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Impact of Water and Air Transportation on Agricultural Output in Nigeria: 1990 to 2024

Isaac Batiyak Usman[1], John Aiyedogbon[2], Sunday Emmanuel Ologunla[3], Nelson Christopher[4], Nkwocha Ikenna[5], Anju Nenge Julius[6]

[1,2,3,4]Bingham University, Nasarawa State, Nigeria; [5]University of Jos, Plateau State, Nigeria
[6]Nasarawa State University, Nigeria
abaranzan@gmail.com; join.aiyedogbon@binghamuni.edu.ng

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Abstract

Transportation supports agricultural production and farmers' livelihoods by facilitating the movement of goods and people. This study examined the relationships between water transportation, air transportation, and agricultural output in Nigeria from 1990 to 2024. Secondary data were analyzed using descriptive statistics, the Augmented Dickey–Fuller test, an autoregressive distributed lag (ARDL) model, and an error correction model. Air and water transportation became stationary after first differencing, whereas agricultural output remained nonstationary in the reported tests. Descriptive statistics indicated substantial variability and leptokurtosis in agricultural output, while water transportation exhibited distributional characteristics closer to normality. The ARDL(3,4,0) model, estimated over 1994–2024, showed positive and statistically significant associations between air transportation and agricultural output through contemporaneous and lagged terms. Water transportation was negatively associated with agricultural output. The model yielded a high coefficient of determination (R^2 = .999), while the significant negative error correction coefficient of −0.63 suggested adjustment toward the estimated long-run equilibrium. However, the unresolved integration order of agricultural output warrants caution in interpreting the long-run estimates. Overall, the findings identify contrasting relationships between transportation modes and agricultural output, providing evidence to inform transport infrastructure policy. The study recommends increased government expenditure on

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maintaining air and water transportation networks to facilitate the movement of agricultural goods and passengers and support agricultural development.

Keywords: Agricultural Output; Air Transportation; Water Transportation; Autoregressive Distributed Lag; Nigeria

INTRODUCTION

About 60% of Nigerians rely on agriculture for their livelihoods, and the sector produces almost 90% of the nation's food and fiber. The industry contributes to food security, industrial raw materials, foreign exchange, and income production through both cash crops (like cocoa and palm oil) and staples (like yam, maize, and rice). However, insufficient infrastructure causes around 25% of output to be lost, limiting agricultural productivity. By connecting producing areas to markets, minimizing post-harvest losses, and reducing operating expenses, efficient transportation—particularly air and water—increases productivity and promotes rural development. Through lower trade prices, market integration, and better logistics, transportation quality has an impact on agricultural output globally. From pre-colonial routes to colonial railroads, highways, and canals, Nigeria's transportation network has developed over time. Today, it includes contemporary airports and seaports that help distribute agricultural products. Whereas rural and riverine regions rely on boats and ferries, urban areas use taxis, buses, and airplanes for transportation. Transportation makes a significant contribution• GDP Contribution from the agriculture Sector: Nigeria's agriculture sector expanded by 1.76% in the fourth quarter of 2024, accounting for 25.59% of the country's 3.84% GDP growth. The sector's importance to the national economy is highlighted by this performance. Post-Harvest Losses at The Nation Newspaper Owing to Poor Infrastructure: Poor cold storage and transportation infrastructure cause Nigeria to lose about 40% of its food output each year, costing the country more than N3.5 trillion, according to the Organization for Technology Advancement of Cold Chain in West Africa (OTACCWA). An independent newspaper Nigeria’s requirement for cold chain infrastructure: In order to address the nation's cold chain infrastructure deficiencies which are essential for lowering post-harvest losses and improving food security OTACCWA also underlined the need for 100 big cold rooms and 5,000 cold vehicles. Ecological Economy Government of Nigeria Efforts to Promote Agriculture: $2.2 billion is being raised by the African Development Bank (AfDB) to create

agricultural processing zones in 28 states in Nigeria. By strengthening agricultural value chains and lowering post-harvest losses, this program seeks to increase food security and create jobs. Reuters has a major impact on GDP and affects employment, pricing, and production costs. Nigeria's agricultural industry continues to operate poorly, accounting for less than 10% of GDP in recent years, despite government initiatives encouraging infrastructural investment and private sector involvement. Problems include insufficient infrastructure, corruption, and bad government, all of which raise the cost of manufacturing and transportation. In order to find strategies for improving sector performance and promoting sustainable economic growth, this study looks at how air and water transportation affected Nigeria's agricultural output between 1990 and 2024.

Objectives of the Study

This study aims to investigate the impact of transportation costs on agricultural output growth in Nigeria. The specific objectives of the study are:

i. To investigate the relationship between water transportation costs and agricultural output growth in Nigeria.

ii. To assess the effect of air transportation costs on agricultural output growth in Nigeria.

Literature Review

This section will review key concepts discuss below

Transportation cost

Transportation cost encompasses all expenses incurred in moving goods or services from one place to another, including direct costs such as fuel, maintenance, tolls, and wages, and indirect costs like insurance, packaging, and customs duties. Scholars such as Edith and Adebayo (2013) and Jean-Paul and Notteboom (2010, 2021) highlight that these costs are influenced by infrastructure, labor, and fuel, while Pigou's (2022) theory emphasizes managing externalities through mechanisms like congestion pricing. Transportation is essential for trade, economic growth, and social development, with different modes—road, rail, air, water, and pipeline—chosen based on the nature of goods. Efficient transport systems enhance accessibility, market reach, and business competitiveness, while high transportation costs can increase consumer prices. Studies using the gravity model, such as those by Baier and Hummels (2009, 2023), show that

distance, trade barriers, and economic size significantly impact trade flows and overall economic performance.

Agricultural output

Agricultural output refers to the value of final products derived from farming activities for consumption, export, or processing, and it is typically measured as the ratio of outputs to inputs. According to Omekwe (2018), who analyzed Nigeria's agricultural output from 1985–2016 using econometric techniques such as co-integration and error correction models, factors like government funding, agricultural credit, and climate change have significant positive impacts on agricultural output. The study recommends increased infrastructural investment and improved access to credit for rural farmers to enhance productivity. Agricultural output is assessed through indicators such as crop yield, sales, stock changes, and products used for processing or self-consumption, while total factor productivity (TFP) measures the efficiency of input use.

Transportation services

Transportation services encompass the movement of people, goods, and animals through various modes land, air, sea, and pipeline facilitated by both public and private sectors to ensure efficient, safe, and reliable mobility. They are vital to economic growth, linking industries such as agriculture, manufacturing, and tourism, and enabling trade, market access, and social connectivity. Scholars like Coyle et al. (1996) and Ogunsanya (1988) emphasize transportation's role in development, especially in rural areas where inadequate infrastructure limits productivity and increases poverty. Studies in Nigeria (Filani, 1993; Aderamo & Magaji, 2010) reveal that poor road conditions and limited access impede agricultural marketing and rural development, as perishable goods often spoil before reaching markets. Efficient transport networks roads, railways, airways, waterways, and pipelines enhance accessibility, stimulate investment, and reduce transaction costs, particularly in Sub-Saharan Africa where road infrastructure remains underdeveloped (Paul et al., 2009). Ultimately, transportation services not only drive economic activity and trade but also influence environmental sustainability, urban planning, and the overall quality of life by connecting production centers to consumers and fostering socioeconomic progress.

Water Transport

Water transportation plays a vital role in Nigeria's agricultural and economic development by enabling the efficient movement of goods, people, and agricultural inputs

across rivers, lakes, and coastal waters. It serves as a cost-effective and reliable mode of transport, particularly beneficial in areas with poor road infrastructure, such as rural farming communities. Modes of water transport include inland waterways like the Niger and Benue Rivers, coastal shipping, ferries, canoes, and small boats, all of which enhance market access, reduce transportation costs, and connect remote areas to urban centers. The maritime industry comprising shipping, cargo handling, and port services supports both agricultural and industrial activities by facilitating the flow of raw materials, finished goods, and exports. Water transport also contributes to food security, reduces post-harvest losses, promotes value addition, supports the fishing industry, and creates employment opportunities. Overall, by improving accessibility, reducing costs, and expanding market reach, water transportation significantly boosts agricultural productivity, rural development, and Nigeria's economic growth.

Air transport services

Air transportation plays a vital role in enhancing Nigeria's agricultural output and overall economic growth by enabling the rapid and efficient movement of goods, people, and services. It reduces spoilage of perishable produce, connects remote farming areas to major markets, and supports time-sensitive deliveries that maintain product quality and freshness. According to Nwaogbe Obioma (2024), the aviation sector contributes to Nigeria's GDP and employment through direct, indirect, induced, and catalytic effects, fostering trade, tourism, and job creation. Air transport services—including passenger, cargo, charter, express, and medical flights—facilitate globalization by linking domestic and international markets and promoting economic integration. For agriculture, air transport enhances productivity, income, and export potential while generating foreign exchange earnings. However, challenges such as high costs and inadequate infrastructure limit its accessibility, highlighting the need for policy support and investment in airports and air traffic systems to maximize its developmental impact (Okorie, 2020).

Empirical Review

This literature review on water and air transportation mode undertakes a comprehensive examination of the intricate relationships between transportation, logistics, infrastructure development, and economic growth, with a particular emphasis on the Nigerian context. The reviewed studies collectively underscore the significance of water and air efficient transportation systems and logistics infrastructure in facilitating economic

development, improving agricultural output, and enhancing overall well-being. Below are various research done by different scholars focusing on different indicators which will be used as independent variables such as water and Air transportation to determine the dependent variable which is agricultural output.

Effect of Water Transportation on Agricultural Output

Obioma (2024) describes the significance and the catalytic nature of air transport/aviation sector for the nation and global economic development through job creation, tourism and facilitation of global trade. The objective of this paper is to examine the impact of air transport to economic development via- income generation, trade and other social opportunities to Nigeria. The air transport sector supports Gross Domestic Product and the employment of Nigerians through four different routes: direct route, indirect route, induced route and catalytic route. Airlines contribute over NGN58 billion to the economy of country and support 61,000 jobs in Nigeria. Furthermore, air freight may only account for 0.5% of the tonnage of global trade with the rest of the world and in value terms it makes up around 34.6% of the total freights.

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Similarly, Jacob *et al.* (2019) investigated the development and contribution of the water transport sector to Nigeria's gross agricultural product, with a view to understanding the relationship between transportation infrastructure development and Agricultural output. Their study employed regression analysis using the OLS method, and the findings revealed a positive relationship between transportation infrastructure development and Agricultural output. This underscores the importance of transportation infrastructure development in promoting Agricultural output and reducing poverty. The importance of

transportation infrastructure development in enhancing Agricultural output and reducing poverty has been emphasized by several studies.

Olatunji & Etukomeni (2016) examined the impact of infrastructural investment on water transportation on Agricultural output leading to industrial growth in Nigeria. Their study employed the Autoregressive Distributed Lag (ARDL) bound testing approach, and the findings revealed that infrastructural investment has a positive impact on industrial growth. The relationship between logistics performance and competitiveness has also been explored Victor (2015) studied the relationship between maritime logistics and international trade in Nigeria. His findings revealed that maritime logistics has a significant impact on international trade, highlighting the importance of logistics efficiency in promoting international trade.

Uma *et al.* (2014) examined the effect of the transportation network in Nigeria on agricultural output. Their study employed both primary and secondary data, and the findings revealed that road transport has a significant impact on real gross domestic product. This underscores the importance of maritime transportation infrastructure development in promoting agricultural output and economic development.

In another study, Seinchez *et al.* (2014) investigated the performance of logistics on economic development of maritime transportation to improve agricultural output and Economy growth. The focus of the study was to show if the probability of an economy being developed is due to differences in logistic performance (logistic gap). Using a probabilistic approach, the study found that the probability of an economy being developed increases with improvement in the logistic performance of the economy. The logistic performance index sourced from World Bank and other variables were used in the study.

Theoretical Framework

The theoretical framework of this study is rooted in Alfred Weber's Location Theory, which provides a systematic lens through which to analyze the determinants of industrial location, with a particular focus on transportation costs. Weber's theory suggests that industries seek to minimize transportation expenses by locating in regions where factors such as resource availability, distance, and infrastructure are optimized. It emphasizes that transportation variables like weight, distance, and type of transport along with regional characteristics such as road networks and topography, significantly influence

location decisions. Furthermore, Weber incorporates both primary factors (e.g., cost of land, labour, materials) and secondary factors (agglomerative and deglomerative forces) into his analysis. This framework is applied in the study of empirical analysis and impact of water and air transportation mode on agricultural output growth in Nigeria, positing a direct functional relationship between efficient transport systems and improved agricultural productivity.

METHODOLOGY

This study adopts a quantitative research approach using time-series data and an ex-post facto research design to examine the relationship between water and air transportation modes and agricultural output growth in Nigeria. This design allows for the identification of antecedent events and prevailing conditions, enabling the analysis of potential correlations between independent and dependent variables, and providing insights into how transportation influences agricultural productivity (Creswell, 2014).

Data Collection

Data for this study were sourced from the Central Bank of Nigeria (CBN) Statistical Bulletin, National Bureau of Statistics (NBS), and the Nigerian Railway Corporation. Key variables include: Agricultural Output (AO) dependent variable Measured as the annual value of agricultural output, water transportation (WT) independent variable Quantified by the total length of paved roads and annual water maintenance expenditures, air transportation (AT) assessed through the total length of operational rail lines and freight volume transported and Pipeline transportation (PT) both are all independent variables Evaluated based on the length of pipelines and volume of agricultural products transported via pipelines. The data will span from 1990 to 2024, comprising time-series and annual data. This comprehensive dataset will provide valuable insights into the relationship between transportation sand agricultural output growth in Nigeria.

Model Specification

The study adapted Lowry's (1964) original model. The Lowry model is a land-use and transportation model that generates locations for population and service employment based on the location of basic industries. It uses the economic base method, where basic

employment (exporting goods/services) drives local employment (service employment) and population. This model utilized two gravity models with constraints related to land use accounts and minimum service establishment sizes. The model is modified in its implicit function as:

The study employs a multiple linear regression model to analyze the relationship:

$$AO = F(WAT, AIT) \text{ ……..(1)}$$

Where:

AO = Agricultural Output

WAT = Water Transportation

AIT = Air Transportation

Which was an adaptation of Lowry's (1964) original model. This model utilized two gravity models with constraints related to land use accounts and minimum service establishment sizes. This equation will be further specified to establish the explicit relationship between transportation indicators and agricultural output in Nigeria,

Variable Description and Measurements

Table 1: Description of the Variables Used for the Model

Variable	Measurement	Type	Source	Apriori Expectation
AO	Agricultural Output (AO) is the dependent variable, representing the contribution of agricultural output to Nigeria's gross domestic product (GDP), measured in billions of Naira, with data obtained from the Central Bank of Nigeria (CBN) for the year 2022.	Independent	CBN, 2022	
WAT	Water Transport (WAT) is an independent variable, measuring the contribution of road transport to Nigeria's gross domestic product (GDP), quantified in billions of Naira.	Independent	CBN, 2022	$B_1 >< 0$
AIT	Air Transport (AIT) is an independent variable, representing the contributions of rail and pipeline transport to Nigeria's gross domestic product (GDP), valued in billions of Naira.	Independent	CBN, 2022	$B_2 >< 0$

Source: Author Compilation, 2025

The anticipated relationship between water transport and agricultural output growth in Nigeria, represented by the coefficient β1, suggests that changes in water transport services—whether improvements or declines can significantly influence

agricultural output, with the effect being either positive or negative depending on contextual factors such as efficiency, cost, and accessibility. A similar dynamic is reflected in the coefficient β2 for air transport, where variations in transport costs or availability may either hinder or enhance agricultural output growth. These relationships highlight the critical role of transportation infrastructure in shaping agricultural performance, underscoring the need for nuanced analysis of how different modes of transport affect the sector.

Method of Data Analysis

To investigate the relationship and effect of transportation indicators on agricultural output in Nigeria using the Autoregressive Distributed Lagged Model (ARDL), equation (3.4) will be reformulated as:

$$\Delta lnAOt = \alpha 0 + \sum \alpha 1i\Delta lnWATi\text{-}1 + \sum \alpha 2i\Delta lnAITti\text{-}1 + \sum \beta 1i\ lnWTi\text{-}1 + \sum \beta 2i\ lnATti\text{-}1 + \sum + \theta 1lnAOt\text{-}1 + \mu t \ldots\ldots (2)$$

Equation (2) represents the Autoregressive Distributed Lagged Model (ARDL), which will facilitate the examination of both current and lagged relationships between transportation indicators and agricultural output in Nigeria.

RESULTS

Unit Root Test Results

The presented table provides the results of the Augmented Dickey-Fuller (ADF) test conducted to assess the stationarity properties of the variables. Stationarity is a critical property in time series analysis, as non-stationary data can lead to spurious regression results. The ADF test is employed to determine whether a unit root exists in each series, thereby guiding the appropriate econometric modeling techniques.

Table 2: Summary of Unit Root Test Result

Variables	ADF Values	Critical Values	Order of Int.
AO	-6.450025	-3.639407	I(0)
AIT	-3.271920	-1.955020	I(1)
WAT	-3.828351	-2.954021	I(1)

Source: Author's Computation, using E- views 12, 2025

The Augmented Dickey-Fuller (ADF) test for the AO variable strongly rejects the null hypothesis that AO has a unit root, indicating AO is stationary. The test statistics are -6.45, which is well below the critical values at the 1%, 5%, and 10% levels (-4.36, -3.60, and

-3.23 respectively), with a highly significant p-value of 0.0001. This suggests that AO does not follow a random walk and is mean reverting. The model includes a constant and a linear trend, both showing significance, supporting the presence of a deterministic trend in AO.

Based on the Augmented Dickey-Fuller (ADF) unit root test for the variable AIT, the test was conducted on the first difference of AIT (D(AIT)) with no exogenous variables and a lag length of 8 selected automatically. The ADF test statistic is -3.27, which is more negative than the 5% critical value of -1.955, and the associated p-value is 0.0439, which is less than 0.05. This means we reject the null hypothesis that AIT has a unit root at the 5% level, suggesting that AIT is stationary after first differencing in simple terms, AIT is integrated of order one, I(1). This indicates that while AIT is not stationary in levels, it becomes stationary once we take the first difference, making it suitable for further time series analysis like cointegration or VAR models.

The Augmented Dickey-Fuller (ADF) test for the first difference of WAT rejects the null hypothesis of a unit root at the 1% significance level, indicating that D(WAT) is stationary when including a constant but no trend. The test statistic (-3.83) is more negative than the critical values, confirming strong evidence against non-stationarity. The coefficient on the lagged differenced variable is significantly negative (-0.65), showing mean reversion in the series. The presence of a significant positive intercept suggests the differenced series has a non-zero mean. Overall, WAT is integrated of order one, I(1), and becomes stationary after first differencing with a constant but no deterministic trend.

Descriptive Statistics

Table 3 presents the descriptive statistics for Agricultural Output (AO), Air Transportation (AIT), and Water Transportation (WAT) based on 35 annual observations. These statistics provide an overview of the central tendency, dispersion, and distributional characteristics of the variables, which serve as a preliminary step in understanding their behavior and relationships before applying econometric analysis.

Table 3: Summary of Descriptive Statistics

	AO	AIT	WAT
Mean	6986.436	68.64914	4.996000
Median	2913.260	25.44000	3.540000
Std. Dev.	8980.221	87.77435	3.739022

	AO	AIT	WAT
Skewness	1.491808	1.445293	0.772607
Kurtosis	3.941870	3.936532	2.291939
Jarque-Bera	14.27574	13.46418	4.213178
Probability	0.000794	0.001192	0.121652
Observations	35	35	35

Source: Author's Computation, using E- views 12, 2025

The mean values reflect the average performance of each variable over the study period. Agricultural Output (AO) recorded the highest mean value of 6,986.44, indicating that, on average, the agricultural sector exhibited substantial productivity across the observed years. Air Transportation (AIT) followed with a mean of 68.65, suggesting moderate activity levels in the aviation sector, while Water Transportation (WAT) had a mean of 4.99, implying relatively lower engagement or operational intensity in water-based transport services. The disparity between the mean and median values for AO (2,913.26) and AIT (25.44) indicates that these variables are positively skewed a sign that a few years of exceptionally high output and air transport activities pulled up the average values. Conversely, WAT shows a smaller difference between its mean (4.99) and median (3.54), implying a more balanced distribution of observations over time.

The standard deviation provides insight into the degree of variability or volatility in the data. AO, with a standard deviation of 8,980.22, exhibits the highest variability, suggesting that agricultural performance fluctuated significantly over the years, possibly due to climatic changes, policy interventions, or market conditions. AIT also shows considerable dispersion (87.77), reflecting instability in air transport activities that could be linked to infrastructural constraints or changes in passenger and cargo traffic. In contrast, WAT displays a lower standard deviation (3.74), indicating that water transport operations were relatively stable and less affected by external shocks during the study period.

In terms of skewness and kurtosis, all three variables show positive skewness, indicating right-tailed distributions where higher values occur infrequently. AO (1.49) and AIT (1.45) are more strongly skewed than WAT (0.77), reinforcing the observation that a few exceptionally high values exist in the output and air transport series. The kurtosis values reveal that AO (3.94) and AIT (3.94) are leptokurtic, meaning their distributions are more peaked than the normal distribution and have heavier tails, while WAT (2.29) is platykurtic, suggesting a flatter distribution with fewer extreme values.

The Jarque-Bera (JB) statistics further test the normality of the data. The probabilities for AO (0.000794) and AIT (0.001192) are below the 5% significance level, indicating that both variables deviate significantly from normality. However, the probability for WAT (0.121652) exceeds the 5% threshold, implying that the distribution of water transportation data does not significantly differ from normal.

F-statistic, indicating a good model fit with strong explanatory power of the lagged terms.

Cointegration Test

Table 4 presents the results of the ARDL Bounds Test for cointegration among Agricultural Output (AO), Water Transportation (WAT), and Air Transportation (AIT). The objective of this test is to determine whether a long-run equilibrium relationship exists among the variables. The null hypothesis of the test states that there is *no levels relationship* (that is, no cointegration) among the series, while the alternative hypothesis suggests the presence of a stable long-run relationship.

Table 4: Bound Test-Co-integration Results

F-Bounds Test		**Null Hypothesis: No levels relationship**		
Test Statistic	**Value**	**Signif.**	**I(0)**	**I(1)**
Asymptotic: n=1000				
F-statistic	16.13488	10%	2.63	3.35
K	2	5%	3.1	3.87
		2.5%	3.55	4.38
		1%	4.13	5

Source: Author's Computation, using E- views 12, 2025

The computed F-statistic value is 16.13488, which is compared against the critical lower and upper bound values at various significance levels. At the 10%, 5%, 2.5%, and 1% significance levels, the respective lower and upper bound critical values are (2.63, 3.35), (3.10, 3.87), (3.55, 4.38), and (4.13, 5.00). Since the calculated F-statistic (16.13) is far greater than the upper bound value at all conventional significance levels, the null hypothesis of no long-run relationship is strongly rejected.

This outcome provides compelling evidence of a long-run cointegrating relationship among Agricultural Output, Water Transportation, and Air Transportation. In other words, despite short-term fluctuations, these variables move together over time toward a common equilibrium path. This suggests that changes in the performance of the

transportation sectors both air and water have significant and enduring implications for agricultural productivity in the economy.

Economically, the existence of cointegration implies that improvements or disruptions in transportation infrastructure and services exert long-term effects on agricultural output. Efficient air and water transport systems enhance the distribution of agricultural inputs and outputs, reduce post-harvest losses, and facilitate market accessibility. Conversely, inefficiencies or underinvestment in these transport modes can hinder agricultural growth and limit rural–urban linkages.

Model Estimation and Results Evaluation

Table 5 presents the results of the ARDL–ECM short-run and long-run estimations examining the dynamic relationship between Agricultural Output (AO), Air Transportation (AIT), and Water Transportation (WAT). The short-run component captures the immediate adjustments of agricultural output to changes in air and water transportation, while the long-run estimates reveal the sustained equilibrium effects of these variables on agricultural productivity.

Table 5: ARDL-ECM Short run- Long run Regression Result for Transportation Sector and variables of Agricultural Output

Dependent Variable of Agricultural Output (AO)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
AO(-1)	0.608389	0.27187	2.237816	0.0368
AO(-2)	-0.33868	0.3143	-1.07758	0.294
AO(-3)	-0.40807	0.19804	-2.06048	0.0526
AIT	52.12491	4.52331	11.52363	0.0000
AIT(-1)	-5.90327	11.539	-0.51159	0.6145
AIT(-2)	58.87589	8.4365	6.978709	0.0000
AIT(-3)	24.0062	18.9412	1.267405	0.2196
AIT(-4)	23.62099	8.36064	2.825262	0.0105
WAT	-769.155	152.484	-5.04419	0.0001
C	591.9837	178.424	3.317851	0.0034
@TREND	112.3005	25.9833	4.322019	0.0003
CointEq(-1)*	-0.63226	0.07314	-8.64465	0.0000
R-squared	0.999533			
Adjusted R-squared	0.999299			
F-statistic	4278.764			
Prob(F-statistic)	0.0000			
Durbin-Watson stat	2.125499			
LONG RUN				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
AIT	100.0728	9.5619	10.46579	0.0000
WAT	277.0854	171.672	1.614038	0.123
C	165.2958	251.126	0.658219	0.5183

In the short run, several key findings emerge. The lagged values of agricultural output (AO) reveal mixed effects on current output performance. Specifically, AO(-1) has a positive and statistically significant coefficient (0.608, $p = 0.0368$), suggesting that previous levels of agricultural output positively influence current output, implying some degree of persistence or inertia in agricultural production. However, AO(-3) is negative and marginally significant (–0.408, $p = 0.0526$), indicating that output shocks from three periods earlier have a dampening effect, possibly due to cyclical fluctuations or lagged effects of resource adjustments.

Regarding air transportation, the results indicate a strong and consistent positive impact on agricultural output in the short run. The contemporaneous value of AIT (52.125, $p < 0.01$) and several lagged terms particularly AIT(-2) (58.876, $p < 0.01$) and AIT(-4) (23.621, $p = 0.0105$) are highly significant, suggesting that improvements in air transport services substantially enhance agricultural performance both immediately and over subsequent periods. This underscores the role of air transportation in facilitating rapid movement of agricultural inputs, perishables, and exports, thus boosting productivity and market efficiency.

Conversely, water transportation (WAT) exhibits a significant negative coefficient (–769.155, $p < 0.01$) in the short run, implying that inefficiencies or constraints in water transport systems may have hindered agricultural distribution and market access during the study period. This could reflect infrastructural bottlenecks, poor maintenance of waterways, or limited integration of water transport into agricultural logistics networks. The trend variable is positive and highly significant (112.30, $p < 0.01$), indicating steady growth in agricultural output over time, possibly reflecting broader structural improvements in the sector.

The coefficient of the error correction term, CointEq(–1), is negative (–0.632) and highly significant ($p < 0.01$), which confirms the presence of a stable long-run equilibrium relationship among the variables. The magnitude of this coefficient indicates that approximately 63% of any short-run disequilibrium in agricultural output is corrected within one period, demonstrating a relatively fast speed of adjustment toward the long-run path.

The diagnostic statistics further reinforce the robustness of the model. The high R-squared (0.9995) and adjusted R-squared (0.9993) values indicate that the explanatory

variables collectively account for nearly all the variations in agricultural output. The F-statistic (4278.76, $p < 0.01$) confirms the overall significance of the model, while the Durbin–Watson statistic (2.13) suggests the absence of serial correlation, supporting the reliability of the estimates.

In the long run, the results show that air transportation exerts a strong and statistically significant positive effect on agricultural output, with a coefficient of 100.07 ($p < 0.01$). This implies that, in the long term, enhanced air transport infrastructure and operations contribute substantially to agricultural productivity, likely through improved logistics, access to distant markets, and reduced post-harvest losses. Although the coefficient of water transportation (277.09) is positive, it is statistically insignificant ($p = 0.123$), suggesting that while improvements in water transport may support agricultural activities, their impact has not been strong or consistent enough to achieve significance within the study period. The constant term is positive but also insignificant, indicating that other unobserved factors may account for baseline variations in output.

Post Estimation Test

Table 6: Post Estimation Tests

Test type	F- Statistic	Prob
Heteroskedasticity Test	1.619360	0.1717
Breusch-Godfrey Serial Correlation LM	0.706241	0.5074
Normality Test	110.9505	0.00000

Source: Author's computation using EVIEWS 12.0, 2025.

The Breusch-Godfrey Serial Correlation LM Test results indicate no evidence of serial correlation in the residuals up to 2 lags, as both the F-statistic (0.706, p=0.5074) and the Chi-square test (2.378, p=0.3045) fail to reject the null hypothesis of no serial correlation. The model's residuals also do not show significant heteroskedasticity based on the Breusch-Pagan-Godfrey test, where the p-values (F-statistic p=0.1717, Chi-square p=0.1825) are above the 5% significance level, indicating homoskedasticity. However, the model overall explains very little of the variance in residuals (low R-squared of 0.077 for serial correlation test and 0.484 for heteroskedasticity test) and the regression fit is weak, as reflected by the insignificant coefficients and high standard errors. In summary, the diagnostic tests suggest that the model's residuals are free from serial correlation and heteroskedasticity, but the model itself may have limited explanatory power.

Normality Test

The EViews normality test results, typically based on the Jarque-Bera statistic, assess whether the residuals from a regression model are normally distributed. If the test yields a high Jarque-Bera statistic with a corresponding p-value below 0.05, this suggests a rejection of the null hypothesis of normality indicating that residuals are not normally distributed. Empirical studies, such as those by Bera and Jarque (1981, foundational and widely cited through the 1990–2024 period), consistently highlight the importance of this test in validating classical linear regression assumptions. Non-normal residuals can imply model misspecification or the presence of outliers, potentially affecting inference reliability. Thus, interpreting normality test results in EViews is essential for ensuring the robustness of econometric models, in line with standard empirical practice in applied econometrics across decades.

DISCUSSION

Findings from the study revealed that air transportation (AIT) exerts a positive and statistically significant effect on agricultural output (AO) in both the short and long run. In the short run, the positive contemporaneous effect and the significance of several lagged terms (AIT, AIT(-2), and AIT(-4)) indicate that improvements in air transport infrastructure and operations directly enhance agricultural performance by facilitating the rapid movement of perishable produce, inputs, and high-value exports. This result suggests that efficient air transport services help reduce post-harvest losses, improve logistics efficiency, and expand access to distant and international markets for agricultural products. In the long run, the significant positive coefficient (100.07, $p < 0.01$) confirms that sustained development in air transportation continues to promote agricultural productivity over time. This implies that increased air transport connectivity and cargo capacity enhance the competitiveness of the agricultural sector, particularly in the export of time-sensitive goods. The finding aligns with the works of Adeniran and Alege (2021), who reported that transport infrastructure significantly enhances agricultural value-chain efficiency in Nigeria, and Eboh and Nwafor (2020), who emphasized that improvements in aviation logistics have a strong spillover effect on agricultural exports. However, this result contrasts with Nwachukwu and Onwuka (2018), who found that the benefits of air transport to agriculture are often limited by high operational costs and weak rural linkages. The stronger

significance found in this study suggests that recent infrastructural investments and air logistics partnerships have begun to yield measurable impacts on agricultural productivity.

Conversely, findings show that water transportation (WAT) exerts a significant *negative* influence on agricultural output in the short run, though its long-run effect is positive but statistically insignificant. In the short run, the negative coefficient (–769.16, $p < 0.01$) implies that inefficiencies and infrastructural deficiencies in the water transport system have constrained agricultural output during the study period. This may be attributed to poor maintenance of inland waterways, inadequate port facilities, or insufficient integration of water transport routes into rural agricultural distribution networks. The result suggests that challenges such as navigational hazards, seasonal variations, and high transportation costs undermine the efficiency of waterborne agricultural logistics. Although the long-run coefficient (277.09) is positive, its insignificance ($p = 0.123$) implies that improvements in water transport infrastructure have not been consistent or sufficient to produce enduring benefits for agricultural growth. This finding is consistent with Ogundele and Adeyemi (2020), who reported that infrastructural decay and policy neglect in Nigeria's maritime and inland water transport sectors limit their contribution to agricultural market access. Similarly, Ezenwaji and Iwuoha (2019) observed that water transport remains underutilized in facilitating rural-urban agricultural trade despite its cost advantages. The result underscores the need for policy reform and targeted investments in inland waterway development to unlock its long-term potential in supporting agricultural output.

The study also established the existence of a stable long-run equilibrium relationship among agricultural output, air transportation, and water transportation, as indicated by the negative and highly significant error correction term (–0.632, $p < 0.01$). This implies that short-term deviations from equilibrium are corrected by approximately 63% within one period, suggesting a strong tendency of the system to revert to its long-run equilibrium path. The high R-squared (0.9995) and adjusted R-squared (0.9993) values further indicate that variations in agricultural output are largely explained by the transportation variables, while the Durbin–Watson statistic (2.13) confirms the absence of serial correlation. This reinforces the robustness and reliability of the model.

CONCLUSION

The study concludes that transportation infrastructure, particularly air and water transport systems, plays a crucial role in determining agricultural performance in Nigeria. The empirical results reveal that air transportation has both significant short-run and long-run positive effects on agricultural output, underscoring its importance in facilitating the efficient movement of agricultural commodities, enhancing market integration, and supporting export competitiveness. In contrast, water transportation exerts a negative short-run influence and an insignificant long-run effect on agricultural output, suggesting that the sector's potential remains largely untapped due to infrastructural decay, policy neglect, and operational inefficiencies. The existence of a stable long-run relationship among the variables confirms that transportation improvements are fundamental to sustaining agricultural growth over time. Thus, strategic investments in transport infrastructure especially in air and water networks are essential for unlocking Nigeria's agricultural potential and enhancing its contribution to national development.

In light of the study's findings, specific and targeted policy recommendations are essential

i. The government, through the Ministry of Aviation and its regulatory agencies, should intensify investment in cargo-oriented air transport infrastructure, particularly in rural-based agro-clusters and export corridors. This should include the establishment of specialized agro-cargo terminals, improvement of airfreight logistics, and incentivization of private sector participation in agricultural air transport services. Such initiatives would enhance the efficiency of agricultural supply chains, reduce post-harvest losses, and promote export-led agricultural growth.

ii. The Federal Ministry of Transportation, through NIWA, should prioritize the rehabilitation and modernization of inland waterways to enhance their functionality in agricultural logistics. This should involve dredging critical river channels, constructing rural loading terminals, and integrating water transport routes with key agricultural production zones. Strengthening water transport infrastructure will lower transportation costs, improve rural market access, and facilitate bulk movement of agricultural goods, thereby transforming the sector into a viable complement to road and air transport systems.

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APPENDIX A
DATA FOR REGRESSION

Table 1: Data for Regression (Measured in Billions of Naira ~~(N))~~

YEAR	AO	WAT	AIT
1990	87.96	0.85	1.38
1991	115.03	1.01	1.41
1992	159.95	0.95	1.93
1993	231.02	1.39	2.82
1994	370.16	1.32	3.81
1995	619.85	1.52	4.64
1996	780.48	1.72	5.26
1997	848.33	1.94	6.37
1998	838.53	2.03	6.82
1999	891.29	2.13	7.69
2000	984.08	2.31	9.20
2001	1146.68	2.53	10.54
2002	1358.53	2.51	14.03
2003	1635.05	2.55	15.37
2004	1968.56	2.75	16.76
2005	2326.31	2.97	18.29
2006	2689.08	3.21	22.41
2007	2913.26	3.54	25.44
2008	3263.82	3.59	25.75
2009	3406.69	3.78	29.20
2010	3578.64	4.23	32.67
2011	4527.45	5.04	56.49
2012	5588.82	5.57	65.61
2013	7233.32	6.22	76.91
2014	8685.43	7.15	84.41
2015	8973.77	8.07	95.74
2016	8903.24	8.92	94.50
2017	10044.48	9.43	105.86
2018	12455.53	9.86	149.35
2019	16781.06	10.12	198.62
2020	19539.55	8.60	151.05
2021	25725.87	9.41	206.54
2022	27508.52	11.54	268.67
2023	28611.46	12.65	288.73
2024	29733.45	13.45	298.45

Source: CBN Statistical Bulletin December, 2024