Infrastructure and economic growth in ECOWAS member states: The Westerlund co-integration approach

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Abstract

This research explores the impact of infrastructure on member states' economic growth in the Economic Community of West African States (ECOWAS). Utilizing panel secondary data sourced from the World Bank Development Indicators (WDI) and the African Infrastructure Development Index (AIDI) across all fifteen ECOWAS Member States over eighteen years, the study employs the panel Non-linear Autoregressive Distributed Lag (NARDL) model and the Westerlund co-integration test for analysis. The findings reveal that investments in infrastructure, improvements in the African Development Index, and enhancements in the Electricity Composite Index significantly contribute to the economic growth of ECOWAS countries. Specifically, infrastructure investment is associated with a 0.01 percent increase in the Gross Domestic Product (GDP) of the ECOWAS countries studied. In comparison, the African Development Index and the Electricity Composite Index are linked to increases in GDP by 0.292 percent and 0.987 percent, respectively, in the long term. Based on these outcomes, the study recommends that ECOWAS country authorities enhance policies to optimize government spending on infrastructure quality. Furthermore, adopting quality-enhancing and efficiency-driven financing policies in infrastructure is advocated to complement ECOWAS's ongoing infrastructural development efforts. The realization of these recommendations hinges on the availability of accurate data for informing decisions and guiding policymakers. Hence, the study underscores the need for the ECOWAS Commission to bolster its capacity for collecting reliable data on infrastructure variables and other indicators. It also proposes that future research should focus on promoting sub-regional peer-review mechanisms for infrastructure indicators among member states and establishing structures to fortify infrastructure in West Africa.

Keywords: *Economic growth, Infrastructure development, Westernlund co-integration NARDL*

JEL Classification: H41, H54, O47 J24; O18; P20

INTRODUCTION

The relationship between infrastructure investment and economic growth is well-explored in development economics literature. This body of work encompasses diverse theoretical perspectives that support the connection between the two, albeit with varying propositions. One notable theory is the traditional Harrod-Domar model, which implicitly highlights the role of infrastructure in setting the economy on a trajectory towards sustainable growth. According to this theory, investment in infrastructure can lead to capital accumulation, spurring long-term economic growth.

For an economy to grow, it is necessary to redirect some resources from consumption to infrastructure investments, considered public goods and services. This redirection fosters an increase in the productive sectors and, consequently, the economic development of society (MacDonald, 2008). The economic advancement of emerging economies such as China, Singapore, and the United Arab Emirates (UAE) over the years can be attributed to significant investments in infrastructure.

The discourse on the relationship between infrastructure investment and economic growth continues in development economics. It is posited that increased spending on infrastructure boosts consumer demand and productivity sectors in the long run. Numerous studies (Ekeocha et al., 2021; Munim & Schramm, 2018; Haider et al., 2012) have identified infrastructure as a critical driver of productivity and economic growth. Therefore, building infrastructure at the initial stages of development is essential to meet economic demand.

Following World War II, Japan, and South Korea benefited from substantial loans and subsidies at favorable interest rates, aiding in reconstructing their economic infrastructures. These invaluable experiences have given them a comparative advantage in providing infrastructure development cooperation to developing countries. Infrastructure serves as a reliable indicator for measuring economic growth. To augment output and stimulate economic growth, several governments, including those of Singapore, Denmark, Canada, and the Netherlands, have turned to investments in infrastructure.

Despite its significance, investment in infrastructure on the African continent remains relatively low. A recent study by the World Bank highlights that inadequate infrastructure in Africa has reduced the economic growth of most countries by two percent and the efficiency of business productivity by 40 percent. Consequently, Africa continues to be the continent with the lowest productivity despite its vast human, mineral, and other natural resources.

The West African region has made strides in promoting regional infrastructure by integrating countries within the Economic Community of West African States (ECOWAS). However, substantial infrastructure gaps persist across all sectors, both in terms of accessibility and service delivery. Nonetheless, infrastructure investment is universally acknowledged as a crucial driver of economic growth. Therefore, enhancing infrastructure investment is recognized as a key pillar in developing national development programs, as the quality, quantity, and accessibility of economic infrastructure in developing countries lag behind those of developed economies.

The increase in the average growth rate among ECOWAS member states has been attributed to infrastructure development (Foster & Briceno-Garmendia, 2009). Yet, infrastructure deficiency continues to be a major barrier to socio-economic development in Africa (Calderon & Servén, 2008). The benefits of integration have yet to be fully realized, as nearly average productive firms in ECOWAS member states shut down due to the lack of necessary infrastructure to expand businesses (World Bank, 2020). Thus, infrastructure investments in West Africa are deemed insufficient (Bhattacharya et al. 2015).

Various works on the impact of infrastructure investments on the economic growth nexus include studies by Straub (2007) and Chakamera & Alagidede (2017). Aschauer's (1989) seminal work on the importance of infrastructure in economic growth revealed a significant relationship between the two. Calderon and Servén (2008) highlighted a positive long-term relationship between economic growth and increased infrastructure stock. Calderon (2009) further emphasized that infrastructure services' stock and quality positively influence economic growth. Similarly, Loayza & Odawara (2010) observed that infrastructure development generally determines Egypt's economic growth. In contrast, Chakamera & Alagidede (2017) found infrastructure investment to have a negative significance.

Given the diverse perspectives, this study examines the nexus between infrastructure investment and economic growth in ECOWAS member states. It is hypothesized that infrastructure investment does not significantly affect growth in ECOWAS member states.

Infrastructure is defined broadly as government investment in physical assets and social services (Ogun, 2010). It represents development strategies to close gaps, enhance growth, and broaden economic participation (IMF, 2018). Infrastructure includes public goods and services that complement traditional production factors such as capital, labor, and entrepreneurship (Anochiwa & Maduka, 2014). Furthermore, infrastructure can be classified into two categories: economic infrastructure, which promotes economic activity (e.g., roads, railroads, electricity, telecommunications, airports, seaports, and water supply), and social infrastructure, which improves the health, education, and cultural standards of the population.

Economic growth is characterized by a persistent increase in the country's output of goods and services. However, Usman & Adeyinka (2019) argue that translating growth into development involves a persistent increase in real per capita income levels and in the economy's output, urbanization, redistribution of income, and wealth within the population, reducing poverty and unemployment in a country.

Endogenous growth theory emphasizes investment as a means to boost productivity. It is rooted in microeconomic theories, focusing on investments in inputs such as roads, electricity, and human capital to achieve economies of scale and scope. This theory considers human capital as an input regarding the externalities that spill over from one economic agent to another. Hirschman highlights the significance of infrastructure development in driving growth through investments in transport, telecommunications, and other strategic sectors of the economy. He posits that such investments open up new possibilities for investment, laying the groundwork for sustained economic expansion. Hirschman suggests that growth is transmitted from leading sectors of the economy to the next across industries and businesses and views development as a series of imbalances that should be maintained rather than eradicated. According to him, profits and losses are indicators of these spillovers. He argues that developing countries should concentrate on one or two key sectors or industries, investing heavily in them to achieve competitive advantage and economic growth by developing advanced factors through investments in education, infrastructure, and skill acquisition, which are crucial for innovation. Hirschman's work is associated with the unbalanced growth theory.

Apurv & Uzma (2021) explored the impact of public investment in infrastructure on the economic growth of the BRICS nations (Brazil, Russia, India, China, and South

Africa) from 1980 to 2017, employing the panel least square method, panel least square fixed-effect model, and panel least square random effect model. Their findings indicate that while investment in energy infrastructure supports economic growth, investment in telecom infrastructure is significantly and negatively associated with the economic growth of BRICS countries. Country-specific OLS estimates revealed that Brazil and South Africa exhibit an insignificant relationship between infrastructure investment and economic growth. In Russia, energy and transportation infrastructure investments bolster economic growth. In contrast, China sees a negative relationship between transportation infrastructure investment and economic growth, and India's investment in telecommunications infrastructure negatively impacts economic growth.

Khurriah & Istifadah (2019) investigated the relationship between public infrastructure spending and economic growth in Indonesia from 2011 to 2017, using data from 34 provinces. Employing a growth model derived from aggregate production functions and the generalized method of moments (GMM) estimation techniques, they found that spending on water and telecommunications infrastructure positively affected growth, while spending on road infrastructure negatively and significantly impacted growth. Similarly, Maruf & Masih (2019) utilized the non-linear ARDL model to determine whether the relationship between infrastructure spending and economic growth is symmetric or asymmetric. Their findings suggest an asymmetric relationship in the long run but a symmetric relationship in the short run. Moreover, they established a causal path of Indonesian economic development from gross fixed capital accumulation to labor.

Lenz et al. (2018) investigated the impact of transport infrastructure spending on economic growth, utilizing panel data from 1995 to 2016 and employing methods such as pooled ordinary least squares, fixed effects, and random effects. Their findings indicate positive effects for all estimated variables except for railway infrastructure, where the effects appear negative. The study highlights that low funding results in inefficient and outdated railway infrastructure in Central and Eastern European Member States (CEMS).

Azam & Bakar (2017) analyzed the effect of infrastructure development on economic growth in Malaysia from 1975 to 2015. Using the OLS method, their results show that infrastructure development significantly positively affects Malaysia's economic growth during the study period. Additionally, foreign direct investment (FDI) and human capital positively affected economic growth.

Oyewunmi & Christiana (2017) explored the influences of infrastructure development on economic growth in Nigeria from 1980 to 2015, modeling infrastructure as a stock variable using the Cobb-Douglas production function and OLS technique. The study reveals that air transport, communication, energy, and railway infrastructure positively and significantly affect economic growth.

Kodongo & Ojah (2016) examined the contribution of infrastructure to economic growth, using panel data from 45 Sub-Saharan African countries and systematic GMM from 2000 to 2011. Their findings suggest that infrastructure spending and increased access to infrastructure significantly influence economic growth and development in Sub-Saharan Africa.

Donou-Adonsou et al. (2016) investigated the role of telecom infrastructure in Sub-Saharan Africa, employing the system GMM with its instrumental variable on panel data from 47 countries between 1993 and 2012. The study found that internet and mobile phone usage significantly increase economic growth, with a 1% increase in internet and mobile phone usage leading to growth increases of 0.12% and 0.03%, respectively.

Anochiwa & Maduka (2014) examined the impact of human capital and infrastructure investment on economic growth in Nigeria using co-integration and error-correction models from 1970 to 2010. Their study reveals that human capital has a positive and statistically significant influence on growth, while the infrastructure variable (electricity) has a positive but statistically insignificant influence on growth.

The studies above present mixed outcomes regarding the impact of infrastructure investment—a component of advanced factors—on economic growth. A second motivating factor is the scarcity of research on the nexus between infrastructure and economic growth within the ECOWAS region. Given this context, there is a clear need for further research to enhance our understanding of the relationship between infrastructure and economic growth in the ECOWAS region. This study aims to examine the impact of infrastructure on economic growth in ECOWAS member states to address this gap, employing the Non-linear Autoregressive Distributed Lag (NARDL) and the Westerlund panel co-integration methods to achieve this objective.

METHODS

Model specification

This study employs the Non-linear Autoregressive Distributed Lag (NARDL) model that Shin et al. (2014) developed to examine the nexus between infrastructure investment and economic growth. The choice of NARDL is motivated by its ability to address the limitations of linearity inherent in the standard ARDL model. Unlike the standard ARDL, which assumes a linear relationship between the regressor(s) and the regressand, implying that a 1% increase in the regressor leads to a proportional change in the regressand, the NARDL model accommodates both symmetry and asymmetry. This allows for the inclusion of partial sums of positive and negative changes, recognizing that a positive impact on the dependent variable does not necessarily negate a negative effect.

The advantages of using NARDL include improved co-integration results in small samples as compared to classical co-integration approaches (Romilly et al., 2001) and its applicability when regressors are stationary at level or the first difference (I(0) or I(1)), though not when regressors are I(2). The NARDL framework is especially suited for analyzing short- and long-run asymmetries, uncovering unobserved co-integration in a model. It effectively captures the varying impacts of positive and negative shocks in the short and long run.

The NARDL model specification decomposes the positive and negative partial sums of advanced factors (GOSE, INFR, REDE) for each country, represented as follows:

$$ln\text{AIDI} = ln\text{AIDI}0 + ln\text{AIDI}t{+} + ln\text{AIDI}t{-} \quad (1)$$

$$ln\text{INFRE} = ln\text{INFRE}0 + ln\text{INFRE}t{+} + ln\text{INFRE}t{-} \quad (2)$$

$$ln\text{ELECT} = ln\text{ELECT}0 + ln\text{ELECT}t{+} + ln\text{ELECT}t{-} \quad (3)$$

The terms lnAIDI$t+$, lnINFRE$t+$, lnELECT$t+$ and lnAIDI$t-$, lnINFRE$t-$, lnELECT$t-$ represent the partial sums of the positive and negative changes of lnAIDIt, lnINFREt, and lnELECTt, respectively. This can be stated as follows:

$$POS = \ln\text{AIDIt}+ = \sum_{j=1}^{t} \Delta\ln\text{AIDI}_{j+} = \sum_{j=1}^{t} max(\Delta\ln\text{AIDI}_{j}, 0) \ldots\ldots\ldots\ldots\ldots(4a)$$

$$NEG = \ln\text{AIDIt}- = \sum_{j=1}^{t} \Delta\ln\text{AIDI}_{j-} = \sum_{j=1}^{t} \max(\Delta\ln\text{AIDI}_{j}, 0) \ldots\ldots\ldots\ldots\ldots(4b)$$

$$POS = \ln\text{INFREt}+ = \sum_{j=1}^{t} \Delta\ln\text{INFRE}_{j+} = \sum_{j=1}^{t} max(\Delta\ln\text{INFRE}_{j}, 0) \ldots\ldots\ldots\ldots(5a)$$

$$NEG = \ln\text{INFREt}- = \sum_{j=1}^{t} \Delta\ln\text{INFRE}_{j-} = \sum_{j=1}^{t} max(\Delta\ln\text{INFRE}_{j}, 0) \ldots\ldots\ldots\ldots(5b)$$

$$POS = \ln\text{REDEt}+ = \sum_{j=1}^{t} \Delta\ln\text{REDE}_{j+} = \sum_{j=1}^{t} max(\Delta\ln\text{REDE}_{j}, 0) \ldots\ldots\ldots\ldots(6a)$$

$$NEG = \ln\text{ELECTt}- = \sum_{j=1}^{t} \Delta\ln\text{ELECT}_{j-} = \sum_{j=1}^{t} max(\Delta\ln\text{ELECT}_{j}, 0) \ldots\ldots\ldots\ldots(6b)$$

Models 4a, 4b, 5a, 5b, 6a, and 6b derive the non-linear equation by substituting positive (POS) and negative (NEG) values. This process leads to the formulation of the non-linear Autoregressive Distributed Lag (ARDL) model as proposed by Shin et al. (2014). Consequently, the non-linear ARDL equation can be expressed as follows:

$$\begin{aligned}\text{RGDPi, t} = \theta_0 &+ \sum_{q=1}^{n} \theta_{1q}\Delta\text{RGDP}_{i,t-q} \\ &+ \sum_{q=1}^{n} \theta_{2q}\Delta\text{AIDI}_{i,t-q} + \sum_{q=1}^{n} \theta_{3q}\Delta\text{INFRE}_{i,t-q} + \sum_{q=1}^{n} \theta_{4q}\Delta\text{ELECT}_{i,t-q} \\ &+ \sum_{q=1}^{n} \theta_{5q}\Delta\text{POS}_{i,t-q} + \sum_{q=1}^{n} \theta_{6q}\Delta\text{NEG}_{i,t-q} + \Upsilon_1\Delta\text{RGDP}_{i,t-q} \\ &+ \Upsilon_2\Delta\text{AIDI}_{i,t-q} + \Upsilon_3\Delta\text{INFRE}_{i,t-q} + \Upsilon_4\Delta\text{RGDP}_{i,t-q} + \Upsilon_5\Delta\text{ELECT}_{i,t-q} \\ &+ \Upsilon_6 POS_{i,t-q} + \Upsilon_7 NEG_{i,t-q} + \mu t \ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)\end{aligned}$$

The nonlinearity of equation 7 relates to the partial sums of POS and NEG. That is, when coefficients of POS and NEG assume the same sign and size, a conclusion can be made that changes in independent variables have a symmetric influence on the RGDP. The influence is asymmetric when the signs and sizes are different. That is, short-run influences are coefficients of the first-differenced variables, and the long-term effects are assessed by setting the non-first-differenced lagged component of the model (7) to zero and normalizing ϒ_2 to ϒ_7 on ϒ_1. Shin et al. (2014) reveal that the bounds-testing procedure of Pesaran et al. (2001) is applicable in this case.

Sources of data

The study employs secondary data from the World Bank Development Indicators (WDI) and the African Infrastructure Development Index (AIDI). The cross-sectional data were collected for each of the fifteen ECOWAS Member States. The variables for which data were collected include the real Gross Domestic Product (RGDP), the African Infrastructure Development Index (AIDI), infrastructure (INFRE), and the

Electricity Composite Index (ELECT). The dataset covers nineteen years, from 2003 to 2021, for each member state of ECOWAS.

Westerlund co-integration model

The Westerlund co-integration model was applied to panel data to examine the long-term relationship among the studied variables. This choice of the Westerlund co-integration model is based on its capability to perform residual-based co-integration tests in both pure time series and panel data, necessitating that the long-term parameters for variables at their levels should be equivalent to the short-term parameters for the variables in their differences. This requirement termed a common-factor restriction by Kremers et al. (1992), is crucial because its violation significantly reduces the power of residual-based co-integration tests.

Four-panel co-integration tests are introduced to address this issue, not relying on residual dynamics but on structural elements, thereby eliminating the need for a common-factor restriction. These tests evaluate the null hypothesis of no co-integration by examining if the conditional panel error-correction model coefficient equals zero. They are normally distributed and are designed to accommodate unit-specific short-term dynamics, trends, slope parameters, and cross-sectional dependencies. Among these four tests, two assess the alternative hypothesis that the panel data is co-integrated, while the other two examine if at least one unit within the panel is co-integrated.

The Westerlund co-integration model is noted for delivering robust results with small sample sizes and is applicable for error term-based co-integration analyses in panel data. It can be employed regardless of the presence or absence of cross-sectional dependency, utilizing Bootstrap distributions for the former and standard asymptotically normal distributions for the latter. Furthermore, it is applicable when the series follows:

$$y\ I \rightarrow (1) \text{ and } \forall \rightarrow X\ I\ '\ (1).$$

The Westerlund error correction panel co-integration encompasses four tests, divided into panel and group statistics. Panel statistics derive from the overall panel data, whereas group statistics are based on individual units within the panel. The hypotheses for these statistics are as follows:

Panel statistics:

H_0: α_i = Co-integration does not exist for $\forall i'$

H_A: $\alpha i = \alpha < 0$ Co-integration exists for $\forall i'$

Group statistics:

H_0: α_i = Co-integration does not exist for $\forall i'$

H_A: $\alpha i = \alpha < 0$ Co-integration exists for $\forall i'$

Two of the four tests are parametric panel error correction co-integration tests, and two are nonparametric. This necessitates a lag length test for the parametric tests. Furthermore, small sample sizes in parametric tests, with many parameters to estimate, may lead to deviations in results.

The Error Correction Panel Co-integration Model is stated as:

$$\Delta \mathrm{yit} = \theta'_i \theta_t + \alpha i\left(\mathrm{y}_{i,t-1} - \beta' \mathrm{x}_{i,t-1}\right) + \sum_{j=1}^{pi} \alpha_{ij} \Delta \mathrm{y}_{i,t-j} + \sum_{j=1}^{pi} \Upsilon_{ij} \Delta \mathrm{x}_{i,t-j} + ei \ldots \ldots (8)$$

Equation (8) omits the deterministic composition $\theta i'$ and vector parameters θt, focusing on the error correction parameter αi. When estimated using the error correction model, it yields:

$$\left(y_{i,t-1} - \beta' X_{i,t-1}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

The parameterized version of Equation (8) is expressed as:

$$\Delta yit = \theta'_i \theta_t + \alpha i\, y_{i,t-1} - \lambda'^{X_{i,t-1}} + \sum_{j=1}^{pi} \alpha_{ij} \Delta y_{i,t-j} + \sum_{j=1}^{pi} \Upsilon_{ij} \Delta x_{i,t-j} + ei \ldots\ldots\ldots (10)$$

Group statistics

In the analysis of Group Statistics, three stages are employed to formulate the Group Mean Statistic. In the first stage, represented by Equation (11), all units in the panel are estimated using Ordinary Least Squares (OLS):

$$\Delta yit = \theta''\theta''_t + \alpha' i\, y'_{i,t-1} - \lambda'' X'_{i,t-1} + \sum_{j=1}^{pi} \alpha'_{ij} \Delta y'_{i,t-j} + \sum_{j=1}^{pi} \Upsilon'_{ij} \Delta x'_{i,t-j} + e' i \,.(11)$$

In Equation (11), *ρi* represents the lag length, which may vary from one unit to another. The error correction parameter, *ρi*, is estimated in the second stage of the Group Statistics as:

$$\alpha(1) = 1 - \sum_{j=1}^{pi} \alpha_{ij} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

The parametric method is preferred for estimation thus:

$$\alpha'^{(1)} = 1 - \sum_{j=1}^{pi} \alpha'_{ij} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

However, given that the parametric method may lead to deviations in results, especially with small sample sizes, making parameter estimation ambiguous and influenced by its differing values (Autoregressive), an alternative estimation method is necessary. The Kernel approach serves as such an alternative, and it is articulated as:

$$(\omega)2 = 1/(1-T) \sum_{j=-M}^{Mi} 1 - \left(\frac{j}{Mi+1}\right) \sum_{j=1}^{pi} \Delta y_{it}\, \Delta y_{it-1} \ldots\ldots\ldots\ldots\ldots\ldots (13)$$

In Equation (13), Mi is the bandwidth parameter for the covariance number within the Kernel approach, and (*ω*)2 is the long-run variance ofΔ*yit*. Here, Δ*yit* is (*ω*)2/(1). Essentially, (*ω*)2 represents the long-run variance of the error term.

Pre-estimation diagnostics

In the pre-estimation diagnostics phase, this study employs the Harris-Tzavalis Unit Root Test for panels to examine the stationarity of the data. The Harris-Tzavalis unit root test is formulated as follows:

$$y_{it} = \eta_{it} + \sum_{k=1}^{p+1} \beta_{ik}\, x_{i,t-k} + \varepsilon_t \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

This test specifically estimates the null hypothesis of a different stationary process:

$$H_0: \sum_{k=1}^{p+1} \beta_{ik} - 1 = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (15)$$

Conversely, the alternative hypothesis suggests that the panel series is stationary, with: $\sum_{k=1}^{p+1} \beta_{ik} - 1 < 0$

For all ii. The vectors used for the test statistics are defined as:

$$Y_i^* = AY_i = \left[y_{i,1,}^* y_{i2,}^*, \ldots., y_{i,T}^*\right] \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

and

$$X_i^* = AX_i = \left[x_{i,1,}^* x_{i2,}^*, \ldots., x_{i,T}^*\right]', \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

The standardized forms of the equations (11) and (12) for calculating the Harris-Tzavalis test statistic are given as:

$$\lambda_{\mathrm{B}} = \frac{\sum_{i=1}^{N} \sigma_1^{-2}\, Y_i^{*'} X_i^{*'}}{\sqrt{\sum_{i=1}^{N} \sigma_1^{-2} X_i^{*'} A'^{AX_I^*}}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (18)$$

This equation enables testing the unit root hypothesis across the panel, considering cross-sectional independence and providing a method for identifying the presence of unit roots in panel data series.

RESULTS AND DISCUSSION

The estimation from the panel unit root test for stationarity, as illustrated in Table 1, indicates that the variables GDP, AIDI, and ELECT are not stationary at their levels since their probability values exceed 5 percent. This result leads to the acceptance of the null hypothesis, suggesting that GDP, AIDI, and ELECT are not stationary at the level. However, when taking the first difference, the estimated probabilities fall below 5 percent for GDP, AIDI, and ELECT, indicating that the stationarity of these variables is achieved at the first difference, denoted as I(1). Conversely, INFRE is stationary at the level, as the probability value of INFRE is less than 5 percent at level I(0). The presence of unit roots in some variables suggests that co-integration may exist, necessitating a co-integration test to determine the long-run relationships among the variables.

Table 1. Harris-Tzavalis unit root test (panel)

Variables	Rho (level)	z-Statistic (Level)	P-value (Level)	Rho (1st Diff)	Z-Statistic (1st Diff)	P-value (1st Diff)	Order of Integration
GDP	0.936	2.231	0.987	0.692	3.181*	0.0007	I(1)
INFRE	0.632	4.995*	0.000	-------	-------	--------	I(0)
AIDI	0.999	3.740	0.999	0.214	-13.96*	0.0000	I(1)
ELECT	0.867	0.581	0.719	-0.208	-23.47*	0.0000	I(1)

** denotes significant at 1%*

Five information criteria were employed to assess the optimal lag length (Table 2), of which three (AIC, SC, and HQ) suggest that a lag length of one is optimal. Conversely, the FPE and LR criteria indicate a preference for a lag length of three. Consequently, one lag length was selected for use in the Westerlund co-integration test and subsequent diagnostic tests.

Table 2 details the results of the lag selection for the panel co-integration test, highlighting the chosen lag lengths as indicated by asterisks (*). These selections are based on the lowest values suggested by the criteria, with a lag length of one being optimal according to the AIC, SC, and HQ criteria, while FPE and LR favor a lag length of three.

Table 2. Result of lag selection for panel co-integration test

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1266.542	NA	7.88e+24	68.67797	68.85212	68.73937
1	-1142.179	215.1151	2.27e+22	62.82049*	63.69125*	63.12747*
2	-1122.782	29.35777	1.95e+22	62.63686	64.20424	63.18944
3	-1090.465	41.92423*	8.79e+21*	61.75488	64.01888	62.55305

* *indicates lag order selected by the criterion*

Utilizing the Westerlund-based panel co-integration test, with bootstrapping to correct for correlations among the panel's cross-sectional units and thereby obtaining robust critical values, the co-integration of GDP, infrastructure expenditure (INFRE), the Africa Infrastructure Development Index (AIDI), and the Electricity Composite Index (ELECT) was evaluated. The bootstrapping procedure involved specifying single and lagged effects based on constant and trend over 170 replications.

According to the results presented in Table 3, the Westerlund co-integration test reveals significant findings. Both cross-sectional statistics (Ga and Gt) display robust P-values of 0.000, leading to the rejection of the null hypothesis of 'no co-integration'. Moreover, Pa exhibits a robust P-value of 0.000 in the two-panel statistics, whereas Pt shows a non-robust P-value of 0.729. These results suggest that three variables co-integrate, indicating a long-run equilibrium relationship among the units within the panel model. This finding paves the way for estimating the long-run coefficients of the variables involved.

Table 3. Result of Westerlund panel co-integration test

Statistic	Value	Z-value	P-value
Gt	-19.473	82.544	0.000
Ga	-18.932	-4.096	0.000
Pt	-7.659	0.610	0.729
Pa	-17.351	-5.445	0.000

Table 4 presents the findings from the parsimonious long-run Non-linear Autoregressive Distributed Lag (NARDL) model. This model is described as economical because it automatically excludes coefficients of variables that are statistically insignificant to enhance the significance levels of the variables retained in the estimated model. Specifically, the coefficients for INFRE_POS, AIDI_POS, and ELECT_POS were discarded due to their high statistical insignificance.

The results indicate a positive relationship between increased infrastructure investment and the GDP of ECOWAS countries, aligning with findings from Akeju et al. (2022) and Deen-Swarray et al. (2011). Specifically, the model suggests that a 1 percent increase in infrastructure investment (INFRE), ceteris paribus, leads to an approximate 0.01 percent rise in the GDP of the ECOWAS countries examined in this study. This estimate is statistically significant, as evidenced by a probability value 0.0395, and aligns with prior expectations.

Additionally, the model highlights the negative impacts of the variables AIDI_NEG and ELECT_NEG on the outcome, with coefficients of -0.292028 and -0.625833, respectively, which are statistically significant at the probability levels of 0.0073 for AIDI_NEG and 0.0247 for ELECT_NEG. The constant term (C) in the model, despite its large coefficient of 2928.829, is not statistically significant. Its probability value of 0.4597 indicates that it does not significantly affect the studied relationship.

Table 4. Result of parsimonious long-run panel NARDL model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INFRE_POS	0.010100	0.004169	2.422643	0.0395
AIDI_NEG	-0.292028	0.105809	2.759954	0.0073
ELECT_NEG	-0.625833	0.322237	1.942151	0.0247
C	2928.829	3914.746	0.748153	0.4597

The findings underscore that all infrastructure categories—economic, social, and institutional—play a critical role in supporting the economic growth of ECOWAS member states. Economic infrastructure encompasses public goods such as power, telecommunications, drinking water, sanitation, dams, canals, irrigation, and drainage, alongside the transportation sector, including roads, railroads, port transportation, and airports. Social infrastructure covers health and education facilities, such as schools, libraries, hospitals, health centers, housing, and recreational areas like parks and museums. Institutional infrastructure involves law enforcement, administrative control and coordination, and cultural aspects.

This comprehensive support for economic growth aligns with the research conducted by Amarachi (2016) and Ariantika & Ikhsan (2016), which posited that infrastructure positively correlates with the economic prosperity of developing states. The analysis reveals a significant inverse relationship between the African Infrastructure Development Index (AIDI) and economic performance. Specifically, a 1 percent decrease in AIDI is associated with a roughly 0.29 percent decrease in the GDP of ECOWAS member states. Conversely, a 1 percent increase in AIDI corresponds to a similar increase in GDP, emphasizing the critical role of physical infrastructure in enhancing resource availability, reducing input costs, and promoting economic efficiency and growth within ECOWAS. This outcome supports economic theories related to the impact of physical assets on growth. It mirrors the current conditions in Africa, resonating with findings from Awan & Anum's (2014) study on Pakistan's economy.

Similarly, the Electricity Composite Index (ELECT) substantially impacts the GDP of ECOWAS member states. A 1 percent decrease in ELECT leads to a decrease of approximately 0.626 percent in GDP, whereas a 1 percent increase in ELECT is expected to enhance GDP by the same magnitude. This reflects the essential need for consistent, efficient, and sufficient electricity supply in powering the industrial sectors of ECOWAS countries. The negative impact of ELECT suggests the challenges posed by unreliable power supply in many African states, which has been a significant barrier to productivity and economic growth. This finding aligns with studies by Azam & Badhan (2020) and Donou-Adonsou (2019), highlighting the critical link between energy infrastructure and economic development.

The results from the short-run Autoregressive Distributed Lag (ARDL) model, as displayed in Table 5 and estimated at the first difference by the optimal lag length selected by the lag selection criteria, reveal a statistically significant negative error correction term (ECMt-1) at the 5 percent level. This negative sign indicates the adjustment mechanism from short-run to long-run equilibrium among the study's variables, signifying the economy's responsiveness in correcting deviations from equilibrium in the short run towards long-run equilibrium. The coefficient of ECMt-1 suggests an annual adjustment rate from long-run disequilibrium of about 0.156 percent per annum. This means that errors from previous years' disequilibrium are corrected by approximately 16 percent in the current year.

Furthermore, the short-run estimated coefficients align with those of the long-run estimates and maintain statistical significance. Specifically, the coefficient for INFRE is positive at 0.00017, indicating that, all else being equal, a 1 percent increase in infrastructure investment (INFRE) leads to a 0.0002 percent increase in the GDP of ECOWAS countries in the short run. Conversely, the coefficients for AIDI and ELECT are negative, at -0.456 and -0.987, respectively, suggesting that, ceteris paribus, a 1 percent decrease in the African Infrastructure Development Index (AIDI) leads to a 0.46 percent decrease in GDP of ECOWAS. In contrast, a 1 percent decrease in the Electricity Composite Index (ELECT) results in a 0.987 percent decrease in the GDP of ECOWAS. These findings highlight the significant influence of infrastructure investments and conditions on the short-run economic performance of ECOWAS countries.

Table 5. Result of short-run panel NARDL model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INFRE_POS	0.000172	5.09E-05	3.381502	0.0019
AIDI_NEG	-0.456477	0.074523	6.125287	0.0000
ELECT_NEG	-0.978257	0.332437	-2.942690	0.0370
ECM_{t-1}	-0.156313	0.021793	-7.172495	0.0000

The post-estimation diagnostics presented in Table 6 highlight several key tests conducted to ensure the reliability of the study's findings. The Breusch-Godfrey Serial Correlation LM Test, with a probability value of 0.1084, exceeds the 0.05 threshold, indicating the absence of autocorrelation in the model. This result is critical for confirming that the residuals from one period do not influence those of another, ensuring the independence of observations across time.

Similarly, the probability value from the Heteroskedasticity Test: ARCH, standing at 0.2160, also surpasses the 0.05 benchmark. This outcome suggests the absence of heteroskedasticity, meaning there is no systematic change in the dispersion of the residuals. In other words, the variance of the error terms remains constant, which is crucial for the validity of standard errors, test statistics, and confidence intervals derived from the model.

Additionally, the CUSUM plot referenced in Figure 1 indicates that the estimated parameters of the study remain stable within the 5% critical lines for the period under investigation. Stability in this context means that the model's coefficients do not exhibit significant fluctuations over time, affirming the reliability of the model's predictions.

Contrastingly, the normality test, as evidenced by the Jarque-Bera value and its corresponding probability in Figure 2, yields a value of 1328 with a probability of 0.0000. These figures lead to the rejection of the null hypothesis that the error terms of the data used in the study are normally distributed. The implication here is significant since the assumption of normal distribution of error terms underpins many inferential statistics. The rejection of normality suggests that the error terms are not evenly distributed around zero, potentially affecting the robustness of certain hypothesis tests. However, it's important to note that many econometric techniques remain robust even when this assumption is violated, especially in large samples.

Table 6. Result of post-estimation diagnostics

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	1.686067	Prob. F(3,30)	0.1084
Obs*R-squared	1.044422	Prob. Chi-Square(3)	0.1060
Heteroskedasticity Test: ARCH			
F-statistic	0.151594	Prob. F(10,18)	0.2160
Obs*R-squared	2.865970	Prob. Chi-Square(10)	0.1114

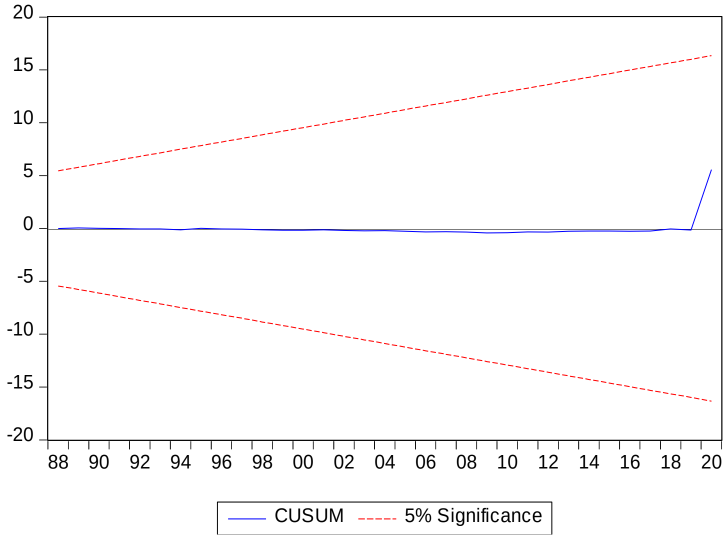

Figure 1. Stability test

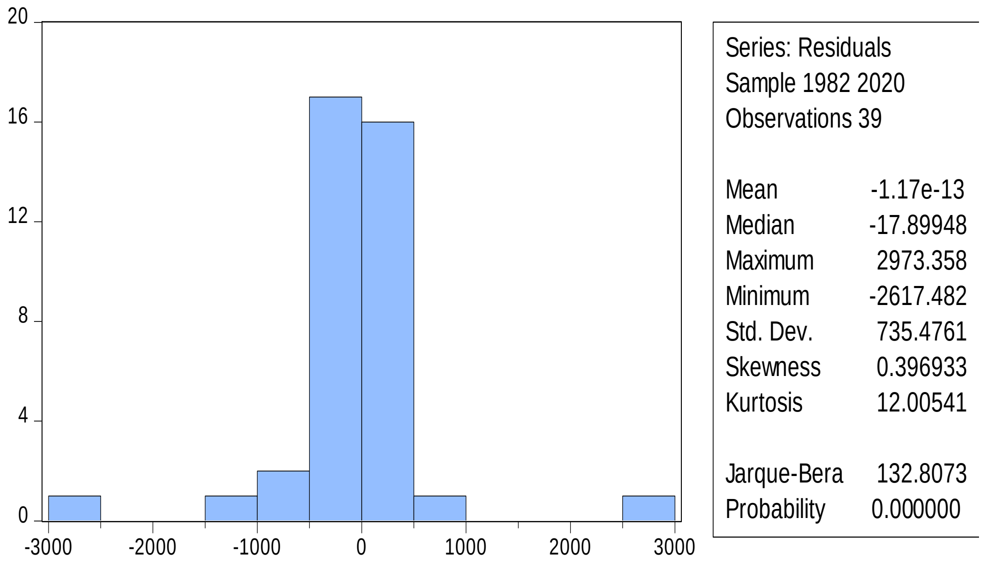

Figure 2. Normality test

CONCLUSION AND RECOMMENDATIONS

Conclusion

This research utilizes a panel Non-linear Autoregressive Distributed Lag (NARDL) model alongside the Westerlund co-integration test to investigate the relationship between infrastructure investment and economic growth within West African countries. The econometric analysis, covering ECOWAS member states from

2003 to 2021, reveals that infrastructure investment, as well as improvements in the African Development Index and the Electricity Composite Index, contribute positively to the economic growth of the ECOWAS region. Specifically, the study finds that infrastructure investment results in approximately a 0.01 percent increase in GDP for the ECOWAS countries examined. In the long run, the African Development Index and the Electricity Composite Index boost the GDP of ECOWAS by 0.292 percent and 0.987 percent, respectively. The conclusion drawn from these findings is that infrastructural investment plays a significant role in enhancing the economic growth of ECOWAS countries.

Recommendations

Based on the insights gained from this study, several recommendations are put forward:

1. Authorities in ECOWAS countries are encouraged to refine government spending policies to improve infrastructure quality significantly. Enhanced infrastructure quality is pivotal for sustaining economic growth and development in the region.
2. There is a pressing need to bolster the energy sector to ensure efficient and sufficient energy supply. A robust energy sector is crucial for maximizing industrial output, which drives the economic growth of ECOWAS countries. Strengthening this sector would involve strategic investments in energy infrastructure and adopting policies that encourage the development of renewable and sustainable energy sources.

By implementing these recommendations, ECOWAS countries can leverage infrastructure development as a key driver of economic growth, ensuring that the benefits of such growth are widespread and sustainable over the long term.

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