# Transport Infrastructure and Industrial Sector Productivity in ECOWAS Region

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## Abstract

*The state of the ECOWAS road network serves as a discouragement to many foreign investors seeking to aid industrial development. Many foreign industries have ceased to operate, infant companies find it difficult to grow, and many private businesses are struggling to survive as a result of high production costs and shortages of skilled labour or industrial manpower. This is a result of poor road networks. Thus, this study looked at how road networks and transport infrastructure investments affected the productivity of the industrial sector in ECOWAS nations. The study adapted an endogenous growth model to analyse data sets for fifteen ECOWAS countries spanning the years 1975 to 2022. In order to evaluate panel causality and cross-sectional autoregressive distributed lag (CS-ARDL) models, data was obtained from the World Development Indicator (WDI). The results demonstrated that overall road network and transport infrastructure investment had both short-term and long-term positive and significant effects on industrial sector productivity. Also, a unidirectional causality was recorded between the road network and industrial sector productivity, and a feedback causal relationship was recorded between investment in transport infrastructure and industrial sector productivity. Consequently, governments and moguls in the production industry should prioritise transportation improvements as a critical strategy for enhancing industrial efficiency and competitiveness.*

***Keywords:*** Transport infrastructure, Industrial sector productivity, Road network, Cross-sectional autoregressive distributed lag (CS-ARDL), Panel data set

***JEL Classification*:** L9

## Introduction

A strong and efficient transit system is essential for the expansion of cities and regions as well as the productivity of the industrial sector. Good roads, railroads, ports, and aero planes are a few examples of effective transportation systems that can increase output and raise people's standards of living. Investments in transport infrastructure and other types of infrastructure can significantly help the economy's industrial sector productivity and performance growth. Infrastructure spending for transportation lowers the cost of travel between origins and destinations and, as a result, reduces the cost of transportation, commuting, and shipping through the recently constructed road transport infrastructure, which enables these activities to be completed more quickly and for less money (Venables et al., 2014; De Palma et al., 2011). For businesses, decreased transport expenses result in lower production costs since they can be used to offset costs associated with input variables, such as the shipment of raw materials (Mechouar et al., 2022). For instance, newly constructed road infrastructure that links industries to the ports of raw material entry is likely to assist businesses economically.

The reduced travel costs have an impact on the transport network's matrix, which causes changes in the routes of the road network as a result of transportation infrastructure expansion. In this way, such expansion results in the building of several routes as well as improvements to the existing infrastructure. This includes location adjustments for the industries and changes in land use. The development of new road transit, for instance, may result in changes to the network's centrality. Some areas become more important in terms of proximity to resources. Firms that want to remain competitive are likely to transfer their operations in response to these developments, either to reduce production costs or to expand business opportunities. Similar to this, people are more likely to relocate to a location with more career prospects and a variety of amenities (Fujita et al., 2001).

The state of the ECOWAS road network serves as a discouragement to many foreign investors seeking to aid industrial development because both the government and stakeholders failed to invest to improve the condition of the roadways despite repeated appeals. The prosperity and influence of many industrialized nations have been significantly boosted by their investments in road infrastructure. Road infrastructure in the United States expanded exponentially as a result of the coordinated effort to build a vast network of roads between 1890 and 1930, which culminated in the creation of the interstate highway system. This development sparked previously unheard-of economic growth, sending the nation to new heights of wealth and power. The ECOWAS countries can gain valuable insights from the United States' strategic investment in its road networks. The available estimates of transport infrastructure needs in developing countries vary greatly. For the ECOWAS region to reach the global average road network densities, they would need to construct almost 200,000 km of paved roads at a cost of about US$1.5 billion (World Bank Africa Region Sustainable Development Unit). According to the Africa Development Bank (2020), in order to construct the requisite road network density that could support industrial sector productivity, ECOWAS nations will have to spend more than 4% of their yearly gross domestic product (GDP) on roads alone over the course of the next ten years.

According to the United Nations Office of the High Representative for the Least Developed Countries (UN-OHRLLS), the ECOWAS area has a lower road network density than both world averages and transit-developing nations. The road system in the ECOWAS area was started in 1975 and has been in terrible shape since 1985. The overall road network decreased from 9.5 km to 4.8 km in 1985, then to 4.7 km in 2005, and finally to 4 km in 2020 (World Bank 2021). This result demonstrates the state of the road system in the ECOWAS area and the degree to which it has harmed the region's industrial sectors.

## Literature Review

Numerous studies have examined the relationship between production levels and transport infrastructure in both regional and national contexts. However, inconclusive results revolve around a positive or negative relationship between the two. Piyapong (2020) was one of the studies that examined the consequences of transport infrastructure investment on local employment and manufacturing companies in the United States. The study employed panel data for 48 nearby US states and country-level panel data for the state of North Carolina to evaluate the link between time and location using dynamic panel and spatial econometric techniques. According to the research, adding more lanes to major intrastate highways can boost the growth of the service sector's employment while delaying that of the manufacturing sector. However, the analysis discovered a causal link between employment, the slowing down of manufacturing sectors, and the rapid construction of roads, which resulted in an increase in the volume of the main non-interstate roadway.

Demetriades and Mamuneas (2000) also examined how public infrastructure investments affected employment and industrial sector productivity in 12 OECD economies. Co-integration analysis was used in the inquiry for the study. The research found that in all 12 countries, the growth of public infrastructure had an impact on industrial sector productivity supply and input demand both immediately and later on. As opposed to the long-run rate, which is substantial but steadily dropping, the short-run rate effect is comparatively low. These statistics showed that in the 1970s and 1980s, there was a serious underinvestment in infrastructure, which was eventually closed in the early 1990s, which spurred industrial sector performance.

Bimba et al. (2020) examined the influence of public infrastructure spending on China's industrialization from 1981 to 2016. The study used variance decomposition and impulse response function analysis to validate the findings after using Augmented Dickey-Fuller statistics (ADF) to ascertain the order of integration of the variables. Findings revealed a long-term impact of infrastructure spending on industrial production. The study concluded that China's industrialization and public infrastructure development are positively and significantly correlated. Khalid et al. (2020) investigated the relationship between Pakistan's industrial output and investment in transport infrastructure. The study examined how Pakistan's industrial output was affected by several forms of transportation infrastructure, such as ports, airports, railroads, and highways. The findings showed that all significant variables had a long-term equilibrium connection. Pakistan's labour force, ports, and highways are the main drivers of its industrial output. According to long-term elasticities, industrial value added rises by 0.36% and 0.28%, respectively, for every 1% increase in port and road infrastructure. Inadequate railways hampered industrial output, but airways had no discernible impact.

The impact of newly built highways on employment and transport-induced labour productivity in Britain was analysed by Stephen et al. (2019) using data from industrial firms. The road network was employed as a proxy for exposure to transportation improvements in the study to estimate changes in the minimum time required for labour to go from home to work. The study discovered a strong positive relationship between freshly built roadways, employment, and neighbourhood businesses. According to the findings, newly built highways draw and recruit transportation-intensive firms to the area. This leads some already-established companies to restructure their production processes. Na et al. (2011) investigated how roads affected labour market activity in 19 OECD nations. In a study conducted over 17 years, from 1990 to 2006, the network impact of highways will increase labour productivity per worker, according to a number of models that included dependent, independent, and control factors. According to the findings of 19 OECD nations, there is a correlation between highway use and employment activity.

Castaeda and Shemesh (2000) investigated the impact of road infrastructure and labor accessibility on manufacturing sectors in Mexico from 1993 to 2018. The study used an autoregressive distributed lag (ARDL) model and discovered that industrial productivity increases by 0.62% to 0.96% for every 10% increase in road transport infrastructure. While the immediate effect may be small, the long-term impact is more significant. Sun (2018) investigated how China's industrial structure was impacted by transport infrastructure between 2005 and 2018. The work presented a dynamic panel model with hysteresis effects and established a benchmark panel regression model using panel data from 31 Chinese cities and provinces. The findings showed that secondary industry is significantly influenced by roads, but that the influence of railways is considerably greater. Urbanisation, human capital, and economic growth are some of the main elements that greatly hurt the primary sector while favouring the tertiary sector.

**Research Methodology**

This study uses endogenous growth theory to examine how investments in road networks and transport infrastructure affect industrial productivity in the ECOWAS area. According to this idea, the main forces behind economic growth are increases in productivity, which are fuelled by developments in knowledge, innovation, and human capital. In accordance with the paradigm established by Mankiw, Romer, and Weil (1992), we develop a model to investigate this connection.

$$K(t)^{\alpha} A(t)L(t)^{1-\alpha} = Y(t) \quad (1)$$

Where A is the technological level, $K_i$ is the capital, $L_i$ is the labour, and $Y_i$ is the output.

$$K(t)^{*} = \left(\frac{S}{\delta}\right)^{\frac{1}{1-\alpha}} A(t)L(t) \quad (2)$$

Note that $K, A$ and $L$ are function of time, and $S, \delta$ and $\alpha$ are all constants, $L(t)$ is the labour force with growth at rate $n$ and $A(t)$ is the technology growth at rate $g$.

$$y(t)^{*} = \left(\frac{S}{\delta}\right)^{\frac{\alpha}{1-\alpha}} A(t)L(t) \quad (3)$$

Equation (4) is the output per labour, which is replaced with the growth of the economic sector (GES), and this serves as the foundation for the theoretical framework underpinning this study.

$$gy = g + n \tag{4}$$

Expanding the theoretical framework to delve into the dynamic interplay between investment in transport infrastructure and road networks and the productivity of the industrial sector within the Economic Community of West African States (ECOWAS), this study builds upon the model previously employed by Chukwuebuka and Jisike (2020).In this model, the independent variable is the level of investment in transport infrastructure ($TI_{it}$), while the dependent variable is the value added by the industrial sector ($INDV_{it}$) at time $t$. The following is the expression for the model's functional form:

$$INDV_{it} = f(TI_{it}) \tag{5}$$

In expanding transport infrastructure, total investment in transport infrastructure and total road network were examined in terms of industrial sector productivity.

$$INDV_{it} = f(\,TITI_{it}; TRN_{it}; V_{it}) \tag{6}$$

In equation 6, industrial sector productivity ($INDV_{it}$) was measured using data on industry value added, following the methodologies of Chen and Golley (2014), Chenery (1960), and Sveikauskas, Rowe, Mildenberger, Price, and Young (2018). Investment in transport infrastructure ( $TITI_{it}$ ) was quantified by the total investment in transport with private participation. The total road network ($TRN_{it}$) was measured in kilometres per square kilometre of arable land. Additionally, the vector of control variables denoted by $V_{it}$ comprises the following: Gross capital formation ($GCF_{it}$), labour force participation rate ($LF_{it}$) credit to the private sector ($CRED_{it}$) and defense budget ($DB_{it}$). These control variables are in line with those used by Chukwuebuka and Jisike (2020) and Azolibe and Okonkwo (2020).

$$INDV_{it} = f\left(TITI_{it}; TRN_{it}; GCF_{it}; LF_{it}; CRED_{it}; DB_{it}\right) \tag{7}$$

Equation (7) explores how investment in transport infrastructure, the total road network, and other control variables influence industrial sector productivity. The semi log-linear form of the model is specified as follows:

$$INDV_{it} = \beta_0 + \beta_1 TITI_{it} + \beta_2 TRN_{it} + \beta_3 GCF_{it} + \beta_4 LF_{it} + \beta_5 CRED_{it} + \beta_6 DB_{it} + \mu_{it} \quad (8)$$

Where $InINDV_{it}$ is the natural log of industrial value added for country $i$ in period $t$. $lnTITI_{it}$ is the natural log of total investment in transport infrastructure for country $i$ in period $t$. $InTRN_{it}$ is log of total road network measured by total length of roads (per square kilometre of arable land) of country $i$ in period $t$, $GCF_{it}$ is the natural log of gross capital formation for country $i$ in period $t$. $LF_{it}$ represents the labour force participation rate, defined as the percentage of the total population aged 15 and above that is actively engaged in the labour market. It serves as a proxy for the availability of vibrant and skilled labour crucial for industrial production.$CRED_{it}$ is the ratio of credit to the private sector to GDP for country $i$ in period $t$. As defined by Olowofeso et al. (2015), this includes financial resources provided to the private sector, such as loans, advances, purchases of non-equity securities, trade credits, and other accounts receivable that establish a claim for repayment. Adequate credit to the industrial sectors enhances investment levels and productivity. $DB_{it}$ is the ratio of government expenditure on defense to GDP for country $i$ in period $t$. Government spending on defense helps create a secure environment free from internal and external threats, promoting business activities and ensuring the safety of investments, which in turn boosts industrial productivity is the ratio of government expenditure on defense to GDP for country $i$ in period $t$. Government spending on defense helps create a secure environment free from internal and external threats, promoting business activities and ensuring the safety of investments, which in turn boosts industrial productivity. $\mu_{it}$ is the error term. This model helps in understanding how changes in investment in transport infrastructure, along with other economic factors, impact the productivity of the industrial sector in different countries over time.

The second objective identified the direction of causality among the investment in transport infrastructure, total road network, and industrial productivity in the ECOWAS region. The Granger causality test was utilised to achieve this objective. Hurlin's (2005) panel causality test also necessitates covariancestationary variables for the variables being examined. Granger (1969) permits testing of the causal links between variables after the stationarity of the variables has been established. The Panel Granger causality test, which integrates cross-sectional and time-series data, is a better technique for determining causality than the well-developed Granger causality test for time-series data. Compared to using solely time-series data, it is more efficient (Hurlin & Venet, 2001). In 1988, Holtz-Eakin, Newey, and Rosen created the Panel Granger test. They take into account the subsequent fixed-effect model: In this study, attempts were made to determine whether investment in transport infrastructure and the total road network influence industrial sector productivity in ECOWAS or vice versa. Thus, the model is specified as:

$$\ln INDV_{it} = \beta_{1i} + \sum_{k=1}^{k} \partial_{11i} \ln INDV_{it-1} + \sum_{k=1}^{k} \partial_{12i} \ln TITI_{it-1} + \sum_{k=1}^{k} \partial_{13i} \ln TRN_{it-1} + \varepsilon_{1t} \quad (9)$$

$$\ln TITI_{it} = \beta_{2i} + \sum_{k=1}^{k} \partial_{21i} \ln TITI_{it-1} + \sum_{k=1}^{k} \partial_{22i} \ln INDV_{it-1} + \sum_{k=1}^{k} \partial_{23i} \ln TRN_{it-1} + \varepsilon_{2t} \quad (10)$$

$$\ln TRN_{it} = \beta_{3i} + \sum_{k=1}^{k} \partial_{31i} \ln TRN_{it-1} + \sum_{k=1}^{k} \partial_{32i} \ln INDV_{it-1} + \sum_{k=1}^{k} \partial_{33i} \ln TITI_{it-1} + \varepsilon_{3t} \quad (11)$$

$\ln INDV_{it}, \ln TITI_{it}$ and $\ln TRN_{it}$ represent industrial sector productivity, total investment in transport infrastructure, and total road network for country $i$ in period $t$, respectively. $\varepsilon_{it}$ represents the error term, which is assumed to be serially uncorrelated and have zero mean. Additionally, $\beta_{1i}$ represents the constant drifts. These equations (9, 10, and 11) form a system of simultaneous equations that facilitates testing Granger causality within a panel data framework. This setup helps to understand the causal relationships between industrial sector productivity, investment in transport infrastructure, and the total road network across the selected countries over time.

Panel data from all fifteen (15) ECOWAS members was employed in this study. Benin, Burkina Faso, Cabo Verde, Cote d'Ivoire, The Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Nigeria, Senegal, Sierra Leone, and Togo are the nations that make up the ECOWAS. The choice of ECOWAS countries was due to a lack of infrastructure and a decline in industrial sector productivity. Many ECOWAS nations are classified as low- and middle-income countries.

**Table 1: Description of Variables**

| Abbrev. | Description | Measurement |
|---|---|---|
| $INDV$ | Industrial sector productivity | Industry Value Added |
| $TITI$ | Investment in transport infrastructure | Total investment in transport with public private participation |
| $TRN$ | Total Road Network | Total length of roads (per square km of arable land) in km |
| $GCF$ | Gross capital formation | The stock of private capital used in the production at annual percentage growth rate |
| $LAB$ | Labour | Total labour force participation rate (percentage of people from 15 to 65 years old) |
| $CRED$ | Credit to private sector | Credit to the private sector as a percentage of GDP |
| $DB$ | Defense Budget | The ratio of government defense budget to GDP |

*The World Bank Development Indicators (WDI) of numerous topics up to 2022 was used to generate panel data for the study, which spans the years 1975 through 2022.*

This study examined how transport infrastructure affects industrial production in ECOWAS nations using three different methodologies. First, we examined the data using descriptive statistics. This involved calculating averages and using tests like Jarque-Bera to check if the data followed a normal distribution (Gujarati & Dawn, 2009). Also, we performed correlation analyses to avoid issues with multicollinearity (when variables are highly correlated). Panel unit root tests were then used in the study to determine whether the data showed a time trend. (was increasing or decreasing over time). These tests considered two scenarios: one where all countries behaved independently (first-generation tests), and another where they might influence each other (second-generation tests). Among the second-generation tests, the factor-based approach was used because it can handle situations where countries' economies are interconnected. Finally, the Cross sectional Augmented Autoregressive Distributed Lag (CS-ARDL) model is the particular model used. Using this model, the 15 ECOWAS nations' industrial production was predicted to be impacted by changes in transport infrastructure. The root mean square error (RMSE) was calculated in order to evaluate how well the model predicted outcomes. A more successful model is indicated by a lower RMSE.

**Presentation and Analysis of Results**

Table 2 shows the descriptive statistics, including the mean, maximum, minimum, standard deviation, skewness, Jacque-Bera statistic, and number of observations for each variable. These variables encompass the dependent variable, Industrial sector productivity ($INDVA$), as well as independent variables such as total investment in transport infrastructure $(TITI)$ and total road network $(TRN)$. Additionally, control variables including gross capital formation $(GCF)$, labour force participation rate $(LAB)$, credit to the private sector $(CRED)$, and defence budget $(DB)$ are included. These statistics cover data from all fifteen (15) ECOWAS nations spanning the period from 1975 to 2022.

**Table 2: Summary Statistics of Variables**

| Variables | INDVA | TITI | TRN | LF | GCF | CRED | DB |
|---|---|---|---|---|---|---|---|
| Mean | 38.0143 | 19.8703 | 4.2061 | 49.6165 | 54.5874 | 14.6325 | 1.7411 |
| Maximum | 253.7166 | 296.5093 | 5.2887 | 79.2900 | 515.6162 | 73.1921 | 29.7277 |
| Minimum | 3.4067 | 0.0145 | 3.0414 | 23.8550 | 5.3539 | 0.0000 | 0.0087 |
| Std. Dev. | 36.4500 | 39.8103 | 0.5645 | 13.5441 | 83.8012 | 11.3264 | 2.8718 |
| Skewness | 2.6316 | 3.3979 | -0.0932 | 0.0649 | 3.4774 | 1.8238 | 6.6188 |
| Kurtosis | 11.4404 | 16.0032 | 2.5769 | 2.0884 | 15.8314 | 7.8719 | 50.9641 |
| Jarque-Bera | 2906.41 | 6323.40 | 6.279 | 24.90 | 6256.85 | 1088.05 | 72726.31 |
| Obs | 705 | 705 | 705 | 705 | 705 | 705 | 705 |

*Note: Std. Dev. = Standard Deviation, and Obs =number of Observations. The bolded values imply significance at 5%.*
***Source: Author's Computation, 2024***

The table includes values across the entire range, from the minimum to the maximum, indicating a tendency towards a normal distribution. Skewness values are positive for all variables except total road network, while kurtosis values exceeding 3 suggest leptokurtic distributions for all variables except for road network and labour force, which exhibit platykurtic distributions (kurtosis values below 3). Jarque-Bera statistics indicate that all series are not normally distributed, with statistically significant p-values at a 5% level, rejecting the normality assumption. Therefore, the variables do not follow a normal distribution over the period studied.

Table 3 presented the correlation matrix coefficients of the dependent variable, Industrial sector productivity $(INDVA)$; independent variables, namely total investment in transport infrastructure development $(TITI)$, transport road network $(TRN)$ and the control variables such as gross capital formation $(GCF)$, labour force participation rate $(LAB)$, credit to private sector $(CRED)$, and defense spending $(DB)$ for all the fifteen (15) ECOWAS nations from the period between 1975 and 2022. The correlation among the covariate regressors is also established using the reported individual coefficient of each variable. Evidently, there is an absence of perfect correlation among the covariate regressors since the correlation matrix coefficients ranged from -0.7100 to 0.8259, which is less than 0.90. Therefore, this suggests the absence of multicollinearity among the regressors in the study.

**Table 3: Results of Correlation Matrix Coefficients**

| | INDVA | TITI | TRN | GCF | LF | CRED | DB |
|---|---|---|---|---|---|---|---|
| **INDVA** | 1.0000 | | | | | | |
| **TITI** | 0.0961 | 1.0000 | | | | | |
| **TRN** | 0.3236 | -0.5302 | 1.0000 | | | | |
| **GCF** | 0.1469 | 0.1294 | -0.0923 | 1.0000 | | | |
| **LF** | 0.0723 | -0.0291 | 0.1085 | -0.0440 | 1.0000 | | |
| **CRED** | -0.0609 | 0.0310 | -0.2365 | -0.2947 | -0.2453 | 1.0000 | |
| **DB** | -0.1116 | -0.0520 | -0.0216 | 0.1337 | 0.1205 | -0.1395 | 1.0000 |

***Source: Author's Computation, 2024***

Table 3 presented the correlation matrix coefficients of the dependent variable, industrial sector productivity (independent variables, namely total investment in transport infrastructure development and transport road network)) and the control variables, such as gross capital formation, labour force participation rate, credit to the private sector, and defence spending, for all fifteen (15) ECOWAS nations from the period between 1975 and 2022. The correlation among the covariate regressors is also established using the reported individual coefficient of each variable. Evidently, there is an absence of perfect correlation among the covariate regressors since the correlation matrix coefficients ranged from -0.7100 to 0.8259, which is less than 0.90. Therefore, this suggests the absence of multicollinearity among the regressors in the study.

A cross-sectional dependence test presented in Table 4 was estimated before estimating the model for the link between total investment in transport infrastructure, the total road network, and industrial sector productivity in ECOWAS. Cross-sectional dependence is a common statistical attribute of panel datasets, often driven by unified economic policies and financial and economic integration among countries, particularly within regions like ECOWAS. Therefore, testing for cross-sectional dependence in the variables is essential to determining the appropriate techniques for examining their relationships.

**Table 4: Cross-sectional Dependence tests**

| Variables | Bruesch-Pagan LM | Pesaran Scaled LM | Bias-corrected scaled LM | Pesaran CD |
|---|---|---|---|---|
| $IND_{VAL}$ | 2150.1640*** | 141.1297*** | 140.9667*** | 31.7376*** |
| TITI | 1927.4470*** | 125.7608*** | 125.5977*** | 21.0501*** |
| TRN | 1782.9150*** | 115.7871*** | 115.6241*** | -0.0389 |
| $GCF$ | 1378.7750*** | 87.8988*** | 87.7358*** | 28.9727*** |
| $LAB$ | 2391.1200*** | 157.7573*** | 157.5942*** | 17.0657*** |
| $CRED$ | 1386.2230*** | 88.4128*** | 88.2497*** | 22.2571*** |
| $DB$ | 1058.5840*** | 65.8035*** | 65.6405*** | 0.1571 |

***Note: *** represents statistical significance at 1%***
***Source: Author's Computation, 2024***

The study used four well-known cross-sectional dependency tests-the Breusch-Pagan LM test, the Pesaran Scaled LM test, the Bias-corrected Scaled LM tests, and the Pesaran Cross-sectional Dependence (PCD) test-to assess the degree of dependency among the ECOWAS nations in order to assure robustness. These tests' results, which are shown in Table 4, show that all variables have cross-sectional dependence, with statistical significance mostly at the 1 percent level. This result suggests that cross-sectional dependence is an important consideration for the analysis.

Further pre-test analysis was conducted to identify the variables' orders of integration (see Table 5). To verify that the series used in the analysis were stationary, a unit root test was conducted. In particular, it used robust second-generation unit root tests against cross-sectional dependence in panel data, such as the cross-sectional augmented Dickey-Fuller (CADF) test and the cross-sectional augmented lm, Pesaran, and Shin (CIPS) test. The results of the second-generation unit root test show that the variables have a mixed order of integration. Thus, the model that is most suitable for this study is Cross-sectional Autoregressive Distributed Lag (CS-ARDL) model, which is strong enough to handle mixed order of integration and robust to cross-sectional dependence in panel data.

**Table 5: Panel Unit Root Tests**

| | CIPS | | | CADF | | |
|---|---|---|---|---|---|---|
| **Variables** | **Level** | **1st Difference** | **Integ. Order** | **Level** | **1st Difference** | **Integration order** |
| INDVA | -2.5230*** | -6.0360*** | *I*(0) | -1.9850 | -2.6800*** | *I*(1) |
| TITI | -2.8340*** | -5.9570*** | *I*(0) | -1.4410 | -3.0190*** | *I*(1) |
| TRN | -2.7680*** | -4.3640*** | *I*(0) | -1.5430 | -2.2420** | *I*(1) |
| *GCF* | -2.9000*** | -5.6370*** | *I*(0) | -1.8130 | -2.8900*** | *I*(1) |
| *LF* | -1.5480 | -2.5050*** | *I*(1) | -0.5740 | -3.4280*** | *I*(1) |
| *CRED* | -1.6740 | -5.8090*** | *I*(1) | -1.4250 | -2.9410*** | *I*(1) |
| *DB* | -2.2650*** | -5.6640*** | *I*(0) | -1.2940 | -2.2380** | *I*(1) |

***Note: *******P** *< 0.01 and **P < 0.05; Critical values: -2.03, -2.11, -2.26 for 10%, 5%, and 1% significance level respectively.* ***Footnote****: cross-sectional augmented Dickey-Fuller (CADF) test and the cross-sectional augmented lm, Pesaran, and Shin (CIPS)*
***Source: Author's Computation, 2024***

This study employed both first-generation (Pedroni and Kao residual) and second-generation (Westerlund) cointegration tests to assess the possibility of a cointegrating relationship among variables with varying orders of integration. To account for potential cross-sectional dependence among the variables, these tests were chosen to investigate the existence of a cointegrating relationship. Four indicators were utilised to confirm cointegrating variables. The Pedroni residual cointegration test results revealed significant cointegration estimates across seven statistics from the panel and group strands, validating the study's conclusion of cointegrating among the variables. Additionally, the Kao residual cointegration test yielded a statistically significant t-statistic of -6.3217 at the 1% level, further supporting the existence of a cointegrating relationship. To complement the first-generation tests, the Westerlund cointegration test results demonstrated statistical significance in all four statistics, providing robust evidence of cointegration among the variables.This comprehensive analysis justifies the examination of relationships involving total investment in transport infrastructure, transport road networks, transport-induced labour accessibility, and industrial productivity across ECOWAS nations. These findings are detailed in Table 6, offering robust evidence of cointegration among the variables under investigation.

**Table 6: Panel Cointegration Tests**

| Panel A: Pedroni Residual Cointegration Test | | | |
|---|---|---|---|
| Panel Statistic | | Group Statistics | |
| Panel v-Statistics | 0.9557(0.1696) | | |
| Panel rho-Statistics | -0.7408(0.2294) | Group rho-Statistics | -0.0336(0.4866) |
| Panel PP- Statistics | -2.5362***(0.0056) | Group PP- Statistics | -2.3569***(0.0092) |
| Panel ADF- Statistics | -2.0608**(0.0197) | GroupADF- Statistics | -1.5867*(0.0563) |
| Panel B: Kao Residual Cointegration Test | | | |
| t-Statistic | -6.3217***(0.0000) | | |
| Residual Variance | 69.1233 | | |
| HAC Variance | 84.5658 | | |
| Panel C: Westerlund Cointegration test | | | |
| $G_t$ | -2.8780**(0.0400) | $P_t$ | -13.3480***(0.0000) |
| $G_a$ | -13.6870**(0.0300) | $P_a$ | -14.7300***(0. 0000) |

*Note: Values in parentheses denotes probability values. ***, **, and * represent statistical significance at 1%, 5%, and 10% respectively.*
***Source: Authors' Computation, 2024***

Table 7 presents the findings from the Cross-sectional Augmented Autoregressive Distributed Lag (CS-ARDL) technique. This technique was chosen due to the presence of cointegration, non-stationarity, and cross-sectional dependence in the series. Additionally, to evaluate causality, the panel causality test by Dumitrescu and Hurlin (2012) was utilised.

**Table 7: Result of Effects of Investment in Transport Infrastructure on Industrial Sector Productivity in ECOWAS**

| **Dependent variable:** $INDVA$ | | | | |
|---|---|---|---|---|
| **Panel A: Long-run Estimates** | | | | |
| **Variable** | **Coefficient** | **Std. Error** | **t-Stat** | **Probability** |
| $TITI$ | 1.8637** | 0.9461 | 1.97 | 0.049 |
| $GCF$ | 0.1793 | 0.1018 | 1.76 | 0.078 |
| $LF$ | -0.4010 | 1.0452 | -0.38 | 0.701 |
| $CRED$ | -0.0119 | 0.1232 | -0.10 | 0.923 |
| $DB$ | 1.2463** | 0.5522 | 2.26 | 0.024 |
| **Panel B: Short-run Estimates** | | | | |
| **Variable** | **Coefficient** | **Std. Error** | **t-Stat** | **Probability** |
| $\Delta INDVA$ | 0.0251 | 0.0425 | 0.59 | 0.555 |
| $\Delta TITI$ | 1.7669** | 0.8944 | 1.98 | 0.048 |
| $\Delta GCF$ | 0.1771 | 0.1018 | 1.74 | 0.082 |
| $\Delta LF$ | -0.3237 | 0.9757 | -0.33 | 0.740 |
| $\Delta CRED$ | -0.0425 | 0.1191 | -0.36 | 0.721 |
| $\Delta DB$ | 1.2815** | 0.5181 | 2.47 | 0.013 |
| $ECM_{t-1}$ | -0.9749*** | 0.0425 | -22.94 | 0.000 |
| **Panel C: Diagnostic test** | | **Statistic** | **Prob** | |
| RMSE | | 2.28 | 0.0000 | |

*Note: ***, **, and * represent statistical significance at 1%, 5%, and 10% respectively.*
***Source: Authors' Computation, 2024***

The findings in Panel A reveal that investment in transport infrastructure, gross capital formation, and defence spending positively impact industrial sector productivity in ECOWAS over the long term. In contrast, the labour force participation rate and credit to the private sector negatively affect industrial sector productivity in the region over the long term. (TIT= 1.8637, t-stat= 1.97, p< 0.05; and DB = 1.2463, t-stat= 2.26, p< 0.05). This implied that investment in transport infrastructure and defence spending were significant factors influencing changes in the industrial sector in ECOWAS in the long run. Conversely, labour force participation rate, gross capital formation, and credit to the private sector had insignificant effects on industrial sector productivity in ECOWAS in the long run.

(LAB= -0.4010, t-stat= -0.38, p> 0.05; GCF= 0.1793, t-stat= 1.76, p > 0.05; and CRED= -0.0119, t-stat= -0.10, p> 0.05). This implied that the labour force participation rate, gross capital formation, and credit to the private sector contributed insignificantly to the changes in industrial sector productivity in ECOWAS in the long run. The magnitudes of the estimated parameters indicate that a 1 percent increase in investment in transport infrastructure results in a 1.8637 percent increase in industrial sector productivity. A similar increase in gross capital formation leads to a 0.1793 percent increase, and a unit increase in defence spending corresponds to a 1.2463 percent increase in industrial sector productivity. Conversely, a unit increment in the level of labour force participation rate and credit to the private sector leads to a decline of 0.4010 and 0.0119 percent, respectively, in industrial sector productivity in ECOWAS over the long term.

Based on the short-run estimates, it is evident that transport infrastructure investment, gross capital formation, and defence spending have positive effects on industrial sector productivity in ECOWAS. In contrast, the productivity of the industrial sector is negatively impacted in the short term by the labour force participation rate and private sector lending. Specifically, the effect of investment in transport infrastructure and defence spending is statistically significant at the 5% level. (TITI= 1.7669, t-stat= 1.98, $p < 0.05$; and DB = 1.2815, t-stat= 2.47, $p < 0.05$). However, labour force participation rate, gross capital formation, and credit to the private sector have insignificant effects on industrial sector productivity in ECOWAS in the short run. (LAB = -0.3237, t-stat= -0.33, $p > 0.05$; GCF= 0.1771, t-stat= 1.74, $p > 0.05$; and CRED = -0.0425, t-stat= -0.36, $p > 0.05$). This suggests that the relationship between the variables remains consistent over both short-run and long-run periods.

The rate at which variables adapt to shocks and return to their equilibrium levels is shown by $ECM_{t-1}$. Generally speaking, one should anticipate a negative coefficient of $ECMt{-}1$, with an absolute value below one and statistically significant at a selected significance level of the coefficient of the error correction term ($ECM_{t-1}$-0.9749, t-stat = -22.94, $p < 0.05$) was estimated to be negative and statistically significant at the 1 percent level. This implied that deviations from the equilibrium trend of industrial productivity would be corrected by about 97 percent by the following year. In conclusion, the process of industrial productivity adjustment is proceeding at a rapid pace between 1975 and 2022. Furthermore, the significance of the error correction term coefficient, which confirms the existence of a long-run equilibrium link in the model predicted for transport road networks and industrial productivity, supports the findings of the cointegration tests shown in Table 6. The findings showed that the estimated model successfully explains the connection between ECOWAS's industrial sector productivity and transport infrastructure investment, with a comparatively low root mean square error (RMSE) of 2.28.

**Table 8: Results for Effects of Transport Road Networks on Industrial Productivity in ECOWAS Region**

| **Dependent variable:** $INDVA$ | | | | |
|---|---|---|---|---|
| **Panel A: Long-run Estimates** | | | | |
| **Variable** | **Coefficient** | **Std. Error** | **t-Stat** | **Probability** |
| $TRN$ | 0.7879** | 0.3407 | 2.31 | 0.021 |
| $GCF$ | 0.1645* | 0.0978 | 1.68 | 0.093 |
| $LF$ | 1.0743 | 0.8030 | 1.34 | 0.181 |
| $CRED$ | -0.1080 | 0.2467 | -0.44 | 0.661 |
| $DB$ | 3.4651 | 3.4276 | 1.01 | 0.312 |
| **Panel B: Short-run Estimates** | | | | |
| **Variable** | **Coefficient** | **Std. Error** | **t-Stat** | **Probability** |
| $\Delta INDVA$(-) | 0.4396 *** | 0.0569 | 7.73 | 0.000 |
| $\Delta TRN$ | 0.4508*** | 0.1767 | 2.55 | 0.011 |
| $\Delta GCF$ | 0.1326* | 0.0814 | 1.63 | 0.103 |
| $\Delta LF$ | 0.6682 | 0.4670 | 1.43 | 0.152 |
| $\Delta CRED$ | -0.0504 | 0.1187 | -0.42 | 0.671 |
| $\Delta DB$ | 1.6653 | 1.5996 | 1.04 | 0.298 |
| $ECM_{t-1}$ | -0.5604*** | 0.0569 | -9.85 | 0.000 |
| **Panel C: Diagnostic test** | | **Statistic** | **Prob** | |
| RMSE | | 5.08 | 0.0000 | |

*Note: ***, **, and * represents statistical significance at 1%, 5%, and 10% respectively.*
***Source: Authors' Computation, 2024***

According to the findings in Panel A, there is evidence indicating that transport road networks and gross capital formation exhibit positive impacts on industrial productivity. Specifically, they both demonstrated a statistically significant effect. (lnTRN = 0.7879, t = 2.31, $p < 0.05$; lnGCF = 0.1645, t = 1.68, $p < 0.10$), suggesting that these factors are significant drivers of changes in industrial sector productivity in the ECOWAS region. Conversely, credit to the private sector demonstrated a negative and insignificant effect on industrial productivity in ECOWAS in the long run (CRED = -0.1080, t = -0.44, $p > 0.05$). This implies that credit to the private sector does not significantly contribute to changes in industrial productivity in the long term. Moreover, the estimated coefficients reveal the magnitudes of these effects: a 1 percent increase in transport road network and gross capital formation corresponds to a positive change of 0.7879 percent and 0.1645 percent increase, respectively, in industrial productivity. Also, a unit increase in labour force participation rate and defence spending led to about 107.43 and 346.5 percentage increase changes, respectively, in industrial productivity. Conversely, a unit increase in credit to the private sector leads to a decrease of 10.8 percent in industrial productivity in the long run.

As displayed on Panel B, it is evident that total road network, gross capital formation, labour force, and defence spending show a positive impact on industrial productivity, while only total road network and gross capital formation have significant effects on industrial productivity (lnTRN = 0.4508, t = 2.55, p < 0.05; lnGCF = 0.1326, t-stat = 1.63, p < 0.10). Conversely, credit to the private sector has negative but insignificant effects on industrial productivity in the short run (CRED = -0.0504, t = -0.42, p > 0.05). This suggests that the relationships observed between these variables are consistent across both short-run and long-run periods. The ECT, denoted as $ECM_{t-1}$, indicates how quickly variables adjust to shocks and return to their equilibrium levels. Typically, a negative coefficient of $ECM_{t-1}$, with an absolute value less than one and statistically significant at a chosen significance level, is expected. The coefficient of the error correction term ($ECM_{t-1}= -0.5604$, $t= -9.85$, $p < 0.05$) was estimated to be negative and statistically significant at the 1 percent level. This suggests that by next year, deviations from the industrial productivity equilibrium trend will be adjusted by roughly 56 percent. In summary, from 1975 to 2022, the industrial productivity adjustment process is moving quickly. Moreover, the results of the cointegration tests presented in Table 5 are supported by the importance of the error correction term coefficient, which validates the existence of a long-run equilibrium relationship in the model estimated for transport road networks and industrial productivity.

A residual test was carried out to guarantee the accuracy and dependability of the parameter estimates and to make solid inferences from the findings. The results showed that the estimated model’s root mean square error (RMSE) is 5.08. A low RMSE score indicates that the model's ability to explain how transport road networks affect industrial productivity in the ECOWAS region is very effective. This suggests that the model fits the data well and the estimated correlations are statistically significant, which strengthens the validity of the study's findings about how transit infrastructure affects industrial production in the area.

**Table 9: The result of direction of causality among investment in transport infrastructure, total road network, and industrial Sector productivity in ECOWAS**

| | W-stat | Prob | Remarks |
|---|---|---|---|
| A: Total Investment in Transport Infrastructure and Industrial Sector Productivity | | | |
| $TITI \nRightarrow INDVA$ | $4.4642^{***}$ | 0.0000 | |
| $INDVA \nRightarrow TITI$ | $5.2722^{***}$ | 0.0000 | Bidirectional causality |
| B: Transport Road Network and Industrial Sector Productivity | | | |
| $TRN \nRightarrow INDVA$ | $3.7902^{***}$ | 0.0033 | |
| $INDVA \nRightarrow TRN$ | 3.1464 | 0.0692 | Uni-directional causality |
| C: Transport Road Network and Total Investment in Transport Infrastructure | | | |
| $TRN \nRightarrow TITI$ | 1.8947 | 0.7132 | |
| $TITI \nRightarrow TRN$ | $14.3157^{***}$ | 0.0000 | Uni-directional causality |

*Note: ***, **, and * represent statistical significance at 1%, 5%, and 10% respectively. $\nRightarrow$ represents homogenously Granger causes*

***Source: Authors' Computation, 2024***

The findings indicate several significant causal relationships: Bidirectional causation exists between investment in transport infrastructure and industrial sector productivity in the ECOWAS Region. Unidirectional causality is observed from the total road network to industrial sector productivity. Investment in transport infrastructure exhibits unidirectional causality towards the total road network in the ECOWAS region. These results underscore complex interrelationships among the total road network, labour accessibility, and industrial sector productivity within ECOWAS, providing insights into the dynamic interactions shaping economic development in the region.

## Conclusion and Policy Recommendations

The findings showed that while credit to the private sector had negative and negligible effects on industrial productivity in ECOWAS, investment in transport infrastructure, the entire road network, and gross capital formation had a positive and significant impact on industrial sector productivity. Both short-term and long-term periods show the same connections between these factors. This was consistent with research by Demetriades, Mamuneas, and Piyapong (2020). Bimba and associates (2020) Stephen et al. (2019); Castaeda and Shemesh (2000) Research conducted in a number of established and developing nations revealed that investments in road and transport infrastructure have had positive and noteworthy impacts on industrial output.

Based on the empirical findings of this study, several conclusions can be drawn. First, an assessment of current transport infrastructure across ECOWAS nations reveals a trend of declining or stagnant development between 1975 and 2022. However, the study also finds that promoting transport infrastructure development could be achieved through increased investment, given the evidence of bidirectional causality among the variables. Second, there is limited road connectivity within and between ECOWAS countries, restricting the free movement of labour and goods. Poor-quality roads significantly extend commute times, decreasing productivity and negatively impacting workers' quality of life and job satisfaction. In light of these conclusions, the study proposes the following recommendations: There should be a focus on directing more investment towards the development of new transport infrastructure to complement existing ones. ECOWAS leaders should upgrade the existing road networks to meet international standards, focusing on durability and capacity to handle increased traffic. Develop and modernise border posts with advanced facilities to improve efficiency in customs and immigration processes. Establish logistics hubs near borders to facilitate the efficient movement of goods and people across borders.

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