Vol. 16(1), pp. 1-15, January-March 2024
DOI: 10.5897/JEIF2023.1208
Article Number: 7A6AD3A71794
ISSN 2006-9812

http://www.academicjournals.org/JEIF

ACADEMIC JOURNALS
expand your knowledge

Journal of Economics and International Finance

Full Length Research Paper

Environmental consequences of energy commodities and economic growth: Evidence from Nigeria

Okezie A. Ihugba*, Osmond Okonkwo, Precious L. Akobundu, Joseph Ukwunna, Pamela A. Ndukwe-Ani and Olanyinka Oyelade

Department of Economics, Alvan Ikoku University of Education, Owerri Imo State, Nigeria.

Received 1 December, 2023; Accepted 3 January, 2024

This study explored the relationship between energy commodities, economic growth, and Nigeria's carbon dioxide (CO_2) emissions spanning from 1981 to 2021. Employing the Vector Error Correction Mechanism (VECM) process, the study revealed a negative correlation between fossil fuel consumption, economic growth, and carbon dioxide emissions. Long-term elasticities indicate that carbon dioxide emissions would rise by 24 and 211% if both fossil fuel consumption and economic growth decreased by 1%, contradicting the Environmental Kuznets Curve (EKC) theory in Nigeria. Nevertheless, a positive correlation was observed between carbon dioxide emissions and the total annual population. As per the error correction model (ECM = -2.64441), two years are required for carbon dioxide emissions to return to long-term equilibrium, with 26.4% of a shock in the variable resolved within a year. Upon closer examination of the impulse response function, it is evident that GDPPC and FFC will exert a negative short- and long-term impact on CO_2 emissions. The study proposes that Nigeria's government should implement a comprehensive strategy to bolster investments in renewable energy. This encompasses creating a stable policy environment, establishing ambitious targets for renewable energy capacity, providing financial incentives, and introducing feed-in tariffs, given that the country's consumption of fossil fuels has not yet reached a point where emissions are increasing.

Key words: CO_2 emission, fossil fuel consumption, GDP per capita, VECM.

INTRODUCTION

Energy commodities, encompassing nuclear, chemical, mechanical, thermal, radiation, and electrical energy, contribute to economic growth by enhancing productivity and employment. They exist in various forms—liquids, solids, and gases—yet their environmental impact is intricate, particularly with the combustion of fossil fuels contributing to global warming. The production, transportation, and consumption of energy almost invariably result in significant environmental consequences.

The consumption of fossil fuels can lead to localized air pollution and climate change (Han et al., 2019). Recent research by the WEF (2022) indicates that certain pollutants related to fossil fuels actually have a cooling effect. According to Bölük and Mert (2015), natural gas is less aggressive than oil, accounting for only half of the CO_2

*Corresponding author. E-mail: okezieihugba@gmail.com.

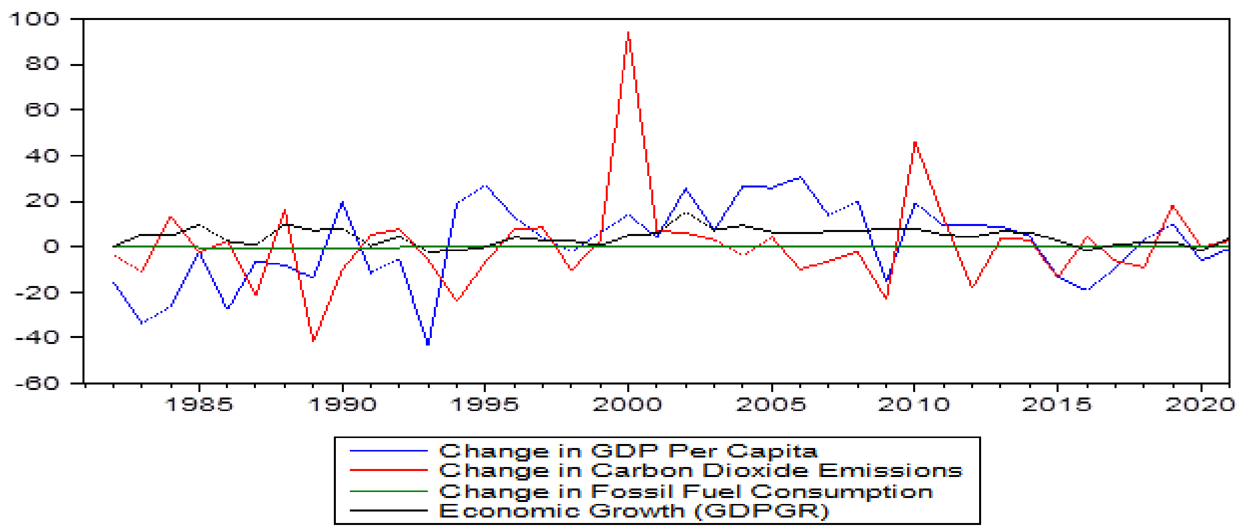

Figure 1. Carbon dioxide emissions, energy consumption and economic growth.

emissions compared to coal. On average, the combustion of oil (in the form of petroleum) releases approximately 33% less carbon dioxide (CO_2) per unit of energy produced compared to the combustion of coal.

In many emerging nations like Nigeria, fossil fuels remain the primary source of energy (Sugiawan and Managi, 2019). Despite their numerous benefits, such as providing thermal power plants with more precise operational control and monitoring (Vincent and Ezaal, 2022), these systems face various challenges that have been extensively studied. Robinson et al. (2007) note that Nigeria is not an exception to the escalating environmental concerns. Okafor and Joe-Uzoegbu (2010) emphasize the environmental impact of urbanization in Nigeria, where rural communities rely on traditional biomass for energy, resulting in greenhouse gas emissions. This imbalance contributes to global warming and environmental degradation, with Nigeria experiencing some of the highest CO_2 emissions worldwide.

Elevated carbon dioxide emissions are primarily associated with economic growth, as proposed by the Environmental Kuznets (1955) Curve (EKC) hypothesis and supported by studies such as those conducted by Han et al. (2018), Acheampong (2018), Abbas et al. (2019), and Esmaeili et al. (2023). The EKC theory posits that income contributes to environmental degradation in the early stages of development but diminishes once certain income levels are reached. However, the EKC exhibits diverse shapes, suggesting different policy implications. The validity of this hypothesis is debated due to variations in methodology, independent variables, examined sectors, and modeling. Few empirical studies focus on Nigeria, and no recent dataset has been employed to analyze Nigerian CO_2 emissions, unlike the studies by Chuku (2011), Ogundipe (2013), Alege and Ogundipe (2013), and Okon (2021). To our knowledge, as of the time of writing, no paper concentrating on Nigerian CO_2 emissions has utilized a more recent dataset.

Nigeria's economy remains susceptible to the risks associated with climate change due to the country's escalating energy consumption and the ensuing CO_2 pollution. Figure 1 illustrates the shift in energy consumption from negative to positive after 1995, resulting in a 7.4% increase in CO_2 emissions in 1996 compared to the negative rates of 24.1% and 6.7% in 1994 and 1995, respectively. Concurrently, due to the rising energy consumption, GDP per capita rose from 18.9% in 1995 to 27.03% in 1996, and the overall economy expanded from -0.1% in 1995 to 4.2% in 1996. The year 2010 marked the most significant change in CO_2 emissions (46%) and the highest GDP per capita (19.3%) during the research period, with an 8% expansion in the economy. Conversely, the lowest changes occurred in 1989, with a -0.35% change in energy consumption and a -41.7% change in CO_2 emissions. Although both CO_2 emissions and GDP deviated from their 1981 values, the growth rate of CO_2 emissions exceeded that of GDP. This suggests limited evidence of absolute decarbonization, indicating that the nation's CO_2 emissions were not proportional to economic growth. Figure 1 demonstrates that from 1981 to 2021, Nigeria's economy did not follow a low-carbon trajectory. Policymakers need to comprehend the directional and causal relationship between energy commodities, economic growth, and the environment.

The increase in CO_2 emissions over the past 70 years is also attributed to the expansion of the human population. A growing population results in increased demands for commodities, energy, and food, leading to higher emissions from transportation, industry, and agriculture. However, to minimize emissions per person, additional measures such as enhancing energy efficiency, transitioning to renewable sources, and altering consumption habits must be implemented alongside population policies (The Conversation, 2023). Globally, CO_2 emissions are distributed unevenly, with high- and upper-middle-income countries, housing slightly less than half of the world's population, responsible for over 80% of global CO_2 emissions. According to Our World in Data (2023), the average person in high-income countries emits over ten times as much CO_2 as the average person in low-income countries.

This study addresses several gaps in existing literature. Firstly, it focuses on Nigeria from 1981 to 2021, as data before the 1980s are incomplete. Secondly, it employs the Vector Error Correction Model (VECM) to explore longitudinal cointegration and causal links between the environment, energy commodities, and economic growth, providing fresh empirical data for the ongoing discussion about their relationship.

LITERATURE REVIEW

The links between energy consumption, CO_2 emissions, and economic growth are the subject of three broad genres of literature. The first discusses whether the relationship between economic growth and CO_2 emissions is consistent with the environmental Kuznets curve (EKC) theory. According to this theory, some pollutants and per-capita income have an inverted U-shaped connection (Grossman and Krueger, 1995). The Environmental Kuznets Curve (EKC) is a relationship between income change and environmental quality, based on Kuznets' work. It suggests that rapid industrialization leads to increased pollution and resource use, putting pressure on the environment. As income increases, people value the environment more, leading to a decline in pollution levels. The EKC hypothesis reveals how environmental quality changes as a country's fortunes change, with an inverted U-shaped curve when pollution indicators are plotted against income per capita (Dinda, 2004). Richer consumers put more pressure on lawmakers to enact environmental laws and regulations, in addition to being prepared to spend more money on eco-friendly goods. The majority of the examples where emissions have decreased while income has increased can be attributed to institutional reforms at the local and national levels, including environmental laws and market-based incentives aimed at halting environmental degradation.

In their study, Özokcu and Özdemir (2017) verified the "inverted U shape theory." However, Friedl and Getzner (2003) hypothesize a long-term link that takes the form of an N or another shape rather than an inverted U between CO_2 emissions and per-capita income. Although He and Richard (2010) and Agras and Chapman (1999) maintain that there is no correlation between CO_2 emissions and economic growth in their non-existence theory, the primary issue with these early investigations on the EKC hypothesis is that they may be biased by missing variables. This happens when one or more independent variables that correlate with one or more of the included independent variables and have an impact on the dependent variable are excluded from a statistical model (Tong et al., 2020).

Recently, the Granger causality test, an econometric technique particularly well-suited for time series and panel data analyses, was proposed to examine the connection between economic growth and carbon emissions. For example, Hossain (2012) discovered that in newly industrialized nations, there was unidirectional short-run causality between economic growth and carbon dioxide emissions, as well as between urbanization and economic growth. Wang et al. (2016) discovered that economic growth was a Granger cause of CO_2 emissions in China between 1995 and 2012, and Hamit-Haggar (2012) found a unidirectional causality relationship between the economy and greenhouse gas emissions in both the short and long runs in their investigation of the Canadian industrial sector. In contrast to Omri (2013), who discovered only a one-way Granger causation linking CO_2 emissions to economic growth in some European, Central Asian, Latin American, and Caribbean countries, Salahuddin and Gow (2014) showed a two-way Granger causal association between the two components.

Abubakar and Cudjoe (2021) estimate the short-run and long-run impacts of energy consumption on Nigeria's environment through total CO_2 emissions using error correction models and normalized estimations. Results show that GDP has a significant long-run tendency to reduce total CO_2 emissions in Nigeria, confirming the Kuznets curve hypothesis for climate. The research also supports the suggestion that environmental destruction increases with per capita income during early economic development stages and decreases with an increase after reaching a plateau. Rafindadi (2016) modeled the relationships between economic development, energy use, and emissions. The model had collinearity issues because the study takes into account CO_2 emissions as a function of income, income squared, and income cubed in addition to other explanatory variables like energy consumption.

In his paper, Okon (2021) used the auto-regressive distributed lag approach to investigate the applicability of the Environmental Kuznets Curve in Nigeria from 1970 to 2018. According to the bounds test, there exists an equilibrium relationship over a long period of time between the gross domestic product per capita, the square of the GDP per capita, waste, combustible renewable energy, alternative and nuclear energy, adjusted savings, or net forest depletion. However, neither short-run nor long-run results are consistent with the Environmental Kuznets Curve hypothesis, nor there is no evidence of an inverse U-shaped link between growth and fluorinated greenhouse gas emissions in Nigeria. Omisakin (2009) tested the Environmental Kuznets Curve (EKC) hypothesis in Nigeria, finding no long-term causal relationship between

Table 1. Variables measurement and sources of data.

S/N	Variable	Measurement	Expected sign	Sources of data
1	carbon dioxide CO_2 emissions per capital	Annual CO_2 emissions per capital measures how much Nigeria emits from fossil fuels and industry divided by its population in a given year		https://data.worldbank.org/indicator/EN.ATM.CO₂E.PC?locations=NG
2	Gross domestic product per capita (GDPPC)	It analyzes Nigeria's GDP per capita and gauges the prosperity of Nigerians by looking at our GDP growth. It is computed by dividing the nation's GDP by its total population. We expect a positive relationship between the variables	+	https://data.worldbank.org/indicator/NY.GDP.PCAP.KN?locations=NG
3	Gross fixed capital formation	Measure capital stock, this study employed the Gross fixed capital formation, which is essential to any country's economic growth. We expect a positive relationship between the variables	+	Central bank of Nigeria (CBN) statistical bulletin volume 32, December 2021
4	Fossil fuel energy consumption (% of total)	It refers to the use of petroleum, natural gas, and coal as sources of energy. We expect a positive relationship between the variables	+	https://data.worldbank.org/indicator/EG.USE.COMM.FO.ZS?locations=NG
5	Population	The total population of Nigeria during the different study years, expressed in millions. An increase in population will result in more land being cleared for agriculture, business, or other uses, as well as more energy use (fossil fuel). Global CO_2 emissions are greatly increased by these activities. Therefore, a positive correlation between the variables is what we anticipate	+	https://data.worldbank.org/indicator/SP.POP.TOTL?view=chartandlocations=NG

Source: Researcher's compilation, 2023.

carbon emissions and income. The regression line shows an "U-shaped" pattern, suggesting that income increases carbon emissions before rising again. Other studies have shown a long-term relationship between environmental pollution indicators, per capita income, institutional variables, and trade. Alege and Ogundipe (2013) found no EKC in Nigeria due to its early development stages. Egbetokun et al.'s (2020) study found that SPM and CO_2 have an EKC, while other environmental contamination measures did not significantly affect economic development.

METHODOLOGY

Granger causality, a linear regression model, and cointegration tests will all be used to examine the collected data. Using the unit root test, the initial step will be to determine the stationarity and order of integration among the study variables. Using cointegration tests, the second phase will look at the long-term relationship between the research variables. In the third, regression analysis will be used to examine how the independent study variables affect CO_2 emissions. The Granger causality test will be used in the fourth step to determine the causal relationship between the research variables.

Data and sources

The Central Bank of Nigeria's (CBN) statistical bulletins and the World Bank 2023 Development Indicators (WDI) provided the data used in the study's empirical analysis. Table 1 lists the variables' names, meanings, and measurements.

Model specification

Based on the empirical literature in energy economics, it makes sense to write the long-term relationship between CO_2 emissions, energy commodities, and economic growth in the form of a linear logarithmic quadratic. This will allow us to test the EKC hypothesis in the following way (Equation 1):

$$\mathrm{CO2} = f(\mathrm{FFC}, \mathrm{GDPPC}, \mathrm{GFCF}, \mathrm{POP}) \quad (1)$$

In this case, POP stands for population, GFCF for gross fixed capital formation, GDPPC for gross domestic product per capita, FFC for fossil fuel energy consumption, and C02 for carbon dioxide emissions per capita. Equation 2 can be expressed as follows in the natural log form for C02, GDPPC, GFCF, and POP as well as in the econometric model:

$$\mathrm{LCO2}_t = \beta_0 + \beta_1\mathrm{FFC}_t + \beta_2\mathrm{LGDPPC}_t + \beta_3\mathrm{LGFCF}_t + \beta_4\mathrm{LPOP}_t + \varepsilon_t \quad (2)$$

Stationarity test

Since it can affect a series' behavior, stationarity is a significant phenomenon. Regressing X on Y in Equation (3) will result in spurious or gibberish regression if X and Y are two non-stationary series (Yule, 1926).

$$Y_t = \beta_0 + \beta_1 X_t + \varepsilon_t \quad (3)$$

The series is considered non-stationary if it has a unit root. The series is stationary if it doesn't have a unit root. The purpose of the stationarity test is to determine if an autoregressive model has a unit root or not. To ascertain the sequence of the variables' integration, the unit root test is helpful. To verify if the provided series is stationary, the augmented Dickey-Fuller test (ADF) and Phillips-Perron test (PP) have been employed.

Co-integration test

To determine whether there is a co-integration relationship between the two variables' non-stationary series, the Johansen-Juselius test is used. We can determine whether there is co-integration between two non-stationary series using the Johansen-Juselius co-integration procedure. This indicates that 0<rank (π) = r <n, which is the maximum rank that the matrix π can have. In terms of the vector or matrix of adjustment parameters α and the vector or matrix of co-integrating vectors β', π can be expressed as $=\alpha\beta'$, where (r) is the number of co-integration vectors and (n) is the number of variables. Based on a likelihood ratio test (LR), this procedure uses the Trace test and the Maximum Eigenvalues test (λmax) to calculate the number of co-integration vectors between variables. The definition of a trace test is:

$$\lambda_{trace}(r) = -T \times \sum_{i=r+1}^{n} \log(1-\hat{\lambda}_i)$$

In contrast to the alternative hypothesis, which states that there are r co-integration vectors, the null hypothesis states that there are ≤r co-integration vectors.

The Maximum Eigenvalues test $(\lambda_{\max})$ is defined as: $\lambda_{\max}(r, r+1) = -T \times \log(1-\lambda_{r+1})$ The null hypothesis that the number of co integration vectors = r against the alternative those they $r+1.$

Granger-causality

The results of the stationarity and co-integration tests will determine the Granger-Causality test's application in the following ways: The following vector auto-regression (VAR) should be estimated in order to perform the conventional Granger-Causality test to determine whether the series (FFC), (LGDPPC), (LGFCF), (LPOP), and (LCO_2) are stationary.

$$FFC_t = \alpha + \sum_{i=1}^{m} \beta_{1i} FFC_{t-1} + \sum_{i=1}^{m} \beta_{2i} LCO2_{t-i} + \varepsilon \tag{4}$$

$$LCO2_t = \alpha + \sum_{i=1}^{m} \beta_{3i} LCO2_{t-1} + \sum_{i=1}^{m} \beta_{4i} FFC_{t-i} + \varepsilon \tag{5}$$

$$LGDPPC_t = \alpha + \sum_{i=1}^{m} \beta_{5i} LGDPPC_{t-1} + \sum_{i=1}^{m} \beta_{6i} LCO2_{t-i} + \varepsilon \tag{6}$$

$$LCO2_t = \alpha + \sum_{i=1}^{m} \beta_{7i} LCO2_{t-1} + \sum_{i=1}^{m} \beta_{8i} LGDPPC_{t-i} + \varepsilon \tag{7}$$

$$LGFCF_t = \alpha + \sum_{i=1}^{m} \beta_{9i} LGFCF_{t-1} + \sum_{i=1}^{m} \beta_{10i} LCO2_{t-i} + \varepsilon \tag{8}$$

$$LCO2_t = \alpha + \sum_{i=1}^{m} \beta_{11i} LCO2_{t-1} + \sum_{i=1}^{m} \beta_{12i} LGFCF_{t-i} + \varepsilon \tag{9}$$

$$LPOP_t = \alpha + \sum_{i=1}^{m} \beta_{13i} LPOP_{t-1} + \sum_{i=1}^{m} \beta_{14i} LCO2_{t-i} + \varepsilon \tag{10}$$

$$LCO2_t = \alpha + \sum_{i=1}^{m} \beta_{15i} LCO2_{t-1} + \sum_{i=1}^{m} \beta_{16i} LPOP_{t-i} + \varepsilon \tag{11}$$

In models (Equations 4 and 11), the subscripts denote time periods and ε is a white noise error. The constant parameter α represents the constant growth rate of FFC_t in Equation 4; $LCO2_t$ in Equation 5; $LGDPPC_t$ in Equation 6; $LGFCF_t$ in Equation 8 and POP_t in Equation 10. We can obtain eight tests from this analysis: the first examines the null hypothesis that the FFC_t does not Granger-cause $LCO2_t$ and the second test examine the null hypothesis that the $LCO2_t$ does not Granger-cause FFC_t . The third examines the null hypothesis that the $LGDPPC_t$ does not Granger-cause $LCO2_t$ and the fourth test examines the null hypothesis that the $LCO2_t$ does not Granger-cause $LGDPPC_t$. The fifth examines the null hypothesis that the $LGFCF_t$ does not Granger-cause $LCO2_t$ and the sixth test examines the null hypothesis that the $LCO2_t$ does not Granger-cause $LGFCF_t$. The seventh examines the null hypothesis that the $LPOP_t$ does not Granger-cause $LCO2_t$ and the eight test examines the null hypothesis that the $LCO2_t$ does not Granger-cause POP_t .

Vector error correction model (VECM)

The conventional VECM is written compactly as (Equation 12):

$$\Delta Y = \alpha + \sum_{i=1}^{k-1} \gamma \Delta Y_{t-1} + \sum_{i=1}^{k-1} \eta \Delta X + \sum_{1=i}^{k-1} \varphi \Delta R + \lambda ECT + \mu \tag{12}$$

where ECT_{t-1} = OLS residual with a lag derived from the long-run cointegrating formula (Equation 13):

$$Y_t = \sigma + \eta_j X_t + \xi_m R_t + \mu_t \tag{13}$$

And express as (Equation 14):

$$ECT_{t-1} = [Y_{t-1} - \eta_j X_{t-1} - \xi_m R_{t-1}] \tag{14}$$

λ = coefficient of the ECT and the speed at which changes to X and R cause Y to stabilize. The specific VECM for this study is as follows (Equations 15 to 19):

$$\Delta LCO2_t = \sigma + \sum_{i=1}^{k-1} \alpha_i \Delta LCO2_{t-1} + \sum_{m=1}^{k-1} \varphi_m \Delta FFC_{t-1} + \sum_{n=1}^{k-1} \eta_n \Delta LGDPPC_{t-1} + \sum_{p=1}^{k-1} \phi_p \Delta\, LGFCF_{t-1} + \sum_{q=1}^{k-1} \xi_q \Delta LPOP_{t-1} + \lambda ECT + \mu \tag{15}$$

$$\Delta FFC_t = \sigma + \sum_{i=1}^{k-1} \alpha_i \Delta LCO2_{t-1} + \sum_{m=1}^{k-1} \varphi_m \Delta FFC_{t-1} + \sum_{n=1}^{k-1} \eta_n \Delta LGDPPC_{t-1} + \sum_{p=1}^{k-1} \phi_p \Delta\, LGFCF_{t-1} + \sum_{q=1}^{k-1} \xi_q \Delta LPOP_{t-1} + \lambda ECT + \mu \tag{16}$$

$$\Delta LGDPPC_t = \sigma + \sum_{i=1}^{k-1} \alpha_i \Delta LCO2_{t-1} + \sum_{m=1}^{k-1} \varphi_m \Delta LGDPPC_{t-1} + \sum_{n=1}^{k-1} \eta_n \Delta FFC_{t-1} + \sum_{p=1}^{k-1} \phi_p \Delta\, LGFCF_{t-1} + \sum_{q=1}^{k-1} \xi_q \Delta LPOP_{t-1} + \lambda ECT + \mu \tag{17}$$

$$\Delta LGFCF_t = \sigma + \sum_{i=1}^{k-1} \alpha_i \Delta LCO2_{t-1} + \sum_{m=1}^{k-1} \varphi_m \Delta LGFCF_{t-1} + \sum_{n=1}^{k-1} \eta_n \Delta LGDPPC_{t-1} + \sum_{p=1}^{k-1} \phi_p \Delta\, FFC_{t-1} + \sum_{q=1}^{k-1} \xi_q \Delta LPOP_{t-1} + \lambda ECT + \mu \tag{18}$$

$$\Delta LPOP_t = \sigma + \sum_{i=1}^{k-1} \alpha_i \Delta LCO2_{t-1} + \sum_{m=1}^{k-1} \varphi_m \Delta LPOP_{t-1} + \sum_{n=1}^{k-1} \eta_n \Delta FFC_{t-1} + \sum_{p=1}^{k-1} \phi_p \Delta\, LGDPPC_{t-1} + \sum_{q=1}^{k-1} \xi_q \Delta LGFCF_{t-1} + \lambda ECT + \mu \tag{19}$$

Table 2. ADF and PP unit root test results.

Variable	ADF test statistic				PP test statistic			
	Constant	**Constant and trend**	**None**	**First difference**	**Constant**	**Constant and trend**	**None**	**First difference**
LCO_2	-1.04	-2.14	0.56	-6.59*	-1.03	-2.11	0.62	-6.61*
FFC	-2.82	-3.23	-0.41	-6.55*	-2.85	-3.32	-0.60	-8.08*
LGDPPC	-1.20	-1.88	1.72	-4.00*	-0.48	-3.06	0.66	-4.00*
LGFCF	-0.75	-2.01	1.29	-4.96*	-0.87	-0.74	2.37	-4.94*
LPOP	-1.64	0.33	2.73	-3.18*	-1.64	0.33	12.88	-3.18*

ADF: Test critical values at 5% (At level: constant = -2.94, Constant and trend = -3.54, none = -1.95 while at First difference = -2.95); P-value= Probability value, * signifies stationarity. PP: Test critical values at 5% (At level: constant = -2.94, Constant and trend = -3.53, none = -1.95 while at First difference = -2.94); P-value= Probability value, * signifies stationarity.
Source: Researcher's calculations from Eviews 10, 2023.

This model was selected because empirical studies show that when economic variables show individual cointegration, or a strong long-term relationship, the VECM performs well for model estimation. Another advantage is its capacity to integrate the short-run dynamic and long-run equilibrium models into a single, efficient system. It also guarantees accuracy, conceptual rigor, and data integrity (Abubakar and Cudjoe, 2021).

RESULTS AND FINDING

The empirical estimation result and a suitable justification are presented in this section to support the study's argument.

Stationarity test

The study initiated by examining the stationarity of relevant variables using tests detailed in the methodology section. The Augmented Dickey-Fuller (ADF) and Phillips and Perron (PP) unit root tests were employed to determine if the variables are stationary. Table 2 presents compelling evidence that all our variables are integrated at order one (that is, I(1)). The data reveals that for each variable, at least one of the tests does not reject the null hypothesis of the unit root at levels, indicating non-stationarity. In contrast, it is found that every variable in the first difference is stationary. The subsequent step involves confirming whether our variables of interest exhibit a long-run relationship since all the variables in our model are integrated of order one, according to at least one of the tests employed.

Endogeneity analysis

In order to ascertain whether variables are exogenous or endogenous, Endogeneity analysis is necessary. To verify it, apply the paired Granger causality test. Table 3 displays the outcomes of the pairwise Granger causality tests. The null hypothesis is rejected at F-statistic critical values of 1, 5, and 10%. First, the study indicates that fossil fuel consumption does not Granger-cause CO_2 emissions in Nigeria based on the pairwise Granger causality test.

Table 3. Pairwise granger causality test (Lags: 3).

Null Hypothesis:	Obs	F-Statistic	Prob.
FFC does not Granger Cause LCO_2	38	1.5097	0.2314
LCO_2 does not Granger Cause FFC		1.37356	0.2691
LGDPPC does not Granger Cause LCO_2	38	0.55583	0.6481
LCO_2 does not Granger Cause LGDPPC		3.17565	0.0378**
LGFCF does not Granger Cause LCO_2	38	2.0334	0.1296
LCO_2 does not Granger Cause LGFCF		1.4502	0.2472
LPOP does not Granger Cause LCO_2	38	3.28918	0.0336**
LCO_2 does not Granger Cause LPOP		0.51413	0.6756
LGDPPC does not Granger Cause FFC	38	2.00407	0.1339
FFC does not Granger Cause LGDPPC		0.75542	0.5277
LGFCF does not Granger Cause FFC	38	1.96521	0.1397
FFC does not Granger Cause LGFCF		1.04618	0.386
LPOP does not Granger Cause FFC	38	1.68859	0.1898
FFC does not Granger Cause LPOP		0.11114	0.9529
LGFCF does not Granger Cause LGDPPC	38	1.5466	0.2221
LGDPPC does not Granger Cause LGFCF		5.68459	0.0032*
LPOP does not Granger Cause LGDPPC	38	0.44513	0.7225
LGDPPC does not Granger Cause LPOP		0.62673	0.6032
LPOP does not Granger Cause LGFCF	38	15.0869	0.00*
LGFCF does not Granger Cause LPOP		1.36982	0.2703

*Causality at 1 % critical level; ** Causality at 5 % critical level.
Source: Researcher’s calculations from Eviews 9, 2023.

Table 4. VAR Lag order selection criteria.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	36.54388	NA	1.31e-07	-1.660204	-1.444732	-1.583541
1	246.0650	352.8776	8.03e-12	-11.37184	-10.07901*	-10.91186*
2	267.2214	30.06440	1.06e-11	-11.16955	-8.799356	-10.32625
3	308.1256	47.36277*	5.55e-12*	-12.00661*	-8.559060	-10.78000

*indicates lag order selected by the criterion.
Source: Researcher’s calculations from Eviews 10, 2023.

Secondly, CO_2 emissions in Nigeria, a proxy for the environment, do not have any feedback from gross domestic product per capita, a proxy for economic growth, and instead Granger-cause it. Third, gross fixed capital formation is a proxy for investment without feedback and population growth, Granger-cause CO_2 emissions in Nigeria. Fourth, gross fixed capital formation, a stand-in for investment that lacks feedback, Granger-causes gross domestic product per capita (a proxy for economic growth).

Lag selection

The Vector Error Correction Model (VECM), the Phillips and Perron (PP), the Augmented Dickey-Fuller (ADF), and the co-integration tests are sensitive to the number of lags when they are run. Thus, the Schwarz Information Criterion (SIC) and Akaike Information Criterion (AIC) were used to determine the actual amount of lags used. Table 4 displays the proper lag length for each variable. Table 4 shows that the AIC value at lag 3 is the lowest and is likewise lower than the SIC value at lag 1. To estimate Equation (1), the model (Lag 3) is selected as a result. Below is the cointegration result.

Cointegration test

The relevant hypothesis is that there is no long-run relationship in order to ascertain whether the variables are cointegrated over the long term, such as:

Hypothesis: $\lambda1 = \lambda2 = \lambda3 = \lambda4 = 0$ (no long-term association exists).

Table 5. Cointegration results.

Hypothesized	Trace	0.05		Hypothesized	Max-Eigen	0.05	Prob.**
No. of CE(s)	Statistic	Critical Value	Prob.**	No. of CE(s)	Statistic	Critical Value	
None *	115.2717	69.81889	0.0000	None *	46.24334	33.87687	0.0011
At most 1 *	69.02839	47.85613	0.0002	At most 1 *	31.44267	27.58434	0.0151
At most 2 *	37.58572	29.79707	0.0052	At most 2 *	22.25237	21.13162	0.0347
At most 3	15.33335	15.49471	0.0529	At most 3	12.49434	14.26460	0.0934
At most 4	2.839018	3.841466	0.0920	At most 4	2.839018	3.841466	0.0920

Source: Researcher's calculations from Eviews 9, 2023. * Denotes rejection of the null hypothesis at the 0.05 level.

Hypothesis 1: $\lambda 1 \neq \lambda 2 \neq \lambda 3 \neq \lambda 4 \neq 0$ (a long-term relationship exists)

The next step is to run a cointegration test after confirming that all variables are integrated to order one and that I(1) cannot be refused. Johansen (1988) and Johansen and Juselius (1990) suggested the multivariate cointegration technique, which is used with multivariate time series to find stable long-term links between carbon dioxide emissions, GDP per capita, gross fixed capital formation, energy use from fossil fuels, and population. Because the cointegration vectors will be used for the subsequent vector error correction model (VECM), it should be emphasized that the cointegration test is conducted before the VECM.

The Johansen test, for instance, rejects the existence of one or fewer cointegrating relations but fails to reject the existence of at most two in model 1. This suggests that there are two cointegrating equations in model 1.

Using trace test statistics, the null hypothesis is rejected because the probability value is less than 5% (P-value = 0.00) and the trace statistic value is greater than the critical value (115.2717>69.81889). This suggests the existence of at least one cointegrating vector. A second evaluation states that since the trace statistic value is higher than the essential values, we reject the null hypothesis for asterisks ranked one through two. Every associated probability value is less than five percent. In summary, the results indicate that two equations are cointegrated to order one (1) at the 0.05 critical level, and there is at least one cointegrating vector.

Based on the Max-Eigen results, the null hypothesis that there are no cointegrating equations is likewise rejected. This is because the probability value is less than 5% (P-value = 0.00) and the Max-Eigen Statistic is bigger than the important value (46.24334>33.87687). This suggests the existence of at least one cointegrating vector. Based on the trace statistical test and the Max-Eigen test, the series are cointegrated to the same order (1), as seen in Table 5. This study also takes advantage of a series that has a long-standing relationship. This study will estimate the VECM using trace value statistics since it offers a more accurate alternative hypothesis that specifies the number of cointegrating vectors. Consequently, one may contend that there is a long-term relationship between the variables and that both their short- and long-term dynamics can be found using the VECM model.

Vector Error Correction Model (VECM) Estimation

Using the same variables, two distinct vector auto-regression models (VAR and VEC) were made to determine which one more accurately captured the relationship between Nigeria's economic growth, energy commodities, and environmental factors in the real world. Despite not being as structural as the VAR, the VEC model functioned well as a limited substitute. Meanwhile, as Table 5 illustrates, the cointegration relationship between the variables made the VAR ineffective. The optimum model to apply in this situation is the Vector Error Correction Model (VECM). Table 6 displays the outcomes of the vector error correction model (VECM) for the cointegrated series' first, second, and third differences. It also includes the error-correction terms from Equation 20. The results are displayed in two sections: the first section displays the cointegrating equations, and the second section displays the outcomes of the vector error correction models. Table 7 displays the regression's result.

The target equations D(LCO_2), D(FFC), and D(LGFCF) have error correction terms that are negative (-0.26), -0.62), and (-0.29), respectively, according to Table 6 above, but D(LGDPPC) and D(LPOP) have positive (0.01) and (0.01) error correction terms, respectively. You can see that the VEC model can explain about 69% of the changes in the variables that you can depend on, 43% of the changes in the target variable D(LCO_2), and 48% of the changes in the D(FFC), D(LGDPPC), D(LGFCF), and D(LPOP) equations. This suggests that all five models fit the data.

Using the VECM approach, VAR generated and computed a simultaneous equation in Table 6. On the other hand, the simultaneous equation computed under VAR using the VECM technique only yields coefficients, standard errors, and t-statistics; probability values are absent. Therefore, in order to evaluate the relationship between the environment, energy commodities, and economic growth in Nigeria, the simultaneous equation

Table 6. Result of vector error correction model.

Error correction	D(LCO_2)	D(FFC)	D(LGDPPC)	D(LGFCF)	D(LPOP)
CointEq1	-0.26441	-0.61929	0.00521	-0.28608	0.006606
D(LCO_2(-1))	0.613878	1.776507	-0.00819	0.138049	-0.01796
D(LCO_2(-2))	0.244417	-1.86185	0.062476	0.001947	0.003407
D(LCO_2(-3))	0.051727	1.5099	0.026343	-0.0204	0.00066
D(FFC(-1))	-0.01916	-0.07085	0.005477	-0.02495	0.001968
D(FFC(-2))	-0.06956	-0.00549	-0.00787	-0.00871	-0.0003
D(FFC(-3))	0.029308	-0.2188	-0.00081	0.009983	-0.00064
D(LGDPPC(-1))	0.545291	10.80161	0.20044	0.308252	-0.00737
D(LGDPPC(-2))	-2.11356	-5.04213	0.174456	-0.27486	-0.02001
D(LGDPPC(-3))	0.953829	-1.77635	0.216952	-0.23228	0.060429
D(LGFCF(-1))	0.298227	-2.11953	-0.09216	0.078878	0.001702
D(LGFCF(-2))	0.383874	3.812528	-0.01415	-0.33249	-0.01275
D(LGFCF(-3))	-0.99292	-3.68757	-0.08668	-0.16357	0.004461
D(LPOP(-1))	-15.5998	-85.5505	0.598577	5.120971	0.597994
D(LPOP(-2))	11.06517	76.31806	1.603627	9.906224	-0.47507
D(LPOP(-3))	46.46782	78.23341	-0.45335	9.690744	-0.33768
C	-0.47937	-0.97033	-0.01343	-0.27	0.013134
R-squared	0.688011	0.427355	0.478992	0.876091	0.464581

Source: Researcher’s calculations from Eviews 9, 2023.

Table 7. Error correction result.

Variable	Coefficient	Std. error	t-Statistic	Prob.
ECT	-0.26441	0.133009	-1.98791	0.06
D(LCO_2(-1))	0.613878	0.293756	2.089752	0.05
D(LCO_2(-2))	0.244417	0.170257	1.435579	0.17
D(LCO_2(-3))	0.051727	0.178407	0.28994	0.77
D(FFC(-1))	-0.01916	0.03487	-0.5495	0.59
D(FFC(-2))	-0.06956	0.024123	-2.88355	0.01
D(FFC(-3))	0.029308	0.022384	1.309342	0.21
D(LGDPPC(-1))	0.545291	0.996284	0.547325	0.59
D(LGDPPC(-2))	-2.11356	0.869941	-2.42954	0.02
D(LGDPPC(-3))	0.953829	0.901595	1.057935	0.30
D(LGFCF(-1))	0.298227	0.260901	1.143066	0.27
D(LGFCF(-2))	0.383874	0.246858	1.555042	0.14
D(LGFCF(-3))	-0.99292	0.387884	-2.55985	0.02
D(LPOP(-1))	-15.5998	8.24766	-1.89142	0.07
D(LPOP(-2))	11.06517	12.38013	0.893784	0.38
D(LPOP(-3))	46.46782	10.60304	4.382499	0.00
C	-0.47937	0.237238	-2.02064	0.06

R-squared, 68%; Adjusted R-squared, 44%.
Source: Researcher’s calculations from Eviews (2023).

must be evaluated. This is due to the fact that within-group designs and two samples are the ideal settings for the t-statistic's application. This makes the simultaneous model of t-statistic-based result interpretation insufficient. Second, t-statistics are inappropriate for sample sizes greater than or equal to 30 ($n \geq 30$). The independent variables are not homogeneous; they have variations for both groups (Engle and Granger, 1987). The impact of the explanatory factors on Nigeria's carbon dioxide emission is estimated using the simultaneous equation in the study using ordinary least squares (OLS).

The error correction term (ECT) in Table 7 indicates the

Table 8. Breusch-Godfrey serial correlation LM test.

F-statistic	**0.205142**	**Prob. F (3,17)**	**0.8914**
Obs*R-squared	1.292661	Prob. Chi-Square (3)	0.7309

Source: Researcher's calculations from Eviews 9, 2023.

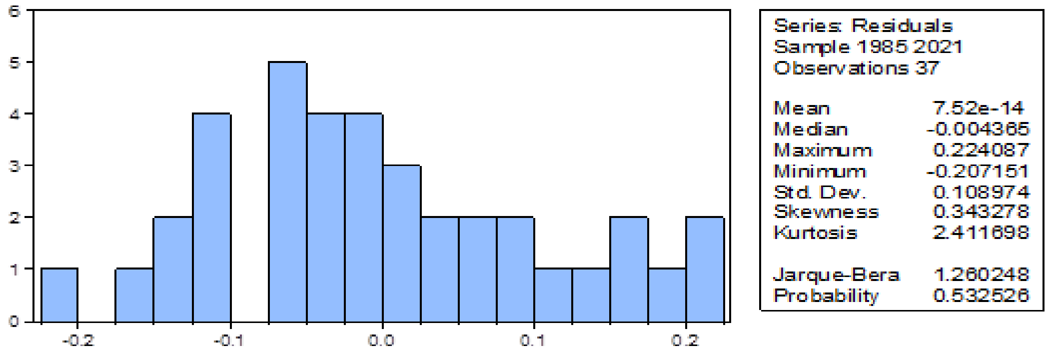

Figure 2. Normality test.

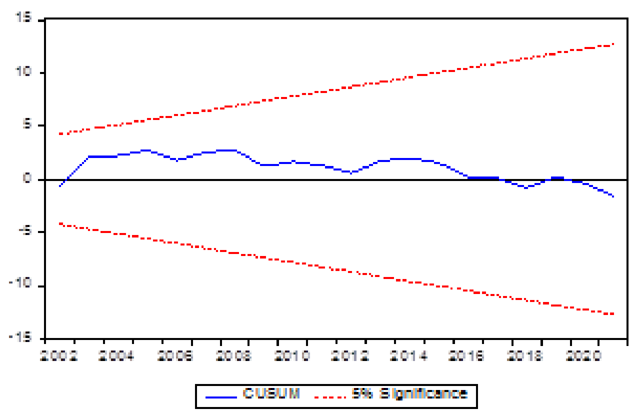

Figure 3. Plot of CUSUM.

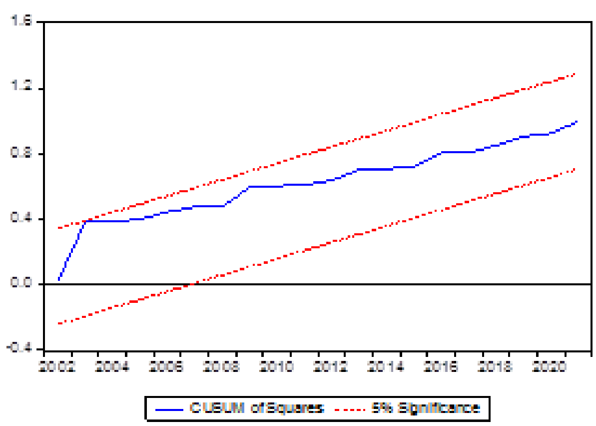

Figure 4. Plot of CUSUMSQ.

rate of correction of the disequilibrium between the long-run and short-run estimations. The value indicates that only about 26% of errors generated in the previous period are corrected in the current period for the equation. With a p-value of 0.06 at a 5% confidence level and a standard error of 0.133009, this value is significant.

Model checking

The null hypothesis (H0) is accepted if the probability is more than 5%, indicating no serial correlation in the long-run model in Table 8. The normality test shows a kurtosis of 2.81 and skewness of 0.36, indicating normal distribution. The heteroscedasticity test shows continuous variance, indicating continuous variance. The stability test shows the Cusum of squares plots do not pass the 5% critical line, indicating the model is stable and suitable for economic study.

Autocorrelation Residual LM Test

Test for normality

A normal model is indicated by residual skewness and kurtosis, and confirmed by JB test (Figure 2).

Test for stability

The Figures 3 and 4 show the results of the stability tests

Table 9. Breusch-Pagan-Godfrey tests for Heteroscedasticity.

F-statistic	0.892884	Prob. F (20,16)	0.6001
Obs*R-squared	19.51504	Prob. Chi-Square (20)	0.4886
Scaled explained SS	4.024741	Prob. Chi-Square (20)	1.0000

Source: Researcher's calculations from Eviews 9, 2023.

Table 10. ARCH tests for Heteroscedasticity.

F-statistic	0.318784	Prob. F (3,31)	0.8117
Obs*R-squared	1.047440	Prob. Chi-Square (3)	0.7898

Source: Researcher's calculations from Eviews 9, 2023.

Table 11. Wald tests and short-run test.

Dependent variable: $DLCO_2$			
Variables	**Chi-square test**	**Prob.**	**Relationship**
D(FFC)	11.58	0.00	Short-run causality
D(LGDPPC)	5.84	0.05	Short-run causality
D(LGFCF)	5.20	0.07	No Short-run causality
D(LPOP)	6.77	0.03	Short-run causality
ALL	25.41	0.00	Short-run causality

Source: Researcher's calculations from Eviews 9, 2023.

(CUSUM and CUSUMSQ). They show that the estimates, variance, residuals, and square residual are stable because they are all within the 5% critical boundaries for both the CUSUM and the CUSUMSQ. Both the CUSUM and CUSUMSQ tests accept parameter stability as one of their null assumptions (Tables 9 and 10).

Simultaneous equation short-run simulation and analysis

The results of the short-run test are presented in Table 11. The Chi-square joint statistics probability values show that, aside from LGFCF, there is a short-run relationship between the explanatory variables and the independent variable according to our findings in Table 11. If the p-value of the chi-square test for (FFC) fossil fuel energy consumption, (LGDPPC) gross domestic product per capita, and (LPOP) annual total population is less than 0.05, the null hypotheses ($H0$): β5=0 will be rejected, therefore they cause LCO_2 in the short run, while (LGFCF) gross fixed capital formation as a proxy for investment does not cause LCO_2 in the short run. The VECM systems Granger causality tests results dos not conform to the Pairwise Granger causality tests except for LGDPPC and LPOP. The next step is to conduct exante forecasting involving impulse response and variance decomposition tests.

Impulse response function

According to Table 12, Nigeria's carbon dioxide emissions forecast are on the positive side, with sporadic variations brought on by innovations and shocks. The findings demonstrate that (FFC) fossil fuel energy consumption, (LGDPPC) gross domestic product per capita, and (LGFCF) gross fixed capital formation will all contribute to explaining the country's increased carbon dioxide emissions. A one-standard deviation positive own shock will result in a short-term change from 0.14 to 0.07 and a long-term increase at a decreasing rate to 0.037. Second, projections indicate that the energy consumption of fossil fuels (FFC) has a short-term negative impact on carbon dioxide emissions (-0.01) and a long-term positive impact (0.01). This indicates that FFC has a long-term beneficial effect on carbon dioxide emissions.

Third, the simulation shows that in the short run, carbon dioxide emissions will rise by 0.015 in response to a one-positive standard deviation shock from (LGDPPC) gross domestic product per capita. The shocks will ultimately be negative (-0.021). Fourth, innovations for (LGFCF) gross

Table 12. Impulse response analysis.

Response of LCO_2					
Period	**LCO_2**	**FFC**	**LGDPPC**	**LGFCF**	**LPOP**
1	0.143419	0	0	0	0
2	0.065792	-0.01005	0.014749	0.033842	-0.0955
3	0.03158	-0.02308	-0.04123	0.050493	-0.15446
4	0.049118	0.001002	-0.03575	0.008647	-0.09152
5	0.037665	0.011291	-0.02109	0.031796	-0.08607

Source: Researcher's calculations from Eviews (2023).

Table 13. Variance decomposition of LCO_2.

Period	LCO_2	FFC	LGDPPC	LGFCF	LPOP
Short-run	85.1	0.1	0.3	1.6	12.9
Medium-term	105.0	0.6	1.8	4.5	38.2
Long-run	140.2	1.5	5.9	9.6	92.7

Source: Researcher's calculations from Eviews (2023).

fixed capital formation result in higher carbon dioxide emissions over a five-year period. Simulations show that carbon dioxide emissions rise by 0.034 in the short term and 0.032 in the long term for every standard deviation increase in LGFCF. Accordingly, the amount invested has a significant impact on carbon dioxide emissions. Fifth, projections indicate that, despite both short- and long-term declines, Nigeria's annual population will not be a cause for concern when it comes to carbon dioxide emissions.

Variance decomposition

To predict the error variance effects for each endogenous variable in a system, variance decomposition is used. Any change in time in a simple linear equation corresponds to a change in the dependent variable (Wickremasinghe 2011). This study's forecast consists of three time periods: short-term (two years), medium-term (five years), and long-term (ten years), all based on the Monte Carlo method and Cholesky's ordering. LCO_2, FFC, LGDPPC, LGFCF, and LPOP are the outcomes of the variance decomposition forecast for endogenous variables.

In the short run, impulses, innovations, or shocks to carbon dioxide emissions account for 85.1% of fluctuations in carbon dioxide emissions. However, carbon dioxide emissions own shock fluctuations continuously increase to 140.2% in the long run. Meanwhile, shocks to fossil fuel energy consumption account for 0.1% of fluctuations in carbon dioxide emissions in the short run. The fluctuations in carbon dioxide emissions due to fossil fuel energy consumption increase in the long run to 1.5%. In the short run, shocks to gross domestic product per capita account for 0.3%, gross fixed capital formation accounts for 1.6%, and annual population accounts for 12.9%. In the long run, shocks to gross domestic product per capita increase to 5.9%, gross fixed capital formation increases to 9.6%, and the annual population accounts for 92.7%. Shocks to carbon dioxide emissions will account for the highest fluctuations in Nigeria's carbon dioxide emissions, followed by its own shock (Table 13).

DISCUSSION

The primary objective of this paper was to investigate the relationship between CO_2 emissions, energy commodities, and economic growth between 1981 and 2021 in Nigeria. The vector error correction model (VECM) method was utilized to estimate Equation 2 using annual data. Both the Phillips and Perron (1988) and Dickey and Fuller (1981) Augmented Dickey-Fuller (ADF) unit root-testing methods are used to check the time series properties of the variables in Equation 1. In Equation 1, all the series seem to have a unit root in their levels, but their first differences show that they are stationary.

The analysis of the data collected has revealed some notable findings that make this study a significant contribution to knowledge in the area of carbon dioxide emissions in Nigeria. Firstly, The findings does not support the Kuznets Curve (EKC) hypothesis for climate change by demonstrating that economic growth as measured by GDP per capita has a significant negative long-run tendency to reduce total CO_2 emissions in Nigeria. The adjustment term (-2.11356) in the second year from the estimated result in Table 7 is statistically significant. The findings indicate that when income rises, emissions fall, and vice versa. The World Bank (2018), divides Nigeria's income distribution into five quintiles. In 2018, the second 20% of the population held an income share of 11.60%, while the third 20% of the population held an income share of 16.20 percent. 22.70 percent of the population, or the fourth 20%, had an income share. The richest 20% of the population owned 42.40% of the total income. Nigeria's 2022 Gini coefficient for nations with high levels of wealth inequality was 35.1%. Nigeria is ranked 100th out of 163 countries worldwide and 11th in West Africa with this score (Harmon, 2023).

This can be as a result of changes in consumption patterns, energy efficiency, technology, or income inequality. The findings can also be attributed to institutional reforms at the local and national levels, including environmental laws and market-based incentives aimed at halting environmental degradation not necessarily increase in income. The finding of the negative effect of income on CO_2 emissions agrees with the findings of Friedl and Getzner (2003), He and Richard (2010), Agras and Chapman (1999) and Alege and Ogundipe (2013) but disagrees with the findings of Dinda (2004), Özokcu and Özdemir (2017), Abubakar and Cudjoe (2021) and Okon (2021). The pairwise Granger causality test also indicates that CO_2 emissions in Nigeria, a proxy for the environment, do not have any feedback from gross domestic product per capita, a proxy for economic growth, and instead Granger-cause it. This finding is line with the study of Omisakin (2009), Omri (2013) and Wang et al. (2016). Salahuddin and Gow (2014) findings do not agree with our pairwise Granger causality test result.

Secondly, this study found that, in the long run, fossil fuel consumption had a negative effect on CO_2 emissions. The results show that fossil fuel use and carbon dioxide emissions are inversely correlated; a decrease in fossil fuel use corresponds to a decrease in atmospheric carbon dioxide emissions. Even when it is the biggest cause of air pollution in developed countries, It impacts positively in the current year but negatively after a year of fossil fuel consumption. The findings suggest that the quantity of fossil fuel used for energy production, transport, or industrial processes is still low in the country. In 2014, the nation's share of global energy consumption from fossil fuels was 18.9%, lower than the 79.4% global average for the same year. The pairwise Granger causality test indicates that fossil fuel consumption does not cause CO_2 emissions in Nigeria. The findings of the negative effect of fossil fuel consumption on CO_2 emissions do not agree with the findings of Abubakar and Cudjoe (2021).

Thirdly, investments proxied by gross fixed capital formation have the long-term possibility of reducing total CO_2 emissions if increased, and finally, the total annual population has a significant positive effect on total CO_2 emissions in the long run. This signifies that an increase in total annual population has a possibility of rising Nigerian total CO_2 emissions in the future. Also, the implication of the finding is that increasing total annual population threatening Nigeria's effort to meet the global goal for O2 emission reduction as outlined in the 2015 Paris Climate Change Conference. This finding agrees that the increase in CO_2 emissions during the past 70 years has also been attributed to the expansion of the human population.

Conclusion

This paper empirically analyzes the dynamic relationships between CO_2 emissions, energy commodities, and economic growth in Nigeria, using CO_2 emissions as a proxy for the environment. The long-run relationship, with CO_2 emissions as the dependent variable, is examined to test the short-run and long-run elasticities of CO_2 emissions with respect to explanatory variables.

Contrary to the typical positive correlation between income and emissions, indicating higher emissions per capita in wealthier nations, our findings reveal the opposite trend. However, this relationship is not constant, suggesting that emissions rise at varying rates based on income levels. In high-income countries, consumption-based emissions tend to exceed production-based emissions, while the reverse is observed in low-income countries. This implies that high-income countries are net importers of emissions, while low-income countries are net exporters.

The significant impact of fossil fuel usage on the environment is acknowledged in our study. Surprisingly, our findings indicate a significantly negative impact on the environment of Nigeria, as fossil fuel usage influences the amount of CO_2 emissions. This relationship mirrors the social and economic development of the nation. Given the high prices and limited supply of fossil energy in Nigeria, insufficient to meet the demands of its over 200 million inhabitants and expanding economy, there is a pressing need for a substantial increase in energy efficiency. Additionally, the creation of new energy consumption structures, particularly those based on affordable renewable sources like solar energy, is essential for sustainable growth over time.

Furthermore, our empirical results challenge the Environmental Kuznets Curve (EKC) theory of climate change, which posits that higher income can lower a nation's environmental pollution once a certain threshold is reached.

RECOMMENDATIONS AND POLICY CONSEQUENCES

The study's conclusions lead to the recommendation that, to mitigate environmental degradation in Nigeria, governments should support initiatives educating and training rural residents to use fewer non-renewable energy sources. Despite nonrenewable resources being widely utilized for fuel, industrial production, and residential energy consumption in Nigeria without currently causing substantial environmental harm, the suggestion is for the nation to prioritize energy sources causing minimal environmental damage. Policymakers, serious about preventing long-term environmental damage, should enact policies promoting the use of environmentally friendly machinery, vehicles, utilities, and equipment.

Considering fossil fuel consumption has not yet reached a point where CO_2 emissions are increasing, Nigerian policymakers should focus more on adopting renewable energy sources to reduce emissions from other sources. All energy-related investments and developments in the country should prioritize renewable energy and include it as a key performance indicator in investment appraisal considerations.

While concerns about economic growth are valid, this study suggests a bi-directional causal relationship between GDPPC and CO_2 in Nigeria. Policymakers should consider both factors when making decisions, emphasizing the need for a comprehensive strategy to boost renewable energy investments. This includes creating a stable policy environment, setting ambitious targets for renewable energy capacity, providing financial incentives, and implementing feed-in tariffs. The government should invest in research and development, workforce development, and public-private partnerships, encouraging private sector participation. Risk mitigation instruments should be introduced to reduce perceived risks associated with renewable energy projects. Infrastructure development should incorporate grid integration and energy storage. Sustainable finance initiatives, such as green bonds, public investment, community engagement, and awareness campaigns, should be established. International support can be leveraged through climate finance, technology transfer, and streamlined permitting processes. Performance monitoring should be instituted to ensure projects meet their objectives, attracting investors and accelerating project development.

The study's general conclusions propose that, to reduce poverty and lower CO_2 emissions in Nigeria, the government should directly deliver goods and services, including free medical services, subsidized housing, and education. Implementing negative income taxes to supplement the earnings of the poor and providing a guaranteed income are additional measures suggested.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abbas M, Dalia S, Fausto C, Nanthakumar L, Masoumeh K (2019). Carbon dioxide (CO2) emissions and economic growth: A systematic review of two decades of research from 1995 to 2017. The Science of the Total Environment. 649(1):31-49.

Abubakar SI, Cudjoe D (2021). The Environmental Impact of energy consumption in Nigeria: Evidence from CO_2 Emissions. Retrieved from https://www.researchsquare.com/article/rs-420727/v1

Acheampong AO (2018). Economic growth, CO2 emissions and energy consumption: What causes what and where? Energy Economics 74:677-692.

Agras J, Chapman D (1999). A dynamic approach to the environmental Kuznets curve hypothesis. Ecological Economics 28(2):267-277.

Alege PO, Ogundipe AA (2013). Environmental quality and economic growth in Nigeria: A fractional co-integration analysis. International Journal of Development and Sustainability 2(2):20-29.

Bölük G, Mert M (2015). The renewable energy, growth and environmental Kuznets curve in Turkey: An ARDL approach. Renewable and Sustainable Energy Reviews 52:587-595.

Chuku AC (2011). Economic development and environmental quality in Nigeria: Is there an environmental Kuznets curve? MPRA Paper No. 30195, posted 18 Apr 2011 11:38 UTC pp. 83-98. https://mpra.ub.uni-muenchen.de/30195/Cooperation

Dickey D, Fuller W (1981). Likelihood ratio statistics for autoregressive time series with a unit root. Econometrica 49:1057-1072.

Dinda S (2004). Environmental Kuznets curve hypothesis: A survey. Ecological Economics 49(4):431-455.

Egbetokun S, Osabuohien E, Akinbobola T, Onanuga OT, Gershon O, Okafor V (2020). Environmental pollution, economic growth and institutional quality: Exploring the nexus in Nigeria. Management of Environmental Quality 31(1)18-31.

Engle R, Granger W (1987). Co-Integration and error correction: representation, estimation, and testing. Econometrica 55:251-276.

Friedl B, Getzner M (2003). Determinants of CO_2 emissions in a small open economy. Ecological Economics 45(1):133-148.

Grossman GM, Krueger AB (1995). Economic growth and the environment. Quarterly Journal of Economics 60(2):353-375. http://www.jstor.org/stable/2118443

Hamit-Haggar M (2012). Greenhouse gas emissions, energy consumption and economic growth: A panel cointegration analysis from Canadian industrial sector perspective. Energy Economics 34(1):358-364.

Han J, Tianyi D, Chao Z, Xuepeng Q (2018). Correlation analysis of CO_2 emissions, material stocks and economic growth nexus: evidence from Chinese provinces. Journal of Cleaner Production 180:395-406.

Han S, Lin C, Zhang B, Farnoosh A (2019). Projections and recommendations for energy structure and industrial structure development in China through 2030: A system dynamics model. sustainability 11(18):1-20.

Harmon C (2023). Gini coefficient shows progress in Nigeria's wealth distribution under democracy. Accessed from https://nairametrics.com/2023/03/21/gini-coefficient-shows-progress-in-nigerias-wealth-distribution-under-democracy.

He J, Richard P (2010). Environmental Kuznets curve for CO_2 in Canada, Ecological Economics 69(5):1083-1093.

Hossain S (2012). An econometric analysis for CO_2 emissions, energy consumption, economic growth, foreign trade and urbanization of Japan. Low Carbon Economy 3(3A):92-105.

Johansen S, Juselius K (1990). Maximum likelihood estimation and inference on cointegration — with applications to the demand for money. Oxford Bulletin of Economics and Statistics 52(2):169-210.

Johansen S (1988). Statistical analysis of cointegrating vectors. Journal of Economic Dynamics and Control 12(2/3):231-54.

Kuznets S (1955). Economic growth and income inequality. American Economic Review 45(1):1-28.

Okafor ECN, Joe-Uzoegbu CKA (2010). Challenges to development of renewable energy for electric power sector in Nigeria. International Journal of Academic Research 2(2):211-216.

Okon EO (2021). Nigeria: Is there an environmental Kuznets Curve for fluorinated gases?, Open Economics, ISSN 2451-3458, De Gruyter, Warsaw 4(1):57-71.

Omisakin OA (2009). Economic growth and environmental quality in Nigeria: Does environmental Kuznets curve hypothesis hold? Environmental Research Journal 3(1):14-18.

Omri A (2013). CO_2 emissions, energy consumption and economic growth nexus in MENA countries: Evidence from simultaneous equations models. Energy Economics 40:657-664.

Özokcu S, Özdemir Ö (2017). Economic growth, energy, and environmental Kuznets curve. Renewable and Sustainable Energy Reviews 72:639-647.

Phillips PC, Perron P (1988). Testing for a unit root in time series regression. biometrika, 75(2):335-346.

Rafindadi AA (2016). Revisiting the concept of environmental Kuznets curve in period of energy disaster and deteriorating income: Empirical evidence from Japan. Energy Policy 94:274-284.

Robinson P, Shaheen EI, Shaheen EI (2007). Environmental pollution control. In ‘Practical Advances in Petroleum Processing’ pp. 395-447.

Salahuddin M, Gow J (2014). Economic growth, energy consumption and CO_2 emissions in Gulf Cooperation Council countries. Energy 73:44-58.

Sugiawan Y, Managi S (2019). New evidence of energy-growth nexus from inclusive wealth. Renewable and Sustainable Energy Reviews 103:40-48.

Tong T, Ortiz J, Xu C, Li F (2020). Economic growth, energy consumption, and carbon dioxide emissions in the E7 countries: a bootstrap ARDL bound test. Energy, Sustainability and Society 10(1):1-17.

Vincent M, Ezaal O (2022). Fossil fuel consumption, economic growth, and environmental degradation: is the 'energy consumption- growth' nexus sustainable in Nigeria? IOSR Journal of Economics and Finance 13(2):51-68.

Wang S, Zhou C, Li G, Feng K (2016). CO_2, economic growth, and energy consumption in China's provinces: Investigating the spatiotemporal and econometric characteristics of China's CO_2 emissions. Ecological Indicators 69:184-195.

Wickremasinghe G (2011). The Sri Lankan stock market and the macro economy: an empirical investigation. Studies in Economics and Finance 28(3):179-195.

Yule U (1926). Why do we sometimes get non-sense correlations between time-series? A Study in Sampling and the Nature of Time-Series. Journal of the royal statistical society 89(1):1-63.