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An analysis of the long run effects of economic growth, urbanization & population density on transport emissions in Nigeria: A bounds testing approach

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Abstract
Global concern on environmental quality and human existence demands cutting down the emissions of carbon dioxide (CO2) from all affiliate productive sectors. Empirical identification of the emissions drivers is pre-requisite for its effective mitigation. Transport sector as one of the highest CO2 emitting sectors over a decade in Nigeria received scanty empirical investigation. The study empirically assessed the long run nexus among transport CO2 with economic growth, urbanization as well as rural population over the period 1971 to 2018 for informed mitigation strategies. The paper used the ARDL bounds testing co-integration approach, Dynamic Ordinary Least Square (DOLS) as a robustness check in addition to the pre and post estimation diagnostics tests, it adopt theoretical Stochastic Impact by Regression on Population Affluence and Technology (STIRPAT). In satisfying the ARDL condition, none of the series is co-integrated of order two and there exists a long run equilibrium relationship with correct sign of speed of adjustment (ECM). In the long run, Economic growth, Urbanization, population density and rural population have significant positive effects on transport carbon emissions in Nigeria. The paper recommends the need for the adoption of fuel efficient and environmentally friendly transport system, improvement of the transport infrastructures and subsidized public transport by government. Relocation of some government institution that help in reducing rural urban movement that trigger increase in transport energy demand and emissions is another policy option. There is need for further studies to incorporate other transport related variables like transport energy consumption, transport intensity, and panel-based analysis among others.

Keywords: Transport CO_2, Economic growth, Urbanization, STIRPAT, ARDL, DOLS.

1.0 Introduction

The quality of environment is of paramount concern to humanity as life and economic activities go down well only in a clean and conducive environment. Emission of CO_2which lead to climate change influences country's economic activities, urbanization as well as population density. By the same token, improvement in these variables could equally have significant influence on the emission of CO_2in societies. A lot of resources and measures like reforestation, biofixation of CO_2, carbon capture and storage, increase in energy efficiency, environmentally friendly electric vehicles, sustainable mobility and city panning among others, have been used in mitigating the negative impacts of CO_2 emissions. Regardless of their level of development, countries had to join hands in addressing the common environmental threat as each is negatively affected by the climate change.

This call for the existence of a near-universal agreements in an effort to address climate change triggered by toxic environmental pollution in order to reduce the average temperature below 2^0c and to limit its rise to 1.5^0c in line with the Paris agreement of the United Nations Framework Convention for Climate Change (UNFCCC, 2015) which Nigeria and more than 180 countries are party to. In fact, the global community adopted the historic Paris Agreement in December 2015, the first international climate agreement to extend mitigation obligations to all countries.

It has been scientifically established that "the concentration of Green House Gases (GHGs) in the earth's atmosphere is directly linked to the average global temperatures on earth; the concentration has been rising steadily, and mean global temperatures along with it, since the time of the industrial revolution; and the most abundant GHG, accounting for about two-third of GHGs, carbon dioxide (CO_2), is largely the product of burning fossil fuels."(United Nation, 2019). This indicates that, air pollution is a serious threat to all countries economic activities and human existence.

World Health Organization (WHO) maintained that air pollution claims millions of lives annually, with estimate of about 20,000 people each day. It further buttresses that out of the millions deaths; almost one-seventh are from Africa which is above those of Europe. Moreover, among the main sources of CO_2 emissions identified were; industry and energy supply, and transport (WHO, 2018). Although Nigeria is not highly industrialized and power supply have been epileptically intermittent, yet its CO_2 has been increasing especially from the transport sector of the economy that had more than doubled from 1990 levels of 12 metric tons to more than 50 metric tons in 2017,International Energy Agency (IEA, 2019).

Obviously, countries differ in economic structures, emissions sources and efficient use of available resources including fossil fuel. While the industrialized countries were far ahead in terms of industrial production and energy consumption from manufacturing and other related emissions sources, same cannot be obtained in less developed African country like Nigeria. These point the need to empirically identify areas that worsen environmental quality with the drivers to such emissions in addition to studies on industrial sector in Nigeria. Sector specific investigation is important in bringing out mitigation areas (Guo*et al*, 2018).This will serve as an empirically informed remedy in the context of the prevailing structure of the Nigerian economy.

IEA 2017 report on World CO_2 emissions from fuel combustion indicates that CO_2 emissions trend varies across countries with key drivers among others being: population, GDP per capita and total primary energy supply (TPES). The report further shows that globally, transport with electricity and heat are the top two sectors with most disturbing CO_2 emissions by producing two-third (66.6%) of CO_2 emissions from fuel combustion in 2015, and transport sector CO_2 alone accounts for 24%. The 2015 transport CO_2 emissions was 68% higher than the 1990 levels and such increase was led by road sector, which accounts for three-quarters of the transport emissions in 2015.

In terms of countries CO_2 emissions, China, United States (U.S) and India remain the top three. All the countries are very populous with huge transport demand. Nigeria seems to have resembling features with top CO_2 emitters like China and India, considering its highest population in Africa and ever increasing demand for increase in economic growth above its 1.93% growth rate in 2018 to serve the huge and increasing population of 198.9 million as of 2018. Thus, there is the need for mobility or transportation of humans and goods, given the existence of almost fifty-fifty rural and urban population. There is even a worrying rate of population growth rate in Nigeria of about 2.6% in 2018 which even exceeded those of China (0.5%), and India (1.03%) and the world average of 1.1% as of 2018 (World Bank, 2020). The transport emissions in Nigeria not only has increasing trend but has maintained highest level for more than a decade over other sectors of the economy like industry, other energy industries and electricity among others.

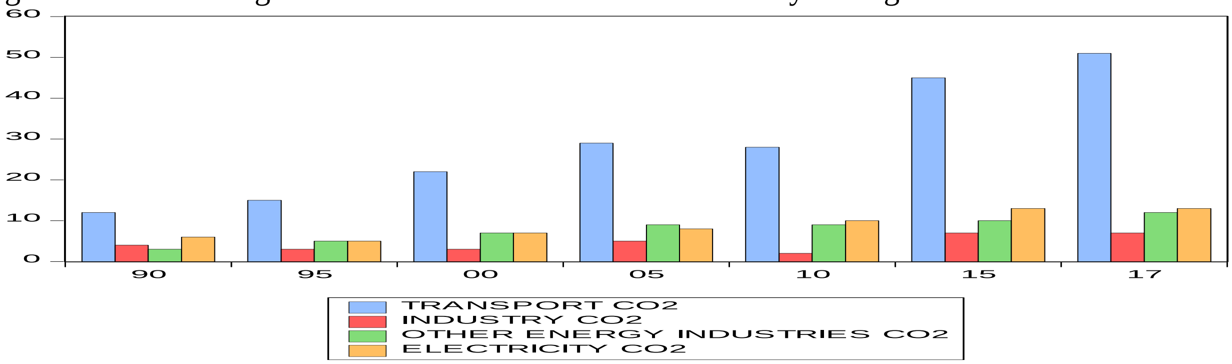

Fig 1 Trend of CO_2 emissions in metric tons (Mt) by sectors in Nigeria from 1990 to 2017 Source: International Energy Agency (IEA, 2019) data and statistics. Using E-views 10

Fig 1. Above shows that from 1990 to 2017 the trend of transport CO_2 emissions from fuel combustion in metric tons (Mt) exceeds that of all other sectors of the Nigerian economy. It starts with 12 metric tons and end with 51 Mt respectively. This is far above the respective 13, 7, 12 Mt highest values for electricity, industry and other energy industries. Considering the decades of rising trend and dominance of carbon emitting fossil fuel in our energy mix for transport sector as revealed by IEA energy and statistics database in 2019, coupled with rising population growth rate and density in the country, transport CO_2 trend may exacerbate in future. The issue now is what are the drivers to this emissions trend in the African most populous country, (Nigeria)? Subject to empirical verification, economic growth, population density, rural and urban population could be among the key variables in determining transport services and by extension transport emissions in Nigeria. Therefore, the study empirically considered these variables to determine their long run effect on transport CO_2emission in Nigeria. Review of literature indicates paucity of empirical research on Nigeria's transport CO_2 emission and its drivers. Thus, the result will serve as an important source for policy recommendation to mitigate theCO_2emissionin the country.

The problem that prompted the research is, transport sector has been the highest emitting sector for decades in Nigeria and there was no empirical investigation on the drivers of such sector's CO_2 emissions despite the quest for Nigeria to address carbon dioxide emissions as evidenced in Nigeria's commitments to various climate change agreements of the United Nations like the Kyoto Protocol and Paris agreement. Even similar researches on drivers of transport CO_2 emissions elsewhere recorded contradictory findings and revealed divergent drivers (Zhang and Nian, 2013 ;

Alshehry and Belloumi, 2017; Ahmed *et al.*2020). The study therefore sees the need to empirically identify peculiar drivers of the most disturbing CO_2 emitting sector in Nigeria for easy mitigation and compliance with the international climate change agreements signed by Nigeria.

The remaining part of the paper proceeds as follows. Section 2 briefly reviews the literature. Section 3 describes the data and methodology. Section 4 presents the empirical results and discussion. Section 5 concludes the paper and provides policy recommendations.

2.0 Review Empirical Literature

Although substantial transport related studies exist, only few with inconsistent result focuses on transport emission and the drivers of such emissions that varies across countries. Review of certain literature indicates that urbanization is one of the drivers to transport carbon emissions. This is mostly due to the society's level of congestion and the need for mobility. In a study on China, the most populous Asian country which is similar to Nigeria in African population context, Xu and Lin (2015), using dynamic vector auto regression approach investigates carbon dioxide emissions reduction in the transport sector over the period of 1980 to 2012. The findings indicates that energy efficiency, number of private cars and urbanization have significant effects on CO_2 emissions. Nevertheless, in another study involving urban transport related emissions (CO_2 emissions, volatile hydrocarbon, and nitrogen emissions) and GDP per capita, using a panel of developing and developed countries, Liddle and Liddle (2015) shows that urban intensity and fuel prices dampened emissions.

Danish, Baloch and Suad (2018) in addition to ARDL model used VECM to investigate the effect of transport-related energy consumption and CO_2 emissions in Pakistan for the period 1990 to 2015. The result indicates that energy consumption in the transport sector had a significant role in overall CO_2emissions. This suggests the compatibility and a room for complementarities of ARDL with other model(s). Similarly, Shahbaz et al. (2015) found that in Tunisia, increasing emission of $CO_2$is significantly contributed by the road transport sub-sector. On the contrary, in Beijing, energy intensity and economic growth were found to be the drivers that increases transport carbon emissions (Chen and Lei, 2017). Igbojionu, Anyadiegwu, and Anyanwu (2019), in a study based on technical and economic evaluation using compressed natural gas as a transportation fuel found reduction in environmental pollution, fuel cost and scarcity in Nigeria. Maduekwe, Akpan, and Isihak (2020) employed the Long range energy alternative planning (LEAP) model for the energy-emission analysis. The findings shows that in order to achieve the 2020 to 2032 fifty percent emission cut in Lagos, old vehicles, growth rate of vehicles and mileage had to be addressed. Alshehry and Belloumi (2017) applied ARDL modeling technique to investigate the famous Environmental Kuznets Curve (EKC) hypothesis between CO2 emissions from the transport sector and economic growth in Saudi Arabia from 1971 to 2011. Although their result does not support the EKC hypothesis, but there is bi-directional linkage between transport CO_2 emissions and road transport energy consumption in both the short run and long run. Thus, the study recommends energy long run conservation policy.

Considering the literature based on sectors analysis, a lot of the growth-emission nexus have centered on issues like the theoretical

Kuznets curve analysis of aggregate GDP or GDP per capital and carbon dioxide emissions. Nevertheless, emissions analysis is not exclusive to aggregate CO_2 emission, energy consumption, or aggregate growth. As obtained in certain literature, Soava, *et al.* (2019); Raza, Shah and Sharif (2019) and Hajko (2015) – studies that considered disaggregated sectors with mixed findings, suggest the need for further sector specific empirical investigation in order to develop CO_2emission mitigation strategies in Nigeria. Furthermore, although the negative contribution of transport sector carbon emissions is a global issue, African countries particularly country like Nigeria with massive and rising population growth rate coupled with environmentally unfriendly technology should be more worried. Empirically, developing countries environmental situation is exacerbated mainly due to rapid economic growth, urbanization, as well as little or absence of pollution mitigation technology for the environment (Tahir *et al*.2014 & Wang *et al*.2019).

Empirical evidence on transport emissions drivers remained mixed. For instance, Ahmed *et al.*(2020), used combined co-integration and bounds test based on Kripfganz and Schneider's approximations in investigating the drivers of transport CO_2 emission in India over the period 1980 to 2015. The study incorporates road transport energy, economic growth, industrialization, urbanization, oil prices, and road infrastructure. Their result shows that drivers to transport CO_2 were found to be road sector energy use, economic growth, industrialization and nature of road infrastructure, but urbanization reduces transport emissions and transport energy was insignificant to transport emissions. Contrarily, in China regional analysis, transport sector has been established empirically as an important sector of the economy but a significant source of CO_2 emissions (Zhang and Nian, 2013). Nevertheless, Danish and Baloch (2018) shows that transport energy consumption doesn't have any impact on emissions and economic growth has a negative impact on emissions in the case of Pakistan as obtained in an investigation of the connection between transport energy consumption, economic growth and environmental quality from 1971 to 2014 using ARDL model. In another study, Andreoni and Galmarini (2012) found economic growth as an important factor that influences emission in water and aviation transport for Eurostat.

Summarily, best on the literature reviewed above, the following literature gaps were identified:

1. There is no empirical study on transport emissions drivers in Nigeria despite the decades of transport emission maintaining highest level based on sectors.
2. There exist mix findings in studies on transport emissions drivers generally.
3. Joint contributions of economic affluence or growth with demographic factors like population density, urbanization and rural population on transport CO_2 emissions were not empirically explored in Nigeria and drivers of such emissions varied among countries.
4. Transport studies received scanty of robust econometric diagnostics (like compliance with all OLS assumptions) methodological and theoretical underpinnings and robustness checks (like theoretical STIRPAT, DOLS in addition to

ARDL model) in Nigeria which this study sought to address.

3.0 Methodology

3.1 Data

This section presents the data and the methodology used in the research. That is, the section comprised of the nature and sources of the data, the estimation techniques as well as the pre and post estimation diagnostic checks employed. All the data are time series and covered the period from 1971 to 2018 Data on Transport carbon dioxide emissions (TE) in metric tons (Mt) is sourced from Energy Database for Global Atmospheric Research, urbanization is proxy by Urban Population (UP) in log form to conform with other variables in rates, Population Density (PD) People per square kilometer of land area is adopted as a measure of population density from the work of Rasool et' al (2019) in the literature, Economic Growth rate per capita (YG) and Rural Population rate (RP) that captured rural dwellers were obtained from World Bank, world development indicators.

3.2 Method

The estimation technique used is informed by the nature of the data. Autoregressive Distributed Lag (ARDL) developed by Pesaran and Pesaran (1997), Pesaran, Smith, & Shin (2001) is applied in estimating the data. As a long run robustness check, Stock & Watson (1993) Dynamic Ordinary Least Squares (DOLS) method is used.

This research paper follows and modifies the framework of Xu and Lin (2015) and Talbi (2017) in estimating the transport emission drivers for Nigeria. The functional form of the research model is presented as:

$$TE_t = f(YG_t, PD_t, UP_t, RP_t) \qquad (1)$$

However, the linear specification form of the model is presented in equation (2)

$$TE_t = \beta_0 + \beta_1 YG_t, + \beta_2 PD_t + \beta_3 UP_t + \beta_4 RP_t + \mu_t \qquad (2)$$

Where: TE is the transport emission while μ is a white noise error term, β_0 is a constant, the rest of the β's are parameter coefficients of the explanatory variables. The study hypothesize that economic growth (YG), population density (PD), rural population (RP) and urbanization (UP) will lead to an increase in transport demand and its environmental pollution or carbon emissions in Nigeria as fuel for economic activities including transportation are fossil fuels. Thus, the expectation is $\beta_1 YG>0$, $\beta_2 PD>0$, $\beta_3 UP>0$, and $\beta_4 RP>0$.

3.3 Theoretical Justification

One of the widely used methodological framing of the emissions versus economic growth modeling and the theoretical underpinnings of such nexus has been the environmental Kuznets theory (Kuznets, 1955) that was a modified from income inequality and growth relationship to income (economic growth) versus environmental quality nexus and tests for emissions turning points that was later captured independently by empirical studies (Shafic and Bandyopadhyay, 1992; Grossman and Krueger, 1995).

However, since this study is not testing emissions turning point and have in addition to economic growth, population variables, and the study is striving to empirically estimate transport emissions driving factors in Nigeria, thus STIRPAT (Stochastic Impact by Regression on Population Affluence and Technology) has been identified to be appropriate theoretical support for CO_2 emissions function and population variables as it has been successfully adopted in the past to analyze the effects of driving forces of environmental pollution (Dietz and Rosa, 1997; Cramer, 1998; Wang and Zhao, 2015; Tan and Wang 2017). In addition, STIRPAT results has been found to be identical to those that come from theoretical EKC (Shahbaz et al. 2017), and compatible with ARDL model (Ali, Abdul-Rahim, and Ribadu 2016).) it is therefore adopted as theoretical basis for this study.

The specification of STIRPAT model is from reformulation of IPAT (Integrated Population Affluence and Technology) identity that emerged out of the Ehrlich-Holdren/Commoner debate in the early 1970s about the principle driving forces of anthropogenic (human) environmental impacts (see Ehrlich and Holdren 1970 and Commoner, et al 1971), the STIRPAT is as follows:

$$I_i = aPi^b A_i^c T_i^d e_i$$

with retention of proportionality assumptions (a= b = c = d = e = 1) obtained from the original IPAT. I = total emissions, a = constant, e = error term, P = Population or demographic variables, A = GDP, and T = CO_2 emission per unit of GDP which the autoregressive nature of the ARDL model can capture via the lagged values of the CO_2 Emission from the transport sector.

3.3 Unit Root Test

Considering the common non-stationery nature of time series data and the possibility of having variables that may be stationery only after second differencing, unit root test via Augmented Dickey Fuller (ADF), see Dickey and Fuller (1979) test and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) as robustness to complement the ADF in small sample, are conducted to ensure none of the series used is I(2) stationery to avoid spurious regression considering the ARDL technique applied. The ADF is based on the specification below:

$$\Delta y_t = \lambda + \phi_t + \beta y_{t-1} + \sum_{i=1}^{k} \alpha \Delta y_{t-1} + \mu_t \qquad (3)$$

H_O: $\beta = 0$, H_1: $\beta < 0$

Δy_t is its first difference of y, μ_t is the variable that adjust the autocorrelation or the serial correlation errors. $\lambda, \phi, \beta, \alpha$ are parameters of the model estimated, while H_0 and H_1 are the null and alternative hypothesis for the unit root y_t respectively.

3.4 Lag Selection Criteria

The ARDL bound testing by Pesaran et al (2001) requires adequate lag length in variables to remove any serial correlation. An optimal lag selection via Akaike Information Criteria (AIC) or Bayession Information Criteria (BIC) was selected based on the option with smallest value – coincidentally both the AIC and SIC have indicated lag 3. Thus, the model will be within the bounds of the lag order.

3.5 ARDL Co-integration and DOLS Models

The paper mainly aimed at the long run analysis of the transport emission drivers in Nigeria. Therefore, ARDL bounds testing approach to co-integration developed by Pesaran and Pesaran (1997), Pesaran et al (2001) is selected based on the nature of the series (mixture of integration order but none is I(2)) and the numerous advantages of ARDL such as avoidance of endogeneity problem. The approach corrects for residual serial correlation, it also allows for the use of different lags of variables in the data generating process and has ability of handling small sample (Pesaran and shin, 1999). As a robustness check for the long run estimates from the ARDL model, Dynamic Ordinary Least square model (DOLS) is applied given its advantages. The DOLS adopts a parametric approach in estimation of a long-run relationship in a model in which the variables are integrated in a different order, but still co-integrated (Masih and Masih, 1996), as in the case of these series. This model deals with simultaneity bias and small sample bias by including leads and lags (Kurozumi and Hayakawa, 2009). The estimators of DOLS can be derived from least-squares estimates, and these estimators are not only unbiased but asymptotically efficient even in the presence of the endogenous problem. The parameters also adjust the possible autocorrelation and residual non-normality (Herzer et al., 2006; Stock and Watson, 1993). In addition, associated pre estimation tests and post estimation diagnostics will also be conducted in line with the study objectives. The unrestricted ARDL model is stated as follows:

$$\Delta TE_t = \beta_0 + \sum_{i=1}^{a} \Delta\beta_{1i} TE_{t-1} + \sum_{i=0}^{a} \Delta\beta_{2i} YG_{t-1} + \sum_{i=0}^{a} \Delta\beta_{3i} UP_{t-1} + \sum_{i=0}^{a} \Delta\beta_{4i} PD_{t-1} + \sum_{i=0}^{a} \Delta\beta_{5i} RP_{t-1} + \phi_{1i} TE_{t-1} + \phi_{2i} YG_{t-1} + \phi_{3i} UP_{t-1} + \phi_{4i} PD_{t-1} + \phi_{5i} RP_{t-1} + \varepsilon_i \quad (4)$$

Where: β_0 is the constant, Δ denotes change, $\sum$ is summation sign, a is maximum number of lag length, β_1 to β_5 are coefficients of the short run estimates. But, our main concern in this model is the long run coefficients for the long run analysis which are the $\phi's$ and the error correction term which can be obtained from the error correction model (ECM) and denoted below with ψECT_{t-1} with its coefficient ψ as in equation (5) below, and the t is the time series.

The ARDL bounds testing approach to co-integration depends upon the tabulated critical values by Pesaran et al. (2001) to make a decision about co-integration among the variables. The null hypothesis of no co-integration in the model is:

$$\beta_1 YG_t = \beta_2 PD_t = \beta_3 P_t = \beta_4 RP_t = 0$$

The alternative hypothesis of co-integration among variables is

$$\beta_1 YG_t \neq \beta_2 PD_t \neq \beta_3 P_t \neq \beta_4 RP_t \neq 0$$

After which, is to compare the calculated F-statistics with lower critical bound and upper critical bound values from Pesaran and Pesaran (1997) and Pesaran et al. (2001). There is co-integration among variables if calculated value of F-statistics is more than upper critical bound. If the lower critical bound is more than computed F-statistics then there is no co-integration. On the other hand, if the calculated F-statistics is between lower and upper critical bounds then decision about co-integration is inconclusive. Then, we rely on the significance of the lagged error correction term (ECT) for co-integration or long run relationship. If there exists a long run relationship among variables, the short run behavior of variables is to be estimated by the vector of ECM model, but our main concerned is not on the short run behavior, rather the coefficient of ECT (speed of adjustment to long run equilibrium) to be negative and statistically significant. Therefore we present the vector of the ECT model in equation (5) to capture the error correction term below

$$\Delta TE_t = \beta_0 + \sum_{i=1}^{a} \Delta\beta_{1i} TE_{t-1} + \sum_{i=0}^{a} \Delta\beta_{2i} YG_{t-1} + \sum_{i=0}^{a} \Delta\beta_{3i} UP_{t-1} + \sum_{i=0}^{a} \Delta\beta_{4i} PD_{t-1} + \sum_{i=0}^{a} \Delta\beta_{5i} RP_{t-1} + \psi ECT_{t-1} + \varepsilon_i \quad (5)$$

Where:

$\Delta =$ Change parameter, $\beta_0 =$ Intercept parameter, β_1 to $\beta_5 =$ short run coefficients,

ψ = coefficient of error correction term, t = Time series, ECT = error correction term and ε =Error term. The ECT signal deviation in the dependent variables for the short span of time and the rate at which it will restore to long run equilibrium, its coefficient is expected to be negative and statistically significant.

Long run ARDL model

$$TE_t = \phi_0 + \sum_{i=1}^{a} \phi_{1i} TE_{t-1} + \sum_{i=0}^{a} \phi_{2i} YG_{t-1} + \sum_{i=0}^{a} \phi_{3i} UP_{t-1} + \sum_{i=0}^{a} \phi_{4i} PD_{t-1} + \sum_{i=0}^{a} \phi_{5i} RP_{t-1} + \varepsilon_i \quad (6)$$

Where:

$\phi_0 =$ Intercept, ϕ_1 to ϕ_5 = long run coefficients, a =Maximum lag length, t = Time series and ε =Error term. We present below the of error correction term equation.

$$ECT_t = \Delta TE_t - (\beta_0 + \sum_{i=1}^{a} \Delta\beta_{1i} TE_{t-1} + \sum_{i=0}^{a} \Delta\beta_{2i} YG_{t-1} + \sum_{i=0}^{a} \Delta\beta_{3i} UP_{t-1} + \sum_{i=0}^{a} \Delta\beta_{4i} PD_{t-1} + \sum_{i=0}^{a} \Delta\beta_{5i} RP_{t-1} + \varepsilon_i) \quad (7)$$

Where ECT represent the error correction term, which is our concern, not the short run parameter estimates.

3.6 Post estimation reliability checks

After estimation, the paper subject the ARDL model to reliability tests and conform to Ordinary Least Square (OLS) assumptions in order to be able to avail the model for policy making. Such tests are: Breauch-Godfrey Serial correlation LM, Autoregressive Heteroskedasticity, Breauch-Pagan heteroskedasticity test, Jarque-Bera normality test, REMSEY RESET functional form test, CUSUM and CUSUM of Square stability test.

4.0 Empirical Results and Discussions

4.1 Descriptive statistics

As presented in table 1 below, there is small sample size (30-80) with total of 48 observations. The Narayan (2005)'s critical values is then employed for co-integration test for this study. With the exception of economic growth variable (YG), all the variables are normally distributed with Jaque-Bera probability values above five percent (5%) which allow us to accept hypothesis of normality of the series.

Table 1. Descriptive statistics of the data

	TE	UP	YG	RP	PD
Mean	17.99948	40657879	0.872438	67.49338	124.3677
Median	16.60215	34066694	1.830202	68.05200	117.0669
Maximum	32.59278	98611179	12.45747	81.84900	215.0650
Minimum	2.977048	10399975	-15.45037	49.65600	62.91049
Std. Dev.	7.942207	25647386	5.568806	9.694179	44.55745
Skewness	-0.080749	0.711235	-0.716268	-0.209641	0.425557
Kurtosis	2.119290	2.369022	4.032577	1.878388	2.029961
Jarque-Bera	1.603463	4.843108	6.236748	2.867621	3.330744
Probability	0.448552	0.088784	0.044229	0.238399	0.189120
Observations	48	48	48	48	48

Source Author's Computation (2020), using e-views 10.

Each series has 48 observations and, raw data was used in preparing and presenting the table 1. All the variables are within the range of the normal zero skewness which is desirable, yet, some are negatively skewed. Urbanization (UP) and rural population (RP) are the two positively skewed variables. As for the kurtosis only economic growth variable (YG) has leptokurtic with a value higher than 3 (4.03) which implies higher values above the mean, all other variables are platykurtic.

Estimating a model with non-stationary series gives spurious estimates, to avoid that the paper employed the Augmented Dickey-fuller unit root test with structural break and complements it with Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test.

4.2 Unit Root tests

Table 2. Results of Unit Root tests

Variables	**ADF TEST**		**KPSS TEST**	
At level. I(0) & Intercept	Intercept	Trend & Intercept	Intercept	Trend
lnUP	-4.35(0.07) [1976] ^{y}	NA	0.907{0.739}	0.185{0.216}^{x}
YG	-6.14(0.01) [1983]^{x}	- - -	0.191{ 0.739}^{x}	--
RP	-1.30(0.99) [2000]	-4.77(0.13) [1990]	0.192{0.216}^{x}	--
PD	0.82(0.99) [1995]	-3.42(0.85) [1997]	0.897{0.739}	0.235{0.216}
TE	-2.71(0.83) [1999]	-6.68(0.01) [2000]^{x}	0.862{0.739}	0.071{0.216}^{x}
At 1st diff. I(1) Trend & Intercept		Intercept	Trend & Intercept	Intercept
lnUP	-13.20(0.01) [1990]^{x}	- - -	- -	- -
YG	- - -	- - -	- -	- -
RP	-3.21(0.56) [2000]	- 15.23(0.01)[2011]^{x}	--	--
PD	-1.99(0.98) [1999]	-6.93(0.01) [1991]^{x}	0.866{0.739}	0.212{0.216}^{x}
TE	- - -	- - -	- -	- -

Source : Author's estimation (2020) using E-views software version 10.Note that: Values in() are p-value, values in [] is break year, while ^{x} and ^{y} are respective 1% and 5% levels of significance, Values in {} is KPSS Asymptotic critical values.

The unit root test resultsin table 2 shows mix order of integration (I(0) & I(1)) with none of the series having I(2). Using ADF Break-point unit root test and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, thus, ARDL bounds test for co-integration and DOLS co-integration regression can be applied. Other test of co-integration like Johansen and Juselius (Johansen, 1995) and Johansen (Johansen and Juselius, 1990) cannot be applied as the series are not having the same order of integration.

4.3 Lag Selection Criteria

The ARDL bound testing by Pesaran*et al* (2001) requires adequate lag length in variables to remove any serial correlation. Optimal lag selection via Akaike Information Criteria (AIC), Bayession Information Criteria (BIC), among others was used and the selection was based on the one with smallest value.

Table 4. Optimal lag length selection for co-integration test

Lag	LogL	LR	FPE	AIC	SC
$f(te_t Ilnup_t, rp_t, yg_t, pd_t)$					
0	-443.0334	NA	305.8969	19.91260	20.11334
1	136.7691	1004.991	6.03e-09	-4.745292	-3.540850
2	235.5897	149.3290	2.36e-10	-8.026211	-5.818068
3	328.7652	120.0929^x	1.28e-11 ^x	-11.05623 ^x	-7.844388 ^x

At 5%, the suggested lag is 3 as indicated by **x**. SC is Schwarz information criterion, AIC is Akaike information criterion, FPE is final prediction error, LR is the sequential modified LR test statistic.

Table 5. Result of ARDL bounds test for co-integration

					Critical bounds	
Model	f-statistics	Lag	K	Sig. level	I(0)	I(1)
$f(te_t Ilnup_t, rp_t, yg_t, pd_t)$	6.594	3	4	Narayan (2005)'s critical values (restricted constant no trend)		
				1%	3.892	5.173
				5%	2.850	3.905
				10%	2.402	3.345
n = 45						

The F-statistic of 6.594 is greater than all the three significant upper bounds which imply the existence of long-run relationship (co-integration) among the series, we reject null hypothesis of no co-integration, this pave way for running the long run models as presented below

4.4 The Long Run ARDL and DOLS Models

Table 6. Results of the ARDL Long-run coefficient and Short-run ECT, and Dynamic Ordinary Least Square coefficients.

	Long-run ARDL			Dynamic OLS		
Regressors	Coefficients	t-statistics	p-value	Coefficients	t-statistics	p-value
Dependant variable = TE_t,						
$lnUP_t$	71.49	8.05	(0.000) ^x	81.01	5.22	(0.000)^x
YG_t	0.211	2.59	(0.000) ^x	1.031	2.92	(0.008) ^x
RP_t	10.68	7.48	(0.015) ^y	10.85	3.28	(0.003) ^x
PD_t	1.246	6.76	(0.000) ^x	1.334	3.75	(0.001) ^x
C	-2086.3	-8.12	(0.000) ^x	-2294.4	-5.09	(0.000) ^x
ARDL Short-run ECT_{t-1}:						
Dependent variable : ΔTE_t						
ECT_{t-1}	-1.13	-6.79	(0.000) ^x			
R^2 = 0.58, Adj. R^2=0.47	DurbinWatson = 2.05			R^2 =0.95 Adj.R^2=0.90		

Source: Author's estimation (2020) using E-views software version 10.Note that: Values in (p-value), while ^x and ^y are respective 1% and 5% levels of significance.

The coefficient on urbanization which is proxy by urban population is found to be positive and statistically significant at 1% level. This suggest that one percent increase in urbanization on average leads to about 71.49Mt increase in transport carbon dioxide emissions in Nigeria during the period under study. The sign and size of the urbanization variable could be attributed to massive increase in urban population from mere 10.3 million in 1971 to 98.6 million in 2018, which trigger more transport services demand and emissions due to expansion of dwelling places far away from places or work and traffic congestion. The result is consistent with (Liddle, 2014; Xu and Lin, 2015). The estimated coefficient on economic growth is also found to be positive and significant. This implied that a unit increase in GDP per capita in Nigeria increases transport sector carbon dioxide emission by about 0.211 units of Metric tons which, is in line with Chen and Lei (2017). The result further shows the coefficient on population density is significant and positive; suggesting that population density has a positive influence on transport CO_2 emission in Nigeria. This result confirms Liddle (2014) and Rasool *et al*, (2019) analysis on the association between transport emission and population. Rural population was also found to be positive and significant; meaning it equally exerts positive effect on the emission of transport CO_2. This might be attributed to mass movement of rural people toward white collar jobs and enjoying urban infrastructure in cities as, reflected in decreasing trend in rural population rate from 81.8% in 1971 to less than 50% in 2018. Furthermore, poor nature of rural roads, insufficient vehicle inspection officers in rural communities coupled with poverty that forced people to used highly environmental damaging vehicles, among other things, also worsen the country's environmental quality.

In the short run model, the error correction term value -1.13 of speed of convergence to equilibrium carries the correct negative sign and is statistically significant at 1%. The magnitude indicate faster speed of adjustment to long run equilibrium, this conform with the work of Riti, Gubak and Madina (2016) as their speed of convergence also about -1.44, and it will take this model approximately 9 months (1/1.13 = 0.884) to converge to long run equilibrium.

Generally, robust and consistent estimates of the long run coefficients were obtained from the DOLS model, where the entire coefficients were found to have the same signs relative to those obtained using the ARDL model. The explanatory power of the DOLS model even exceed that of the ARDL model, as it has R^2 of 0.95 and Adjusted R^2 of 0.90, which means the model is capable of explaining at least 90% of variations in the system as against the respective values of 0.58 and 0.47 coefficients.

The ARDL model passed all the post estimation tests above given the probability values for the serial correlation, heteroskedasticity, REMSEY RESET and Jaque-Bera normality are above five percent (>5%). Both CUSUM and CUSUM of square stability test are within the 5% critical bounds as presented below. This indicates that the model is stable and in general reliable for policy making as it passed all the necessary tests in conformity with Ordinary Least Square (OLS) assumptions.

The blue line never cut the pair of red ridge lines for both CUSUM and CUSUM of Square stability bounds, this show that the model is stable within the 5% significance bounds as reflected in Fig. 2 and Fig. 3 above.

Table 7. Results of the post estimation Diagnostics test

Test statistics		LM-Version	F-Version
Serial correlation	Breusch-Godfrey	CHQ{2} 0.4876 (0.7836)	0.1533 (0.8585)
Heteroskedasticity	Breusch-Pagan-Godfrey	6.7828 (0.9428)	0.3803 (0.9706)
	ARCH	0.6271 (0.4284)	0.6073 (0.4402)
Functional form	REMSEY RESET	Not applicable	3.1710 (0.0854)
Normality	Jaque-Bera	4.3926 (0.1112)	Not applicable
Stability	CUSUM CUSUMSQR	Both are Stable at 5% level of significance	

Source: Author's estimation (2020) using E-views software version 10.Note that: Values in (p-value).

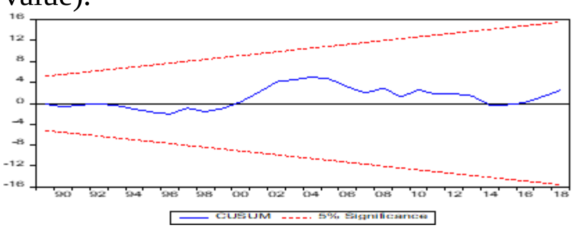

Fig2. Cusum stability bound

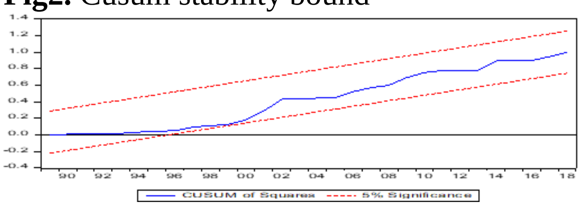

Fig3. Cusum of square 5% stability bound

5.0 Conclusion, recommendation and policy options

The paper evaluates the Long run effects of economic growth, urbanization and population density on transportCO_2 emissions in Nigeria over the period of 1971 to 2018. Both the pre and post estimation test conformed to the ARDL and DOLS estimation requirements. The importance of mitigating the emission of carbon dioxide in order to avoid its negative consequences of climate change motivates Nigeria and many other countries to go into emissions mitigation agreements. Identification of drivers of carbon emission is an excellent step towards mitigation, hence, the need for the empirical evaluation of the contributions of economic growth, urbanization, population density and rural population to transport CO_2 emissions in the country. The empirical result found that the identified variables are significant in increasing transport sector CO_2.The pronounced effects of these variables on aggregate transport CO_2indicates that the emission has quite advanced in Nigeria. Therefore, the result suggest that the seemingly comforting believe that the less industrialized nature of Nigeria would be enough to relatively cushion the effect of these transport CO_2 emission drivers does not seem to be holding. Although there is no general consensus on drivers of transport emissions in the literature, the results in this study presents a step toward having a common stand on determinants of transport CO_2 drivers or drivers and by extension total CO_2 emission.

The policy implication is that policy makers should take appropriate measures to prevent the escalation of transportCO_2 emission and by extension total CO_2 emission. This could be done through the adoption of fuel efficient and environmentally friendly transport system, improvement of the transport infrastructures and promotion of the use of mass transit buses instead of private carbon emitting vehicles. Another policy option is subsidized public transport by government and carpooling initiative measures be promoted where people from the same place of work are encourage to be collectively using vehicle together instead of individuals using personal vehicles. Emissions dangers enlightenments in both rural and urban areas could also be done. Other policy recommendation includes; establishment or relocation of some government institution like ministries of agriculture in all states in Nigeria to rural areas, that can help in reducing rural urban movement that trigger increase in road transport energy demand and emissions, conversion of transport vehicles from the use of highly CO_2 emitting ones to less, like the use of compressed natural gas instead of petrol for vehicles, deployment of environmentally friendly solar powered transport means since the country have abundant source of solar power. There is need for further studies to incorporate other transport related variables like the transport final energy consumption, transport intensity, and panel-based analysis, and other sectors emissions drivers among others.

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