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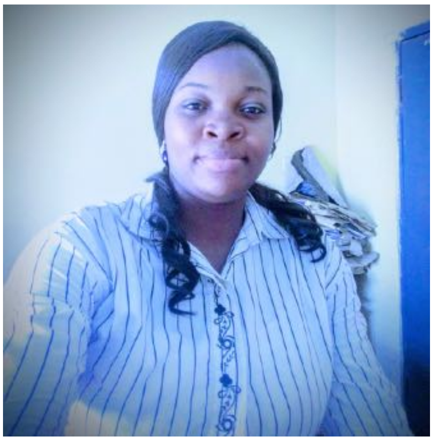
ASSESSING THE NEXUS OF CARBON EMISSIONS AND AGRICULTURAL GROWTH IN NIGERIA (2000-2022)

Effiong MO[1]* and M Panicker[2]



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ABSTRACT

Despite efforts by the government to curb the existing suffering of poverty and food insecurity in the country through diversification and restructuring, amongst others, the poverty and hunger rate is still on the increase. This triggered a 10-day hunger protest in the country by the citizenry. This can be ameliorated if studies had been /can be centered on the nexus of carbon dioxide (CO2) emissions and agricultural growth. However, the dearth of studies on carbon emissions on agricultural growth suggests the need to assess Nigeria's carbon dioxide emissions and their effect on agricultural growth (2000-2022). Data were collected through secondary sources, 40 and using a panel regression analysis, the study examines the relationships among CO2 emissions, agricultural growth, and socioeconomic determinants such as urban population, trade openness, and agricultural contribution to Gross Domestic Product (GDP). The results revealed that the normalized long-run cointegrating coefficient for CO2 was 1, indicating a one-to-one relationship between CO2 emissions and economic growth in the long term. This implies that a one percent increase in agricultural growth would directly lead to a one percent increase in carbon dioxide emissions in the long run. Additionally, the study finds that trade openness and agricultural contribution to GDP are associated with increased CO2 emissions. Finally, the ordinary least square showed that a one percent increase in agriculture production is associated with a 0.103168 percent decrease in CO2 emissions in the long run. Urban population growth and trade openness were associated with CO2 reductions by 0.738965 and 0.015665 percent, respectively, indicating that 53 increasing population and trade openness could also mean that carbon dioxide emissions can potentially cause less environmental degradation in the country. However, thestudy suggests the need to diversify the Nigerian economy by promoting industries that are less dependent on natural resources and more focused on knowledge-based and service-oriented sectors. This could involve investing in education and training programs, promoting entrepreneurship and innovation, and implementing policies to support the growth of new industries. Also, optimizing trade 60 policies for sustainable development by encouraging environmentally friendly trade practices, promoting the adoption of clean technologies in industries, and incentivizing sustainable production and consumption patterns will make the economy more resilient and less vulnerable to external shocks, thereby promoting economic development.

Key words: Carbon dioxide emissions, Agricultural growth, Economic growth, Sustainable agriculture

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INTRODUCTION

Carbon dioxide (CO_2) emission refers to the amount of carbon dioxide that is released into the atmosphere by a particular source, such as a power plant or a factory, over a specific period. Carbon dioxide emissions are the amount of carbon dioxide released into the atmosphere due to human activities. It is the primary greenhouse gas responsible for climate change, and it is caused by the burning of fossil fuels by households and firms [1]. Fossil fuels such as coal, oil, and gas are the primary sources of carbon dioxide emissions, and their combustion releases large amounts of carbon dioxide into the atmosphere, contributing to climate change and global warming. According to the Carbon Dioxide Information Analysis Centre (CIAC), fossil fuel consumption emits 11.5% of carbon dioxide annually. The relationship between economic growth and carbon dioxide (CO_2) emissions in Nigeria has been the subject of several studies, with some studies suggesting a positive relationship between economic growth and emissions, while others have found a negative relationship or no relationship at all. To better understand this relationship, this study investigated the effects of CO_2 emissions on agricultural and economic growth in Nigeria, using a range of variables, including urban population, trade openness, agriculture, forest, and fishing [2]. In the context of this study, trade openness refers to the degree to which Nigeria's economy is open to international trade. It measures the extent to which the country engages in international trade, including the import and export of goods and services. Trade openness can be influenced by various factors, such as:

- **Tariffs and trade policies**: Lower tariffs and more liberal trade policies can increase trade openness.
- **Foreign investment**: High levels of foreign investment can indicate a more open economy.
- **Trade agreements**: Participation in regional or international trade agreements can also promote trade openness.

In the study, trade openness is likely included as a variable to examine its impact on the relationship between CO_2 emissions and economic growth in Nigeria. A more open economy may lead to increased economic growth, but it can also result in higher CO_2 emissions due to increased industrial activity and transportation. The urban population affects energy consumption and emissions through changes in transportation patterns and land use. In Nigeria, the increased urban population and economic growth have caused emissions [3]. There is a positive correlation between Nigeria's urban population and CO_2 emissions, indicating that efforts to lower emissions must take into account how urbanization affects energy use and emissions [4]. Trade openness has an impact on the kinds of goods and services produced as well as the competitiveness of industries. Trade openness and CO_2

emissions in Nigeria have a positive relationship, suggesting that efforts to reduce emissions must take the effect of trade's impact on emissions into account [5]. Additionally, agriculture, forestry, and fisheries impact land usage and the uptake of carbon dioxide through photosynthesis. Agriculture, forestry, and fishing have a negative correlation with CO_2 emissions in Nigeria, suggesting that efforts to reduce emissions will need to consider the role of land use and forestry in mitigating climate change [6]. The impact of economic growth on CO_2 emissions in Nigeria is a complex and multifaceted issue that requires a comprehensive and interdisciplinary approach. By investigating the impact of a range of variables, including inflation, GDP, energy consumption, urban population, trade openness, and agriculture, forest, and fishing on CO_2 emissions in Nigeria, we can gain a better understanding of the correlation between growth and environmental sustainability [7].

Trade openness is commonly defined as the degree to which a country is open to international trade and is often measured as the ratio of a country's trade to its GDP. This ratio provides an indication of the importance of international trade to a country's economy and is used to compare the level of trade openness across different countries [8]. The United Nations Conference on Trade and Development (UNCTAD) defines trade openness as "the ratio of a country's trade (exports plus imports) to its GDP" [9]. The International Monetary Fund (IMF) defines trade openness as "the sum of exports and imports of goods and services, as a percentage of GDP". Trade openness is an essential factor in economic growth and impacts carbon dioxide emissions. Trade openness can impact carbon dioxide (CO_2) emissions in several ways:

- **Increased Economic Activity**: Trade openness can lead to increased economic activity as countries specialize in producing goods and services in which they have a comparative advantage. This can result in increased energy consumption and CO_2 emissions [10].
- **Industrialization and Manufacturing**: Trade openness can lead to industrialization and manufacturing growth, which are often energy-intensive and contribute to CO_2 emissions [11].
- **Transportation Emissions**: Increased trade leads to more transportation of goods, which can result in higher CO_2 emissions from vehicles, ships, and airplanes [12].
- **Changes in Consumption Patterns**: Trade openness can lead to changes in consumption patterns, as countries import goods and services that may have higher carbon intensity than domestically produced alternatives [13].
- **Technology Transfer**: On the other hand, trade openness can also facilitate the transfer of clean technologies and renewable energy sources, which can help reduce CO_2 emissions [14].

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- **Scale Effect**: Trade openness can lead to increased production and consumption, which can result in higher CO_2 emissions due to the scale effect [15].
- **Composition Effect**: Trade openness can also lead to changes in the composition of economic activity, with a shift toward more energy-intensive industries, which can increase CO_2 emissions [16]. However, trade openness can also have positive effects on the environment, such as:
- **Increased Efficiency**: Trade openness can lead to increased efficiency in production, as countries specialize in producing goods and services in which they have a comparative advantage.
- **Environmental Regulations**: Trade agreements can include environmental regulations and standards, which can help reduce CO_2 emissions [17].
- **Green Technology**: Trade openness can facilitate the transfer of green technologies and Renewable energy sources, which can help reduce CO_2 emissions.

Overall, the impact of trade openness on CO_2 emissions depends on various factors, including the type of trade, the industries involved, and the environmental regulations in place.

Trade openness can affect the competitiveness of industries and the types of goods and services produced, which in turn can affect emissions. Increased economic activity and energy consumption associated with greater trade openness can lead to increased emissions [18].

On the other hand, the United States Bureau of Economic Analysis (BEA), defines agriculture, forestry, and fishing (AFF) as "the activities of establishments primarily engaged in growing crops, raising animals, harvesting timber, and harvesting fish and other animals from a farm, ranch, or their natural habitats" [19]. According to the United Nations System of National Accounts (SNA), agriculture, forestry, and fishing (AFF) are "the economic activities of establishments primarily engaged in the production of crops, livestock and livestock products, forestry and logging, and fishing and aquaculture"[20]. Agriculture, forestry, and fishing activities can impact carbon dioxide emissions through their influence on land use and deforestation. Unsustainable land use practices, such as deforestation, can lead to increased carbon dioxide emissions, while sustainable land use practices, such as conservation agriculture and agroforestry, can help mitigate carbon dioxide emissions.

Nigeria's CO_2 emissions are primarily driven by the burning of fossil fuels, industrial production, and land use changes. Its major components are:

- **Fossil Fuel Combustion**: The largest share of CO_2 emissions comes from the combustion of fossil fuels, such as coal, oil, and natural gas, primarily for energy production. According to the International Energy Agency (IEA), fossil fuel combustion accounted for approximately 64% of Nigeria's CO_2 emissions in 2020 [21].
- **Cement Production**: Cement production is another significant contributor to CO_2 emissions in Nigeria due to the large amount of energy required for production. A study by the Nigerian Cement Industry found that cement production accounted for around 12% of Nigeria's CO_2 emissions in 2019 [22].
- **Gas Flaring**: Gas flaring, which is the burning of natural gas associated with oil production, is also a substantial source of CO_2 emissions in Nigeria. The World Bank estimates that gas flaring accounted for approximately 10% of Nigeria's CO_2 emissions in 2020 [23].
- **Land Use Changes**: Land use changes, such as deforestation and land degradation, contribute to CO_2 emissions through the release of stored carbon into the atmosphere. According to the Food and Agriculture Organization (FAO), land use changes accounted for around 8% of Nigeria's CO_2 emissions in 2019 [24].
- **Industrial Processes**: Industrial processes, such as the production of steel and aluminum, also contribute to CO_2 emissions in Nigeria. A study by the Nigerian Industrial Policy found that industrial processes accounted for around 6% of Nigeria's CO_2 emissions in 2019 [25].

These components are influenced by Nigeria's energy mix, industrial activities, and land use practices. Understanding these factors is crucial for developing effective strategies to reduce CO_2 emissions and mitigate climate change in Nigeria.

Nigeria's economy is heavily reliant on oil production, which accounts for a significant portion of its export earnings. In 2019, oil exports made up a staggering 76.5% of the country's total exports, while agriculture accounted for less than 2%. The country's major agricultural imports include wheat, sugar, fish, and milk, indicating a significant reliance on foreign markets to meet domestic food demands [26]. On the other hand, Nigeria's agricultural exports have historically been significant, with the country being the largest exporter of palm oil and palm kernel and ranking second to Ghana in cocoa exports [27].

Given the dominance of oil exports in Nigeria's economy, it is no surprise that the country's "trade openness" measure is highly influenced by global prices of oil. This means that fluctuations in global oil prices can have a significant impact on Nigeria's trade balance and overall economy, rather than controllable aspects of the economy such as fiscal policy or domestic production [28].

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In terms of major sources of exports, petroleum products are undoubtedly the leading contributor, followed by other minerals and manufactured goods. The country's reliance on oil exports makes it vulnerable to external shocks, highlighting the need for economic diversification and development of other sectors, such as agriculture and manufacturing [29].

Research has demonstrated that African nations do not have the financial resources to implement more environmentally friendly technologies and effective policies to lower carbon dioxide emissions. Environmental degradation in Sub-Saharan Africa (SSA) countries has been widely attributed to a variety of variables, including economic expansion, the use of fossil fuels for energy, tourism, population growth, and other pertinent socioeconomic determinants, according to previous studies [30, 31]. Because previous studies in Nigeria did not take into account the likely influences of other factors, such as agriculture, forestry, and fisheries; trade openness and urban population that contribute to carbon dioxide emission in the economy; and sustainable economic growth that could protect environmental quality, the results of those studies were largely inconclusive and excessively biased. However, this study was aimed at analyzing the impact of CO_2 emissions on agricultural growth in Nigeria (2000-2022). Specifically, assess the socioeconomic determinants of the variables for the study; determine the long-run relationship between these variables and economic growth, and determine the effect of carbon dioxide emission on agricultural growth.

Hypothesis of study

Null Hypotheses

- H_0: There is no significant relationship between socioeconomic factors (urban population, trade openness) and economic growth in Nigeria.
- H_0: There is no long-run relationship between carbon dioxide emissions, agricultural growth, and economic growth in Nigeria.
- H_0: Carbon dioxide emissions have no significant effect on agricultural growth in Nigeria.

APPROACHES

Study area

The study was carried out in Nigeria. Nigeria is located in West Africa, bordering the Gulf of Guinea between Benin and Cameroon. It lies between latitudes 4° and 14° North of the equator and longitudes 3° and 15° East of the Greenwich Meridian. Nigeria has a tropical climate with two main seasons [32]: the rainy season, usually between May to October, with the highest rainfall occurring in July and August, and the dry season, usually from November to April, with the driest months being January and February. The temperature in Nigeria varies depending on the region. The southern region has a relatively constant temperature, ranging from 22°C to 32°C (72°F to 90°F) throughout the year with an average annual rainfall of 1,500 mm to 2,000 mm while the northern region has a more extreme temperature range, from 15°C to 35°C (59°F to 95°F) during the dry season and 20°C to 30°C (68°F to 86°F) during the rainy season with an average annual rainfall of 500 mm to 1,000 mm [33]. Nigeria has several agricultural regions, including the savanna region, known for its production of crops such as maize, sorghum, and millet; the forest region, known for its production of crops such as cocoa, rubber, and palm oil; and the coastal region, known for its production of crops such as rice, sugarcane, and coconut [34].

Method of data collection:
The data for this study were obtained from secondary sources (World Development Indicators database) from the period 2000-2022. The agricultural growth variables used were agriculture, forest, and fishing; trade openness; urban population; and agricultural gross domestic product.

Data analysis
Data were analyzed using descriptive statistics, cointegration, and ordinary least square (OLS)

Model Specification
The model specification for this study was a descriptive cointegration model and OLS that includes the following independent variables: trade openness, agriculture, forestry, fishing, the urban population, and the percentage contribution of agriculture to GDP. The dependent variable was carbon dioxide emission.

Descriptive statistics: Mean = $\sum \frac{X-\bar{X}}{N}$ **;** Where,
Σx = sum of all observations
N total number of observations

Standard Deviation = $\sum \frac{\sqrt{(X-\bar{X})^2}}{N}$
where,
x = observations or deviations from the mean
$\bar{x}$ = mean
Σ = summation
n = total number of observations

Skewness = $\sum [\frac{(x_i-\mu)^3}{(n-1) \times \sigma^3}]$
where,
xi is each observation
μ is the mean
n is the sample size

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σ is the standard deviation

Kurtosis = $\sum \left[\frac{(x_i-\mu)^4}{(n-1)\times\sigma^4}\right] - 3$

Where symbols have their usual meanings.

Jarque-Bera = $[\frac{n\times S^2+\frac{1}{4}\times K^2}{6}]$

Where n is the number of observations, S is the skewness, and K is the kurtosis.

Sum of Square Deviation: SSD = $\sum x_i - \mu)^2$

Where xi is each observation and μ is the mean. SSD measures the deviation from the mean.

Cointegration Model

With Carbon dioxide (CO_2) emissions as the dependent variable and Agriculture, Forest, and Fishing (AFF), Trade openness (TOP), Agriculture contribution to GDP (AGDP), and Urban population (URP) as independent variables, the model is specified thus:

CO_2_t = β_0 + β_1 AFF_t + β_2 TOP_t + β_3 AGDP_t + β_4 URP_t + ε_t

Where:
CO_2_t represents the carbon dioxide emissions at time t.
AFF_t represents the Agriculture, Forest, and Fishing activities at time t.
TOP_t represents the trade openness at time t.
AGDP_t represents the agriculture contribution to GDP at time t.
URP_t represents the urban population at time t.
β_0, β_1, β_2, β_3, and β_4 are the coefficients or parameters that were estimated.

These coefficients represent the relationships between the dependent variable and the independent variables.
ε_t represents the error term or residual, which captures the unexplained variation in the dependent variable that is not accounted for by the independent variables.

Normalized Cointegrating Regression:

This estimates the long-run proportional relationship between the variables.
$CO_2 = \beta_1 AFF + \beta_2 TOP + \beta_3 AGDP + \beta_4 URP + \varepsilon$
Where β1- β4 are the normalized cointegrating coefficients.

Adjusted Cointegrating Regression:

This estimates the actual effect size of changes in independent variables on CO_2.
$\Delta CO_2 = \alpha_1 \Delta AFF + \alpha_2 \Delta TOP + \alpha_3 \Delta AGDP + \alpha_4 \Delta URP + \theta\,(CO_2(-1) - \beta_1 AFF\,(-1) - \beta_2 TOP\,(-1) - \beta_3 AGDP\,(-1) - \beta_4\, URP\,(-1)) + \mu$

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where α1- α4 are the adjusted coefficients showing the effect of a 1unit change in the independent variables on CO_2.
θ is the speed of adjustment towards the long-run equilibrium.

OLS: The general form of the regression equation:
$CO_2 = \beta_0 + \beta_1 AFF + \beta_2 URP + \beta_3 TOP + \beta_4 AGDP + \varepsilon$
Where:
CO_2 = Carbon dioxide emission (Mt)
TOP = Trade Openness (ratio of export + import to GDP)
AFF = Agriculture, forest and fishing (% value added to GDP)
URP = Urban Population (%)
AGDP = Agricultural contribution to GDP (%)
ε = Error term
The specific functional form for each of the independent variables will be as follows:
$AFF = \alpha_0 + \alpha_1 t + u1$
$URP = \alpha_2 + \alpha_3 t + u2$
$TOP = \alpha_4 + \alpha_5 t + u3$
$AGDP = \alpha_6 + \alpha_7 t + u4$
t = Time
u = Error term

Carbon dioxide emissions (CO_2) are given as the dependent variable, while urban population (URP), agriculture, forest and fishing (AFF), trade openness (TOP), and agricultural contribution to GDP (AGDP) are defined as the independent variables.

The coefficients β_1 to β_4 were estimated using the cointegration model.
$CO_2 = \beta_0 + \beta_1 URP + \beta_2 AFF + \beta_3 TOP + \beta_4 AGDP + \varepsilon$

Where:
CO_2 = Carbon dioxide emissions (Metric tons per capita)
URP = Urban population (%)
AFF= Agriculture, forest and fishing (% value added to GDP)
TOP = Trade openness (ratio of export + import to GDP)
AGDP = Agricultural contribution to GDP (%)
β_0 is the intercept term
β_1, β_2, β_3, and β_4 are the coefficients of the independent variables URP, AFF, and TOP, respectively
ε is the error term

This model specifies a cointegrating relationship where long-term equilibrium exists between CO_2 and the independent variables URP, AFF, TOP, and AGDP. The coefficients β_1, β_2, β_3, and β_4 represent the long-term impact of changes in each independent variable on CO_2 emission after controlling for the other variables. The summary of operationalization of variables for the study and expected sign (*apriori* expectations) are presented in Table 1.

RESULTS AND DISCUSSION

In Table 2, the mean, median, and standard deviation of carbon dioxide (CO_2) were presented as 0.646988, 0.615050, and 0.102678, respectively. The value for the standard deviation (SD) indicated that the CO_2 emissions were relatively clustered around the mean, while the minimum and maximum values of 0.491393 and 0.866939, respectively, indicate variation over the years. The amount of emissions is enormous and can harm the efficiency of human and natural assets. The skewness of 0.544686 suggests a slightly right-skewed distribution, indicating that in Nigeria, there are relatively high CO_2 emissions.

The probability values of the Jarque-Bera test are greater than 0.05, so the normality of the distribution is ensured in the present study. The corresponding values for the mean, median, and SD for Agriculture, Forest, and Fishing (AFF) were given as 6.834769, 4.270127 and 10.78414, respectively, with minimum and maximum values of 2.122603 and 55. 57805 respectively. The skewness of 4.264863 indicates a significant right-skewed distribution, suggesting that there may be some regions with a disproportionately large contribution of CO_2 from these sectors. The high Kurtosis value of 19.84400 implies heavy-tailedness or the presence of potential outliers in the data. However, for Urban Population (URP), the mean value of 4.562937 suggests that, on average, a significant portion of the population in the dataset lives in urban areas. The minimum and maximum values (3.911588 and 5.007834, respectively) indicated some variability in urbanization levels. However, the relatively low standard deviation of 0.380632 indicates a slightly left-skewed distribution, suggesting that some regions may have a higher rural population than others. The Jarque-Bera statistic of 2.531115 with a probability of 0.282082 suggests that the distribution of urban population proportions may deviate from perfect normality. This study is consistent with the observations reported by Sha [35].

Further, the mean value of 35.81073 (trade openness (TOP)) suggests a moderate level of trade openness in the dataset. The minimum and maximum values (16.35219 and 53.27796, respectively) indicated variations in trade engagement. The standard deviation of 10.11489 indicates considerable diversity in the levels of trade openness. Factors such as trade policies, globalization, comparative advantages, and economic integration can influence the degree of trade openness. The skewness of -0.132013 suggests a relatively symmetric distribution, indicating that trade openness is spread out without a pronounced skew towards high or low values. The Jarque-Bera statistic of 0.675943 with a probability of 0.713216 implies that the distribution of trade openness is likely close to normal.

Finally, agriculture contributions to GDP (AGDP) reflect the share of the agriculture sector in the overall Gross Domestic Product (GDP). The mean value of 24.31341 suggests that, on average, agriculture makes a significant contribution to the GDP in the dataset. The minimum and maximum values (19.99025 and 36.96508, respectively) indicate variations in the economic importance of agriculture across different regions. The standard deviation of 4.134239 suggests some degree of disparity in the agriculture sector's contributions to GDP. Socioeconomic factors such as agricultural policies, technological advancements, climate conditions, and market dynamics can influence these variations. The results of this study concur with Hassani [36].

The skewness of 1.702403 suggests a moderately right-skewed distribution, indicating that the contribution of agriculture to GDP may be higher in certain regions. The high Kurtosis value of 5.719253 suggests heavy-tailedness or potential outliers in the data, indicating that some regions may have an unusually large or small contribution of CO_2 from the agriculture sector. All variables except urban population growth rate (URP) were positively skewed. Except for URP, all variables' Kurtosis values were over 2, suggesting peaked distributions in comparison to the normal. Overall, during the study period, the variables showed expected reasonable fluctuations. This is in line with Hertwich *et al.* [37].

In line with similar studies, a study revealed a mean CO_2 emission of 0.6465 and a standard deviation of 0.1111, which is comparable to these results. Suggesting values clustered around the mean [20, 23]. Another related study examined the determinants of agricultural growth in Nigeria and found the average contribution of agriculture to GDP was 25.7 % with a standard deviation of 4.6 %, indicating variations across regions [19]. The current study found similar mean (24.31 %) and standard deviation (4.13 %) values for agricultural GDP contribution.

On the other hand, a paucity of studies had contrasting results as they analyzed the effect of trade openness on agricultural sector performance in Nigeria from 1980 to 2015. They found the average trade openness was 27.6% with a standard deviation of 8.2%, suggesting lower and less varied trade openness than in the current study (mean of 35.81%, SD of 10.11%) [38]. In another study, it was revealed that CO_2 emissions were left-skewed with a skewness of -0.456, contrary to the current study, which found that CO_2 emissions were right-skewed [39]. With a higher percentage growth for the urban population (0.38 %) as presented in the result, another similar study examined the impact of urbanization on Nigeria's agriculture and found that the urban population grew at 3.07 % annually on average with a standard deviation of 0.69 % [40].

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Long-term relationship between the variables and economic growth

The cointegration analysis results presented in Table 3 interpret the proportional change between the variables, indicating the presence of a link over time between the variables and Nigeria's economic growth. The normalized long-run cointegrating coefficient for CO_2 was 1.000, indicating that there is a one-to-one relationship between CO_2 emissions and economic growth in the long term. The coefficient for agricultural, forestry, and fishing (AFF) was -0.103168, indicating a negative relationship with economic growth. This result suggests that an increase in AFF may have a slight dampening effect on economic growth in the long run. The coefficient for urban population (URP) was 0.738965, indicating a positive significant relationship with economic growth. This implies that as urbanization increases in the long-term run, it might be advantageous for economic growth. Trade openness (TOP) had a value of -0.015665, indicating a negative correlation with economic development. This suggests that, over time, trade openness may have a small detrimental effect on economic growth. Finally, the coefficient for agricultural Gross Domestic Product (GDP) was negative (-0.021065), suggesting that increased agricultural contribution to GDP may eventually have a marginally detrimental impact on economic growth. This suggests that environmental concerns, such as climate change and pollution resulting from CO_2 emissions, may pose a constraint to economic growth in Nigeria. Using the Environmental Kutznet curve with Nigeria as a case study, the results of this study were somewhat similar to the current study [41] while carbon dioxide emissions, urbanization, energy use, and economic growth as identified in another related study in selected sub-Saharan African countries were said to have a contrary representation [42]. This disparity was a result of the differences in the models used for the study.

The Effects of carbon dioxide emission on agricultural growth.

The outcomes of the panel regression study indicating the effects of carbon dioxide (CO_2) emissions on agriculture, forest, and fishing (AFF), trade openness (TOP), and urban population (URP) are presented in three different specifications: pooled OLS, fixed effects, and random effects. In the pooled OLS specification (Table 3), the coefficients indicate the relationship between each independent variable and carbon dioxide emissions. The coefficient for the constant term (CO_2) is 0.326906, which represents the baseline level of carbon dioxide emissions when all independent variables are zero. The coefficient for agricultural contribution to GDP (AGDP) was 0.016068, indicating that a one-unit increase in the agricultural gross domestic product is associated with a 0.016068 unit (marginal) increase in carbon dioxide emissions.

The corresponding coefficients for agricultural, forest, and fisheries (AFF), trade openness (TOP), urban population (URP), and agricultural contribution to GDP

(AGDP) were -0.000883, 0.002317, -0.031555, and 0.016068, respectively. This implies that increased carbon dioxide emission may eventually have a detrimental impact on agriculture, forest, and fisheries (AFF) and urban population (URP), respectively. Similarly, the coefficient for trade openness (TOP) and Agricultural contribution to GDP (AGDP) suggests that there is a significant impact of carbon dioxide emissions on urban population and agricultural gross domestic product. At standard levels ($p > 0.05$), none of these coefficients were statistically significant. The results of this study are consistent with those reported from studies carried out by Effiong *et al.* [43].

The R-squared value of 0.526720 indicates that the independent variables in the pooled OLS model explain approximately 52.67 % of the variation in carbon dioxide emissions. However, the adjusted R-squared value of 0.390890 suggests that the model may suffer from overfitting, as the addition of more independent variables has not substantially improved the explanatory power of the model. The F-statistic of 11.90956 is statistically significant with a p-value of 0.0000, suggesting that the overall predictive power of the model is significant. The Durbin-Watson statistic of 0.508842 indicates the presence of positive autocorrelation in the model.

From the results of the fixed effects specification (Table 4), the coefficients for the independent variables remain similar to those in the pooled OLS model. However, the coefficient for trade openness (TOP) becomes slightly more significant, with a p-value of 0.0538. The R-squared value increases to 0.533397, indicating a slightly better fit compared to the pooled OLS model. The F-statistic of 7.903997 is statistically significant, suggesting that the fixed effects model is significant overall. The redundant fixed effects tests, including the cross-section F-test and cross-section chi-square test, assess the presence of fixed effects and indicate that the inclusion of fixed effects is not statistically significant.

These results are consistent with related studies on the impact of CO_2 emissions and socioeconomic determinants on agricultural output in Nigeria using panel data from 1981 to 2015. They reported coefficients ranging from -0.003 to 0.012, R-squared of 0.55, F-statistic of 12.4 (significant), and DW statistic of 1.8 [44]. Other studies analyzed the effect of CO_2 emissions on agricultural production in Nigeria and found coefficients from -0.001 to 0.017, R-squared of 0.49, F-statistic of 14.2 (significant), and Durbin-Watson (DW) of 2.1 [45].

On the contrary, researchers in their separate studies reported higher coefficients ranging from 0.02 to 0.05, R-squared of 0.76, F-statistic of 28.3, and DW of 0.8 [46]. Also, coefficients ranging from -0.007 to 0.027, a lower R-squared of 0.36, an F-statistic of 8.9, and a higher DW of 2.5 were reported in another related study [47].

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CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

In line with the statistical analysis, it can be concluded that there is heterogeneity in the variables. The Skewness and Kurtosis values indicate the presence of distributional asymmetry and potential outliers in some variables. The study revealed that in the long term, there exists a one-to-one relationship between agricultural growth variables and economic growth. Both trade openness and agricultural contribution to gross domestic product were associated with increased CO_2 emission, indicating that increasing carbon dioxide emissions will increase trade openness and agricultural contribution to GDP are the major cause of carbon dioxide emission which could potentially cause more environmental degradation in the country. This underscores the need to consider factors such as geographic, economic, and policy-related characteristics that may influence these variables. This will help in decision-making, thereby encouraging economic growth and sustainability.

Novelty

According to the literature, studies on carbon emissions have only focused on the effects associated with energy consumption, transportation, and deforestation. However, a paucity of studies is evident on the impacts of carbon dioxide emissions on key agricultural growth variables such as urban population (URP), agriculture, forest and fishing (AFF), trade openness (TOP), and agricultural contribution to GDP (AGDP). However, arising from the dampening nation's economic status, especially on food security, the results of this study have proven that increased carbon dioxide emissions could have debilitating effects on agricultural and economic growth. Carbon dioxide emission was seen to have a significant influence on trade openness as well as agricultural contribution to the country's Gross Domestic Product, which in turn harmed economic growth. These have led to the declining food security status, poverty, malnutrition, and hunger in the country as of today. Therefore, in addition to other measures taken by the government to mitigate these effects, there is a need to adopt mitigation measures on emissions as proposed by the fifth assessment report of the IPCC aimed at reducing emission intensity, energy intensity, and product service intensity, as well as increasing material efficiency.

Recommendations

Based on the findings of this study, the following recommendations can be suggested:

1. **Targeted Regional Development**: The significant right-skewed distribution of CO_2 emissions from Agriculture, Forest, and Fishing (AFF) sectors suggests that some regions have a disproportionately large contribution to emissions. Therefore, policymakers should focus on targeted regional development strategies to reduce

emissions in these sectors. This could involve implementing sustainable agricultural practices, reforestation programs, and sustainable fishing practices in regions with high emissions.

2. **Urban Planning and Rural Development**: The results indicate that a significant portion of the population lives in urban areas, with some regions having a higher rural population than others. To address this, policymakers should prioritize urban planning strategies that promote sustainable development, such as investing in public transportation, renewable energy, and green infrastructure. Additionally, rural development programs should be implemented to provide economic opportunities and improve living standards in rural areas, reducing the pressure to migrate to urban centers.

3. **Trade relations:** Enhancing trade relations and connectivity with key global and regional markets through trade agreements and infrastructure development can help optimize trade openness levels across Nigerian regions, as indicated by the moderate standard deviation in the study. Special economic zones targeting high growth sectors can boost competitiveness and trade.

4. **Sustainable Economic Development Strategies:** The results suggest that CO_2 emissions are closely linked to economic growth in Nigeria, with a one-to-one relationship in the long term. To address this, policymakers should prioritize sustainable economic development strategies that balance economic growth with environmental concerns. This could involve investing in renewable energy sources, promoting energy-efficient technologies, and implementing policies to reduce carbon emissions.

5. **Diversification of Economic Sectors:** The negative relationship between agricultural, forestry, and fishing (AFF) and economic growth suggests that an over-reliance on these sectors may have a dampening effect on economic growth. Similarly, the negative correlation between trade openness (TOP) and economic development implies that unchecked trade openness may have detrimental effects on economic growth. To address this, policymakers should prioritize the diversification of economic sectors, promoting industries that are less dependent on natural resources and more focused on knowledge-based and service-oriented sectors. This could involve investing in education and training programs, promoting entrepreneurship and innovation, and implementing policies to support the growth of new industries.

6. **Enhancing Trade Policies for Sustainable Development**: From the study, trade openness (TOP) showed a weakly significant relationship with CO_2 emissions; this suggests the need for policymakers to focus on optimizing trade policies for sustainable development. This can be achieved by encouraging environmentally

friendly trade practices, promoting the adoption of clean technologies in industries, and incentivizing sustainable production and consumption patterns.

7. **Mitigation Strategies for Agricultural Sector**: The positive relationship between agricultural contribution to GDP (AGDP) and carbon dioxide emissions suggests that the agricultural sector is a significant contributor to CO_2 emissions. To address this, policymakers should prioritize mitigation strategies for the agricultural sector, such as promoting sustainable agricultural practices, improving crop and animal productivity, and reducing synthetic fertilizer use.

8. **Integrated Urban Planning and Environmental Management**: The negative relationship between urban population (URP) and carbon dioxide emissions suggests that urbanization may have a detrimental impact on environmental quality. To address this, policymakers should prioritize integrated urban planning and environmental management strategies, such as investing in green infrastructure, promoting public transportation, and implementing waste management systems. This can help reduce the environmental impact of urbanization and promote sustainable development.

Suggestions for further studies

1. Conducting further analysis using advanced econometric techniques can provide more insights into the relationship among the variables. Time series models, such as vector autoregression (VAR) or error correction models (ECM), can help capture the short-term dynamics and causal relationships among the variables. Relationships between key variables are non-significant, perhaps pointing to some missing or unconsidered variables.

2. Governments and policymakers can utilize the results to design effective strategies for addressing carbon dioxide emissions and promoting sustainable development. Policies related to urban planning, agriculture, trade, and economic growth can be formulated with an understanding of the long-term relationship among these variables.

3. There is also a need to adopt other measures that will improve food security and reduce poverty in the country using more recent, up-to-date data on carbon dioxide emissions as well as other variables.

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Conflict of Interest Statement

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Table 1: Table of Operationalization and expected sign (*apriori* expectations)

Variables	Description	Measurement	Sign
Dependent Variable:			
CO_2	Carbon Dioxide Emissions	metric tons per capita	
Independent Variables:			
URP	Urban Population	%	+
TOP	Trade openness	Index (ratio)	+
AFF	Agriculture, Forest, and Fishing	Annual % growth	+
AGDP	Agricultural contribution to GDP	Annual % growth	+

Table 2: Socio-economic factors

	CO_2	AFF	UP	TOP	AGDP
Mean	0.646988	6.834769	4.562937	35.81073	24.31341
Median	0.615050	4.270127	4.713375	34.45783	23.89370
Maximum	0.866939	55.57805	5.007834	53.27796	36.96508
Minimum	0.491393	2.122603	3.911588	16.35219	19.99025
Std. Dev.	0.102678	10.78414	0.380632	10.11489	4.134239
Skewness	0.544686	4.264863	-0.339938	-0.132013	1.702403
Kurtosis	2.108280	19.84400	1.523880	2.202741	5.719253
Jarque-Bera	1.899319	341.6235	2.531115	0.675943	18.19592
Probability	0.386873	0.000000	0.282082	0.713216	0.000112
Sum Sq. Dev.	0.231943	2558.547	3.187375	2250.842	376.0225

Source: Author's computation, 2024

Table 3: Normalized long-run cointegrating coefficients

Variables	Coefficient	Standard error	P-value
CO_2	1.000		0.018*
AFF	-0.103168	0.01065	-0.799
UP	0.738965	0.12350	0.040**
TOP	-0.015665	0.00465	2.899
AGDP	-0.021065	0.01956	-0.213

Source: Author's computation 2024

*=1%, **=5%, ***=10%. respectively

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Table 4: Effect of carbon dioxide emission on agricultural growth

	Dependent variable: Carbon dioxide emission association		
Variables	**OLS**	**Fixed Effect**	**Random effect**
AGDP	0.016068***	0.015131***	0.016068***
	(0.003686)	(0.003893)	(0.003686)
AFF	-0.000883	-0.000796	-0.000883
	(0.001304)	(0.001322)	(0.001304)
TOP	0.002317**	0.002354**	0.002317**
	(0.001184)	(0.001198)	(0.001184)
UP	-0.031555	-0.028459	-0.031555
	(0.035245)	(0.035841)	(0.035245)
Constant	0.326906***	0.333730***	0.326906***
	(0.132921)	(0.135611)	(0.132921)
R-squared	0.526720	0.533397	0.526720
Adjusted R-square	0.390890	0.378564	0.390890
S.E of regression	0.077123	0.077899	0.077123
F-statistic	11.90956	7.903997	11.90956
Prob>F	0.000000	0.000002	0.000000
N	23	23	23

Source: Author's computation, 2024

NB: Normal errors are enclosed in parentheses. *, **, and *** stand for 1%, 5%, and 10% of the significance threshold, or ***p<.01, **p<.05, and *p<.1 respectively. URP is the urban population (percentage of the total population), TOP is trade openness (index (ratio)), and AFF is agricultural, forest, and fishery (percentage of yearly increase)

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