Effect of demographic factors and economic development on carbon intensity in nigeria: an insight into the environmental Kuznets curve hypothesis

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Abstract. This paper sought to examine the effect of urbanisation, population growth and economic development on carbon intensity in Nigeria from 1961 to 2014. The study utilised secondary data from the World Bank Development Indicators. The data were analysed using ordinary least squares regression, vector autoregressive model, and threshold regression. Findings from the study revealed that economic development had an inverse and significant effect on carbon intensity in line with the prediction of the Environmental Kuznets Curve. Meanwhile, population growth and urbanisation exerted a positive and significant effect on carbon intensity in Nigeria. The VAR regression result indicated that urbanisation, carbon intensity, and economic development were strongly endogenous in predicting themselves. The threshold regression revealed that the optimal urbanisation level that will not propel carbon intensity in Nigeria is 14.444%. As such, rural development policies should be encouraged to curb massive rural-urban migration, which can drive up the degree of urbanisation in Nigeria.

Keywords: economic development; urbanization; population growth; carbon intensity; environmental pollution

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1. INTRODUCTION

The rising drive towards achieving an environmentally sound economy has generated some concerns about urbanisation, population growth, and economic development in increasing carbon intensity in Nigeria. Though urbanisation is considered as an instrument of economic, social and political progress, it has led to severe socio-economic problems (Rai, 2017). Such socio-economic problems include urban sprawl, urban crimes, overcrowding, unemployment, slums and squatter settlement, transportation, trash disposal, sewage, water, and air and noise pollution. Despite these threats to the socio-economic well-being of society, reasons have been put forward to justify the rising rate of urbanisation. Such include better employment facilities, medical facilities, better facilities for trade and commerce, better facilities for higher education, facilities for entertainment, sports and games, and proximity to administration and important government offices. Sequel of the above reasons, environmental problems arise due to the tremendous increase in the urban population. As such, urbanisation is viewed as "a process that leads to the growth of cities due to industrialisation and economic development" (Rai, 2017).

As an outcome of industrialisation and economic development in the urban areas, urbanisation generates some environmental impacts that are of great concern. Such impacts can be traced to the disorganised and unplanned growth of urban areas and a lack of infrastructure to support the rising urban population. The urban population in Nigeria has been on the increase over the years. Such a trend we depicted in Figure 1.

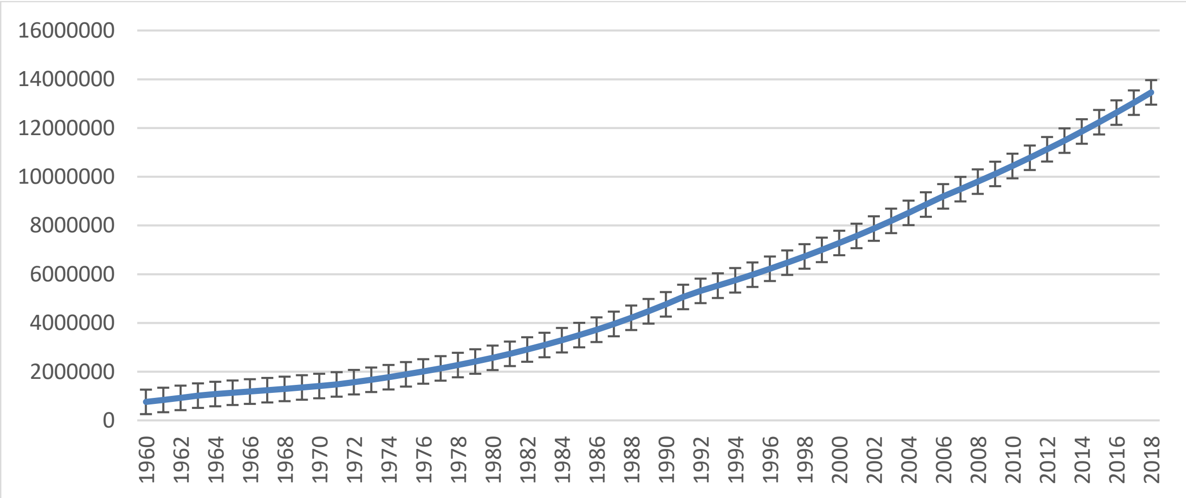

Figure 1. Population in Largest Cities in Nigeria (1960 – 2018)

Source: World Development Indicators (2018)

Given Figure 1, it is evident that the urban population in Nigeria increases quite rapidly, of which the difference is significant between 1960 and 2018, which increase environmental problems.

Such an increase in environmental problems can be viewed in terms of the country's significant increase in carbon dioxide emissions, as portrayed in Figure 2.

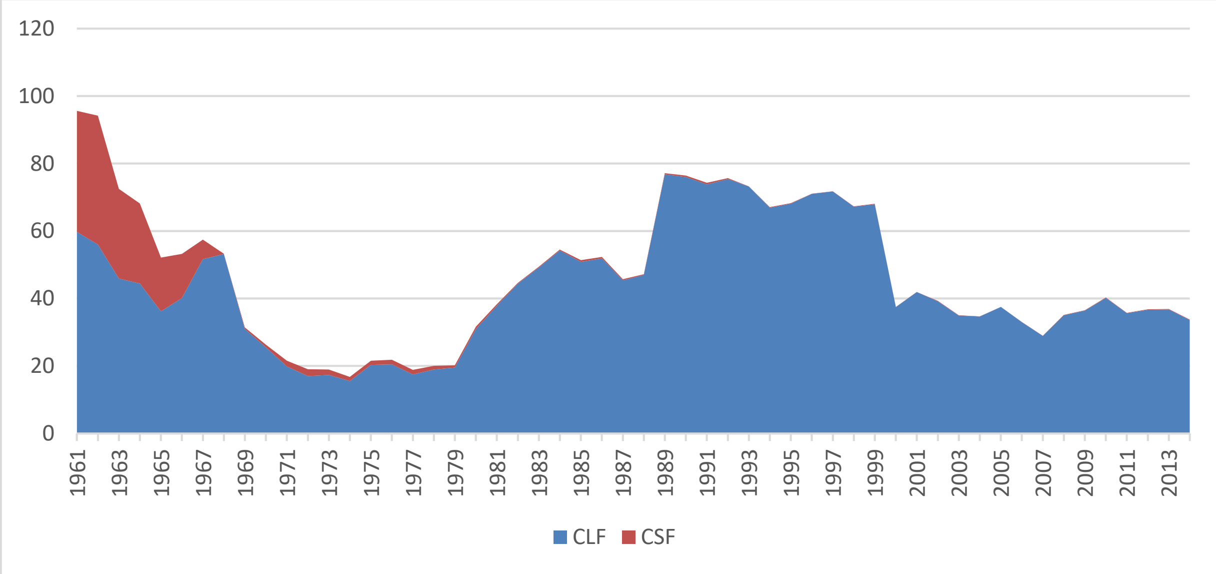

Figure 2. Carbon Dioxide Emissions from Liquid and Solid Fuel Consumption (1961 – 2014)
Source: World Development Indicators (2018)

Figure 2 indicates that carbon dioxide emission from liquid fuel consumption has been higher than solid fuel consumption in Nigeria. It can be captured it in the trend analysis below.

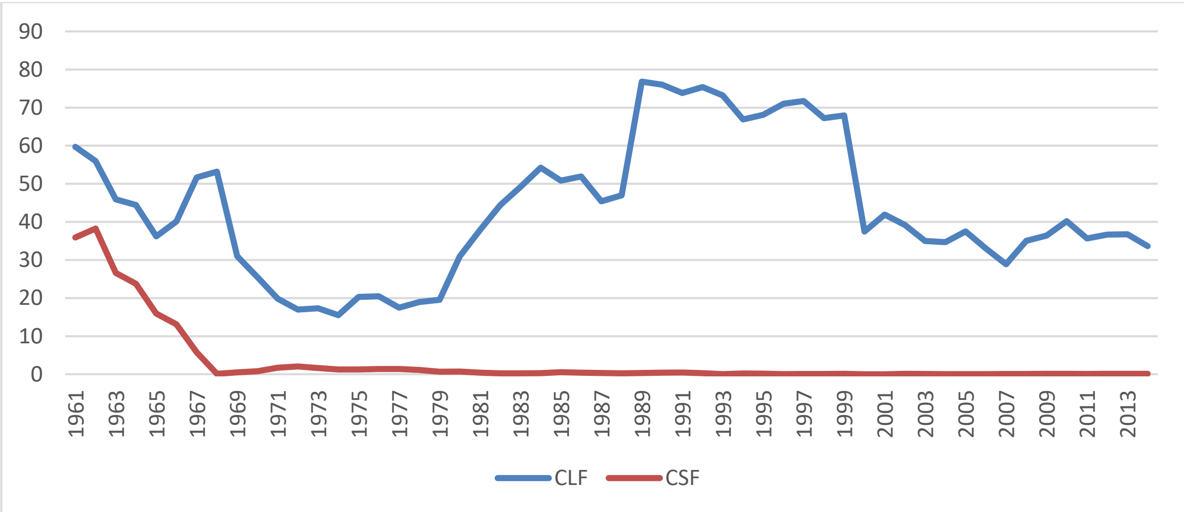

Figure 3. Trend of Carbon Dioxide Emissions in Nigeria (1961 – 2014) Source: World Development Indicators (2018)

The period 1961 to 1977 has been characterised by declining trend in carbon dioxide emissions from liquid fuel consumption. After that, carbon dioxide emissions from liquid fuel consumption took an upward trend from 1978 till 1997 where it started to decline sharply till 1999. Slight oscillations have characterised the decline from 1999 till 2014. The period 1961 to 1968 was characterised by a sharp decline in carbon dioxide emissions from solid fuel consumption in Nigeria. After that, such a trend in carbon dioxide emissions from solid fuel consumption become flattened from 1968 to 2014. This trend can be explained through the shift in energy use over the analysed period. Such dynamics in energy use also generates series of fluctuations in the carbon dioxide emissions in the country, as presented in Figure 4.

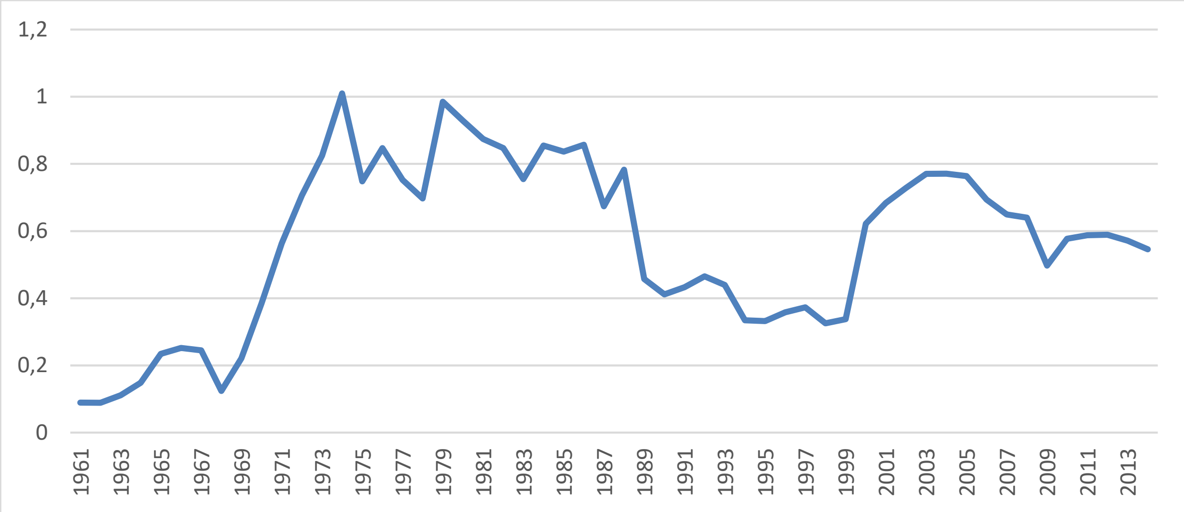

Figure 4. Trend of Carbon Dioxide Emissions in Nigeria (1961 – 2014) Source: World Development Indicators (2018)

The period 1961 to 1974 showcases a massive increase in carbon intensity in Nigeria. Thereafter, there has been some degree of oscillations from 1975 to 1987, after which the trend exhibits some downward movements till 1999. This trend was followed by a sharp rise from 2000 to 2002, where it climaxed and then started to decline till 2014. This decline in carbon intensity can be linked to the prediction of the Environmental Kuznets Curve (EKC) Hypothesis. Presently, extreme emission of Green House Gas (GHG) is tantamount to climate change, and it has received wide attention among the national and international community (Neenu and Nishad, 2021). Such emissions are considered a major environmental threat to human existence (Wang, Su, and Li, 2018). Given such an argument, essential questions, therefore, become pertinent. Such question includes:

$RQ_{1:}$ What is the effect of urbanization and economic development on carbon intensity in Nigeria?

$RQ_{2:}$ What is the link between urbanization, economic development, and carbon intensity in Nigeria?

$RQ_{3:}$ What is the optimal threshold level of urbanization that will not skyrocket carbon intensity in Nigeria?

In this light, this study seeks to examine the effect of urbanization on carbon intensity in Nigeria. The specific objectives are:

– to ascertain the effect of urbanization and economic development on carbon dioxide emission in Nigeria.

– to examine the link between urbanization, economic development and carbon dioxide emission in Nigeria.

– to detect the optimal threshold level of urbanization that will not generate massive carbon dioxide emissions in Nigeria.

The structure of this study is in five sections. Immediately following this introduction is the literature review. Then, in section three, the research methodology is explained, while section four focuses on the empirical analysis and discussion of findings. Finally, section five presents the conclusion and recommendations of the study.

1. 1. Review of Relevant Literature

The theoretical basis of this study is on the *Environmental Kuznets Curve (EKC)* hypothesis. The *Environmental Kuznets Curve (EKC)* hypothesis describes the link between economic growth and environmental degradation as an inverted U-shaped curve (Maneejuk, Ratchakom, Maneejuk, and Yamaka, 2020). This relationship is depicted in Figure 5.

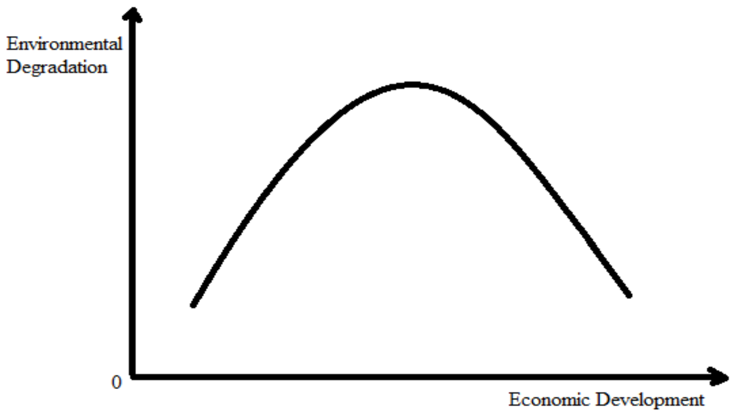

Figure 5: Environmental Kuznets Curve

Based on this hypothesis, the pattern of environmental degradation is in two stages related to society's economic development. First, during the early phase of economic development, environmental degradation increases due to increased pollution emissions and extensive and intense exploitation of natural resources and increased use of production resources and adoption of specific production methods to support rising economic activity (Maneejuk, et al., 2020). This process reaches up to a certain level as income rises. After such level, when GDP rises at a high rate, environmental degradation reduces, owing to growing public knowledge and concern about environmental degradation, as well as research and development efforts being geared more toward the notion of the green economy (Stern, 2004; Kaik and Zervas, 2013). Second, in addition to the prediction of the EKC hypothesis, the IPAT framework has been used to portray that environmental impact is equal to the product of population, affluence and technology.

The I = PAT framework (environmental impact (I) equals the product of population (P), affluence (A) and technology (T), has continued to creep around in the background of much of the discussion about environmental pressures. As pointed out by Martine (1996: 7), "A sizable segment of the literature on population and environment during the past 25 years has taken the ubiquitous I=PAT equation as the starting point" (White, et al., 2009). However, while the IPAT equation (or identity) generate much thinking, there is far less empirical evidence to show how much impact a population increment (or urban population increment) has on environmental quality.

In examining the validity of the EKC, Grossman and Krueger (1991) investigated the environmental impact of NAFTA, using ambient sulfur dioxide (SO2) and suspended particulate matter (SPM) as indicators of environmental quality. The researchers discovered a U-shaped connection between GDP per capita and the two contaminants, confirming the Environmental Kuznets Curve (EKC) theory. The researchers discovered a U-shaped connection between GDP per capita and the two contaminants, confirming the Environmental Kuznets Curve (EKC) theory. Following this research, a significant effort has been made to validate the EKC hypothesis by utilising multiple econometric models and variables to quantify environmental conditions. By examining the link between environmental and financial performance, Cohen, Fenn, and Konar (1997) discovered that investors who pick environmental leaders in an industry-balanced portfolio outperform those who choose environmental laggards.

Li and Ma (2014) examined the relationship among the urbanisation rate, economic development and environmental change for thirty administrative regions in China from 2003 to 2011 using panel data analysis. The pressure-state-response (PSR) model was utilised to ascertain environmental quality indices for the thirty regions. The panel regression result revealed an inverted U-shaped relationship between the urbanisation rate and changes in environmental quality. Furthermore, the study revealed that the turning point generally appeared near a 60% rate of urbanisation. Further, economic development had a significant effect on the regional environment. An improved environment follows a higher degree of economic development, but an extensive economic growth programme aimed at increasing the economic growth of the regions harmed the environment.

The ARDL model was used by Shahbaz, Solarin, and Ozturk (2016) to investigate the EKC for 19 African nations, and the EKC phenomena were identified in just six of them: Algeria, Cameroon, the Congo Republic, Morocco, Tunisia, and Zambia. Atasoy (2017) used two methods to test the EKC hypothesis across the 50 states of the United States and discovered that the Augmented Mean Group (AMG) method provided supporting evidence in 30 states, while the Common Correlated Effects Mean Group Estimator (CCEMG) method indicated that the EKC hypothesis held in only ten states. Aruga (2019) used panel regression and cointegration models to investigate the EKC hypothesis in the Asian-Pacific area. He revealed that the idea held for those with much money. Furthermore, the EKC theory has been validated in developing Eastern European and Central Asian states (Koilo, 2019). However, other studies have found that the EKC does not exist in various nations. Pal and Mitra (2017) used the ARDL model to investigate the relationship between GDP per capita and CO2 emissions in India and China. Their findings revealed the presence of the N-shaped EKC, as CO2 emissions increased faster than GDP growth at first, then decreased as economic activity expanded, but stopped decreasing at a threshold before increasing again.

Mikayilov, Galeotti, and Hasanov (2018) used Autoregressive Distributed Lag Bounds Testing (ARDLBT), Fully Modified Least Squares (FMOLS), Dynamic Least Squares (DOLS), and Canonical Cointegrating Regression (CCR) methods to investigate the relationship between economic growth and CO2 emissions in Azerbaijan. The techniques yielded consistent evidence showing that economic growth has a positive connection with CO2 emissions in the long term in the form of a monotonically rising function, suggesting that the EKC hypothesis does not apply to Azerbaijan. Moutinho, Varum, and Madaleno (2017) used data from 13 main economic sectors, with Gross Value Added (GVA) representing income and CO2 emissions showing environmental degradation, to test the EKC hypothesis for Spain and Portugal using the Panel Corrected Standard Errors (PCSE) technique. They discovered an N-shaped link between GVA and CO2 emissions in Portugal and N-shaped and inverted N-shaped functions in Spain, indicating a deviation from the theoretical EKC since CO2 appeared to be lowered for a while before increasing and decreasing again along the direction of GVA growth.

Studies have uncovered a wealth of information on carbon emissions and economic development. They demonstrated that the economic activity level was adversely linked with carbon intensity on both national and regional levels by studying the significant elements impacting carbon intensity at both national and regional levels (Wang, Zhang, & Liu, 2016). They established the importance of China's economic development in supporting reduced carbon intensity. In China, urbanisation has a direct impact on carbon intensity. Nag and Parikh (2000) used the Divisia decomposition technique to analyse the carbon emissions from the end-use of commercial energy by four key sectors: industrial, transportation, agriculture, and the commercial sector. They concluded that energy intensity has accounted for the majority of the increase in carbon emission intensity. Wang et al. (2018) compared the decoupling impact of economic growth from carbon emissions and its causes. They found a significant impact of urbanisation and industrialisation on India's and China's economic growth.

Investors have become more interested in contributing to global sustainability in various ways in recent years; incorporating environmental, social, and governance aspects into their portfolio is one of their initiatives (Souza, 2019). Such aids in integrating social, ethical, and environmental considerations with economic considerations for investors (Jain, Sharma, & Srivastava, 2019). Using the GARCH model to investigate the impact of macroeconomic factors such as crude oil price, exchange rate, 10-year bond price, and nonfarm payrolls on firms that combine CSR operations with stock securities, Kathiravan, Selvam, Maniam, Venkateswar, and Sigo (2020) looked at the effect of temperature on the top five cities in India - Delhi, Kolkata, Bangalore, Mumbai, and Chennai. They discovered a substantial influence of temperature on the performance of the BSE GREENEX index in India from 2009 to 2018.

Maneejuk et al. (2020) investigate the link between economic progress and environmental degradation under the Environmental Kuznets Curve (EKC) framework. Under the EKC hypothesis, the level of CO2 emissions is employed as an indication of environmental harm to assess whether or not higher economic development may reduce environmental deterioration. The research focused on eight central worldwide economic communities, which included 44 nations from around the world. The kink regression model, which identifies the turning point of a shift in a relationship, was used to assess the connection between economic growth and environmental condition. The findings show that just three of the eight international economic communities, namely the European Union (EU), the Organization for Economic Co-operation and Development (OECD), and the Group of Seven (G7), accept the EKC theory. Further, financial development, the industrial sector, and urbanisation have all been linked to higher CO2 emissions, whereas renewable energy has been shown to alleviate environmental deterioration. In addition to determining if the EKC hypothesis exists in a specific nation, the findings revealed that the EKC hypothesis is valid in just 9 of the 44 countries studied.

Neenu and Nishad (2021) studied the influence of five factors on carbon intensity in India, including economic level, population level, urbanisation level, industry percentage, fossil fuel energy consumption, and methane emission. The study's data was gathered from the World Bank Database and the Bombay Stock Exchange's official website. Using OLS models, researchers assessed the influence of the five factors on carbon intensity. With econometrics methods such as GARCH and EGARCH, they assessed the news' volatility and impact. According to the study, the economic level, fossil fuel energy consumption, population level, urbanisation level, and methane emission all have a substantial positive influence on carbon intensity. However, the economic level and carbon intensity have a negative connection. The SENSEX has a higher volatility than sustainability indices. The study discovered that positive and negative news have asymmetric effects on stock volatility, as the parameter is negative and significant for all indices.

In examining the factors affecting carbon dioxide emission, in Turkey and India, for example, Boutabba (2014) and Pata (2018) offered empirical evidence of a positive connection between financial development and environmental deterioration. Furthermore, the industrialisation process was positively related to CO2 emissions in China and Turkey due to increasing energy consumption for manufacturing operations (Liu and Bae, 2018). Furthermore, research has indicated that urbanisation and renewable energy use are essential contributors to CO2 emissions. Bilgili, Koçak, and Bulut (2016) and Saidi and Omri (2020) also examined the relationship between renewable energy use and CO2 emissions and came to similar conclusions.

The EKC theory was reviewed by Bilgili, Koçak, and Bulut (2016) in light of the possible influence of renewable energy use on environmental quality. They discovered that renewables negatively influenced CO2 emissions in seven OECD nations from 1977 to 2010. Furthermore, Bhattacharya, Churchill, and Paramati (2017) examined the influence of renewable energy on environmental deterioration in several economic zones and found that renewable energies had a negative impact on emissions. According to this research, an area may attain a sustainable environment by limiting fossil fuel energy and encouraging renewable energy sources such as wind, solar, biomass, and geothermal energy. Much prior research has indicated that urbanisation increases carbon emissions (Pata, 2018; Ali, Bakhsh, and Yasin, 2019); Zafar, Ullah, and Majeed, 2020).

2. METHODOLOGY

2.1. Model Specification

The model for the study is specified based on the set objectives. To ascertain the effect of urbanization on carbon dioxide emission in Nigeria, this study employs the modified model of Neenu and Nishad (2021), who examined the impact of *economic level, population level, urbanization level, industry proportion, fossil fuel energy consumption, and methane emission* on carbon intensity in India. The modified model for this study is specified as follows:

$$\text{CEM} = \text{f(CLF, CSF, EDV, POP, URB)}, \quad (1)$$

where:

CEM = CO_2 emissions (metric tons per capita), which is a measure of carbon intensity

CLF = CO_2 emissions from liquid fuel consumption (% of total)

CSF = CO_2 emissions from solid fuel consumption (% of total)

EDV = GDP per capita growth (annual %)

POP = Population growth (annual %)

URB = Population in the largest city (% of urban population), an index of urbanization

Transformation of Equation (1) result in Equation (2) as follows:

$$\text{CEM} = \xi_0 + \xi_1 CLF + \xi_2 CSF + \xi_3 EDV + \xi_4 POP + \xi_5 URB + \mu\,, \quad (2)$$

where ξ_0 is the constant of the regression model; ξ_1 to ξ_5 are the parameters to be estimated; and μ is the random error term. It is expected that $\xi_1, \xi_2, \xi_4, and\ \xi_5$ must be positive. This implies that an increase in carbon emission from liquid fuel consumption, carbon emission from solid fuel consumption, population growth, and urbanization will lead to an increase in carbon intensity and vice versa. Also, it is expected to be negative to align with the prediction of the 'Environmental Kuznets Curve'. Based on this, at the early stage of economic development, the rate of carbon intensity will be high. However, as society develops to a sustainable level, clean energy emerges, which lowers the nation's carbon intensity. Therefore, the following partial differentiation is attainable:

$$\partial CEM/_{\partial CLF} > 0;\ \partial CEM/_{\partial CSF} > 0;\ \partial CEM/_{\partial POP} > 0; and\ \partial URB/_{\partial URB} > 0$$

Similarly, $\partial CEM/_{\partial EDV} < 0$.

In the second objective, we seek to examine the link between urbanization, economic development and carbon dioxide emission in Nigeria. This requires using the vector autoregressive (VAR) model, impulse response function, and variance decomposition. The VAR(1) model is specified as follows:

$$CEM_t = \delta_{01} + \sum_{i=0}^{1} \alpha_1 CEM_{t-i} + \sum_{i=0}^{1} \beta_1 URB_{t-i} + \sum_{i=0}^{1} \beta_2 EDV_{t-i} + \mu_{1t} \quad (3)$$

$$URB_t = \delta_{02} + \sum_{i=0}^{1} \alpha_1 URB_{t-i} + \sum_{i=0}^{1} \beta_1 POP_{t-i} + \sum_{i=0}^{1} \beta_2 EDV_{t-i} + \mu_{2t} \quad (4)$$

$$EDV_t = \delta_{02} + \sum_{i=0}^{1} \alpha_1 EDV_{t-i} + \sum_{i=0}^{1} \beta_1 POP_{t-i} + \sum_{i=0}^{1} \beta_2 URB_{t-i} + \mu_{3t} \quad (5)$$

The estimation of Equations (3) to Equation (5) simultaneously under the VAR framework generates the parameter estimates.

Finally, the threshold regression is carried out to achieve the third objective. The third objective is to detect the optimal threshold level of urbanization that will not generate massive carbon dioxide emissions in Nigeria. The threshold equation is specified as follows:

$$CEM_t = \delta_{URB} + \psi_1 d_t^{URB}(URB_t - URB^*) + \psi_2(1 - d_t^{URB})(URB_t - URB^*) + \varepsilon_t \qquad (6)$$

Where CEM is carbon intensity; URB is urbanization; URB* is the value used for the iteration process in our search for the optimal threshold point. The effect of urbanization is captured by ψ_1 for the period in which urbanization is greater than the threshold (high urbanization regime) while ψ_2 represents the effect of urbanization when urbanization is lower than the threshold value (low urbanization regime). The dummy variable for urbanization (d_t^{URB}) is defined as:

$$d_t^{URB} = \begin{cases} 1 & \text{if } URB_t > URB^* \\ 0 & \text{elsewhere.} \end{cases}$$

2.2. Sources of Data

The data for this study are obtained from the World Bank database on World Development Indicators. The study period is limited to 1960 to 2014 due to data availability on key variables of interest. This, therefore, reflects a period of 54 years which has duly covered some key regimes in the economy.

2.3. Analytical Technique

The study employed diverse techniques to drive home the achievement of the set objectives. The first objective is achieved through the use of the *ordinary least squares* (OLS) regression as specified in Equation 2; the second objective is achieved through the use of vector autoregressive technique as stated in Equations 3 to Equation 5; while the third objective is achieved through the use of *threshold regression* under the *Threshold Autoregressive* (TAR) and *Smooth Transition Autoregressive* (STAR) models as specified in Equation 6.

3. EMPIRICAL FINDINGS

3.1. Descriptive Statistics

The descriptive statistics of the variables in the model is presented in Table 1. The mean, median, maximum, minimum, and standard deviation of the variables represents the measures of the central tendency and dispersion.

Table 1

Descriptive Statistics of the Variables

	URB	EDV	CEM	CLF	CSF	POP
Mean	15.583	1.422	0.563	43.557	3.332	2.524
Median	15.918	2.472	0.588	39.643	0.294	2.542
Maximum	17.308	22.182	1.010	76.819	38.246	3.032
Minimum	11.669	-17.553	0.089	15.518	0.009	2.029
Standard Deviation	1.372	7.186	0.251	17.945	8.584	0.226
Observations	54	54	54	54	54	54

Source: Author Computation using Eviews 10.

From Table 1, it is observed that the index of urbanization averaged 15.583 with a standard deviation of 1.372. This gives the coefficient of variation to be 8.80%, indicating low variability in the variable. The maximum value was 17.308, while the minimum value was 11.669. The index of economic development averaged 1.422%, with a standard deviation of 7.186%. Thus, the coefficient of variation is given to be 505.34% showing a higher degree of variability.

The minimum value of the variable was -17.553%, while the maximum value was 22.182%. Carbon intensity (CO_2 emissions) over the study period averaged 0.563 with a standard deviation of 0.251, thus giving a coefficient of variation to be 44.58%, indicating high variability in the variable. The variable has a minimum value of 0.089 and a maximum value of 1.010. CO_2 emissions from liquid fuel consumption averaged 43.557%, with a standard deviation of 17.945%. Therefore, the coefficient of variation is given to be 41.20%, which gives a high degree of variability. The variable has a minimum value of 15.518% and a maximum value of 76.819%. CO_2 emissions from solid fuel consumption averaged 3.332% with a standard deviation of 8.584%, thus giving a coefficient of variability of 257.62%. Finally, population growth averaged 2.524% with a standard deviation of 0.226%; giving the coefficient of variation to be 8.95%.

3.2. Correlation Analysis

Given that a linear combination of variables utilised in a regression model can generate multicollinearity, the correlations between the variables are ascertained to avoid such defects. The correlation matrix is presented in Table 2.

Table 2

Correlation Matrix

Variables	URB	EDV	CEM	CLF	CSF	POP
URB	1.00					
EDV	-0.1174	1.00				
CEM	0.3899	-0.0340	1.00			
CLF	0.4084	-0.2721	-0.5081	1.00		
CSF	-0.7060	-0.0301	-0.5715	0.0918	1.00	
POP	0.5184	-0.0818	0.7426	-0.2831	-0.6481	1.00

Source: Author Computation using Eviews 10.

The correlation matrix in Table 2 shows a weak inverse relationship between urbanisation and economic development, as indicated by the correlation coefficient of -0.1174. This implies that as urbanisation increases, economic development decreases, and vice versa. Similarly, there is a robust negative relationship between urbanisation and carbon dioxide emission from solid fuel consumption, given the correlation coefficient of -0.7060. Conversely, there is a weak positive relationship between urbanisation and carbon intensity since the correlation coefficient is 0.3899. Thus, an increase in urbanisation is likely to lead to greater carbon intensity and vice versa. Also, there is a weak positive relationship between urbanisation and carbon dioxide emission from liquid fuel consumption. This implies that as urbanisation increases, carbon dioxide emission from liquid fuel consumption also increases, and vice versa. In the same vein, there is a reasonably direct solid relationship between urbanisation and population growth. This implies that as population growth rises, urbanisation also rises and vice versa.

We also observed that carbon intensity, carbon dioxide emission from liquid fuel consumption, carbon dioxide emission from solid fuel consumption, and population growth all have a weak inverse relationship with economic development, given their correlation coefficients of -0.0340, -0.2721, -0.0301, and -0.0818 respectively. Thus, as these variables increases, economic development decreases and vice versa. In the same vein, carbon intensity has a strong positive relationship with population growth, as indicated by the correlation coefficient of 0.7426. This implies that as population growth increases, carbon intensity also increases and vice versa. Meanwhile, carbon intensity has a relatively strong negative relationship with carbon dioxide emission from liquid fuel consumption and carbon dioxide emission from solid fuel consumption, given their respective correlation coefficient of -0.5081 and -0.5715. Thus, carbon intensity increases as these variables decreases and vice versa. We also observed that carbon dioxide emission from liquid fuel consumption has a weak positive relationship with carbon dioxide emission from solid fuel consumption, given the correlation coefficient of 0.0918, but has a weak negative relationship with population growth given the correlation coefficient -0.2831. Then, carbon dioxide emission from solid fuel consumption has a relatively strong negative relationship with population growth, given the correlation coefficient of -0.6481.

Each of the variables correlates perfectly with themselves, thus giving the perfect correlation coefficient of 1.00. Since none of the correlation coefficients among the explanatory variables is very high, then there is no perfect linear relationship among the explanatory variables in the model. Hence, the possibility of multicollinearity in the model is ruled out.

3.3. Ordinary Least Squares Regression

The regression result to ascertain the effect of urbanization on carbon dioxide emission in Nigeria is estimated, and the result is presented in Table 3.

Table 3

OLS Regression Result

Variable	Coefficient	Standard Error	t-Statistic	Probability
CLF	-0.0097	0.0016	-5.9006	0.0000***
CSF	0.0021	0.0037	0.5590	0.5787
EDV	-0.0046	0.0027	-1.7072	0.0943*
POP	0.3242	0.1261	2.5708	0.0133**
URB	0.1019	0.0280	3.6376	0.0007***
C	-1.4208	0.4003	-3.5490	0.0009***
R-squared	0.7514	F-statistic	29.0147	
Adjusted R-squared	0.7255	Prob(F-statistic)	0.0000***	

Note: *, **, and *** denotes significance at 10%, 5%, and 1% level of significance.
Source: Author Computation using Eviews 10.

The OLS regression result shows that urbanization exerts a positive and significant effect on carbon dioxide emissions in Nigeria. This is given by the t-value of 3.6379, which is significant at the 1% significance level. From the coefficient (0.1019), a unit percentage increase/decrease in urbanization will lead to a 10.19% increase/decrease in carbon dioxide emission in Nigeria. Thus, a decrease in urbanization is likely to curb carbon intensity in Nigeria. Pata (2018), Ali, Bakhsh, and Yasin (2019), and Zafar, Ullah, and Majeed (2020) obtained similar findings. People relocate to cities mostly because there are greater job possibilities in cities. Therefore, the number of cars on the road is increasing due to urbanization, which has an impact on traffic emissions.

Also, it is observed that economic development has a negative and significant effect on carbon dioxide emissions in Nigeria. This is portrayed by the t-statistic of -1.7072, which is significant at the 10% significance level. Thus, the coefficient (-0.0046) implies that a unit per cent increase/decrease in economic development will lead to a 0.46% decrease/increase in carbon intensity in Nigeria. This finding aligns with the prediction of the Environmental Kuznets Curve (EKC). According to the EKC, carbon intensity increases with the increase in economic development, climaxed at the middle stage, and then continue to decline as development continues to increase. The result confirms Wang, Zhang and Liu (2016) findings as they proposed that economic level negatively correlated with carbon intensity.

Further, the result indicated that population growth exerts a positive and significant effect on carbon intensity in Nigeria. The significance is indicated by the significance of the t-value (2.5708) at the 5% level of significance. Therefore, a unit per cent increase/decrease in population growth will lead to a 32.42% increase/decrease in carbon intensity in Nigeria.

Carbon dioxide emission from liquid fuel consumption is observed to exerts a negative and significant effect on carbon intensity at the 1% level of significance. This indicates that a unit per cent increase/decrease in carbon dioxide emission from liquid fuel consumption will lead to a 0.97% decrease/increase in carbon intensity. Meanwhile, carbon dioxide emission from solid fuel consumption exerts a positive but insignificant effect on carbon intensity in Nigeria. The constant term (-1.4208) indicates that carbon intensity will be -1.4208 if all the explanatory variables are held constant.

The coefficient of determination, which is the r-squared, is 0.7514 and indicates that the variations in the explanatory variables explain 75.14% of the total variations in carbon intensity. The F-statistic (29.0147) is statistically significant at the 1% level, indicating that the overall model is statistically significant in explaining the variations in carbon intensity in Nigeria.

3.4. Vector Autoregressive (VAR) Estimates

In detecting the linkages between urbanization, carbon intensity, and economic development in Nigeria, the VAR regression result is presented in Table 4.

Table 4

VAR Regression Result

	CEM	EDV	URB
CEM(-1)	0.873895	-6.212847	-0.070350
	(0.06509)	(3.89544)	(0.10863)
	[13.4265]***	[-1.59490]*	[-0.64760]
EDV(-1)	0.001392	0.419963	-0.005174
	(0.00211)	(0.12605)	(0.00352)
	[0.66114]	[3.33166]**	[-1.47195]*
URB(-1)	-0.001944	0.008348	0.918663
	(0.01208)	(0.72276)	(0.02016)
	[-0.16095]	[0.01155]	[45.5791]***
C	0.108059	4.272202	1.365936
	(0.17837)	(10.6751)	(0.29769)
	[0.60583]	[0.40020]	[4.58839]***
R-squared	0.811436	0.229762	0.980593
Adj. R-squared	0.799892	0.182605	0.979405
F-statistic	70.28642***	4.872240**	825.2798***

Note: *, **, and *** denotes significance at 10%, 5%, and 1% level of significance. Standard errors are enclosed in normal brackets ( ) while the t-statistics are enclosed in square brackets [ ].
Source: Author Computation using Eviews 10.

The VAR regression result in Table 4 shows that carbon intensity, economic development, and urbanization are strongly endogenous in predicting themselves. This is because they have a significant effect in predicting themselves, while every other variable does not significantly affect them. For instance, carbon intensity strongly predicts itself since the t-statistic (13.4265) is statistically significant at the 1% level. Hence, carbon intensity is strongly endogenous. Furthermore, the endogeneity of carbon intensity implies that the past realization of carbon intensity is associated with an 87.39% increase in carbon intensity on the average, ceteris paribus. Meanwhile, economic development and urbanization are weakly exogenous in predicting carbon intensity in Nigeria.

Similarly, economic development is strongly endogenous in predicting itself since the t-value (3.33166) is statistically significant at the 5% level. Thus, the past realization in economic development is associated with a 42% increase in economic development on the average ceteris paribus. It is also observed that carbon intensity is strongly exogenous in predicting economic growth since its t-value (-1.5949) is statistically significant at the 10% level of significance. Thus, a unit per cent increase in carbon intensity will lead to a 6.21% decrease in economic development and vice versa. However, urbanization is weakly exogenous in predicting economic development.

Finally, urbanization is strongly endogenous in predicting itself since its t-value (45.5791) is statistically significant at the 1% significance level. Hence, the past realization in urbanization is associated with a 91.87% increase in urbanization in Nigeria. Carbon intensity is weakly exogenous in predicting urbanization, while economic development is strongly exogenous. A unit per cent increase in economic development will exert a 0.52% decrease in carbon intensity. The validity of these results is tested using the variance decomposition.

3.5. Variance Decomposition

The variance decomposition captures the proportion of the forecasted error variance predicted by each of the variables in the VAR framework. The result is indicated in Table 5. The analysis is broken down into the short run (period 1 to period 3) and long run (period 4 and 5).

Table 5

Variance Decomposition for CEM, EDV and URB

Variance Decomposition of CEM:				
Period	Standard Error	CEM	EDV	URB
1	0.1094	100.00	0.0000	0.0000
2	0.1477	99.67	0.3349	0.0006
3	0.1717	99.329	0.6689	0.0018
4	0.1878	99.077	0.9199	0.0035
5	0.1990	98.897	1.097	0.0056
Variance Decomposition of EDV:				
Period	Standard Error	CEM	EDV	URB
1	6.5461	13.046	86.954	0.0000
2	7.0370	11.487	88.513	4.61E-06
3	7.1274	11.657	88.343	3.93E-05
4	7.1750	12.574	87.425	0.0001
5	7.2177	13.594	86.406	0.0003
Variance Decomposition of URB:				
Period	Standard Error	CEM	EDV	URB
1	0.1825	0.0075	1.7716	98.221
2	0.2536	0.7145	5.4364	93.849
3	0.3040	1.3583	8.1282	90.514
4	0.3422	1.8167	9.9451	88.238
5	0.3720	2.1283	11.172	86.699

Source: Author Computation using Eviews 10.

In the short run, carbon intensity explains 100% of its total forecasted error variance while economic development and urbanization contributed nothing. This declined sluggishly to 99.329% in the third period. In the long run, carbon intensity still explained 98.897% of its forecasted error variance, while economic development and urbanization jointly contributed a meagre 1.103% of its total forecasted error variance. This indicated that carbon intensity is strongly endogenous both in the short-run and in the long run.

Similarly, economic development explained 86.954% of its forecasted error variance in the short-run, which increased steadily to 88.343% in the third period. Within the short run, urbanization contributed nothing to the forecasted error variance in economic development. In contrast, carbon intensity contributed up to 11.657% of the forecasted error variance in economic development in the short run. This shows that economic development is strongly endogenous in the short run, with a minor exogenous effect from carbon intensity. However, in the long run, economic development still remained strongly endogenous by explaining up to 86.406% of its forecasted error variance, while carbon intensity explained about 13.594% of the total forecasted error variance in economic development. Thus, economic development remained strongly endogenous, even in the long run.

Regarding urbanization, the variable is also strongly endogenous both in the short-run and in the long run. The variables explained 98.221% of its forecasted error variance in the first period, which declined steadily to 90.514% in the third period. Within the short run, both carbon intensity and economic development are weakly exogenous. For instance, carbon intensity explained 1.36% of the forecasted error variance in urbanization in the third period, while economic development explained 8.13% in the same period. In the long run, urbanization remained strongly endogenous, explaining up to 86.699% of its forecasted error variance in the fifth period, while economic development and carbon intensity jointly explained 13.30% of the total forecasted error variance. Though economic development showed some progress in explaining urbanization, its proportion is relatively small. The decomposition of the effects of the variables on the other is captured by the historical decomposition as well.

3.6. Impulse Response Function

The impulse response function captures the question of how the variables respond to shock in another variable. Such responses are portrayed in Figure 5. The response follows a one standard deviation shock in the variable of interest.

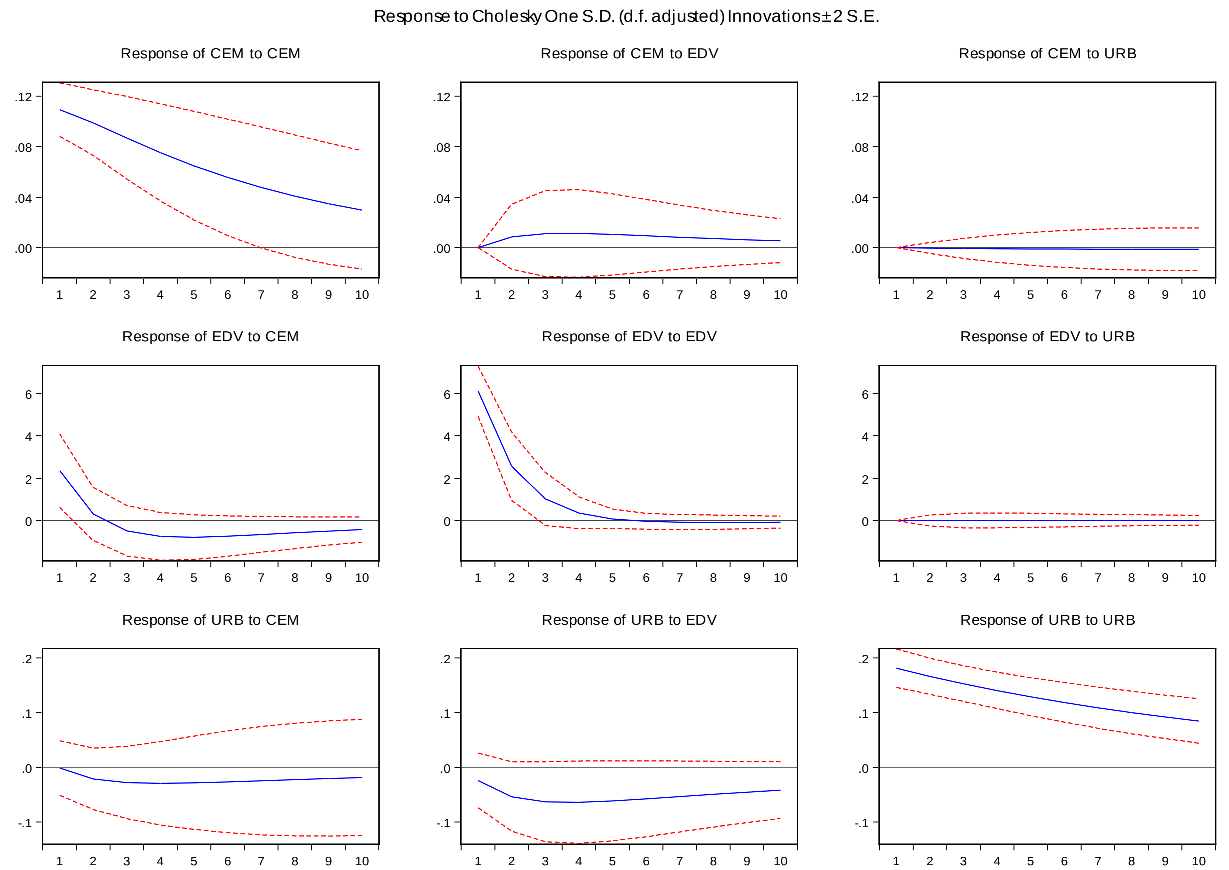

Figure 6. Impulse Response Function for CEM, EDV and URB

From Figure 6, a one-standard-deviation shock in carbon intensity will cause economic development to decline sharply in the short run, but such an effect dies off in the long run. Similarly, a one-standard-deviation shock in carbon intensity will cause urbanisation to decline slowly in the short run but becomes explosive in the long run since such shocks will cause a more significant deviation from the long-run path.

A one-standard-deviation shock in economic development is associated with increased carbon intensity in the short run-up to the third period. But, thereafter, it declined steadily over the long run, though the effect does not die off even in the tenth period. In the same vein, a one-standard-deviation shock in economic development will cause urbanisation to decline up to the second period, then maintained a steady trend over the long run.

The response of carbon intensity to a one-standard-deviation shock in urbanisation looks explosive. However, there is a more significant divergence both in the short run and in the long run. Meanwhile, the response of economic development to a one-standard-deviation shock in urbanisation is less in the short and long run.

3.7. Threshold Regression

The threshold regression is conducted to detect the optimal threshold level of urbanisation that will not generate massive carbon dioxide emissions in Nigeria. The result is presented in Table 6. The result identified both the linear and nonlinear parts of the threshold regression result.

Table 6

Threshold Regression Result

Dependent Variable: CEM Method: Smooth Threshold Regression Transition function: Logistic Threshold variable: URB				
Variable	Coefficient	Standard Error	t-Statistic	Probability
Threshold Variables (linear part)				
URB	-1.0107	2.7551	-0.3668	0.7154
C	10.6155	26.3879	0.4023	0.6893
Threshold Variables (nonlinear part)				
URB	-0.2551	1.1989	-0.2128	0.8324
C	12.6867	16.4044	0.7734	0.4431
Slopes				
SLOPE	0.6731	0.6932	0.9710	0.3364
Thresholds				
THRESHOLD	14.444	1.6165	8.9358	0.0000***
R-squared	0.754053	F-statistic		29.43273
Adjusted R-squared	0.728433	Prob(F-statistic)		0.000000***

Source: Author Computation using Eviews 10.

From the threshold regression result in Table 6, it is observed that there is a linear relationship between carbon intensity and urbanization. This is because both the linear and nonlinear coefficients have the same sign (negative). Therefore, the threshold coefficient (14.444) implies that the optimal threshold level of urbanization that will not generate massive carbon dioxide emission in Nigeria is 14.444%. At this threshold level, the slope coefficient (0.6731), which is statistically insignificant at the 5% level, indicates that urbanization will not have a significant positive effect on carbon intensity in Nigeria. We check on the effect of deviation from the threshold level, and the following threshold estimates are presented in Table 7.

Table 7

Threshold Estimates

Variable	Coefficient	Standard Error	t-Statistic	Probability
URB < 14.2004 -- 9 observations				
URB	0.0599	0.0501	1.1941	0.2383
C	-0.6323	0.6717	-0.9414	0.3512
14.2004 <= URB < 16.4746 -- 27 observations				
URB	0.1166	0.0315	3.7021	0.0006***
C	-1.0697	0.4854	-2.2037	0.0324**
R-squared	0.8045	F-statistic		39.5056
Adjusted R-squared	0.7841	Prob(F-statistic)		0.0000***

Source: Author Computation using Eviews 10.

Given the estimates, if urbanization is less than 14.20% (below the threshold level of 14.444), urbanization will not significantly affect carbon intensity. However, if it is above 14.20% up to 16.47% (above the threshold value of 14.444), it will yield a positive and significant effect on carbon intensity. In this regard, it will increase carbon intensity by 11.66%.

4. SUMMARY OF MAJOR FINDINGS

Based on this study, the following significant findings were obtained:

− Urbanization exerts a positive and significant effect on carbon intensity in Nigeria. Meanwhile, economic development has a negative and significant effect on carbon intensity in Nigeria, which is in line with the prediction of the EKC.

− Carbon intensity, economic development, and carbon intensity are strongly endogenous in the Nigerian context over the study period.

− The optimal threshold level of urbanization that will not generate massive carbon dioxide emissions in Nigeria is 14.444%.

5. CONCLUSION

This study examined the effect of urbanization, population growth, and economic development on carbon intensity. In addition, the optimal threshold of urbanization that will not skyrocket carbon intensity was also examined. The study employed time-series data that covers the period 1961 to 2014. The choice of the time frame was based on data availability. The ordinary least squares (OLS) regression analysis, vector autoregression and threshold regression were utilized in the study. The OLS regression result discovered that economic development has a negative and significant effect on carbon intensity. In contrast, population growth and urbanization both have a positive and significant effect on carbon intensity. A unit per cent increase/decrease in economic development is associated with a 0.46% decrease/increase in carbon intensity. Meanwhile, a unit per cent increase/decrease in population growth and urbanization exerts a 32.42% and 10.19% increase/decrease in carbon intensity in Nigeria.

The VAR regression result indicated that carbon intensity, urbanization, population growth, and economic development are strongly endogenous in predicting themselves. This was further supported by the variance decomposition and the historical decomposition. The impulse response function indicated that a one-standard-deviation shock in carbon intensity would cause economic development to decline sharply in the short run. However, such an effect dies off in the long run. Similarly, a one-standard-deviation shock in carbon intensity will cause urbanization to decline slowly in the short-run but become explosive since such shocks will cause a more significant deviation from the long run path.

The threshold regression result indicated that the optimal threshold level of urbanization that will not generate massive carbon dioxide emission in Nigeria is 14.444%. At this threshold level, the slope coefficient (0.6731), which is statistically insignificant at the 5% level, indicates that urbanization will not have a significant positive effect on carbon intensity in Nigeria. If urbanization is less than 14.20% (which is below the threshold level of 14.444), urbanization will not significantly affect carbo intensity. However, if it is above 14.20% up to 16.47% (above the threshold value of 14.444), it will yield a positive and significant effect on carbon intensity. In this regard, it will increase carbon intensity by 11.66%.

Based on the findings of this study, it can be concluded that as urbanization accelerates, environmental quality declines. It follows that overall environmental quality will decline as urbanization accelerates. Similarly, as the population grows, it generates some undesirable effects on the environment. There is bound to be an increase in carbon dioxide emissions from both liquid and solid fuel consumption with an attendant increase in domestic waste, increasing the country's carbon intensity. Conversely, as the economy develops, there is the likelihood of a reduction in carbon intensity as projected by the Environmental Kuznets Curve (EKC) hypothesis. Thus, there is a need for concerted effort to curb environmental pollution to ensure a better living environment for the citizenry. Regulations on carbon emissions should be made to be quite stringent to discourage excessive carbon emissions. Furthermore, a shift towards the use of clean energy should be promoted and implemented. Moreover, rural development policies should be implemented to curb rural-urban migration, which could increase urbanization in Nigeria.

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