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Urbanization and Climate Change in Nigeria

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Abstract

The study investigates the impact of urbanization on climate change in Nigeria in the period 1981 to 2023, utilising the Cobb-Douglas production function as a framework for analysis. The equations were estimated with the Ordinary Least Squares (OLS) estimator. The urban population growth rate was used as a proxy for urbanization (UBAN), whereas carbon dioxide (CO_2) emissions were used to represent climatic change. Empirical results showed a direct and significant impact of urbanization on carbon dioxide (CO_2) emissions. The nonrenewable energy consumption (NREC) variable also had a direct and significant impact on carbon dioxide (CO_2) emissions. While renewable energy consumption (REC) had an indirect and insignificant impact on carbon dioxide (CO_2) emissions, Domestic investment (GFCF) had an indirect and significant impact on carbon dioxide (CO_2) emissions. Also, population growth (LAB) rate had a direct and insignificant effect on carbon dioxide (CO_2) emissions. Based on the aforementioned results, the government should prioritise urban planning, this can balance the demand for urban growth with the need to reduce carbon dioxide (CO_2) emissions, thereby addressing climate change in Nigeria. Also, there should be strategic investments in green technologies, sustainable infrastructure, and energy-efficient systems in Nigeria. Despite its high cost, it has the potential to cut carbon dioxide (CO_2) emissions and prevent climate change.

Keywords: Urbanization; Climate Change; Carbon dioxide (CO_2) emissions

JEL Classification: O18, Q54, Q53

1. Introduction

Many people are shifting from rural to urban areas for a variety of economic and social reasons (Ali, Law, & Zannah, 2016). Technology and development projects in metropolitan regions, for example, are among the reasons driving people out from villages into urban settlements, resulting in urban population increase. The rising population is also a reason for urban population increase. Urbanisation is the process of changing a location into an urban region. It refers to the migration and increase of people into cities, as well as their socioeconomic and cultural activities (Hussain & Imitiyaz, 2018). Urbanisation could promote higher levels of literacy and education, better human health, a strong willingness to use social services, and opportunities for political, economic, and cultural participation. Urbanisation could also be linked with increase job availability. People in cities are more likely to find good occupations than those in rural areas. They also take an active role in political activities and are more likely to be appointed to political posts and positions by any administration. They are exposed to a variety of cultures, which allows them to meet new people and obtain new experiences while also reducing ethnic and racial divisions (Ali, Law & Zannah, 2016).

The perception of an urban centre varies, based on the country and author. For example, in Canada, 1000 people are considered an urbanised centre; 250 people in Denmark; 10,000 people in Greece; and 200 people in Sweden; whereas in Nigeria, 20,000 people are considered an urban centre (Bodo, 2019). The worldwide urban population has grown from 1.5 billion in 1970 to 4.4 billion in 2019, representing a 36.5% to 55.7% rise (United Nations, 2018). Urbanisation is expected to expand to 66% by 2050, up from 54% in 2014. By 2050, an extra 2.5 billion people are predicted to move to cities as a result of increased population growth (United Nations, 2014). Nigeria is one of Africa's most populous countries, with a population shift since independence in 1960. It has added around 62.5 million people to its urban population, with a projected 226 million by 2050 (Farrell, 2018). Urbanisation may result in climate change mostly an increase in Carbon Dioxide (CO_2) emissions when rapid and unplanned urban growth occurs.

Carbon dioxide (CO_2) emissions is a major contributor to climate change. Because carbon dioxide absorbs infrared light, it contributes to the greenhouse effect. The gases in the atmosphere that let sunlight through, yet absorb heat reflected back from the earth's warmed surface are what generate the greenhouse effect. The effects of greenhouse gas emissions include, but not limited to, increased temperatures, heat waves, drought, and irregular weather patterns; smog and acid rain; and more. As power plants burn more fuel to boost their energy supply, carbon waste absorbs surplus heat (Save on Energy, 2019). In 2017, global emissions grew by 1.6%. The Global Carbon Project predicts that CO_2 emissions would rise by about 2.7% by 2030 (Fogarty, 2018).

Urbanisation may have an impact on carbon dioxide emissions through a complicated interplay between changing lifestyles, industrial activity, transportation needs, and growing energy use. Urbanisation typically results in increasing emissions, but it also offers potential to cut emissions per person through smart city planning, and effective public transit among others. The importance of enhancing our understanding of urbanisation and cities, stems from the fact that it has the potential to significantly enhance living circumstances for current and future generations. At the Habitat III summit in Quito in October 1960, the UN's New Urban Agenda (NUA) strengthened support for the Sustainable Development Goal 11 (to make cities inclusive, safe, resilient, and sustainable) as well as recognition of the importance of nation-states localising all global sustainable development agreements based on the centrality of cities. Since 2015, there have been a number of international agreements recognising the importance of leveraging cities' innovative capacity in order to accomplish the global sustainable development agenda by 2030 (Acuto, Parnell, Seto & Contestabile, 2018).

Although there are still issues with implementation and enforcement, Nigeria has made efforts to reduce CO_2 emissions from urbanisation. Some major efforts include the creation of the Renewable Energy Master Plan and the National Renewable Energy and Energy Efficiency Policy, which promote the use of clean energy sources like as solar, wind, and hydropower. Measures such as Solar Power Naija, National Urban Development Policy, Smart Cities Initiatives, and emission control regulations for industries and vehicles have been implemented to reduce CO_2 emissions from urbanization.

But in spite of these attempts, extreme weather events like droughts, floods, and desertification attributable to CO_2 emissions have become more frequent in Nigeria, particularly in recent years. Water scarcity has grown and agricultural output has decreased as a result of rising temperatures. Nigeria is seeing a rise in deforestation as a result of growing urbanisation, rising emissions, and environmental deterioration. Disruptions in rainfall patterns, as well as an increase in the frequency of extreme weather events, are causing crop failure and food poverty in the country. The coastal cities of Nigeria, including Lagos, are under risk due to rising sea levels brought on by global warming and carbon dioxide emissions. This leads to financial losses due to infrastructure failure, displacement, and property damage. In light of the fact that Nigeria is one of the world's most populous developing nations, it is pertinent to investigate how urbanisation affects climate change in the country in order to propose potential policy avenues to mitigate it, and promote sustainable growth.

Though several studies have examined the impact of urbanization on different climate change variables (Nathaniel & Bekun, 2020; Yusuf, Abubakar & Mamman, 2020; Odugbesan & Rjoub, 2020), however, no empirical study is found to have examined the impact of urbanization on climate change in Nigeria. Thus, this study will examine the impact of urbanization on climate change. This study is significant for policymakers, particularly in Nigeria, as well as academics. It will allow the Nigerian government to implement more appropriate measures. This research is also important for urban planning, which is essential in emerging countries like Nigeria. Besides, the paper produced significant contributions to the area of research and serves as a point of reference.

2. Literature Review

Conceptual and Theoretical Literature

2.1 Urbanization

Lemanski (2020) described urbanisation as the growth of urban populations in towns and cities. It is in the process of becoming increasingly urban. It is produced when people relocate from rural areas to towns and cities. This is sometimes stated as the growing share of the population that lives in urban areas, with the urbanisation rate defined as the yearly growth rate of the urban share (United Nations Population Division, 2014). Aduku, Eboh & Egbuchulam (2021) viewed urbanization as the process of becoming urban, including the movement of people to the urban centres as well as the socio-economic and political activities in the urban areas. McGranahan & Satterthwaite (2014) described urbanisation as a broad-based change from rural to urban,

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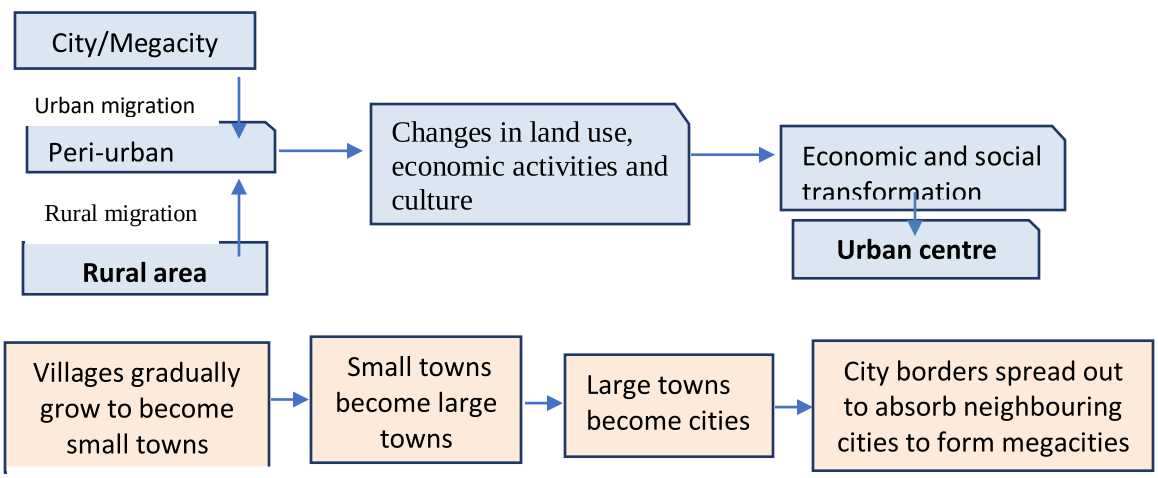
encompassing population, economic activity, land use, culture, and so on. Urbanisation refers to the increasing number of people living in urban settings.

Urbanisation results mostly from migration from rural to urban areas. Urban boundary expansion and the emergence of new urban areas, which is the redefinition of previously, villages owing to changes and developments in order to meet national criteria for urban centres, both contribute to urbanisation. In this study, urbanisation is defined similarly to the United Nations Population Division's (2014) definition, as the growing share of the population that lives in urban areas, with the level of urbanisation interpreted as the share and the urbanisation rate described as the annual growth rate of that share.

To Aduku, Eboh, & Egbuchulam (2021), Nigeria's urbanisation pattern entails individuals moving from megacities and rural areas to peri-urban areas (Areas bounded by a city or town), resulting in an increase in the number of the peri-urban population and developmental changes in peri-urban areas.

Figure 1: Nigeria's Urbanisation Pattern



Source: Aduku, Eboh, & Egbuchulam (2021)

Changes in land use and socio-economic activity lead to gradual, but important economic and social transformations that move from the peri-urban area to the urban centre. Ogun State for example, and particularly the areas surrounded by Lagos, exhibits this pattern of urbanization (Aduku, Eboh, & Egbuchulam, 2021).

2.2 Climate Change

First, it is important to distinguish between weather and climate, following the Canadian Centre for Climate Services (2020). Weather refers to the current atmospheric conditions. It also comprises of changes that are expected over the next few days, such as temperature and rainfall. Climate, on the other hand, refers to the type of weather that is common for a given region. This involves detailing the many circumstances or conditions that can occur (Canadian Centre for Climate Services, 2020). According to the United Nations (2023) and the Canadian Centre for Climate Services (2020), The word "Climate Change" refers to a long-term change in a region's average weather patterns, including rainfall, windiness, and temperature. Climate change means that the range of expected circumstances in many locations will shift over the next few decades. This suggests that harsh situations will alter. The climate naturally fluctuates from year to year and decade to decade. This is due to natural processes that connect the atmosphere, water, and land, as well as variations in solar heat production. Human activity has been linked to climate change as well. The current state of climate change is mostly the result of human influences (Canadian Centre for Climate Services, 2020) traceable to urbanisation. Carbon dioxide emission is the major contributor to climate change.

Carbon dioxide emission is a greenhouse gas emission. Carbon emission is carbon released into the atmosphere. Because greenhouse gas emissions are typically approximated as carbon dioxide, they are commonly referred to as "Carbon Emissions" in the literature on greenhouse effects. It is a faintly shaped, colourless gas with a sour flavour. It is a key greenhouse gas that contributes to global warming. It is a component of the earth's atmosphere, created by carbon combustion. CO_2 emissions come from a variety of sources, including fossil fuel combustion in the power production, residential, industrial, and transportation sectors. Many sources, particularly in the power generation and industrial sectors, have high emission volumes, making them appropriate for the use of CO_2 measurement technology. The increased use of fossil fuels raises carbon emissions. This is due to the expanding human population and their anthropogenic activities, which include land use, deforestation, bush burning, ranching, and so on. This contributes to greenhouse gas emissions in the atmosphere, altering the ecosystem. Carbon emissions are related with human activities, such as land use, which includes recreational, agricultural, commercial, and others (Sulaiman & Abdul-Rahim, 2018).

2.3 Empirical Literature

The empirical font includes the study by Sethi & Vinoj (2024), who investigated the urbanisation and regional climate change-related warming of Indian cities. This study focused on 141 Indian cities. The Sen's slope estimator and Mann-Kendall test were used to analyse the data. It was discovered that urbanisation alone has caused an overall 60% increase in warming in Indian cities, with eastern Tier-II cities leading the way. Le, Vo, Nguyen, Nguyen, & Nguyen (2024) examined the impact of climate change and urbanisation on urban flooding in An Ha, Tam Ky, Quang Nam, using the EPA storm water Management Model for drainage systems. The study discovered that urbanisation reduces initial abstraction capabilities, whereas climate change increases intense rainfall and water levels of receiving sources. The research also revealed that the effects were considerably more significant when the high urbanisation rate increased by more than 70%, combined with climate change. In a similar study, Chai, Ma, Yang, Lu, & Chang (2022) investigated the effect of climate change-induced temperature fluctuations on China's urbanisation rate. The study makes use of panel data from 28 Chinese provinces from 2006 to 2018. They found that the urbanisation level had a significant double-threshold effect on the impact of temperature on urbanisation. When the urbanisation level reaches the associated threshold value, the negative influence of temperature on urbanization becomes weak. Again, Li, Stringer, & Dallimer (2022) examined the combined effects of urbanisation and climate change on African urban thermal environments. 40 peer-reviewed academic publications from 2000 to 2021 were reviewed. It was found that South Africa, Ethiopia, and Nigeria were the most often researched. It was also discovered to have practical ramifications for urban land-use planning, informal settlement management, human well-being and productivity, energy consumption, air pollution, and disease transmission. Ren, Fu, Dong, Zhang, & He (2022) studied the annual dynamics of urban thermal comfort and its relationship to rapid urbanisation and climate change in 183 Chinese cities between 1990 and 2016. Climate change (e.g., decreased precipitation, wind speed, and global warming) and fast urbanisation were found to have a favourable and significant impact on the deteriorating urban thermal environment.

Similarly, Maheshwari, Pinto, Akbar, & Fahey (2020) investigated the effects of urbanisation on temperature, evaporation, and rainfall in three Australian metropolitan cities: Sydney, Melbourne, and Brisbane. Daily maximum and minimum air temperature evaporation and rainfall data from 1960 to 2011 were analysed using a modified segmented regression analysis technique. Urbanisation was found to have an impact on daily maximum and lowest air temperatures, as well as evaporation values. In their study, Wang, Chan, Lau, Li, Yang, & Yim (2019) used a climate model based on land-cover development and two representative concentration paths (RCP4.5 and RCP8.5) to estimate composite climatic changes in China's Pearl River Delta (PRD). It was discovered that increased urban land cover can induce an increase in surface temperature in PRD, and urban temperature will rise as a result of global climate change alone. The study revealed that urbanisation had only a little impact on thermal comfort in PRD, despite increased surface temperatures. Murshed & Saadat (2018) studied the impact of urbanisation and other control variables on the emission of selected greenhouse gases and the average annual temperature in Bangladesh, using Dynamic Ordinary Least Squares (DOLS) and Fully Modified Ordinary Least Squares (FMOLS) to analyse their data. They discovered that while urbanisation initially reduces greenhouse gas emissions and temperature change, the link gradually reverses over time, with urbanisation triggering climate change in Bangladesh. Equally, Chapman, Watson, Salazar, Thatcher, & McAlpine (2017) investigated the influence of climate change and urban growth on future urban temperatures and the possibility of increased heat stress among urban populations. The authors conducted a systematic review of scholarly literature between January 2000 and May 2016. Urbanisation had been shown to have a significant impact on local temperatures, sometimes by up to 5°C in the Northeastern United States. Climate change had raised the heat island in some cities, such as Chicago and Beijing, while decreasing it in others, such as Paris and Brussels.

Although there are empirical studies in the area of research, the majority of studies focused on advanced countries. As a result, there is no empirical evidence of the impact of urbanisation in developing nations like Nigeria on climate change. Nigeria, in particular, has undergone significant urbanisation, which has raised concerns about the influence on climate change. There is no known empirical study that has looked at the impact of urbanisation on climate change in

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Nigeria. Thus, by investigating the impact of urbanisation on climate change, this work contributes to the climate change literature, particularly in developing nations.

3. Methodology

3.1 Theoretical Framework and Model Specification

The framework of analysis is the Cobb-Douglas production function theory developed by Paul Douglas and Charles Cobb. The Cobb-Douglas production function is presented as:

$$Y = AK^{\alpha}L^{\beta} \quad 1$$

Where Y is output growth, K is capital stock which comprises of physical capital and human capital, L is labour force, and A represents total factor productivity. α and β are output elasticities with respects to Capital and Labour respectively.

A few fundamental assumptions are made in order to modify the production function. First, we assumed that the amount of carbon dioxide (CO_2) emissions that contribute to climate change is determined by economic growth (or the expansion of economic activities). Based on this, we use carbon dioxide (CO_2) emissions represent output growth in equation 1. That is,

$$Y = (\text{CO2}) \quad 2$$

Since industrialised nations with higher human and physical capital indices use more energy than developing nations with lower indices, it is also assumed that the level of energy consumption can be influenced by the growth of both human and physical capital. Consequently, energy consumption in the model can be used to represent the capital stock in equation 1. That is,

$$K^{\alpha} = (ENERGY) = ENERGY^{\alpha} \quad 3$$

Where ENERGY represents energy consumption. Energy consumption is classified into renewable energy consumption (REC) and nonrenewable energy consumption (NREC). Thus, we re-specify equation 3 as:

$$K^{\alpha} = (ENERGY) = REC^{\delta},\ NREC^{\rho} \quad 4$$

Furthermore, it is assumed that total factor productivity (A) is determined by prior investments in physical capital, as shown in equation 5:

$$A = (DOI) = DOI^{\tau} \quad 5$$

DOI stands for domestic investment. Domestic investment is proxied as Gross Fixed Capital Formation (DOI = GFCF). Substituting equations 2, 3, 4, and 5 into equation 1 and redefining labour (L) as population growth rate (LAB) gives equation 6 as:

$$CO2 = f(\text{GFCF}^{\tau}, REC^{\delta},\ NREC^{\rho},\ \text{LAB}^{\beta}) \quad 6$$

The urban population growth rate (UBAN) is augmented into equation 6 for the purpose of this study, and the logs of the variables are taken as follows:

$$co_2 = \tau logGFCF + \delta \text{logREC} + \rho logNREC + \beta log\text{LAB} + \vartheta \text{UBAN} \qquad 7$$

Equation 7 is specified in econometric form as:

$$co_2 = \ a + logGFCF + \delta log\text{REC} + \rho logNREC + \beta log\text{LAB} + \vartheta \text{UBAN} + e_1 \qquad 8$$

LAB and UBAN are not logged because the variables are already expressed in rate. Thus, CO_2 = carbon dioxide (CO_2) emission (a proxy for climate change) is a function of renewable energy consumption (% of total final energy consumption), nonrenewable energy consumption (% of total), urbanization (measured by the urban population growth rate) Gross Fixed Capital Formation, (measure for domestic investment), and labour force. τ, δ, ρ, β and ϑ are the output elasticities of the variables respectively. Our a priori restrictions are projected to have positive coefficients, with the exception of renewable energy, which is expected to have a negative coefficient. The coefficient for gross fixed capital formation is predicted to be either positive or negative.

The model is estimated using the Ordinary Least Squares (OLS) technique. This technique is frequently utilised in the literature. The OLS approach is recommended due to its (BLUE) properties. The OLS estimator ranks BLUE among all available estimators. There is no guarantee that economic time series (variables) will always be stationary at the same level. Therefore, the estimation shall continue in the following order: (i) The time series will be evaluated for unit roots using the Augmented Dickey-Fuller Unit Root Test and the Phillips-Perron Unit Root Test. (ii) The series will also be checked for cointegration.

3.2 Data

The data, which covers the periods 1981–2023, is an annual frequency times series. The data is sourced from various issues of the Central Bank of Nigeria (CBN) Statistical Bulletin, and the World Development Indicators (WDI). The data for climate change – measured by carbon dioxide (CO_2) emissions, urbanization (measured by the urban population growth rate), renewable and nonrenewable energy consumption, and population growth rate are sourced from the WDI, while the data for Gross Fixed Capital Formation is sourced from various issues of the CBN statistical bulletin.

4. Results

4.1 Descriptive Statistics of the Variables

The descriptive statistics result is presented in Table 1.

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Table 1: Descriptive statistics of the variables

Variables	Obs	Mean	Standard Deviation	Minimum value	Maximum value	(Skewness)	(Kurtosis)
CO_2	43	85499.4	15367.2	55510.1	105620.7	0.0293	0.2748
REC	43	85.5446	2.2388	80.3422	88.8319	0.0142	0.6185
NREC	43	19.5353	1.5733	15.8541	22.8448	0.5120	0.8468
UBAN	43	4.8935	0.6019	4.1419	6.0352	0.2590	0.0205
GFCF	43	35.7896	19.4997	14.1687	89.3861	0.0085	0.1954
LAB	43	2.6158	0.0696	2.5264	2.7565	0.3535	0.0079

Source: Researchers' computation

The descriptive statistics in Table 1 above, shows measures of central tendency, dispersion and shape of data employed in our study, with 43 observations. The CO_2 variable has a mean of 85499.4, minimum and maximum values of 55510.1 and 105620.7 respectively. Its standard deviation value15367.2, indicates that the distribution has a small spread around its mean value. Its skewness value, which is one of the measures of shape of a distribution, has a value of 0.029, which shows, a positive moderately distribution. This fact is buttressed by its kurtosis value of 0.0275, indicating a platykurtic distribution. The REC variable exhibited similar trend as that of CO_2 given its data in Table 1. All of the variables' minimum values are lower than their respective mean values. While each variable's highest value is greater than its mean value. That is, the data values are either distributed above or below the mean values respectively.

For the skewness, the probability values of carbon dioxide (CO_2) emission and gross fixed capital formation are statistically significant at 5%, while the other variables are not significant. Thus, the null hypothesis of a normal distribution is rejected for carbon dioxide (CO_2) emission and gross fixed capital formation (the data is skewed either to the right or left). However, accepted for the rest of the variables (the data are normally distributed–symmetrical). For the Kurtosis, urbanisation and population growth rate are significant. This suggests that the data is significantly different from the tails of a normal distribution. The other variables have insignificant kurtosis probability values, indicating that the null hypothesis of normal distribution kurtosis is accepted.

4.2. Unit Root Test

The variables were subjected to the Augmented Dickey Fuller and Philips Perron unit root tests to determine their level of stationarity. The results are shown in Table 2.

Table 2: Augmented Dickey-Fuller and Philips–Perron unit root test results

Variable	Augmented Dickey-Fuller Result		Philips–Perron Result		Lag order	~I(d)
	Level	1st Difference	Level	1st Difference		
CO2	-2.386	-3.381 *	-1.932	-6.442 *	2	I(1)
REC	-2.709	-3.886 *	-2.461	-6.383 *	2	I(1)
NREC	-2.285	-3.985*	-2.869	-3.869*	2	I(1)
UBAN	-1.888	-3.064 *	-1.929	-5.667 *	2	I(1)
GFCF	-2.392	-3.892*	-2.756	-3.756*	2	I(1)
LAB	-1.155	-3.462*	-2.336	-4.107*	2	I(1)
The ADF 5% critical values at level is -2.969 and at 1st difference is -2.972. The Philips–Perron critical value at level is -2.964 and at 1st difference is -2.966.						

Source: Researchers' computation

The Augmented Dickey-Fuller critical value was higher than the variables' respective test statistics at levels. Thus, the null hypothesis of the presence of a unit root is accepted. The test was, again, ran at 1st difference. The test statistics at 1st difference exceeded the critical value. This indicates that the variables are stationary at the 1st difference. This is also supported by the Philips-Perron test. None of the variables was stationary at the level. But at the 1st difference, all of the variables became stationary.

4.3 Effect of urbanization on climate change

The Johansen test for cointegration was performed, and the results are shown in Table 3.

Table 3: Result of Johansen test for cointegration

Maximum Rank	Eigenvalue	Trace Statistics	5% critical value
0	-	120.5830	82.49
1	0.7279	72.4118	59.46
2	0.5424	43.4831	39.89
3	0.4066	24.1710*	24.31
4	0.3809	6.4293	12.53
5	0.1105	2.0957	3.84
6	0.0551	-	-
	Coefficient	z-value	p-value
ECM	-0.3721	-3.75	0.000

Source: Researchers' computation

The results in Table 3, revealed three important trace statistics. This signifies that there are three cointegrating equations between the variables in the regression equation. Therefore, the null hypothesis of no cointegration is rejected at the 5% level. This indicates that the variables have a long-run relationship. An error correction model was also estimated to determine the equilibrium adjustment speed. Table 3 also reported a summary of the result. The results indicated a negative and significant coefficient, as expected. It demonstrates that when the economy is out of equilibrium, the variables adjust to equilibrium at a rate of 37.21% each year. This also implies that it takes at least two years to return to equilibrium when there are economic discrepancies. The estimates of the effects of urbanization on climate change is presented in Table 4.

Table 4: Estimates of the effects of urbanization on climate change

CO2	**Coefficients**	**Standard Errors**	**t-stat**	**P-value**
REC	-1.4552	2.8534	-1.51	0.140
NREC	3.1144	0.9763	3.19	0.003
UBAN	1.9962	0.6883	2.90	0.007
GFCF	-3.3873	0.8708	-3.89	0.000
LAB	6.0905	26.4806	0.23	0.822
_cons	-5.6097	11.4483	-0.49	0.625
R-Squared		0.7821		
Adj. R-Squared		0.7491		
F (5, 33)		23.69 (0.0000)		
Durbin-Watson d-statistic		1.1530		
Breusch-Godfrey LM chi		26.259 (0.0124)		

Source: Researchers' computation

The coefficient for urbanization (UBAN) is positive and significant. Based on this, the null hypothesis that urbanisation has no statistical significant effect on carbon dioxide (CO_2) emissions is rejected at 5% level. The significant probability value means that there is an insignificant error in rejecting the null hypothesis. Specifically, a 1% increase in urbanisation resulted in about 2% rise in carbon dioxide (CO_2) emissions.

Nonrenewable energy (NREC) variable use had a direct relationship with the dependent variable (CO_2), and also, highly significant giving its P-Value of 0.003. In specific terms, a 1% increase in NREC, results in a significant 3.11% increase in carbon dioxide (CO_2) emissions.

Furthermore, the Renewable energy (REC) use variable had an indirect and insignificant influence on the dependent variable. In definite term, a 1% increase in renewable energy consumption resulted in a 1.46% reduction in carbon dioxide (CO_2) emissions. The influence, however, is statistically insignificant, as evidenced by the insignificant t-value and p-value. As a

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result, renewable energy consumption had a negative and statistically insignificant effect on carbon dioxide (CO_2) emissions.

Gross Fixed Capital Formation (GFCF) variable exhibited an indirect relationship with the dependent variable. However, the variable was highly significant given its P-Value of 0.000. Specifically, a 1% increase in GFCF results in a 3.39% reduction in carbon dioxide (CO_2) emissions. The t-value result of 3.89 buttressed the P-Value figure that the influence is significant. Thus, the null hypothesis that gross fixed capital formation has no significant effect on carbon dioxide (CO_2) emissions is rejected at a 5% level.

Again, the labour force variable (LAB) had a direct and statistically insignificant effect on carbon dioxide (CO_2) emissions. A 1% rise in labour force causes a 6.09% insignificant increase in carbon dioxide (CO_2) emissions.

The R^2 coefficient value of 0.7821 indicates that the explanatory variables account for over 78% of the systematic variation in the dependent variable CO_2 emissions. The Adjusted R^2 value of 0.7491 supports this result, as it indicates that over 74% of the variation in the dependent variable is accounted for by the explanatory variables, after taking cognizance of the degree of freedom. The remaining percentage change in carbon dioxide (CO_2) emissions is attributed to variables not included in the regression model. The F-statistical value is 23.69, was highly significant, with a P-Value of 0.0000. Thus, there is a significant linear relationship between the explanatory variables taken together and the independent variables in our estimated model. The Durbin-Watson statistic is approximately 1. Therefore, the null hypothesis of no autocorrelation is neither accepted nor rejected because the result is inconclusive. However, the insignificant Breusch-Godfrey LM Chi-square Statistics of 26.259 (P = 0.6124) means that the independent variables are not serially correlated.

4.4 Implications of the Findings

The findings imply that Nigeria's urbanisation is greatly exacerbating climate change-causing variables such as rising carbon dioxide (CO_2) emissions, energy use, and environmental deterioration. Urbanization dilates on CO_2 emissions and intensify climate change, but sustainable practices and policies can mitigate these effects. Also, increased nonrenewable energy use results in higher CO_2 emissions, which worsen global warming and cause extensive disturbances to the environment, the economy, and society. Mitigation calls for a coordinated worldwide effort to adopt carbon management techniques, increase efficiency, and switch to renewable energy. While renewables may lower emissions, their current adoption or impact is insufficient to yield substantial outcomes. This suggests that attempts to prevent climate change may fall short of the Paris Agreement's targets of limiting warming to 1.5°C or 2°C over pre-industrial levels. Furthermore, renewables alone are insufficient to achieve significant emissions reductions. This emphasises the importance of a complete approach that involves aggressive renewable energy deployment, fossil fuel phase-out, energy efficiency improvements, and supportive legislation.

Also, the findings regarding gross fixed capital formation imply that the nature and focus of investments can have a significant impact on the trajectory of emissions and, by extension, global climate change. If orientated towards carbon-intensive projects, gross fixed capital formation has the potential to aggravate climate change by locking economies into high-emission paths. Strategic investments in green technologies, sustainable infrastructure, and energy-efficient systems, on the other hand, can help to speed the transition to a low-carbon economy, reducing greenhouse gas emissions and improving long-term resilience. The increase in the workforce does not have a significant impact on emissions, either due to the low energy intensity of the additional workers' activities or due to economic structural issues. However, it is critical to maintain vigilance and deploy methods that steer this expansion towards low-carbon pathways. The rising labour force can assist both economic and climate resilience goals by creating green jobs, investing in renewable energy, and maintaining energy efficiency, ensuring that emissions are kept under control.

5. Conclusion

The impact of urbanisation on climate change in Nigeria has been investigated. Based on the findings, it is determined that urbanisation contributes significantly to climate change in Nigeria. Also, nonrenewable energy consumption has a significant impact on climate change in Nigeria, whereas renewable energy consumption has an insignificant impact. Other factors, such as domestic investment, significantly mitigate climate change, whereas labour force has a positive and insignificant impact on climate change in Nigeria.

The government should prioritise urban planning. This can balance the demand for urban growth with the need to reduce carbon dioxide (CO_2) emissions, thereby addressing climate change in Nigeria. We also advocate for strategic investments in green technologies, sustainable infrastructure, and energy-efficient systems in Nigeria. Despite its high cost, it has the potential to cut carbon dioxide (CO_2) emissions and prevent climate change.

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