Published by The College of Social and Management Sciences (COSMAS), TASUED, vol. 9, no. 1, pp. 95-106.

COSMAS, TASUED
Ijagun Journal of Social and Management Sciences

The ECOWAS Region's Road Network, Transport-Induced Labour Accessibility, and Industrial Productivity

Kalejaiye, T. G.
Tai Solarin Federal University of Education
Correspondent Author: kalejaiyetg@tasued.edu.ng

Abstract
Poor road conditions and inadequate transport infrastructure increase transportation costs across economies, raising commuting expenses for workers and reducing their disposable income. These constraints limit labour mobility, restrict access to employment opportunities, and heighten the incidence of traffic accidents, thereby posing significant safety risks and further undermining workforce productivity. Against this backdrop, this study investigates the impact of road networks and transport-induced labour accessibility on industrial productivity in the Economic Community of West African States (ECOWAS). Drawing on an endogenous growth framework, the study employs a balanced panel data set covering 15 ECOWAS countries from 1975 to 2023. Data sourced from the World Development Indicators (WDI) were used to estimate Panel Granger causality and Cross-Sectional Autoregressive Distributed Lag (CS-ARDL) models, enabling robust examination of both short-run and long-run dynamics. The empirical results reveal that road network expansion and improved transport-induced labour accessibility exert positive and statistically significant effects on industrial productivity across the region in both the short and long run. Furthermore, the causality analysis indicates a unidirectional causal flow from road network development to industrial productivity, suggesting that improvements in transport infrastructure directly stimulate industrial performance. Additionally, a bidirectional feedback relationship is observed between transport-induced labour accessibility and industrial productivity, highlighting the mutually reinforcing nature of labour mobility and industrial growth. The study concludes that enhancing road infrastructure and reducing transport burdens on workers are critical for boosting industrial efficiency and competitiveness in ECOWAS. It therefore recommends that policymakers and industry stakeholders prioritise sustained investment in road networks and implement supportive measures such as subsidised public transport to strengthen labour accessibility and advance industrial development

Keywords: Road network, labour accessibility, industrial sector productivity, transport infrastructure, Cross-sectional Autoregressive Distributed Lag (CS-ARDL)

1. Introduction

One of the critical factors influencing industrial productivity in the Economic Community of West African States (ECOWAS) region is the quality of road networks and their impact on transport-induced labour accessibility. Road networks are essential for the efficient movement of people, goods, and services, and their quality directly affects workers' ability to access job opportunities. This, in turn, influences labour market dynamics and industrial productivity. A well-industrialised nation is expected to have robust infrastructure, which positively impacts the industrial sector and drives economic growth. Adequate and efficient infrastructure not only enhances the quality of life but also promotes rapid industrialization. Infrastructure development in Africa is vital for fostering economic growth, improving living standards, contributing to human development, reducing poverty, and achieving the Sustainable Development Goals-(African Development Bank, AfDB, 2018).

The expansion of transport infrastructure alters road network routes because lower travel costs affect the transport network matrix. This expansion leads to the construction of new routes and improvements to existing infrastructure, including adjustments in industrial locations and changes in land use. For instance, developing new road transit can change the network's centrality, making some areas more important due to their proximity to resources. Firms aiming to remain competitive may relocate their operations to reduce production costs or expand business opportunities. Similarly, people are more likely to move to areas with better career prospects and a variety of amenities (Fujita et al., 2001).

The quality of road infrastructure in ECOWAS varies widely, with many countries facing significant challenges in building and maintaining efficient road networks (Uduak 2014). These variances impact workers' ability to access industrial zones and urban employment centres, influencing overall productivity and economic development. Addressing these challenges is essential for fostering regional growth and improving the livelihoods of millions in the ECOWAS region. The relationship between road

Kalejaiye, T. G., (2025). The ECOWAS Region's Road Network, Transport-Induced Labour Accessibility, and Industrial Productivity, *Ijagun Journal of Social and Management Sciences (JOSMAS)*, vol. 9, no. 1, pp. 95-106.

network quality and transport-induced labour accessibility in ECOWAS is fraught with challenges that hinder optimal economic performance and industrial productivity (Uduak 2014). Many ECOWAS member countries have inadequate road infrastructure, particularly in rural areas. Poor road conditions limit workers' access to job opportunities outside major urban centres. Limited road connectivity within and between ECOWAS member countries restricts the free movement of labour and goods, vital for regional economic integration and industrial productivity. Existing roads often suffer from poor maintenance, leading to rapid deterioration. Potholes, erosion, and general disrepair make commuting challenging and time-consuming, reducing labour accessibility. Insufficient financial resources allocated to road maintenance exacerbate the deterioration of road infrastructure, affecting the reliability and efficiency of transport systems and further hindering labour mobility (Alinaitwe & Muhammad 2024).

Poor road conditions and inadequate transport infrastructure lead to higher transportation costs, burdening workers with increased commuting expenses (Venables et al., 2014). This reduces their disposable income and limits their ability to access distant job opportunities. Travelling on poor-quality roads significantly extend commute times, decreasing productivity and negatively impacting workers' quality of life and job satisfaction. Additionally, poor road conditions result in higher traffic accident rates, posing significant safety risks and discouraging longer commutes. Unsafe and unreliable transport options contribute to stress and health issues, further reducing workers' productivity and well-being World Health Organization (WHO 2022). The disparity between urban and rural road networks is stark, with urban areas typically enjoying better infrastructure. In contrast, rural areas remain underdeveloped, limiting labour mobility and access to industrial jobs for rural populations. This imbalance contributes to economic disparities, as urban areas attract more investment and development while rural areas lag, perpetuating cycles of poverty and limited economic opportunities.

Improved transport infrastructure can drive economic gains by lowering travel expenses and influencing the spatial distribution of businesses and households (Venables et al., 2014). Enhanced transport networks allow households to live closer to workplaces, saving on travel costs and enabling workers to be more productive by increasing mobility and resource access. Businesses can more easily find suitable workers, enhancing overall labour market efficiency. In the ECOWAS region, road network density is significantly lower compared to transit-developing countries and global averages (UN-OHRLLS). Since its inception in 1975, the region's road network has deteriorated, decreasing from 9.5 km in 1985 to 4 km in 2020 (World Bank, 2021). This decline has severely impacted the industrial sector and overall economic growth in the region.

2. Literature review

The concept of transport infrastructure as a catalyst for labour mobility and productivity has been widely examined across empirical literature. Stephen et al. (2019) conceptualise newly constructed highways as a transformative element that reshapes the spatial relationship between workers and firms. They argue that improved road networks reduce commuting time, expand workers' feasible job-search radius, and stimulate business activity within connected regions. Their study relies implicitly on endogenous growth perspectives that link infrastructure improvements to productivity through knowledge spillovers and firm reorganisation. Their work also aligns with spatial economic theory, which posits that improved accessibility encourages firm clustering and market expansion. The study employed firm-level data and use road network expansion as an exogenous proxy for transportation improvements, estimating variations in minimum home-to-work travel times. Their findings reveal a strong positive impact of newly built highways on employment levels and the performance of local businesses, with evidence that improved roads attract transport-intensive firms and compel existing firms to reorganise production processes.

Na et al. (2011) interpreted road infrastructure as a structural component that enhances labour market functioning by facilitating worker mobility, reducing search frictions, and improving the efficiency of matching processes between employers and employees. They highlight the network externalities embedded in highway systems, where connectivity extends productivity gains beyond localised regions. The study applied infrastructure-led growth principles, suggesting that transport networks enhance human capital utilisation and labour productivity through reduced transaction costs and increased mobility. The study used panel data from 19 OECD countries over 17 years (1990–2006) to estimate multiple econometric models incorporating dependent, independent, and control variables. Their results demonstrate that highway network expansion significantly enhances labour productivity per worker and is positively correlated with employment activity across OECD nations.

Some studies in the literature also attribute the performance of the industrial sector to total road infrastructural development. The effect of road infrastructure and labour accessibility on manufacturing sectors in Mexico was examined by Castaeda and Shemesh (2000), the study, which covered the 25-year period from 1993 to 2018, used an autoregressive distributed lag (ARDL). It found that a 10% increase in road transport infrastructure will increase manufacturing productivity by 0.62% to 0.96%; the immediate effect may be small, but the long-term impact will be greater. Sun (2018) examined the impact of transport infrastructure on industrial structure in China from 2005 to 2018. Panel data from 31 Chinese provinces and cities was used; a benchmark panel regression model was established; and a dynamic panel model with hysteresis effects was introduced. The results showed that roads have a clear driving effect on secondary industry, but railways have a stronger driving effect. In terms of the control factors, the degree of economic development, the level of human capital, and the pace of urbanization considerably favour the tertiary industry while significantly harming the primary sector. Andreas (2003) investigated how road infrastructure affects growth and productivity. Cross-sectional time series data from the manufacturing sector between 1970 and 1993 was used in the analysis. The results suggest that it is less important to understand how infrastructure affects productivity when considering structural changes over time. The outcome showed how crucial road infrastructure is to industrial production. Antle (2003) found a strong and positive relationship between infrastructure quality and total production, in examined the Cobb Douglas production function for 19 developed countries and 47 developing countries. The quantity of infrastructure created per square kilometer of land was used to define the gross national product (GNP) from the transportation and communication sectors.

Some few studies on road network and infrastructure development on industrial sector productivity yielded a variety of findings. Nadabo (2023), Chukwuebuka, and Jisike, (2020) Akekere, et al., (2017), Ogwso and Agu (2016), and discovered that total road network has a negative effect on industrial sector productivity. For instance, Nadabo (2023) used autoregressive distributed lag (ARDL) to examine the impact of institutional quality on the connection between infrastructure development and manufacturing sector performance in Nigeria from 2002 to 2021. The results show that institutional quality on infrastructure development in Nigeria has a negative impact on the manufacturing sector's performance over the long and short term. Similarly, Chukwuebuka, and Jisike, (2020) studied the relationship between industrial sector productivity and infrastructure development in Sub-Saharan Africa. A panel data collection of 17 nations from 2003 to 2018 was used in the study. The panel least squares estimation method was used to analyze the relationships between the variables. The results reveal that the key determinants affecting industrial sector productivity in Sub-Saharan Africa are the quantity and quality of road network and telecommunications infrastructure in that region. The findings indicate that Sub-Saharan Africa's relatively poor industrial sector productivity is mostly due to the region's subpar energy and transport infrastructure, as well as its underutilization of its water supply and sanitation facilities.

Azolibe and Okonkwo (2020) studied the relationship between industrial sector productivity and infrastructure development in Sub-Saharan Africa. A panel data collection of 17 nations from 2003 to 2018 was used in the study. The panel least squares estimation method was used to analyze the relationships between the variables. The results reveal that the key determinants affecting industrial sector productivity in Sub-Saharan Africa are the quantity and quality of telecommunications infrastructure in that region. The findings indicate that the transport infrastructure effect is insignificantly related to industrial sector growth in Sub-Saharan Africa because the region recorded the least transport infrastructure development in terms of road and railroad densities compared to other developing nations in the world. Similarly, Also, Akekere, et al., (2017) analysed Nigeria's governmental infrastructure spending and growth in industrial output. The findings revealed that, on the one hand, there are several correlations between the growth of the industrial sector and public capital infrastructure as measured by the infrastructure development index, human capital development as evaluated by the human development index, and the inflation rate. The wide money supply and exchange rate, on the other hand, were found to have a positive correlation with the growth of the industrial sector in the frameworks. Thus, it can be concluded that Nigeria's infrastructure has a negative impact on the development of the industrial sector. This finding demonstrates that infrastructure accessibility or quality had little impact on industrial expansion.

Stephen (2017) looked at the impact of industrial sector productivity on public infrastructure capital in Nigeria. Co-integration was used in the study to support the existence of linkages, and the results showed that, on the one hand, the expansion of the industrial sector is negatively correlated with public capital infrastructure as measured by the infrastructure development index, human capital development as measured by the human development index, and the inflation rate. The outcome demonstrates that infrastructural accessibility or quality had no bearing on industrial expansion.

Ogwo and Agu (2016) studied the impact of Nigeria's manufacturing enterprises' performance on the availability of transport infrastructure. Both primary and secondary data were used in the study, with the primary data coming from certain manufacturing enterprises that operate in the nation and how their performance status influences the GDP of the nation. According to the result, Nigeria's sub-standard road infrastructure negatively affects the marketing performance of the manufacturing industry, including sales and profitability. Nigeria's quality of road infrastructure has great effect on the use of industrial capacity and has insignificant effect on the manufacturing production index. Once more, how much the industrial and transportation sectors contribute to the development of the nation depends greatly on the annual budgetary allocation to the transportation sector. Mesagan and Ezeji (2016) studied how Nigeria's manufacturing industry performed in relation to its social and economic infrastructure. Considering the autoregressive distributed lag (ARDL) model. The result shows that while ICT and the Toda-Yamamoto causality test had a positive impact on manufacturing performance, electricity and road had a minimal negative impact on manufacturing value added. According to the report, this is true for middle-income countries. ICT significantly and favourably affects industrial production.

This study used cross-sectional augmented autoregressive distributed lag (CS-ARDL) models to underscore the effect of road networks and transport-induced labour accessibility on industrial productivity in the ECOWAS region. This method is the novelty in this study as previous panel studies ignored cross-sectional dependencies among their chosen variables. Based on this method, this study examined the relationship between total road network and industrial sector productivity in the ECOWAS region, the relationship between transport-induced labour accessibility and industrial productivity in ECOWAS region and identified the direction of causality among the total road network, transport-induced labour accessibility, and industrial productivity in the ECOWAS region

3. Methodology

In examining the role of investment in transport infrastructure on industrial productivity in the ECOWAS region, this study is grounded in endogenous growth theory. This theory posits that improvements in innovation, knowledge, and human capital drive increased productivity, thereby positively influencing economic growth. Following the framework established by Mankiw et al. (1992), the analysis is specified as follows:

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

where Y_i is the output, K_i is the capital, L_i is the Labour and A is the level of technological progress.

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

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

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

The below equation 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.

$$gy = g + n \quad (4)$$

Expanding the theoretical framework to encompass the dynamic relationship between transportation infrastructure and industrial productivity in ECOWAS, this study adapts the model used by Chukwuebuka and Jisike (2020). In their model, transportation infrastructure serves as the independent variable, while industrial value added is the dependent variable. The functional form of the model is as follows:

$$INDV_{it} = f(TRN_{it}; TILA_{it}; V_{it}) \quad (5)$$

In this study, industrial productivity was measured with data on industry value added, as in Chen and Golley (2014), Chenry (1960), and Sveikauskas et al. (2018). Also, total road network was measured by the entire road network in kilometres (per square kilometre of arable land); then, transport-induced labour accessibility was calculated by using the labour force divided by total investment in transport infrastructure and is a vector of control variables such as gross capital formation, labour force participation rate, credit to the private sector, and defence budget, as used in Chukwuebuka and Jisike (2020). These variables were used for three objectives in this study. The first objective is the relationship between total road network and industrial sector productivity in the ECOWAS region, and the model is specified below:

$$INDV_{it} = f(TRN_{it}; GCF_{it}; LAB_{it}; CRED_{it}; DB_{it}) \quad (6)$$

The semi-log-linear form of the model is specified as;

$$InINDV_{it} = \beta_0 + \beta_1 InTRN_{it} + \beta_2 InGCF_{it} + \beta_3 LAB_{it} + \beta_4 CRED_{it} + \beta_5 DB_{it} \quad (7)$$

In this model, $InINDV_{it}$ represents the log of industrial value added for country i in period t. $InTRN_{it}$ is the log of the total road network, measured by the total length of roads per square kilometre of arable land for country i in period t. $InGCF_{it}$ denotes the log of gross capital formation for country i in period t. LAB_{it} represents the labour force, a critical component for producing goods and services in country i in period t. The labour force participation rate (percentage of the total population ages 15+) will be used as a proxy for the labour force. $CRED_{it}$ is the credit to the private sector as a percentage of GDP for country i in period t. According to Olowofeso et al. (2015), credit to the private sector includes financial resources provided to the private sector, such as loans, advances, purchases of non-equity securities, trade credits, and other accounts receivable, which establish a claim for repayment. Adequate credit to the industrial sector will enhance investment and productivity, and vice versa. For this study, the ratio of credit to the private sector to GDP was used as a measure of credit to the private sector. DB_{it} represents the defence budget as a percentage of GDP for country i in period t. This refers to government expenditure on defence, which is crucial for creating a conducive environment free from internal and external aggression, thereby ensuring the safety of investments and boosting industrial productivity. The ratio of government expenditure on defence to GDP was used as a proxy for the defence budget.

The second objective investigates the relationship between transport-induced labour accessibility and industrial productivity in ECOWAS region with specified model in Equation (8).

$$INDV_{it} = f(TILA_{it}; CRED_{it}; GCF_{it}; DB_{it}) \quad (8)$$

The semi- log-linear form of the model is specified as:

$$InINDV_{it} = \beta_0 + \beta_1 TILA_{it} + \beta_2 InGCF_{it} + \beta_3 LAB_{it} + \beta_4 CRED_{it} + \beta_5 DB_{it} + \mu_{it} \quad (9)$$

In this model, $InINDV_{it}$ represents the log of industrial productivity, measured using the industry value-added of country i in period t. $TILA_{it}$ denotes transport-induced labour accessibility, which is measured by calculating the transport-induced labour accessibility indicator of the integral index. This integral indicator reflects the total transport costs and is calculated using the

$$Transport - induced\ Labour\ accessibility_{it} = \sum_k \frac{LF_{it}}{InTITI_{it}} \quad (10)$$

where $Transport - induced\ Labour\ accessibility_{it}$ is defined as LAB_{it} is the total labour force of country *i* over period *t*; divided by $InTITI_{it}$ is log of total investment in transport infrastructure (Lee 2019 and lavrinenko et al., 2019).

The third objective identified the direction of causality among the total road network, transport-induced labour accessibility, 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 covariance-stationary 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:

$$y_{it} = \omega_i + \sum_{k=1}^{k} y^{(k)} y_{it-k} + \sum_{k=1}^{k} \beta^{(k)} x_{it-k} + \varepsilon_{it}$$

$$i = 1, \ldots\ldots\ldots\ldots N,\ t = 1, \ldots\ldots. T \quad (11)$$

where ω_i represents the constant influence of the individual and coefficients $Y^{(k)}$ and $\beta^{(k)}$ are expected to be constant throughout the board. The hypothesis for the suggested Granger test is:

$$H_0 : \beta^{(1)} = \beta^{(2)} = \beta^{(k)} = 0 \quad (12)$$

In this study, attempts were made to determine whether total road network and transport-induced labour accessibility determine or influence industrial productivity in ECOWAS or vice versa. Thus, the model is specified in Equations (13), (14) and (15).

For a given country (i) at a given time (t), the variables stand for industrial productivity, the entire road network, and labour accessibility induced by transportation. The error term, denoted by ε, has a zero mean and is serially uncorrelated. The speed of adjustment is also ∅. To illustrate the constant drifting, use β_{1i}. More significantly, the panel causality test for the chosen sample nations in this study is determined using simultaneous equations (13), (14), and (15).

3.1 Data description

All the 15 ECOWAS members, Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo, were represented in this study's panel data. The ECOWAS countries were chosen because the region is classified as low and middle-income due to its pervasive lack of infrastructure and diminishing industrial productivity.

The measured variables included industrial sector productivity (INDV), assessed using industry value-added data. The total road network (TRN) was measure in per square kilometre of arable land. Transport-induced labour accessibility (TILA) was evaluated by calculating the transport-induced labour accessibility indicator of the integral index. Furthermore, V is a vector of control variables, containing the following: the stock of private capital employed in production, expressed as an annual percentage growth rate, is known as gross capital formation (GCF). Total labour force participation rate, represented as a percentage of the population over the age of 15, is what defines labour force participation (LAB). Credit to the Private Sector (CRED): Calculated as the GDP (gross domestic products) divided by the credit to the private sector. Defence Budget (DB): The amount allotted by the government to defence spending as a percentage of GDP. The data used for the analyses was sorted from the World Development Indicators (WDI).

3.2 Estimation technique

This study employs a rigorous, three-stage econometric methodology, comprising pre-estimation diagnostics, actual model estimation, and post-estimation validation to investigate the complex relationship between transport infrastructure and industrial productivity across the Economic Community of West African States (ECOWAS). First, the study 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, it performed correlation analyses to avoid issues with multicollinearity (when variables are highly correlated). The study then employed panel unit root tests to see if the data had 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, we applied a specific model called the Cross-sectional Augmented Autoregressive Distributed Lag (CS-ARDL) model. This model was used to predict how changes in transport infrastructure would affect industrial productivity across the 15

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$$lnINDV_{it}= \beta_{1i}+ \sum_{k=1}^{k} \partial_{11i}\, lnINDV_{it-1}+ \sum_{k=1}^{k} \partial_{12i}\, InTRN_{it-1}+ \sum_{k=1}^{k} \partial_{13i} TILA_{it-1} + \varepsilon_{1t} \quad (13)$$

$$InTRN_{It}= \beta_{2i}+ \sum_{k=1}^{k} \partial_{21i}\, InTRN_{it-1}+ \sum_{k=1}^{k} \partial_{22i}\, TILA_{it-1}+ \sum_{k=1}^{k} \partial_{23i}\, InINDV_{it-1}+ \varepsilon_{2t} \quad (14)$$

$$TILA_{it} = \beta_{3i}+ \sum_{k=1}^{k} \partial_{31i}\, TILA_{it-1}+ \sum_{k=1}^{k} \partial_{32i}\, InTRN_{it-1}+ \sum_{k=1}^{k} \partial_{33i} InINDV_{it-1}+ \varepsilon_{3t} \quad (15)$$

Table 1: Descriptive Statistics (Source: Authors' Computation)

Variables	INDVA	TRN	TILA	LF	GCF	CRED	DB
Mean	38.0143	4.2061	0.0191	49.6165	54.5874	14.6325	1.7411
Maximum	253.7166	5.2887	0.1285	79.2900	515.6162	73.1921	29.7277
Minimum	3.4067	3.0414	0.0017	23.8550	5.3539	0.0000	0.0087
Std. Dev.	36.4500	0.5645	0.0184	13.5441	83.8012	11.3264	2.8718
Skewness	2.6316	-0.0932	2.6414	0.0649	3.4774	1.8238	6.6188
Kurtosis	11.4404	2.5769	11.5187	2.0884	15.8314	7.8719	50.9641
J-B	**2906.4070**	**6.2792**	**2951.4890**	**24.9038**	**6256.8470**	**1088.0510**	**72726.3100**
Probability	(0.0000)	(0.0000)	(0.0433)	(0.0112)	(0.0013)	(0.0002)	(0.0000)
Obs	705	705	705	705	705	705	705

Note: Std. Dev.= Standard Deviation, and Obs=number of Observations. The bolded value implies significance at 5%.

ECOWAS countries. To assess the accuracy of the model's predictions, the root mean square error (RMSE) was estimated. A lower RMSE indicates a more effective model

4. Results and Discussion of Findings

4.1. Descriptive Statistics

Table 1 summarises the data used in the study. It provides key descriptive statistics for various variables, including mean (average) standard deviation, skewness and kurtosis, and Jarque-Bera statistics. The table presents industrial sector productivity (INDVA). The main outcome variable of the study seeks to understand total road network (TRN) and transport-induced labour accessibility (TILA) that might influence industrial productivity. Control variables: factors potentially affecting industrial productivity, such as gross capital formation (GCF), labour force participation rate (LAB), credit to the private sector (CRED), and defence budget (DB).

4.2. Correlation Analysis

Table 1 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 2 displays the correlation matrix coefficients for industrial productivity (INDVA) as the dependent variable and independent variables including total road network (TRN) and transport-induced labour accessibility (TILA), alongside control variables: gross capital formation (GCF), labour force participation rate (LAB), credit to the private sector (CRED), and defence spending (DB). The correlation analysis revealed that the covariate regressors exhibit varying degrees of correlation, as indicated by the coefficients ranging from -0.7100 to 0.8259. None of the correlation coefficients reach 0.90, indicating the absence of perfect multicollinearity among the regressors. This suggests that the variables are sufficiently independent from each other in the regression analysis.

4.3 Cross-sectional Dependence Test

A cross-sectional dependence test presented in Table 3 was estimated before estimating the model for the link between total investment in transport infrastructure, the transport road network, transport-induced labour accessibility, 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.

4.4. Panel Cointegration tests

The study employed four different tests to check for cross-sectional dependence. These tests are the Breusch-Pagan LM, Pesaran Scaled LM, and Bias-corrected Scaled LM Pesaran Cross-sectional Dependence (PCD) tests. The results indicate all the variables significantly depend on each other at the 1% level. This means the economies of the countries in the study are interconnected and should be considered as a group when analysing their industrial productivity.

Table 2: Correlation Matrix Coefficients (Source: Authors' Computation)

	INDVA	TRN	TILA	GCF	LF	CRED	DB
INDVA	1.0000						
TRN	0.3236	1.0000					
TILA	0.2165	0.8259	1.0000				
GCF	0.1469	-0.0923	-0.0231	1.0000			
LF	0.0723	0.1085	-0.0597	-0.0440	1.0000		
CRED	-0.0609	-0.2365	-0.1005	-0.2947	-0.2453	1.0000	
DB	-0.1116	-0.0216	-0.0644	0.1337	0.1205	-0.1395	1.0000

Table 3: Cross-sectional dependence Results (Source: Authors' Computation)

Variables	Bruesch-Pagan LM	Pesaran Scaled LM	Bias-corrected scaled LM	Pesaran CD
INDVA	2150.1640***	141.1297***	140.9667***	31.7376***
TRN	1782.9150***	115.7871***	115.6241***	-0.0389
TILA	2534.5840***	167.6573***	167.4942***	26.1733***
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%. Lagrange Multiplier (LM); CD; Cross-sectional Dependence

Further pre-test analysis was conducted to identify the variables' orders of integration (see Table 5). It is imperative to evaluate the stationarity of the time series prior to conducting the main analysis. 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 Im, Pesaran, and Shin (CIPS) test. The results of the second-generation unit root tests show that the variables have a mixed order of integration. Thus, the model that is most suitable for this study is the 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.

4.5 Cross-sectional Augmented Autoregressive Distributed Lag Tests

This study used both first-generation (Pedroni and Kao residual) and second-generation (Westerlund) cointegration tests to evaluate the possibility of cointegration among variables with varied orders of integration. Taking into account any potential cross-sectional dependence among the variables, these tests were selected to look into the existence of a cointegrating relationship. Four indicators were used as statistical significance at the 1% level to confirm cointegrating variables. The Pedroni residual cointegration test results show significant cointegration estimates across seven statistics from the panel and group strands. This validates the study's conclusion that the variables are cointegrated. A statistically significant t-statistic of -6.3217 was also obtained at the 1% level using the Kao residual cointegration test, which further supported the existence of a cointegrating relationship between the variables. In addition to the first-generation tests, the Westerlund cointegration test results show that all four statistics are statistically significant, indicating robust evidence of cointegration among the variables. This comprehensive analysis supports 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 5, providing robust evidence of cointegration among the variables examined.

Table 6 presents the findings from the Cross-sectional Augmented Autoregressive Distributed Lag (CS-ARDL) technique. The pre-test analyses necessitate the choice of technique used for this study. Panel A of Table 6 indicates significant findings regarding the effects of various factors on industrial productivity over the long run. 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.

4.6 Cross-sectional Augmented Autoregressive Distributed Lag Tests on effects of transport-induced Labour accessibility on industrial sector Productivity in ECOWAS Region

In contrast, credit to the private sector demonstrated negative and insignificant effects on industrial productivity in ECOWAS in the long run (CRED = -0.1080, t = -0.44, $p > 0.05$). This implies that while this factor is included in the model, it does not significantly contribute to changes in industrial productivity in the long term. This could be as a result of inadequate credit assessment mechanisms or a lack of access to credit for small and medium-sized enterprises (SMEs) in ECOWAS, which can limit the benefits of credit. Firms might struggle to access the necessary funds or face stringent borrowing conditions. If credit is not efficiently allocated, it may not reach the most productive or innovative firms. Poor credit allocation

Table 5: Panel Cointegration Results (Source: Authors' Computation)

Panel A: Pedroni Residual Cointegration Test			
Panel Statistics		**Group Statistics**	
Panel v-Statistics	0.9557(0.1696)		
Panel rho-Statistic	-0.7408(0.2294)	Group rho-Statistic	-0.0336(0.4866)
Panel PP-Statistic	-2.5362***(0.0056)	Group PP-Statistic	-2.3569***(0.0092)
Panel ADF-Statistic	-2.0608**(0.0197)	Group ADF-Statistic	-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 the parentheses denote probability values. ***, **, and * represents statistical significance at 1%, 5%, and 10%, respectively.

Table 6: Results for Effects of Transport Road Networks on Industrial Productivity in ECOWAS Region (Source: Authors' Computation)

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
ΔTRN	0.4508***	0.1767	2.55	0.011
ΔGCF	0.1326*	0.0814	1.63	0.103
ΔLF	0.6682	0.4670	1.43	0.152
$\Delta CRED$	-0.0504	0.1187	-0.42	0.671
ΔDB	1.6653	1.5996	1.04	0.298
ΔECM_{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.

can result in funds being used for less productive purposes, thereby not enhancing overall industrial productivity. 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. This means a higher labour force participation rate means more individuals are working or actively seeking employment. This enlarges the pool of labour available for industrial activities, potentially leading to higher production levels and productivity. If the increase in labour force participation involves skilled workers, productivity could increase dramatically due to better utilization of human capital. Skilled workers can operate machinery more efficiently, innovate processes, and contribute to higher output and defense spending often leads to advancements in technology and infrastructure, which can spill over into the civilian industrial sector. Innovations in materials, electronics, and manufacturing processes developed for defense purposes can be applied to industrial production, significantly boosting productivity. Conversely, a unit increase in credit to the private sector leads to a decrease of 10.8 percent in industrial produ4.6 Cross-sectional Augmented Autoregressive Distributed Lag Tests on effects of transport-induced Labour accessibility on industrial sector Productivity in ECOWAS Region.

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 suggested that by next year, deviations from the industrial productivity equilibrium trend are adjusted by roughly 56 percent. In summary, from 1975 to 2023, 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.

The pre-test analyses necessitate the choice of technique used for this study. Panel A of Table 6 indicates significant findings regarding the effects of various factors on industrial productivity over the long run. 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.

The result of the second objective is presented in Table 7. It is evident that transport-induced labour accessibility, gross capital formation, and defence spending exhibit positive impacts on industrial sector productivity, while only transport-induced labour accessibility has a significant effect on industrial productivity in the long run (TILA = 1997.468, t = 1279.16, $p < 0.05$). This suggests transport-induced labour accessibility is a significant factor influencing changes in industrial sector productivity in the long term.

In contrast, credit to the private sector demonstrated negative and insignificant effects on industrial productivity in the long run among ECOWAS countries. (CRED = -0.0003, t = -0.36, $p > 0.05$). Also, gross capital formation and defence budgets demonstrated insignificant effects on industrial sector productivity. This implies that while these factors are included in the model, they do not significantly contribute to changes in industrial productivity in the long term. Moreover, the estimated coefficients reveal the magnitudes of these effects: A 1 unit increase in transport-induced labour accessibility and defence spending will lead to an increase of about 199.75 and 0.4 percentage change increase, respectively in industrial productivity. However, a percentage increase in gross capital formation corresponds to a positive change of 119.86 percent increase in industrial productivity. Conversely, a unit increase in credit to the private sector leads to decreases of 0.03 percent in industrial productivity in the long run.

4.7 Causality Tests

From the short-run estimates, gross capital formation and defence spending continue to exhibit a positive impact but an insignificant effect on industrial productivity, while transport-induced labour accessibility has a positive and significant effect on industrial sector productivity in ECOWAS (TILA = 1996.132, t = 1303.78, $p < 0.05$). Conversely, credit to the private sector has a negative and insignificant effect on industrial sector productivity in the short run (CRED = -0.0003, t = -0.36, $p > 0.05$). This consistency in relationships across both short-run and long-run periods suggests robustness in the model's findings.

In addition, the estimated coefficient of the error correction term (ECM_{t-1}) is negative and statistically significant at the 1 percent level ($ECM_{t-1} = -0.9993$, t = -3123.78, $p < 0.01$). This indicates that deviations from the equilibrium path of industrial sector productivity are corrected by approximately 99 percent within the following year. Hence, the adjustment process for industrial sector productivity in ECOWAS was rapid during the period from 1975 to 2023. Furthermore, the statistical significance of the error correction term coefficient affirms the presence of a long-run equilibrium relationship in the model estimated for transport-induced labour accessibility and industrial sector productivity, aligning with the findings from the cointegration tests reported in Table 5.

The estimated model's root mean square error (RMSE) is 0.02. A low RMSE score indicates that the model does a very good job of understanding the connection between labour accessibility brought about by transportation and industrial sector production in ECOWAS. This suggests that the estimated model fits the data precisely, supporting the validity of its

Published by The College of Social and Management Sciences (COSMAS), TASUED, vol. 9, no. 1, pp. 95-106.

Table 7: Results for effects of transport-induced Labour accessibility on industrial sector Productivity in ECOWAS Region (Source: Authors' Computation)

Dependent variable: INDVA				
Panel A: Long-run Estimates				
Variable	**Coefficient**	**Std. Error**	**t-Stat**	**Probability**
TILA	1997.46***	1.5616	1279.16	0.000
GCF	119.86	107.887	1.11	0.267
CRED	-0.0003	0.0009	-0.36	0.720
DB	0.0040	0.0058	0.70	0.482
Panel B: Short-run Estimates				
Variable	**Coefficient**	**Std. Error**	**t-Stat**	**Probability**
$\Delta INDVA$	0.0007**	0.0003	2.09	0.037
$\Delta TILA$	1996.13***	1.5310	1303.78	0.000
ΔGCF	119.87	107.81	1.11	0.266
$\Delta CRED$	-0.0003	0.0009	-0.36	0.719
ΔDB	0.0041	0.0058	0.71	0.480
ECM_{t-1}	-0.9993 ***	0.0003	-3123.78	0.000
Panel C: Diagnostic test		**Statistic**	**Prob**	
RMSE		0.02	0.0000	

Note: ***, **, and * represents statistical significance at 1%, 5%, and 10%, respectively.

Table 8: The result for direction of causality among total road network, transport-induced labour accessibility, and industrial sector productivity in ECOWAS Region (Source: Authors' Computation)

	W-stat	**Prob**	**Remarks**
A: Transport Road Network and Industrial Sector Productivity			
$TRN \nRightarrow INDVA$	3.7902***	0.0033	
$INDVA \nRightarrow TRN$	3.1464	0.0692	Uni-directional causality
B: Transport-Induced Labour Accessibility and Industrial Sector Productivity			
$TILA \nRightarrow INDVA$	4.3697***	0.0000	
$INDVA \nRightarrow TILA$	5.2398***	0.0000	Bidirectional causality
C: Transport-Induced Labour Accessibility and Transport Road Networks			
$TILA \nRightarrow TRN$	9.9286***	0.0000	
$TRN \nRightarrow TILA$	1.4797	0.2749	Uni-directional causality

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

conclusions on how labour accessibility caused by transportation affects productivity in the region's industrial sector.

The result for the third objective is presented in Table 8. The causal relationship analysis between total road network, transport-induced labour accessibility, and industrial sector productivity in ECOWAS utilised the Dumitrescu and Hurlin (2012) panel causality test.

The findings indicate several significant causal relationships: Bidirectional causation exists between transport-induced labour accessibility and industrial sector productivity in the ECOWAS Region. Unidirectional causality is observed from the total road network to industrial sector productivity. Transport-induced labour accessibility 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.

4.8 Discussion of Results

Based on the results, the productivity of the industrial sector was positively impacted and significantly affected by the entire road network and gross capital formation, while credit to the private sector exhibited negative and insignificant effects on industrial productivity in the ECOWAS. The results implied that while transportation road network, gross capital formation defence budget and labour force participation rate are determinants of positive changes in industrial sector productivity, credit to the private sector undermined the productivity of the industrial sector in ECOWAS in the short-run and long-run periods.

This was in line with the study conducted by Sun (2018), Antile (2003), Chukwuebuka and Jisike (2020), and Andreas (2003). Several developed and developing countries investigated found that road transport infrastructure has demonstrated beneficial and significant effects on industrial productivity. Similarly, some studies, on the other hand, admitted that road network and infrastructure development had contributed insignificantly to the expansion of the industrial sectors in developing countries (Nadabo, 2023; Azolibe and Okonkwo, 2020; Akekere et al., 2017; Stephen, 2017; Ogwo and Agu, 2016; and Mesagan and Ezeji, 2016).

Both short-term and long-term assessments revealed favourable and significant effects of worker accessibility caused by transportation on industrial sector productivity. On the other hand, in both the short and long terms, credit to the private sector had negative and insignificant effects on industrial sector productivity. The results implied that while transport-induced labour accessibility, gross capital formation is a significant determinant of positive changes in industrial sector productivity, credit to the private sector caused a decline in the productivity of the sector in ECOWAS in the short-run and long-run periods. These findings suggest that labour accessibility serves as one of the significant tools that determine the productivity of the industrial sector in ECOWAS. This study is in line with the findings from Jae et al. (2019), Castaeda and Shemesh (2000), Stephen et al. (2019), and Na et al. (2011). Notably, this study is unique in its comprehensive examination of the relationship between total road networks, transport-induced labour accessibility, and industrial sector productivity spanning from the establishment of ECOWAS in 1975 to 2023, potentially contributing to the divergence in findings compared to existing literature.

5 Conclusion and Recommendations

Considering the empirical results of this investigation, some conclusions were drawn regarding the state of transport infrastructure and its impact on industrial sector productivity in ECOWAS countries. It was observed that there is limited road connectivity within and between ECOWAS countries, which restricts 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. However, the study also concluded that transport-induced labour accessibility can undermine the potential growth capacity of the industrial sector because of inaccessibility of skilled labour to industrial sector productivity.

In light of the conclusions, the study proposes the following recommendations: Once total road network and transport-induced labour accessibility are contributing factors to industrial sector productivity, 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. Standardise customs procedures and harmonise tariffs across ECOWAS member states to simplify cross-border trade. Implement uniform transport policies and regulations to ensure smooth transit of vehicles across borders.

To mitigate transport-induced labour accessibility challenges, the government should provide subsidies for public transport to enhance affordability and accessibility for workers, enabling them to commute to job locations despite poor road conditions. Prioritise quick-fix road improvements on critical sections of the network, especially routes leading to major employment centres. Collaborate with private sector entities to develop transportation infrastructure and services, such as company-run shuttle services for employees. To promote bi-directional causality between industrial sector productivity and road network development, governments of ECOWAS member nations should facilitate access to funds through monetary institutions to encourage investment in productive activities within the industrial sector, thereby fostering beneficial outcomes for the transport industry. These recommendations aim to address the identified challenges and capitalise on opportunities to enhance the transport road network and improve industrial sector productivity across ECOWAS member countries. By implementing these measures, policymakers can foster economics with a view to enhancing the transport road network and raising industrial sector productivity throughout ECOWAS member nations.

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