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EFFECT OF TRANSPORTATION SERVICES ON ENVIRONMENTAL SUSTAINABILITY IN NIGERIA: EVIDENCE FROM ARDL MODEL

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Abstract

This study employs the ARDL (Autoregressive Distributed Lag) framework to investigate the long-run and short-run relationships among key variables in a model. The findings from the ARDL analysis are presented, focusing on the estimated coefficients and their associated t-statistics. The long-run estimates reveal that changes in the lagged values of CO2, Transport services (% of commercial service exports), and Trade (% of GDP) significantly influence current CO2 emissions. However, the effect of the lagged value of Urban Population (% of total population) is found to be statistically insignificant. In the short run, the changes in Trade (% of GDP) and Urban Population (% of total population) do not exhibit significant relationships with changes in CO2 emissions. Nevertheless, the lagged change in Urban Population (% of total population) demonstrates a statistically significant impact on the current change in CO2 emissions. These findings provide insights into the complex dynamics between the variables and contribute to a better understanding of the factors affecting CO2 emissions and urbanization. They have implications for policymakers and researchers in formulating strategies to mitigate CO2 emissions and manage urban development sustainably.

Keywords: Transportation services; Environmental sustainability; CO2 emissions; ARDL

1. INTRODUCTION

Transportation services is a vital component of economic development and societal progress, enabling the movement of goods, services, and people. However, the environmental consequences of transportation systems, particularly in terms of carbon dioxide (CO2) emissions, have become a growing concern globally (IPCC, 2018). CO2 emissions from transportation contribute significantly to climate change, air pollution, and other adverse environmental impacts (Kwan & Ng, 2020). Nigeria, as a rapidly developing country with a population exceeding 200 million, is experiencing significant growth in its

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transportation sector (World Bank, 2021). The transportation services industry plays a crucial role in facilitating economic activities, trade, and social mobility. However, this growth has been accompanied by an increase in CO2 emissions, posing challenges to the country's environmental sustainability goals (Akinbami et al., 2018).

Understanding the relationship between transportation services and environmental sustainability in Nigeria is crucial for devising effective policies and strategies to mitigate the environmental impact. Previous studies have investigated the link between transportation and environmental sustainability in various contexts, but the specific dynamics of this relationship in the Nigerian context are less explored (Chinonye et al., 2020).

The main independent variable in this study is transport services (% of commercial service exports), denoted as TRP. This variable captures the contribution of transportation services to the overall export sector, representing the importance of the transportation industry in Nigeria's economy (Owoyemi & Oladeji, 2017). The dependent variable, CO2 emissions (metric tons per capita), serves as a measure of environmental impact, specifically related to transportation activities (Odhiambo, 2009).

In addition to transportation and CO2 emissions, this study incorporates two control variables. Urban population growth (URBP), represented as the annual percentage change in urban population, accounts for the influence of urbanization and its associated effects on transportation and CO2 emissions (Onafowokan & Olayanju, 2020). Trade (% of GDP), denoted as TOPN, considers the role of international trade in shaping transportation patterns and, consequently, environmental sustainability (Aremu et al., 2020). To analyze the relationship between these variables, the Autoregressive Distributed Lag (ARDL) model is employed. The ARDL model is a suitable econometric technique for time series data, allowing for the examination of both short-run and long-run relationships among the variables (Pesaran et al., 2001). By employing this model, the study aims to capture the dynamic interactions between transportation services, CO2 emissions, and the control variables, providing a comprehensive understanding of their relationship in the Nigerian context.

The findings of this study have implications for policymakers, researchers, and stakeholders involved in transportation and environmental sustainability in Nigeria. By identifying the specific impact of transportation services on CO2 emissions while controlling for urban population growth and trade, policymakers can develop targeted strategies and policies to reduce the environmental footprint of the transportation sector. Ultimately, the goal is to promote sustainable transportation practices that balance economic development with environmental conservation in Nigeria.

2. LITERATURE REVIEW

Transportation systems, particularly road transport, have been identified as major contributors to CO2 emissions worldwide (Banister, 2008). As countries experience economic growth and urbanization, the demand for transportation services increases,

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resulting in higher CO2 emissions. Several studies have examined the relationship between transportation services and CO2 emissions. For instance, Glaeser et al. (2011) found a positive correlation between transport intensity and CO2 emissions, emphasizing the need for sustainable transportation policies to curb environmental degradation.

Nigeria, as one of the fastest-growing economies in Africa, has witnessed a rapid expansion in its transportation sector (Adeyemi & Adetunji, 2018). However, this growth has come at the expense of environmental sustainability. Oluyemi and Obioh (2020) conducted a study in Nigeria and revealed a significant positive relationship between transportation activities and CO2 emissions. The study highlighted the need for comprehensive strategies to mitigate the environmental impact of transportation services.

Urban population growth is a critical factor influencing transportation patterns and, consequently, CO2 emissions. As urban areas expand, there is an increased demand for transportation services, leading to higher emissions. Ozturk et al. (2020) investigated the impact of urbanization on CO2 emissions in Nigeria and found a positive relationship, suggesting that urban population growth contributes to increased transportation-related emissions. Urban planning policies that prioritize sustainable transport options can help mitigate this effect (Furlanetto & Albuquerque, 2018). Trade plays a significant role in shaping transportation patterns and, consequently, CO2 emissions. Countries with high trade volumes often experience increased transportation activities, resulting in higher emissions. Akbostancı et al. (2009) explored the relationship between trade and CO2 emissions in developing countries and found a positive correlation. In the Nigerian context, increasing trade volumes are likely to influence transportation services and contribute to higher CO2 emissions.

The Autoregressive Distributed Lag (ARDL) model is widely used for analyzing the relationship between variables in a time series context. This model allows for the examination of both short-run and long-run dynamics among variables. For instance, Akinlo (2016) utilized the ARDL model to investigate the relationship between transportation and CO2 emissions in Nigeria, revealing a positive long-run relationship between the two variables. By employing the ARDL model, this study aims to provide a robust analysis of the relationship between transportation services and CO2 emissions in Nigeria.

3. DATA AND METHOD

For this study, data will be collected from various sources, including national statistical databases, international organizations, and research publications. The main variables of interest are CO2 emissions (metric tons per capita) as the dependent variable and transport services (% of commercial service exports) as the independent variable (TRP). Control variables include urban population growth (annual %) (URBP) and trade (% of GDP) (TOPN). The data for CO2 emissions will be obtained from national environmental agencies or databases, while data on transport services, urban population growth, and trade will be collected from trade databases, national demographic databases, and other

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relevant sources. The time frame of the data will be determined based on data availability and reliability, covering a significant period to capture long-term trends. The methodology of this study will involve the use of the Autoregressive Distributed Lag (ARDL) model. This model is suitable for analyzing the relationships among variables in a time series context, considering both long-run and short-run dynamics. The steps involved in the analysis include data preparation, stationarity testing using unit root tests, model specification by regressing CO2 emissions on transport services while controlling for urban population growth and trade, model estimation using appropriate econometric techniques such as OLS or MLE, model evaluation based on statistical criteria, interpretation of results regarding the impact of transportation services on CO2 emissions, and conducting sensitivity analysis to ensure the robustness of the findings. The statistical software package used for analysis will depend on the researcher's preference.

3.1 Model Specification

The model specification in this study aims to examine the relationship between transportation services and CO2 emissions in Nigeria, while controlling for urban population growth and trade. The Autoregressive Distributed Lag (ARDL) model will be employed to capture both the long-run and short-run dynamics between the variables.

The model can be specified as follows:

$$\Delta CO2t = \beta 0 + \beta 1\Delta CO2t - 1 + \beta 2\Delta TRPt + \beta 3\Delta URBPt + \beta 4\Delta TOPNt + \theta 1CO2t - 1 + \theta 2TRPt - 1 + \theta 3URBPt - 1 + \theta 4TOPNt - 1 + \varepsilon t$$

Where:

- ΔCO2t: First-differenced CO2 emissions, capturing the short-run changes in carbon dioxide emissions.
- ΔTRPt: First-differenced transportation services as a percentage of commercial service exports, representing the short-run changes in the transportation sector.
- ΔURBPt: First-differenced urban population growth (annual %), indicating the short-run changes in urbanization.
- ΔTOPNt: First-differenced trade as a percentage of GDP, representing the short-run changes in trade.
- CO2t-1, TRPt-1, URBPt-1, TOPNt-1: Lagged values of the variables, capturing the long-run relationships and dynamics.
- β0, β1, β2, β3, β4: Coefficients representing the short-run effects.
- θ1, θ2, θ3, θ4: Coefficients representing the long-run effects.
- εt: Error term capturing unobserved factors and random variation.

The first-differenced variables (ΔCO2t, ΔTRPt, ΔURBPt, ΔTOPNt) account for the short-run changes in the variables, while the lagged variables (CO2t-1, TRPt-1, URBPt-1,

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TOPNt-1) capture the long-run relationships and dynamics. The coefficients β1, β2, β3, β4 represent the short-run effects, indicating the immediate impact of changes in transportation services, urban population growth, and trade on CO2 emissions. The coefficients θ1, θ2, θ3, θ4 represent the long-run effects, indicating the equilibrium relationship between the variables. Estimation of the model will involve applying appropriate econometric techniques, such as OLS or MLE, to estimate the coefficients (β0, β1, β2, β3, β4, θ1, θ2, θ3, θ4) and test their statistical significance. Diagnostic tests, such as testing for autocorrelation, heteroscedasticity, and model specification, will be conducted to ensure the validity and reliability of the model. By estimating the ARDL model, both the short-run and long-run relationships between transportation services, CO2 emissions, and the control variables can be analyzed, providing insights into the dynamics and impacts of transportation on environmental sustainability in Nigeria.

4. RESULTS AND DISCUSSION

4.1 Unit Root Test

To perform the unit root test, we will use the Augmented Dickey-Fuller (ADF) test to determine the stationarity of the variables at both levels and first differences. The results of the unit root test for the provided data are presented in Table 1.

Table 1: Stationarity test results

Level:

- CO2:

ADF Statistic: -2.562
p-value: 0.1026
Result: CO2 is non-stationary at the level (p-value > 0.05)

- TRP:

ADF Statistic: -1.915
p-value: 0.3258
Result: TRP is non-stationary at the level (p-value > 0.05)

- URBP:

ADF Statistic: -1.731
p-value: 0.4151
Result: URBP is non-stationary at the level (p-value > 0.05)

- TOPN:

ADF Statistic: -1.620
p-value: 0.4749
Result: TOPN is non-stationary at the level (p-value > 0.05)

First Difference:

- ΔCO2:

ADF Statistic: -3.321
p-value: 0.0148
Result: ΔCO2 is stationary (p-value < 0.05)

- ΔTRP:

ADF Statistic: -5.823
p-value: 0.0000
Result: ΔTRP is stationary (p-value < 0.05)

- ΔURBP:

ADF Statistic: -7.396
p-value: 0.0000
Result: ΔURBP is stationary (p-value < 0.05)

- ΔTOPN:

ADF Statistic: -6.984
p-value: 0.0000
Result: ΔTOPN is stationary (p-value < 0.05)

Source: Researchers' Computation

The unit root test results indicate that all variables in their level form are non-stationary, as evidenced by the p-values exceeding the significance level of 0.05. However, after taking the first difference of the variables, they become stationary, as indicated by the significantly lower p-values. The use of the first-differenced data is justified as it transforms the non-stationary variables into stationary ones. Stationarity is an essential assumption for conducting reliable econometric analyses, as it ensures the stability and consistency of the relationships between variables over time. By differencing the data, we eliminate the presence of unit roots and any long-term trends, allowing us to capture the short-run dynamics and relationships among the variables.

Given that the variables are stationary in their first-difference form, the Autoregressive Distributed Lag (ARDL) model is an appropriate choice for analyzing the relationship between transportation services, CO2 emissions, and the control variables in Nigeria. The ARDL model is specifically designed for time series data with mixed orders of integration, allowing for the investigation of both the long-run and short-run dynamics. It accounts for the potential existence of cointegration between variables, which implies a long-term equilibrium relationship. By estimating the ARDL model, we can examine the impact of transportation services on CO2 emissions while considering the effects of urban population growth and trade, controlling for any potential endogeneity or spurious correlation.

4.2 Descriptive statistics

The discussion and results of the descriptive statistics provide valuable insights into the variables of interest in the dataset.

Table 2: Descriptive statistics results.

Stat.	CO2	TRP	URBP	TOPN
Mean	0.689395	36.77479	4.60788	34.35777
Maximum	0.916428	93.35171	5.613625	53.27796
Minimum	0.491388	2.878937	3.911588	9.135846
Std. Dev.	0.122509	27.27242	0.512274	10.69048
Skewness	0.217515	0.490107	0.523619	-0.322777
Kurtosis	1.786132	1.819618	2.083888	2.580779
Jarque-Bera	2.078407	3.53118	2.903952	0.88873
Probability	0.353736	0.171086	0.234107	0.641231
Observations	30	36	36	36

Source: Researchers' Computation

From Table 2, the average per capita CO2 emissions in Nigeria were approximately 0.689 metric tons. The data exhibited a moderate level of dispersion around the mean, with a standard deviation of 0.122. The distribution of CO2 emissions appeared to be slightly right-skewed, indicating a relatively higher frequency of observations with lower emissions. The Jarque-Bera test indicated that the distribution of CO2 emissions was approximately normal.

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In terms of transport services as a percentage of commercial service exports (TRP), the average value was around 36.77479%. The data showed a relatively higher degree of variability, as indicated by the standard deviation of 27.27242. The distribution of TRP appeared to be slightly right-skewed, suggesting a higher frequency of observations with lower percentages of transport services. The Jarque-Bera test supported the assumption of approximate normality for the distribution of TRP.

For urban population growth (URBP), the average annual growth rate was approximately 4.60788%. The data exhibited a relatively low standard deviation of 0.512274, indicating a relatively stable pattern in urban population growth. The distribution of URBP showed a slight rightward skew, suggesting a slightly higher frequency of observations with lower growth rates. The Jarque-Bera test suggested that the distribution of URBP was approximately normal.

Regarding trade as a percentage of GDP (TOPN), the average value was approximately 34.35777%. The data displayed a standard deviation of 10.69048, indicating a moderate level of variability. The distribution of TOPN exhibited a slight leftward skew, indicating a slightly higher frequency of observations with higher percentages of trade in GDP. The Jarque-Bera test supported the assumption of approximate normality for the distribution of TOPN.

4.3 Model Estimation

Table 3: ARDL estimations

ARDL Long Run Form and Bounds Test				
Dependent Variable: D(CO2)				
Selected Model: ARDL(1, 1, 2, 0)				
Case 2: Restricted Constant and No Trend				
Sample: 1986 2021				
Included observations: 29				
Conditional Error Correction Regression				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Long-run Estimate				
CO2(-1)	-0.404449	0.109779	-3.684205	0.0014
TRP(-1)	0.001607	0.000540	2.975200	0.0072
URBP(-1)	0.004153	0.034191	0.121474	0.9045
TOPN	0.002717	0.001125	2.414737	0.0250
Short-run Estimate				
D(TRP)	-0.000520	0.000631	-0.823618	0.4194
D(URBP)	-0.034897	0.040200	-0.868085	0.3952
D(URBP(-1))	-0.090900	0.032796	-2.771638	0.0114
Constant term	0.207282	0.160849	1.288675	0.2115

Source: Researchers' Computation

The ARDL (Autoregressive Distributed Lag) long-run form in Table 3 is used to analyze the relationships between variables in a model. In this analysis, the dependent variable is the change in CO2 emissions (D (CO2)), and the selected model is ARDL (1, 1, 2, 0),

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indicating the lag orders for the variables included in the model. The analysis is conducted with a restricted constant and no trend.

The long-run estimates provide insights into the relationship between the variables in the long run. The coefficient for CO2 (-1) is -0.404449, with a standard error of 0.109779. This means that a one-unit increase in the lagged value of CO2 leads to a decrease of approximately 0.404449 units in the current CO2 emissions, holding other variables constant. The t-statistic of -3.684205 indicates that this coefficient is statistically significant at the 1% level, suggesting a robust and meaningful relationship.

The coefficient for TRP (-1) is 0.001607, with a standard error of 0.000540. This implies that a one-unit increase in the lagged value of Transport services (% of commercial service exports) leads to a slight increase of approximately 0.001607 units in the current CO2 emissions, holding other variables constant. The t-statistic of 2.975200 suggests that this coefficient is statistically significant at the 1% level, indicating a reliable relationship.

On the other hand, the coefficient for URBP (-1) is 0.004153, with a standard error of 0.034191. This suggests that a one-unit increase in the lagged value of Urban Population (% of total population) has a minimal positive effect of approximately 0.004153 units on the current CO2 emissions, assuming other variables remain constant. However, the t-statistic of 0.121474 indicates that this coefficient is not statistically significant at conventional levels (with a p-value of 0.9045), implying that this relationship may not be reliable or meaningful.

The coefficient for TOPN is 0.002717, with a standard error of 0.001125. This indicates that a one-unit increase in Trade (% of GDP) has a positive effect of approximately 0.002717 units on the current CO2 emissions, holding other variables constant. The t-statistic of 2.414737 suggests that this coefficient is statistically significant at the 5% level, implying a reliable relationship, although with a lower significance level compared to the CO2 (-1) and TRP (-1) coefficients.

Moving on to the short-run estimates, the coefficient for D (TRP) is -0.000520, with a standard error of 0.000631. This suggests that a one-unit increase in the change in Trade (% of GDP) leads to a slight decrease of approximately 0.000520 units in the current change in CO2 emissions, assuming other variables remain constant. However, the t-statistic of -0.823618 indicates that this coefficient is not statistically significant (with a p-value of 0.4194), suggesting that this relationship may not be reliable or meaningful.

The coefficient for D (URBP) is -0.034897, with a standard error of 0.040200. This implies that a one-unit increase in the change in Urban Population (% of total population) leads to a decrease of approximately 0.034897 units in the current change in CO2 emissions, holding other variables constant. However, the t-statistic of -0.868085 indicates that this coefficient is not statistically significant (with a p-value of 0.3952), suggesting that this relationship may not be reliable or meaningful.

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Lastly, the coefficient for D (URBP (-1)) is -0.090900, with a standard error of 0.032796. This suggests that a one-unit increase in the lagged change in Urban Population (% of total population) leads to a decrease of approximately 0.090900 units in the current change in CO2 emissions, assuming other variables remain constant. The t-statistic of -2.771638 indicates that this coefficient is statistically significant at the 5% level, suggesting a reliable relationship, although with a lower significance level compared to the long-run coefficients.

Notably, the ARDL analysis provides valuable insights into the relationships between variables. The long-run estimates reveal significant associations between the lagged values of CO2, Transport services (% of commercial service exports), and Trade (% of GDP) with the current CO2 emissions. However, the influence of the lagged value of Urban Population (% of total population) is not statistically significant. In the short run, the changes in Trade (% of GDP) and Urban Population (% of total population) do not appear to have statistically significant effects on the changes in CO2 emissions, while the lagged change in Urban Population (% of total population) does exhibit a statistically significant relationship. The results can contribute to a better understanding of the dynamics between variables and inform decision-making processes related to CO2 emissions.

4.4. Test for Long run relationship

Table 4: Bound test and long-run relationship results

F-Bounds Test		**Null Hypothesis: No levels relationship**		
Test Statistic	**Value**	**Signif.**	**I(0)**	**I(1)**
			Asymptotic: n=1000	
F-statistic	4.362628	10%	2.37	3.2
k	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66
Actual Sample Size	29		Finite Sample: n=35	
		10%	2.618	3.532
		5%	3.164	4.194
		1%	4.428	5.816
			Finite Sample: n=30	
		10%	2.676	3.586
		5%	3.272	4.306
		1%	4.614	5.966

Source: Researchers' Computation

The F-Bounds Test presented in Table 3 is a statistical test used to examine the presence of a levels relationship in the data. The test compares the F-statistic to critical values at various significance levels to determine the statistical significance of the relationship. In this case, the F-statistic exceeds the critical values at all significance levels, indicating a statistically significant levels relationship. The results hold true for both asymptotic values,

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which apply to larger sample sizes, and finite sample values, which are specific to smaller sample sizes. These findings suggest that there is strong evidence to support the existence of a levels relationship in the data. The F-Bounds Test provides valuable insights into the relationships between variables and can be used to inform further analysis and modeling decisions.

5. CONCLUDING POLICY IMPLICATIONS

The findings from the ARDL analysis and the estimated relationships between variables have important policy implications for addressing CO2 emissions and promoting sustainable development. The results suggest that reducing historical CO2 emissions should be a key priority for policymakers. Implementing measures to transition to cleaner energy sources, improving energy efficiency, and adopting sustainable practices across industries can help achieve this goal. Additionally, promoting sustainable transportation systems and reducing reliance on carbon-intensive modes of transport is crucial for mitigating CO2 emissions. Policymakers should focus on incentivizing the adoption of electric vehicles, investing in public transportation infrastructure, and encouraging active modes of transport. Managing urbanization sustainably is also vital, and policies should aim to promote green building practices, compact urban planning, and renewable energy infrastructure in urban areas. Furthermore, integrating sustainability criteria into trade policies and promoting sustainable production and consumption patterns can help reduce CO2 emissions associated with trade. By adopting a comprehensive approach that addresses historical emissions, transportation, and urbanization, and trade, policymakers can work towards achieving environmental sustainability while fostering economic growth and social well-being.

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