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THE RELATIONSHIP BETWEEN CARBON FOOTPRINTS AND ECONOMIC GROWTH IN NIGERIA: AN EMPIRICAL ANALYSIS

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Abstract

This study investigated the impact of carbon emissions on Nigeria's economic growth from 1990 to 2022. The research focused on key variables including carbon dioxide (CO2), energy consumption, methane emissions (NH4), and inflation rate. Using the Fully Modified Ordinary Least Squares (FMOLS) method, the analysis revealed that CO2 emissions have a significant positive effect on economic growth, indicating that increased emissions may be associated with higher economic activity. Conversely, methane emissions negatively impact growth, highlighting environmental concerns. Energy consumption showed a weak positive relationship, while inflation rate was found to be significantly and negatively related to economic growth. Based on these findings, the study recommends implementing targeted methane reduction strategies, such as improving livestock feed and animal health, to reduce methane production. These measures can help mitigate the adverse effects of methane emissions on Nigeria's economy while promoting sustainable development.

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Keywords: Carbon footprint, Carbon emission, Economic growth, Greenhouse gas

INTRODUCTION

Economic growth refers to the sustained increase in the production of goods and services over time, typically compared across different periods. It signifies an improvement in a nation's economic capacity and is driven by factors such as increases in capital stock, labor force, technological innovation, and human capital development. Essentially, economic growth measures the rise in a country's per capita and national income over a specific timeframe, reflecting the overall expansion of economic activities. It is commonly quantified by the growth in the aggregate market value of goods and services produced within an economy in current monetary terms.

In the 21st century, climate change has emerged as the most significant environmental threat. Driven largely by urbanization and industrialization, climate change has received global attention due to its profound impacts on ecosystems, economies, and societies. The relationship between carbon footprints and economic growth has been a focal point of research, as policymakers and scholars seek to understand how economic activities contribute to environmental degradation. Carbon emissions primarily originate from the combustion of fossil fuels and other activities that release greenhouse gases, such as electricity generation, transportation, industrial processes, agriculture, and residential energy use.

International efforts to combat climate change include the Kyoto Protocol (1997), which was adopted under the United Nations Framework Convention on Climate Change (UNFCCC). The protocol aims to reduce greenhouse gas emissions globally, with 192 countries signing on to its commitments. Nigeria, as a signatory, has pledged to participate in international climate mitigation efforts, recognizing the importance of addressing environmental concerns linked to carbon emissions.

Nigeria, with its large population and the largest economy in Africa by GDP, is among the continent's major carbon emitters after South Africa and Egypt. The country's significant reliance on oil and gas, alongside agricultural activities, contributes substantially to greenhouse gas emissions. Nigeria's diverse climate-related challenges include prolonged heatwaves, altered rainfall patterns, flooding, rising sea levels, desertification, droughts, and declining crop yields. These issues threaten both urban and rural

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populations and pose significant obstacles to sustainable development.

Given Nigeria's rapid urbanization and expanding industrial sectors, understanding the link between economic growth and carbon emissions is essential. Rising economic activity and urban expansion tend to increase reliance on fossil fuels, leading to higher carbon dioxide (CO_2) emissions, which exacerbate climate change (Sarkodie & Adams, 2018). The global community, through conferences like COP28 held in Dubai in December 2023, continues to emphasize the importance of transitioning towards greener energy sources and achieving net-zero emissions in the near future. However, developing countries like Nigeria face significant challenges due to their dependence on hydrocarbons for economic sustenance, which complicates efforts to reduce emissions.

Research on Nigeria's carbon footprint and economic growth has produced mixed results. Nnaji, Chukwu, and Uzoma (2012) found a significant positive relationship between energy consumption, carbon emissions, capital formation, and international trade, indicating that economic growth is closely linked to increased fossil fuel use. Conversely, Okafor and Anosike (2021) identified a unidirectional causal relationship where economic expansion leads to higher carbon emissions, suggesting that in the long run, increased emissions could hinder sustainable growth. Mesagan (2020) examined the period from 1970 to 2018 and observed that, in the short term, economic growth significantly impacts carbon emissions, while in the long term, the relationship becomes negative, implying that efforts to control emissions could eventually promote sustainable development.

Another relevant study by Jibrin, Ibrahim, and Aliyu (2022) revealed that rising carbon dioxide emissions have a significant positive effect on Nigeria's economic growth, highlighting a complex and sometimes contradictory relationship. The divergence in findings across studies may stem from differences in variables considered, estimation techniques employed, data periods, and measurement approaches. These discrepancies underscore the need for further research to clarify the dynamics between carbon footprints and economic growth in Nigeria.

The global discourse on climate change has intensified, especially following the COP28 summit, which reinforced the urgent need for nations to adopt green transition strategies. These strategies involve shifting towards renewable energy sources and implementing policies that promote sustainability. Unfortunately, Nigeria's limited technological and financial resources hinder its capacity to adopt such measures effectively. The country remains heavily reliant on fossil fuels for energy production, transportation, and industrial activities, which perpetuates high carbon emissions and environmental degradation.

The lack of adequate investment in renewable energy infrastructure and technological innovation further complicates Nigeria's climate mitigation efforts. Without substantial policy reforms and resource allocation, Nigeria risks facing more severe climate-related impacts, such as increased flooding, desertification, and food insecurity. The current trajectory underscores the importance of integrating climate considerations into economic planning and development policies.

Given these challenges, the relationship between carbon footprints and economic growth in Nigeria warrants thorough investigation. The primary objective of this study is to examine the effects of carbon emissions, energy consumption, and methane emissions on Nigeria's economic development. The specific aims are to: determine the impact of carbon emissions on Nigeria's economic growth; assess how energy consumption influences Nigeria's economic performance; and explore the relationship between methane emissions and economic growth in Nigeria.

The structure of this paper is organized as follows: Section two reviews existing literature on the subject, highlighting theoretical frameworks and empirical findings. Section three details the research methodology, including data sources and analytical techniques. Section four presents and discusses empirical results, while section five concludes with policy implications and recommendations. Consequently, the nexus between carbon footprints and economic growth remains a critical area of study, especially for developing countries like Nigeria that face the dual challenge of fostering economic development while managing environmental sustainability. Addressing this complex relationship is essential for designing effective policies that promote sustainable growth, mitigate climate change, and ensure long-term environmental health.

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LITERATURE REVIEW

Economic growth refers to an increase in the production of goods and services over time, typically measured by comparing one period to another. It can be assessed using either nominal or real values; this study focuses on real value measurements (Mesegan, 2015). Economic growth signifies an expansion in a nation's capacity to produce goods and services, reflecting an overall increase in economic activity. It is also viewed as a process through which a country's wealth and standard of living improve over time.

Carbon Emissions: Carbon emissions relate to the release of greenhouse gases into the atmosphere. According to the World Bank, carbon emissions primarily originate from the combustion of fossil fuels and cement production, and are defined as carbon dioxide (CO_2) emissions. CO_2 is produced through the burning of solid, liquid, and gaseous fuels, as well as gas flaring. Besides CO_2, other greenhouse gases (GHGs) include methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), ozone (O_3), water vapor, and carbon monoxide (CO). These gases contribute to global warming and climate change (Kaisan, Yusuf, & Nafi'u, 2016).

Theoretically, overlapping Generation Model (OLG): John and Pecchenino (1994) developed the Overlapping Generation Model (OLG) to analyze the relationship between economic activity and environmental quality. The model assumes that environmental quality influences individual utility, and agents can allocate resources toward investments in environmental improvements, such as cleaner technologies or better maintenance practices. The framework highlights a trade-off between consumption of goods and services and environmental preservation.

Ecological Modernization Theory: This theory posits that as countries progress from low to moderate development levels, environmental degradation initially increases due to growth and expansion. However, with further advancement, emphasis shifts toward sustainable growth, technological innovation, and environmental protection. Over time, this leads to a reduction in environmental harm (Majeed & Mazhar, 2019). Ecological modernization underpins this study by suggesting that economic development and environmental sustainability can coexist through technological and policy innovations.

Empirical evidence by Mesagan (2015) examined the relationship between carbon emissions and economic growth in Nigeria from 1970 to 2013 using an error correction mechanism. The results indicated that economic growth positively impacts carbon emissions.

Okafor and Anosike (2021) investigated the effect of carbon emissions on Nigeria's economic growth from 1980 to 2019, employing Granger causality tests and the Vector Error Correction Model (VECM). They found a unidirectional causal relationship: economic expansion causes increased carbon emissions in the short term, but in the long run, carbon emissions may hinder economic growth.

Nnaji, Chukwu, and Uzoma (2012) explored the interactions among CO_2 emissions, energy consumption, and economic growth. Using cointegration tests, ARDL, and Granger causality, they found that energy consumption, carbon dioxide emissions, capital formation, and international trade significantly influence economic growth. The causality tests indicated that these variables positively and directly affect economic growth.

Dantama, Abdullahi, and Inuwa (2020) analyzed the nexus between economic growth and energy consumption in Nigeria from 1980 to 2019. Their findings revealed that oil and electricity consumption significantly contribute to economic growth, while coal consumption shows a positive but statistically insignificant effect. The study concluded that increasing economic activity and energy use contribute to higher carbon emissions over the long term.

Akinlo and Akinlo (2021) examined how trade openness impacts carbon emissions and economic growth in Nigeria, covering 1970 to 2017 using the ARDL approach. They found that trade supports economic growth while helping to reduce carbon emissions: trade openness has immediate benefits for growth but a long-term negative effect on emissions.

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Omisakin (2019), within the framework of the Environmental Kuznets Curve (EKC), studied the dynamic and long-term relationships among energy consumption, carbon emissions, and economic growth in Nigeria using the bound test cointegration approach. Results showed that energy consumption drives GDP growth, GDP growth influences carbon emissions, and carbon emissions also impact energy consumption.

Jibrin, Ibrahim, and Aliyu (2023) explored how carbon dioxide emissions and financial development affect Nigeria's economic growth from 1981 to 2021, employing the ARDL bounds test. They found that increased emissions positively influence economic growth, while domestic investment has a negative but significant impact.

Olugboyega (2021) analyzed the relationship between economic growth and carbon emissions in Nigeria (1970–2018) using ARDL to test the EKC hypothesis. The results indicated that electricity consumption and trade openness negatively relate to CO_2 emissions, while population growth has a positive but insignificant effect. The signs of the coefficients support the existence of the EKC in Nigeria.

METHODOLOGY

The research designs adopted in this study is the Ex-Post-facto and longitudinal research design, where data cannot be manipulated because they already occurred. The population of the study which also the sample size is the Nigerian economy. The census sampling technique in which population equals sample size was used in the study.

Sources of Data: The data utilized in this analysis are annual observations covering a 33-year period from 1990 to 2022. These data were obtained from the World Bank Database and the Central Bank of Nigeria (CBN) Statistical Bulletin (2022).

Model Specification: This study adopts the model developed by Batimoore and Tudok (2010), with slight modifications. The model is expressed as:

GDP=f(POL,TCH,CON) (1)

Where ;POL =Pollution, TCH =Technology & CON = Consumption.

The effect of carbon emissions on economic growth is modelled in linear form as follows:

$GDP = f(CO_2, ECons, NH_4, INFR)$……1

However, the econometric form of equation as stated as follows:

$GDP_t = \alpha_0 + \alpha_1 CO_{2t} + \alpha_2 ECons_t + \alpha_3 NH_{4t} + \alpha_4 INFR_t + \mu$…….....2

Where:

GDP = Gross Domestic Product (a proxy for economic growth)

CO_2 = Carbon Emissions

ECons = Energy Consumption

NH_4 = Methane Emissions

INFR = Inflation Rate

μ is the error term.

Apriori Expectations are: $\alpha_1, \alpha_2, \alpha_3, \alpha_4 > 0$

3.3 Method of Data Analysis: Three analytical methods are employed: correlation coefficient analysis, unit root testing, and Fully Modified Ordinary Least Squares (FMOLS).

The correlation coefficient analysis is used to understand the relationships and background characteristics among the variables.

The unit root test assesses the stationarity properties of the data to prevent spurious regression results.

FMOLS is preferred over ordinary least squares (OLS) because it corrects for small sample bias and endogeneity by incorporating leads and lags of the first-differenced regressors. Additionally, FMOLS requires that all variables are integrated of the same order, specifically I(1), and that the regressors are not cointegrated (Philips, 1993).

RESULTS

In this section, the analysis and interpretation of results carbon emissions and economic growth in Nigeria is carried out. As stated in the previous chapter, the unit root test is used for the stationarity property of the data, the Johansen Multivariate Cointegration test is used to ascertain the long run effect, while the fully modified Least Square (FMOLS) was used to analyze the data for the study.

Unit Root Analysis: The Augmented Dickey Fuller (ADF) test is employed in order to analyze the unit roots. The results are presented in levels and first difference in Table 1. In the result, the ADF test statistic for each of the variables is shown in the second and fifth column, while the 95 percent critical ADF value is shown in the third and sixth column respectively. The result indicates that all the variables are not stationary at levels (see panel 1). However, after the first difference was taken, all the variables

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were now stationary (see panel 2). This implies that the variables are actually difference-stationary, attaining stationarity after the first differences of the variables. Thus, we would accept the hypothesis that the variables possess unit roots. Indeed, the variables are integrated of order one (i.e. I[1]).

Table 1: Unit Root Tests

	At Levels	Panel 1		First	Difference	Panel 2
Variable	ADF Test Statistic	95% Critical ADF Value	Remark	ADF Test Statistic	95% Critical ADF Value	Remark
GDP	0.105966	-2.960411	Non-Stationary	-7.067566	-2.963972	Stationary
CO2	0.787055	-2.957110	Non-Stationary	-11.64359	-2.963972	Stationary
ECONS	-2.011165	-2.957110	Non-Stationary	-6.665075	-2.960411	Stationary
INFR	-2.670184	-2.960411	Non-Stationary	-4.591729	-2.960411	Stationary
HN4	-1.605251	-2.957110	Non-Stationary	-4.746310	-2.960411	Stationary

Source: Authors' Compilation

Cointegration Analysis:

The results from the multivariate cointegration test are presented in Table 4.2 below. This test employs the Johansen system cointegration method. As can be seen from Table 4.2, both the eigenvalue test (λ-max) and the trace test statistics indicate that there are more than one (1) significant cointegrating vectors between carbon emissions and economic growth in Nigeria. This implies that a long run relationship exists among these variables. Hence, the results of the cointegration tests are summarized in Table 2.

Table 2: Johansen Multivariate Cointegration Tests Results.

Trace Test				Maximum Eigenvalue Test		
Null Hypothesis	Test Statistic	Critical Value	Prob.	Test Statistic	Critical Value	Prob.
r = 0*	76.45374	69.81889	0.0134*	34.98276	33.87687	0.0368*
r = 1	41.47098	47.85613	0.1741	25.90199	27.58434	0.0808
r = 2	15.56899	29.79707	0.7422	9.238693	21.13162	0.8127
r = 3	6.330301	15.49471	0.6565	6.291514	14.26460	0.5761
r = 4	0.038788	3.841466	0.8438	0.038788	3.841466	0.8438

Source: Authors' computation

Regression Analysis

In the results of the estimated fully modified least square (FMOLS) regression for the model presented in Table 4.3 below, the diagnostic indicators are quite good, having a high predictive ability of R squared value of 0.91. This shows that over 91 percent of the systematic variations in economic growth is captured by changes in the explanatory variables; even the adjusted R-squared value of 0.90 percent is very high and it implies that the model has a high predictive ability. From Table 4.3 below, it is observed that the coefficient of carbon emissions (CO_2) has significant positive relationship with economic growth in Nigeria. It passed the 1 percent significance level. Indeed, it is seen that as the level of carbon emissions (CO_2) increase, overall economic growth increase by approximately 5.75E+08 percent. The results suggests that with more emissions of carbon dioxide in Nigeria, economic growth is enhanced. The finding aligns with those of Obayagbona (2023), Syafrudin

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et al. (2020), Khan et al. (2020), and Kılavuz and Doğan (2021) who unanimously confirmed that carbon emissions (CO_2) significantly and positively impact economic growth

The coefficient of energy consumption (ECons) has an insignificant negative impact on economic growth in Nigeria, the variable failed the 5 percent level. This follows that, in the determination of the level of economic growth in Nigeria, total energy consumption (ECons) is not a relevant factor to be considered. This finding does not agree with the findings of Obayagbona (2023), Syafrudin et al. (2020) who submitted significant positive and negative effects of energy consumption on economic growth.

The coefficient of methane emissions (NH_4) is significant and passed the 5 percent significance level, suggesting that the variable plays significant role in the determination of economic growth in Nigeria within the investigating period. The negative sign however implies that any increases in methane production reduces economic growth in Nigeria by approximately -5.45E+08 percent. It therefore means that those emissions stemming from human activities such as agriculture and from industrial methane production are significant factors influencing economic activities in the country. This finding strongly corroborate the view of UNEP Convened Initiative (2023) that, "Methane severely exacerbates climate change, but also has a number of indirect effects on human health, crop yields and the health of vegetation through its role as a precursor to the formation of tropospheric ozone". It however disagreed with those of Yusuf, Abubakar and Mamman (2020) who found an insignificant effect of Methane on economic growth.

Those of inflation rate (INFR) has significant negative relationship with economic growth; suggesting that the level of inflation in Nigeria is a relevant factor influencing economic growth. However, the negative sign is an indication that as inflation rate rises, economic growth reduces by -2.37E+11percent.

Table 2: Carbon Emissions and Economic Growth in Nige

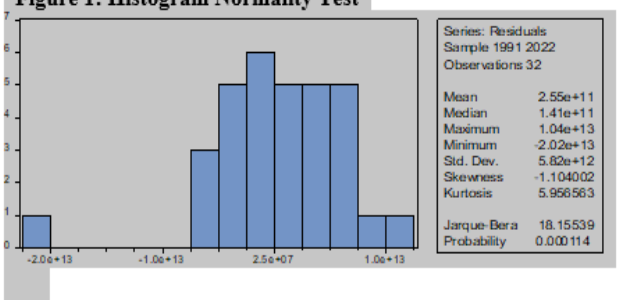
Variable	Coefficient	T-Ratio	Prob.
Constant	-1.26E+	-1.50460	0.1440
CO2	5.75E+0	9.40050	0.0000**
ECONS	1.35E+1	1.56886	0.1283
INFR	-2.37E+	-2.15671	0.0401*
NH4	-5.45E+0	-2.4544	0.0208*
R^2 = 0.9	— 0.90		

Source: Authors' Computation.
Note: ** sig. at 1% level; *sig. at 5% level.

Normality Test

To test for normality test, we employed the histogram normality test (HNT). Since the probability value (0.000301) of the Jarque-Bera statistics in Figure 4.1 is less than 0.05 (5%), we conclude that the data set are not normally distributed.

Figure 1: Histogram Normality Test



Discussion of Findings

Methane being the factor that significantly impact economic growth in this study, is a much stronger greenhouse gas that has not get as much focus as needed (Ericsson, 2022); yet **is a powerful greenhouse gas and short-lived climate pollutant (SLCP) primarily emitted by human activities. It is reported to have an atmospheric lifetime of around 12 years, seriously intensify** climate change with a lots of indirect effects on human health, crop yields and the health of vegetation through its role as a precursor to the formation of tropospheric ozone (UNEP Convened Initiative, 2023). In the process of producing, processing, transporting and distributing natural gas, methane leakages occur, emitting methane into the atmosphere and accelerating global warming (EPA, 2021). It therefore follows that the use of natural gas as an energy source might increase, with

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possible increases in methane emissions (EC, 2022). On the other hand, total energy consumption increases with GDP (Abbas, 2020), leading to higher emissions of greenhouse gases.

Considering the effect of carbon emission and methane on economic growth in Nigeria in this study, there is urgent need to focus on specific strategies towards reducing the adverse effect of these emissions on our environment and by extension general economic activities. Keeping silence will not solve any problem, and it should be noted that global warming is a complex problem and even if we don't have all the answers and solutions now, we cannot wait to take action, it needs to happen now because, effective mitigation of global warming is the basis for achieving sustained economic growth and economic equality in the world (Ericsson, 2022). It should also be noted that "long-term success cannot be achieved by pursuing economic growth at the expense of the environment"

CONCLUSION AND RECOMMENDATIONS

Conclusion

The study has examined the relationship between carbon emissions and economic growth in Nigeria over the period 1990 to 2022. The rationale for the study was based on the realization that economic of any nation is highly dependent on its domestic aggregate carbon emissions. For this reason and in order to ascertain the extent to which carbon emissions have affected economic in Nigeria, this study was undertaken using four carbon emissions-related factors such as carbon emissions (CO_2), energy consumption (ECons) and methane emissions (NH_4), and with inflation rate (INFR) as control variable. Economic growth was proxied by gross domestic products (GDP). The fully modify least square (FMOLS) technique was employed for the analysis of data. The results obtained generally showed that, while carbon emissions (CO_2) has significant positive impact on economic growth, methane emissions (NH_4) has significant negative impact on economic growth. On the other hands, energy consumption (ECons) has a weak positive impact on growth, while inflation rate (INFR) in significantly and negatively related to economic growth. The study conclude that, in the carbon emissions (CO_2) and methane emissions (NH_4) exert significant impact on economic growth in Nigeria hence, government and regulatory authorities must focus their attention on these two factors while initiating any policy measure in enhancing economic growth in relation to carbon emissions.

Recommendations

Base on the findings of from this study, the following specific recommendations for policy decision are made:

First, since Methane emissions in the study have proven to be significantly related to economic growth, through its impact on climate change and public health contributes to a yearly loss of about 400 million hours of work globally due to extreme heat; therefore, targeted strategic methane abatement control measures aim at reducing its adverse effects should be pursued vigorously. This can be achieved by optimized feed and improved animal health which has the capacity to reduce methane production by ruminant animals such as cattle, goats and sheep.

Secondly, government, regulatory agency and policy makers should initiate a more proactive energy policy measures that will help to increase aggregate renewable energy generation and usage. This will reduce over-reliance on energy-supplies from advance countries, thereby reducing aggregate CO_2 emissions in Nigeria.

Lastly, the outcome of this study has shown that energy consumption does not significantly impact economic growth; and theoretically, growth in the economy often enhances aggregate energy consumption, and any shortfall in respect of energy supply constrains economic growth. Therefore, government must constantly ensure the availability, accessibility, and affordability of energy resources not only to the industrial sector but to all asundry because of its critical role in economic growth.

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