructure-economic growth nexus. Therefore, it is imperative to state that, irrespective of the magnitude of the impact, infrastructure can potentially impact growth positively in West Africa through employment, trade, and innovation. In spite of these trends, it is imperative to provide a more formal appraisal of the infrastructure-economic nexus in West Africa.

4.3. Unit root test

To avoid spurious, biased, and inconsistent results, we employed the Pesaran (2007) cross-sectionally augmented Im-Pesaran-Shin (CIPS) unit root test, and the results are given in Table 3.

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Table 3. Descriptive statistics

Variable	@ level	@ first difference	Remark
African Infrastructure Development Index	-1.8288	-4.5074***	I(1)
Electricity Infrastructure Index	-1.1342	-2.4971**	I(1)
Fiscal Balance-GDP ratio	-0.4511	-2.0794*	I(1)
GDP per capita growth	-1.6003	-3.4193***	I(1)
Government Revenue-GDP ratio	-1.1902	-2.6087**	I(1)
ICT Infrastructure Index	-1.0436	-2.5073**	I(1)
Transport Infrastructure Index	-0.8304	-2.3363*	I(1)
Trade openness	-1.4142	-3.0041***	I(1)
Capital stock	-1.7703	-4.1705***	I(1)
Financial development	-0.9901	-2.3915*	I(1)
Water and Sanitation Infrastructure Index	-1.0627	-2.5133**	I(1)

Source: Author's computation.
Note: 1 percent (***), 5 percent (**), and 10 percent (*) significance levels.

The results conclusively rejected the null hypothesis at the 5% significance level, but the results became stationary at first differences.

4.4. Cointegration tests

We employed the Westerlund (2007) cointegration tests to capture the existence or otherwise of a long-run relationship among the variables (Efayena et al., 2024a). The results entail two group means (G_t and G_a) tests and the panel (P_t and P_a) tests, and Table 4 contains the outcomes.

Table 4. PCT Results

Test	Statistics	p-value
G_t	-3.8110***	0.000
G_a	-7.7472***	0.000
P_t	-19.5915***	0.000
G_t	-5.9033***	0.000

Source: Authors' Computation.
Note: 1 percent (***), 5 percent (**), and 10 percent (*) significance levels.

The results are statistically significant, thus rejecting the null hypothesis of no cointegrating relationship. There is an indication of an apparent long-run nexus among the variables.

4.5. Econometric analysis

Despite the relationships discussed in earlier sections, correlation does not imply causation. A formal analysis is required to determine the simultaneous nexus between infrastructure and economic growth. The results of the N-3SLS-GMM estimation are presented in Table 5. The findings indicate that aggregate infrastructure has a substantial and beneficial impact on economic growth.

Table 5. N-3SLS GMM results

Aggregate production equation: Dependent variable = GDP per capita growth					
Variable	Aggregate	Electricity	ICT	Transport	Water
Aggregate infrastructure	0.153*** (0.000)				
Electricity infrastructure		0.013 (0.501)			
ICT infrastructure			0.061 (0.118)		
Transport infrastructure				0.215*** (0.001)	
Water and sanitation infrastructure					0.007** (0.002)
Primary enrolment	-0.042 (0.101)	-0.036*** (0.000)	-0.013** (0.002)	-0.016*** (0.000)	-0.061* (0.006)
Trade openness	0.019 (0.130)	0.051** (0.002)	0.049** (0.043)	0.012 (0.422)	0.015 (0.138)
Capital stock	1.311*** (0.000)	1.835*** (0.001)	1.179*** (0.000)	1.471*** (0.002)	1.213*** (0.000)
Financial development	-0.082*** (0.000)	-0.072*** (0.000)	-0.036*** (0.000)	-0.052*** (0.001)	-0.050** (0.020)
Time trend	-0.183*** (0.000)	-0.153** (0.003)	-0.511*** (0.000)	0.093 (0.154)	-0.115 (0.200)
_con	-11.265*** (0.000)	-8.188*** (0.000)	-10.864*** (0.000)	-13.724*** (0.000)	-12.491*** (0.000)

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Infrastructure demand equation: Dependent variable = *INFRAS*					
GDP per capita growth	2.034*** (0.001)	2.086 (0.126)	0.167 (0.208)	2.631** (0.040)	2.318*** (0.000)
Government revenue-GDP	0.312*** (0.000)	0.307*** (0.000)	0.043*** (0.000)	0.029*** (0.000)	0.107*** (0.001)
Industry value-added/GDP	-1.091*** (0.000)	-0.622*** (0.000)	-0.060** (0.040)	-1.812** (0.031)	-0.122* (0.051)
_con	16.083*** (0.000)	16.888*** (0.000)	21.058*** (0.000)	21.615*** (0.000)	11.215*** (0.000)
Infrastructure supply equation: Dependent variable = *WINFRAS*					
Government revenue-GDP	0.011*** (0.000)	0.012*** (0.000)	0.011*** (0.000)	0.013*** (0.001)	0.010*** (0.001)
Fiscal balance-GDP	-0.021*** (0.000)	-0.021*** (0.000)	-0.019*** (0.000)	-0.020*** (0.000)	-0.020*** (0.000)
Financial development	-0.045*** (0.000)	-0.069 (0.233)	-0.105 (0.117)	-0.008*** (0.000)	-0.081 (0.191)
Resource-rich economy dummy	0.060 (0.301)	0.097 (0.162)	0.148 (0.175)	0.083 (0.102)	0.114 (0.133)
Institutional quality	-0.055*** (0.000)	-0.091*** (0.000)	-0.110*** (0.001)	-0.090*** (0.000)	-0.072*** (0.000)
_con	2.612*** (0.000)	2.801*** (0.000)	2.557*** (0.000)	2.634*** (0.000)	-2.691*** (0.000)
observations	16	16	16	16	16

Source: Author's computation.
Note: 1 percent (***), 5 percent (**), and 10 percent (*) significance levels.

Specifically, the estimate shows that, *ceteris paribus*, a 1-percent rise in aggregate infrastructure has the potential to stimulate economic growth by 0.15 percentage points. The estimations for infrastructure components reveal a positive effect of infrastructure on economic growth, though the magnitude and statistical significance of these effects vary. Electricity and ICT infrastructure indicators demonstrate positive values; however, they are statistically insignificant. These variables have minimal impact on economic growth in West Africa. This hypothesis is highly plausible, as the technology diffusion level in the region is relatively low. Furthermore, most economies in the region experience intermittent power supply, and they heavily rely on electricity from hydraulic or petrol-driven machines, which

can be highly unreliable for economic activities. At any rate, a positive impact of electricity infrastructure on economic growth conforms to previous studies such as Timilsina et al. (2023) and Ojo (2022) but contrasts with the findings of Chakamera and Alagidede (2018).

On the other hand, we observed that transport and water/sanitation infrastructure components have a positive and significant impact on economic growth. Specifically, a 1-per-cent increase in transport and water/sanitation infrastructure increases economic growth by 0.22 and 0.13 percentage points, respectively. Such a positive effect of transport infrastructure on growth corroborates the study of Timilsina et al. (2023) but contrasts with that of Asher and Novosad (2020). It is important to recognise that water and sanitation infrastructure exerts minimal influence on economic growth. It is observed that some infrastructure components have a stronger effect than others. Water and sanitation infrastructure has the least effect. This is possibly caused by epileptic water and environmental sanitation infrastructure in the region. Transport infrastructure's relatively high effect could be attributed to improved road network penetration in West Africa.

Moreover, the estimation of the aggregate infrastructure equation indicates that trade openness does not have a significant impact on economic growth. This applies equally to the transport and water/sanitation infrastructure components. Trade openness significantly influences economic growth in estimations of electricity and ICT infrastructure components. It is essential to note that substantial efforts are still required to enhance educational outcomes in West Africa. The findings suggest that primary enrolment negatively affects economic growth in West Africa, with variations in both magnitude and statistical significance.

Capital stock positively spurs economic growth across the infrastructure categories. Financial development has a significant yet negative impact on West Africa's economic growth. This imbalance is possibly caused by a wide financing gap in private sector credit in the region. Inadequacies in such financing options can potentially limit the economic growth process.

To avoid potential reverse causality and simultaneity issues, it is appropriate to estimate the infrastructure demand and supply equations. The infrastructure demand model results demonstrate that government revenue has a positive and significant impact on infrastructure demand in West Africa. The impact is evident in both the aggregate production and infrastructure component estimations. In addition, the income level (GDP per capita growth) in West Africa significantly improves the region's infrastructure. This improvement is evident in the estimates for both the

aggregate infrastructure and the transport and water/sanitation infrastructure components. The infrastructure components have an average income elasticity of demand of 2, suggesting that infrastructure demand in West Africa is income elastic. We also found that the industry value-added to GDP ratio hurts demand for infrastructure in West Africa. This necessitates improvements to the region's industrial structure. There is an urgent need to strategically move all countries from a typical and traditional agrarian structure to a more industrialized economy.

The infrastructure supply estimation shows that government revenue positively impacts infrastructure supply in West Africa. We find the impact to be statistically significant. In each estimation, however, fiscal balance has a negative impact on infrastructure supply. This hypothesis is plausible, as most West African countries have been experiencing fiscal deficits over the years. This has led to a decrease in the level of investment and infrastructure in these countries. As a result, financial development has had a negative impact on infrastructure supply in West Africa, as evidenced by the coefficients of the credit-to-private-sector GDP ratio variable across infrastructure categories. There is an urgent need to address challenges facing private sector financing in West Africa. We also found a decelerating effect of institutional quality on infrastructure supply in West Africa. This decline is possibly caused by the low institutional quality in the region. For instance, the region hosts some of the world's most corrupt nations, recording poor scores in global governance indices over the years. In addition, the geographical characteristic variable (resource-rich economy dummy) does not significantly explain infrastructure supply in West Africa, possibly caused by the underutilization of natural resources in most West African economies. Even in West African countries with rich natural resources, the need to channel these resources into developing and providing infrastructure has been a constant debate.

The findings above underscore the critical role infrastructure plays in promoting economic development. The findings highlight the necessity for heightened public and private investment in infrastructure development. West African governments need to prioritize budgetary allocations for essential infrastructure projects, including transport networks, energy supplies, water systems, and digital connections. The findings also have implications for regional collaboration. The transnational advantages of infrastructure necessitate the augmentation of regional collaboration to synchronize collaborative infrastructure development projects to promote trade and stimulate economic activity among member states. Coordinated regulatory frameworks and uniform project execution procedures would be essential

for attaining this objective. That implies that efficient governance frameworks are essential for infrastructure advancement. Enhancing institutional capacity for planning, execution, and oversight of infrastructure projects will mitigate delays, cost overruns, and inefficiencies. This will involve policymakers optimizing regulatory frameworks, eliminating bureaucratic obstacles, and offering incentives for private sector participation.

5. Conclusions

Economic realities have shown that investments in infrastructure in West Africa have not matched the growth in the demand for infrastructure, thereby creating a huge deficit or shortage in infrastructure supply. This study, therefore, critically investigated the infrastructure-economic growth nexus in West Africa, taking into account the issues of endogeneity, simultaneity, and reverse causality. The study employs data from 2005 to 2022 and utilizes the N-3SLS-GMM technique, which helps endogenize the infrastructure variable. This simultaneous approach resulted in more robust economic outcomes with comprehensive economic policy implications. The study found a positive nexus between infrastructure and economic growth. The study also found that the industrial level and fiscal balance position could not adequately stimulate demand for and supply of infrastructure, respectively, in West Africa.

There are several policy implications emanating from the study's findings. The study indicates that infrastructural investments have not sufficiently stimulated economic growth potential in West Africa. Governments in the region must intervene to ensure proper implementation and monitoring of infrastructural investments. In addition, the study indicates that demand for infrastructure largely exceeds its supply in West Africa, resulting in debilitating effects on economic growth. To further garner the benefits of infrastructure, the findings show the need for regional cooperation in West Africa to achieve its growth potential through infrastructure development. Countries in the region can synergistically boost their economic performance through regional cooperation and integration. Leveraging public-private partnership (PPP) initiatives in the region can help initiate new infrastructural projects and maintain existing ones. This implies that infrastructural deficits should be financed from internally generated funds, rather than externally sourced funding. Such initiatives can be enhanced through regional synergies between and among the West African States.

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This study offers policymakers valuable insights on how to effectively manage infrastructure demand and supply. This report highlights the need to strengthen public infrastructure planning, procurement, and oversight organizations. Enhancing regulatory frameworks, transparency, and bureaucratic efficiency are crucial. Public procurement reforms should also provide value for money, eradicate corruption, and recruit trustworthy private sector partners. Development partners and regional institutions should support capacity-building activities that teach public officials project finance, contract negotiation, and demand forecasting. Even well-funded infrastructure plans may not generate widespread economic advantages without institutional change and professionalization.

West African resource-rich and resource-poor nations require different tactics. West Africa has diverse resources, requiring distinct policies. Nations rich in resources, such as Nigeria, Ghana, and Côte d'Ivoire, should utilize sovereign wealth funds or infrastructure stabilization funds to allocate a specific percentage of their extractive earnings towards infrastructure investment, thereby improving fiscal administration. Transparent and rules-based fund management may protect infrastructure investments from commodity price volatility.

Resource-poor nations like Liberia, Sierra Leone, and Burkina Faso need creative finance. Regional PPPs, concessional development institution funding, and infrastructure bonds are examples. In such nations, infrastructure investment should prioritize agriculture, trade facilitation, and basic social services, where returns are most likely to boost inclusive development.

In spite of the several policy implications of this study, future studies can extend to the effects of infrastructural investment on economic growth on a sectoral basis. Such a disaggregated analysis will improve policy relevance.

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Author Contributions

OOE and JOO conceived the study and were responsible for the data analysis. CE was responsible for data collection and discussion of findings. OOO and PNB handled the literature review.

Disclosure Statement

The authors have no competing financial, professional, or personal interests from other parties.

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