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The Nexus Between CO2 Emission, Energy Consumption, and Economic Growth in Nigeria

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Abstract: Energy consumption promotes economic growth while simultaneously contributing significantly to carbon emissions, posing a quandary for policymakers in balancing economic growth and pollution reduction. This study empirically explores the relationship between carbon emissions and economic growth in Nigeria using cointegration and dynamic causality analysis with annual time-series data from 1981 to 2021. Several econometric techniques, including unit root tests, Granger causality tests, and cointegration tests using the Autoregressive Distributed Lag (ARDL) Bounds Test and ARDL model approach, are employed. To examine the causal links between the variables, Granger's long-run dynamic analyses are conducted within an Error Correction Model (ECM) framework. The findings reveal a link between CO_2 emissions and economic growth in Nigeria. Throughout the study period, a negative and statistically insignificant relationship exists between CO_2 emissions and long-term economic growth. However, during the lagged period, CO_2 emissions and economic growth exhibit a strong and positive long-term association. Additionally, the study identifies a bidirectional long-run causal relationship between CO_2 emissions and economic growth. A key policy recommendation is for the government to implement clean energy strategies aimed at transitioning from non-renewable to renewable energy sources. This shift would help mitigate the negative effects of CO_2 emissions on economic development while promoting long-term sustainability.

Keywords: ARDL, CO2, Emission, Pollution, Energy, Economic Growth.

Type: Research paper

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1. Introduction

The rapid increase in population, industrialization, energy consumption, and carbon emissions in recent decades has intensified concerns about global warming. Environmental issues are now at the forefront of discussions among experts, including economists and environmental scientists, particularly in both developed and developing economies. A widely accepted view among economists is that economic growth is highly dependent on energy consumption, as energy plays a fundamental role in productivity, income generation, and employment creation (Iorember et al., 2020). However, energy consumption is closely linked to rising carbon emissions, which pose significant threats to human health and environmental sustainability.

Greenhouse gases (GHGs) from residential, commercial, industrial, and transportation activities significantly contribute to global warming. Since Kraft and Kraft's (1978) pioneering study, which examined the relationship between energy consumption and economic growth, there has been ongoing debate regarding the causal relationship between carbon emissions and economic growth. While economies continue to pursue economic expansion and sustainable development, climate change and global warming present significant challenges. This is primarily due to the global reliance on fossil fuels, which remain the dominant source of energy consumption. The continued expansion of global trade and industrialization has led to a dramatic increase in CO_2 emissions, resulting in severe environmental consequences such as floods, droughts, rising sea levels, and more frequent extreme weather events.

Empirical research on the CO_2-economic growth nexus can be divided into two main areas. The first line of inquiry explores the causal relationship between CO_2 emissions and economic growth. Several studies provide strong evidence supporting a bidirectional causal link, contradicting the one-way causality suggested by many bivariate and multivariate approaches. However, in some cases, unidirectional causality is confirmed. The second line of research investigates the Environmental Kuznets Curve hypothesis through studies that find CO_2 emissions have an inverted-U pattern with respect to economic growth. The experimental findings regarding this hypothesis show conflicting results because different researchers support or contradict the theory (Olubusoye & Dasauki, 2020).

Numerous empirical studies about the CO_2-economic growth relationship in Nigeria delivered ambiguous findings regarding the causal linkages between these elements. Akpan and Akpan (2012) establish real income per capita creates a single causal pathway that leads toward CO_2 emissions during the period from 1970 to 2008. According to Alege et al. (2016), the analysis of fossil fuel consumption data during 1970-2013 confirmed CO_2 emissions and GDP per capita were directionally connected to fossil fuel use. Data collected by Shuaibu and Oyinlola (2013) during the period from 1970 to 2011 revealed that CO_2 emissions had no causal relation with GDP. The research of Rafindadi (2016) using real GDP per capita data from 1971 to 2011 depicts a dual causal influence between per capita GDP and CO_2 emissions. More recently, Ushie and Aderinto (2021), analyzing data from 1981 to 2019, report that energy consumption positively impacts CO_2 emissions in both the short and long run. These discrepancies in findings could be attributed to differences in study scope, variable selection, or methodological approaches.

In Nigeria, the primary energy consumption comes from oil, which is a fossil fuel liquid hydrocarbon, and hydropower. In 2013, Nigeria's total energy consumption was 142,953 kilotonnes of oil equivalent, mostly from fossil fuels and hydropower. According to the Energy Information Administration (EIA) in 2013, Nigeria's energy consumption is expected to increase by 56% by 2040 due to rapid population growth (Aiyetan & Olomola, 2018). In 2020, Nigeria's total energy consumption was 162,842 kilotonnes of oil equivalent, and 120.3 million tonnes of carbon dioxide emissions, while in 2021, total energy consumption was 172,902 kilotonnes, and 127 million tonnes of carbon dioxide emissions, expected to increase further as population and industrial activities expand (Enerdata, 2022; Knoema, 2022). Nigeria had the largest gross domestic product (GDP) in Africa in 2018 at $397.2 billion, with 109,890 kilotonnes of CO2 emissions, the highest in history. This could show a link between Nigeria's energy use, CO2 emissions, and economic growth.

Using CO2 emissions per capita to capture total carbon dioxide emissions in Nigeria, this study seeks to answer the question of what relationship exists between CO2 emissions and economic growth using cointegration and dynamic causality frameworks, as well as autoregressive distributed lag and error correction modeling techniques. The purpose of this study is to investigate the relationship between carbon dioxide emissions and economic growth in Nigeria.

To fulfill the study's goal, the hypothesis "there is no significant relationship between CO2 emissions and economic growth" is given as a guide in determining answers to the research questions. The paper is organized as follows. Sections 2 and 3 provide the literature and empirical reviews, respectively. Section 4 outlines the approach, whereas Section 5 presents, analyzes, and interprets the results. Section 6 ends with recommendations.

2. Literature Review

2.1. Concept of Economic Growth (PY)

Industrialization has transformed economic structures worldwide, leading to lasting shifts in production patterns. Many economists argue that industrialization plays a critical role in economic development because it increases productivity, national income, and employment opportunities.

Economic growth generally refers to the increase in Gross Domestic Product (GDP), Gross National Product (GNP), and national income. It is measured in absolute terms or per capita output, often leading to structural shifts in an economy (Haller, 2012). Kuznets (1973) defines economic growth as a sustained increase in a country's ability to produce goods and services, driven by technological progress, institutional changes, and evolving economic ideologies. Todaro (2005) describes it as a continuous process where an economy's productive capacity expands over time, leading to increased national output and higher income levels. PY can be classified as positive, zero, or negative. Positive PY occurs when macroeconomic indicators (particularly GDP) exceed population growth. Zero PY occurs when GDP grows at the same rate as the population. Negative PY happens when GDP growth lags behind population expansion.

Achieving sustainable PY requires the efficient and effective utilization of natural resources while minimizing environmental degradation. Many economies have started adopting technologies and energy conservation approaches that reduce CO_2 emissions to fight environmental damage. The correlation between PY and environmental sustainability measures needs to be active partnerships rather than alternatives according to Ogbonna et al. (2019). CO_2 emissions together with environmental deterioration continue to spread throughout Nigeria regardless of its pursuit of PY.

The economic growth of Nigeria stems primarily from its crude oil exploration sector which constitutes its main focus in the pursuit of modernization. Nigeria maintains its position as a top oil-producing nation in sub-Saharan Africa at the same time being rich with coal resources as well as natural gas reserves and tar sands deposits and wood-derived energy and hydropower capabilities. The increasing requirements for energy have modified production and use patterns while fuel consumption of fossil materials frequently arises. The existing trend causes substantial environmental destruction that affects Nigeria's South-South area where extensive damage has been observed (Godson, 2011).

2.2. Concept of Carbon Dioxide Emissions

Environmental sustainability concerns have grown substantially throughout the last few years because of the increasing importance of the CO_2-PY connection. The principal problem in this evaluation is CO_2 emissions that stem mainly from fossil fuel combustion and cement industry operations (World Bank, 2021). CO_2 emissions constitute a significant portion of greenhouse gases, which are strongly linked to global warming. Other greenhouse gases include methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF_6), and perfluorocarbons (PFCs). The combustion of different fossil fuels leads to varying levels of CO_2 emissions: Coal emits twice as much CO_2 as natural gas; Oil emits about 50% more CO_2 than natural gas; and Cement production releases approximately 0.5 metric tons of CO_2 per ton of cement produced.

The Industrial Revolution marked a significant rise in CO_2 emissions, drastically increasing atmospheric CO_2 concentrations and intensifying global warming. Over time, this has had negative effects on human health and environmental quality. While Nigeria's global emissions contribution remains low, its rapid industrialization and reliance on fossil fuels present substantial environmental risks (Ogbonna et al., 2019).

In highly industrialized economies, factories emit vast amounts of CO_2 and other greenhouse gases during production. Countries like China, the United States, Japan, and Germany are among the largest industrial polluters. In 2020, China alone accounted for 30.64% of global fossil fuel CO_2 emissions (Tiseo, 2021).

Given growing environmental concerns, researchers continue to investigate the CO_2-PY link, though empirical findings remain mixed and sometimes contradictory. Additionally, CO_2 emissions are not accounted for in corporate financial statements, as there is no standardized accounting framework for reporting environmental liabilities (Ogbonna et al., 2019).

2.3. Carbon Dioxide Emission and Economic Growth in Nigeria

Nigeria's primary energy consumption comes predominantly from fossil fuels (oil, coal, and natural gas), along with renewable sources such as hydropower, wind, solar, and biomass (IEA, 2019). As Africa's largest oil producer, Nigeria heavily relies on fossil fuels to meet energy demands. However, this reliance leads to high CO_2 emissions, which contribute to environmental pollution and degradation. Government policies are now focused on expanding energy production to meet the increasing demand, as energy consumption is expected to rise by 56% by 2040 (Aiyetan & Olomola, 2018). Despite fluctuations in total energy consumption per capita (1981–2021), economic growth has shown an upward trend, while CO_2 emissions per capita have remained inconsistent.

As Africa's largest oil producer, Nigeria relies heavily on oil as its primary energy source due to its high energy output. However, oil is a fossil fuel, and its combustion releases large amounts of CO_2 into the atmosphere, contributing to air pollution and environmental degradation. In addition to crude oil, Nigeria has significant reserves of coal, natural gas, and renewable energy sources such as hydropower, solar, wind, and biomass.

Energy generation and consumption are closely linked to CO_2 emissions, making them critical for PY (Bosupeng, 2016). Economic production cannot be separated from energy use, as industrial activities require substantial energy input (Deekor et al., 2020). However, Nigeria's over-reliance on fossil fuels for energy production poses severe environmental risks.

According to an EIA (2017) analysis, 97% of Nigeria's primary energy consumption came from oil (petroleum), natural gas, and other liquid fuels. Renewables (biomass, waste, coal, and hydropower) accounted for only 3%. As of November 2021, fossil fuels contributed 60% of Nigeria's government revenue and 90% of foreign exchange earnings (Ziady, 2021).

Despite fluctuations in total energy consumption per capita (1981–2021), PY per capita has exhibited sustained growth, whereas CO_2 emissions per capita have varied inconsistently over time.

2.4. Environmental Kuznets Curve (EKC): Theoretical Framework

Several economic theories examine the CO_2-PY link, including the Environmental Kuznets Curve (EKC), the Limits to Growth Model, the Pollution Haven Hypothesis, and the Endogenous Growth Theory. This study primarily adopts the EKC hypothesis, introduced by Simon Kuznets (1955). The EKC hypothesis suggests an inverted U-shaped relationship between PY and environmental pollution. Initially, as PY rises, environmental degradation intensifies due to industrialization and fossil fuel use. However, beyond a certain income threshold, economies shift toward sustainable energy solutions, leading to environmental improvements. At the early stages of industrialization, rising income levels coincide with worsening environmental quality. However, at a higher level of PY, economies transition to cleaner technologies, causing a decline in CO_2 emissions. Thus, the EKC model suggests that economic development initially worsens environmental conditions but later leads to sustainability improvements.

3. Empirical Review and Hypothesis

3.1. Empirical Studies in Other Countries

Ang (2007) investigates the causal relationship between CO_2 emissions, energy consumption, and economic output in France from 1960 to 2000, employing cointegration and vector error-correction modeling techniques. The results demonstrate a strong long-term association between CO_2 emissions and output levels, with PY driving energy consumption, which in turn leads to increased CO_2 emissions. Similarly, Menyah and Wolde-Rufael (2010) analyze the relationship between energy use, pollutant emissions, and PY in South Africa (1965–2006). Using the bounds test and Granger causality test in a multivariate framework, they find a unidirectional causal link between pollutant emissions and PY. Several other studies confirm a one-way causal relationship between CO_2 emissions and PY, including research by Hossain (2011), Alam et al. (2012), Alshehry and

Belloumi (2014), Shahbaz et al. (2016), Stamatiou and Dritsakis (2017), Kahouli (2018), Mensah et al. (2019), Adebayo and Akinsola (2020), Thongrawd and Kerdpitak (2020), Gao et al. (2021), and Adebayo et al. (2021). However, some studies suggest a bidirectional CO_2-PY link, such as those by Chang (2010), Alam et al. (2011), and Wang et al. (2011). In contrast, Ozturk and Acaravci (2010) report no causal link between CO_2 emissions and PY.

3.2. Empirical Studies in Nigeria

In the Nigerian context, Akpan and Akpan (2012) examine the relationship between electricity consumption, CO_2 emissions, and PY using annual data from 1970 to 2008. Applying a multivariate vector error correction model, they establish that PY contributes to rising CO_2 emissions, while increased electricity consumption further exacerbates emissions. Their results oppose the Environmental Kuznets Curve hypothesis because their findings establish a single directional causal connection between PY and CO_2 emissions rates. Saibu and Jaiyeola (2013) analyze the connections between energy consumption CO_2 emissions and PY in Nigeria using a period between 1970 to 2011 through ARDL modeling alongside Granger causality tests. The study reveals that investment growth rates and crude oil production and consumption together with gas flaring-related CO_2 emissions have substantial impacts on the PY. According to the study, CO_2 emissions interfere with sustainable PY because there exists a proven causal effect between these variables.

The connection between pollutant emissions and energy consumption with economic growth in Nigeria during the period from 1970 to 2013 is examined by Alege et al. (2016). They apply Johansen Cointegration analysis with Wald Homogeneity Granger Causality examination to prove there exists one-directional relationships from fossil fuel usage towards CO_2 emissions and PY measurement. The study confirms that sustainable sustainable development requires public policies which would encourage clean alternatives in the energy sector. The relationship between CO_2 emissions and PY in Nigeria presents a dual-directional effect according to Rafindadi (2016) and Iorember, Goshit, & Dabwor (2020). The research of Shuaibu and Oyinlola (2013) together with Aiyetan and Olomola (2018) fails to find any significant relationships between these variables.

This literature review highlights a substantial body of research on the CO_2-PY link in Nigeria. To bridge existing gaps, this study extends Alam et al. (2012) (originally conducted in Bangladesh) by analyzing CO_2 emissions per capita and PY per capita for Nigeria between 1981 and 2021. Unlike Alam et al. (2012), which primarily apply the Johansen-Juselius approach, this study adopts the ARDL bound test to assess the cointegration between CO_2 emissions and PY. The differences in scope, location, and econometric methodology distinguish this research from prior studies.

Based on the empirical findings discussed above, the study proposes the following null hypothesis:

H_{O1}: There is no significant relationship between CO_2 emission and economic growth in Nigeria.

4. Methodology

The study employs an ex-post facto research design and a census sampling technique in which the population equals the sample size. It uses secondary data from various reputable sources including the World Bank's World Development Indicator (WDI), Enerdata, the Energy Information Administration (EIA), and Knoema, covering the period from 1981 to 2021 for Nigeria. The data nomenclatures are indicated as follows: PY represents per capita real GDP, and CO2 represents per capita CO2 emissions.

This study modifies the model used by Alam et al. (2012), employing the same variables to investigate the objectives of this study. Thus, the study includes PY for per capita real GDP, and CO2 for per capita carbon emissions (serving as a proxy for environmental pollution). The modified model is subjected to the Autoregressive Distributed Lag Model (ARDL) in explicit form as specified below to investigate the long-run relationships:

$$\Delta CO_{2_t} = \mu + \sum_{i=i}^{q_1} \lambda_i \; \Delta PY_{t-1} + \sum_{j=i}^{q_2} \lambda_j \; \Delta CO_{2_{t-1}} + \alpha_1 CO_{2_{t-1}} + \alpha_2 PY_{t-1} + \varepsilon_1, t \; \dots (1)$$

$$\Delta PY_t = \mu + \sum_{i=i}^{q_1} \lambda_i \; \Delta PY_{t-1} + \sum_{j=i}^{q_2} \lambda_j \; \Delta CO_{2_{t-1}} + \alpha_1 PY_{t-1} + \alpha_2 CO_{2_{t-1}} + \varepsilon_2, t \; \dots (2)$$

Once the cointegration relationship is confirmed using the ARDL bound test approach, the Granger causality test will be applied through the vector error correction mechanism (VECM). The error correction model (ECM) equation will represent the short-run dynamics of the long-run ARDL model previously specified in equations (1) and (2). The presence of cointegration in the bivariate relationship suggests that at least one-directional long-run Granger causality exists. This can be further examined under specific constraints using the Wald test (Mosconi & Giannini, 1992; Dolado & Lütkepohl, 1996). If the α matrix in the cointegration rank matrix (Π) consists entirely of zeros in one column, it implies that no long-run causal relationship exists, as no cointegrating vector is present in that specific block. To analyze both short-run and long-run causal relationships between CO₂ emissions and economic growth, equations (1) and (2) can be redefined in an explicit bivariate form, treating CO₂ emissions and economic growth as the key variables of interest.

$$\Delta CO2_t = \mu + \sum_{i=i}^{q_1} \beta_i \; \Delta CO2_{t-1} + \sum_{j=i}^{q_2} \beta_j \; \Delta PY_{t-1} + \alpha_1 \; ECT_{t-1} + \varepsilon_1, t \; \dots (3)$$

$$\Delta PY_t = \emptyset + \sum_{i=i}^{q_1} \beta_i \; \Delta CO2_{t-1} + \sum_{j=i}^{q_2} \beta_j \; \Delta PY_{t-1} + \alpha_1 \; ECT_{t-1} + \varepsilon_2, t \; \dots (4)$$

Where;

PY = Per capita real GDP

CO_2 = per capita carbon emission (a proxy for environmental pollution)

ECT_{t-1} = denotes the error correction term, while t is the time

α_1 = is the coefficient of ECT in the short run
α_1/α_2 = coefficient in the long run
$\mu/\emptyset$ = constant/intercept
ε = error term/stochastic disturbance
β_i / β_j = co-efficient in the short

Given the linear nature of the model used to examine the CO_2-PY link in Nigeria, this study employs the cointegration approach and the Autoregressive Distributed Lag (ARDL) model for parameter estimation. To achieve the study's objectives, the ARDL estimation method will be applied to analyze the models. This approach will determine cointegration through the Bound test approach and assess Granger causality using the Vector Error Correction Mechanism (VECM). The estimations will be conducted using E-Views 10 Statistical Software for Windows. To mitigate spurious regression issues, which often arise from non-stationary variables, the method of differencing will be applied to convert non-stationary series into stationary ones. The presence of non-stationarity in the dataset suggests that regression coefficients may be unreliable or misleading (Phillips, 1986).

In this study, stationarity tests will be performed using the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test. These tests are widely used to determine whether a data series is difference stationary or trend stationary and to identify the presence of unit roots at different levels.

5. Findings and Discussion

5.1. Unit Root Tests

The unit root test results, conducted using the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test, indicate that both tests produced consistent findings. As presented in Tables 1, 2, 3, and 4, neither the ADF nor PP tests detected stationarity in any of the variables at their level form. However, after applying the first difference, all variables became stationary, as their ADF/PP statistics exceeded the MacKinnon critical value at the 5% significance level.

Table 1: ADF-Unit root test at level

Variables	ADF Test Statistic Value	Mackinnon's critical Value at 5%	Prob.	Remark
CO_2	-3.3629	-3.5266	0.0710	Non-stationary
PY	-2.2591	-3.5403	0.4442	Non-stationary

Source: Author's computation using E-views 10 version (2023)

Table 2: ADF-Unit root test at first difference

Variables	ADF Test Statistic Value	Mackinnon's critical Value at 5%	Prob.	Remark
CO_2	-7.8318	-3.5330	0.0000	$I(1)$
PY	-3.6898	-3.5297	0.0351	$I(1)$

Source: Author's computation using E-views 10 version (2023)

Table 3: PP-Unit root test at level

Variables	ADF Test Statistic Value	Mackinnon's critical Value at 5%	Prob.	Remark
CO_2	-3.4791	-3.5266	0.0554	Non-stationary
PY	-2.8061	-3.5266	0.2035	Non-stationary

Source: Author's computation using E-views 10 version (2023)

Table 4: PP-Unit root test at first difference

Variables	ADF Test Statistic Value	Mackinnon's critical Value at 5%	Prob.	Remark
CO_2	-13.8006	-3.5297	0.0000	$I_{(1)}$
PY	-3.6898	-3.5297	0.0350	$I_{(1)}$

Source: Author's computation using E-views 10 version (2023)

5.2. Cointegration Test

Given these findings, the Autoregressive Distributed Lag (ARDL) model bound test approach was chosen to investigate the long-run relationship among the variables. The unit root test results validated the suitability of the ARDL bounds cointegration test for analyzing long-term associations in this study. Table 5 provides empirical evidence of a long-run relationship between CO_2 emissions and PY. The F-Bound test confirms this, reporting an F-statistic value of 4.592415, which exceeds the lower limit bound I(0) even at the 1% significance level. This result implies that the model exhibits long-run cointegration, indicating that the variables are jointly integrated at the same level and confirming the existence of a long-run CO_2-PY link.

Table 5: F-Bounds test

	ARDL Model	
Bound significance	I(0)	I(1)
10%	2.72	3.77
5%	3.23	4.35
2.5%	3.69	4.89
1%	4.29	5.61
F-Statistics	4.592415	
D.F	3	

5.3. Auto-Regressive Distributed Lag (ARDL) Model Results

To achieve the objective of this study, the ARDL estimation technique is adopted to conduct empirical analysis, as shown in Table 6.

Table 6: ARDL long-run and short-run results

Dependent Variable: PY (Proxy for per capita real gross domestic product)							
Short-Run Estimation				Long-Run Estimation			
Variable	**Coefficient**	**t-Statistic**	**Prob**	**Variable**	**Coefficient**	**t-Statistic**	**Prob**
PY(-1)	0.960488	5.234086	0.0000	D(PY(-1))	0.232812	1.687501	0.1015
PY(-2)	-0.232812	-1.687501	0.1015	D(CO_2)	-260.084220	-1.455122	0.1557
CO_2	-260.0842	-1.455122	0.1557	D(CO_2(-1))	457.360893	2.582779	0.0147

$CO_2(-1)$	-2.437081	-0.011627	0.9908	ECM(-1)	-0.272324	-3.834100	0.0006
$CO_2(-2)$	-457.3609	-2.582779	0.0147				
C	673.8802	1.677253	0.1035				

Source: Author's computation using E-views 10 version (2023)

5.4. Granger Causality Results

From Table 7, per capita real gross domestic product (PY) has a bi-directional causality relationship with carbon emissions (CO_2). This indicates that PY Granger causes CO_2 and vice versa. This finding is consistent with the work of Rafindadi (2016).

Table 7: Granger causality checks

Null Hypothesis	F-statistics	Prob	Test Conclusion	Remarks
PY does not Granger Cause CO_2	3.30553	0.0488	PY granger causes CO_2	Reject null
CO_2 does not Granger Cause PY	6.60234	0.0038	CO_2 granger causes PY	

Source: Author's computation using E-views 10 version (2023)

5.5. Findings

The application of the Autoregressive Distributed Lag (ARDL) model to assess the relationship between PY and CO_2 reveals notable findings.

In the short run, CO_2 emissions negatively impact PY, indicating an inverse relationship between CO_2 emissions and per capita economic growth in Nigeria during the study period. The coefficient values for CO_2—260.0842, 2.437081, and 457.3609—suggest that a 1% increase in CO_2 emissions results in increases of 26008.42%, 243.7081%, and 45736.09% in PY, respectively, for the current period, one-year lag, and two-year lag. However, these effects vary in statistical significance. While the impact of CO_2 at the current period and when lagged one period is statistically insignificant with p-values of 0.1557 and 0.9908, the effect becomes statistically significant at a two-year lag with a p-value of 0.0147.

In the long run, CO_2 emissions continue to exhibit a negative effect on PY in the current period but show a positive effect when lagged by one period. The coefficient estimates for CO_2—260.084220 at the current period and 457.3600893 when lagged one period—suggest that a 1% rise in CO_2 emissions leads to a 26008.4220% decline in PY in the current period but a 45736.00893% increase when lagged by one period. While the current period effect remains statistically insignificant (p-value = 0.1557), the lagged effect is statistically significant (p-value = 0.0147). The findings align with theoretical expectations when CO_2 emissions are lagged, though they deviate from expectations in the current period. These results are consistent with prior studies by Gao et al. (2021) and Adebayo et al. (2021).

The constant term exhibits a positive relationship with PY throughout the study period in both the short run and long run but remains statistically insignificant with a p-value of 0.1035.

The Error Correction Mechanism (ECM), which measures the speed of adjustment to long-run equilibrium, is correctly signed as negative. The ECM coefficient of -0.272324 implies that deviations from equilibrium in the previous period are corrected at a rate of 27.2324% in the subsequent period. This adjustment speed is statistically significant, with a p-value of 0.0006.

5.6. Test of Hypothesis

In the long run, the t-statistic value for CO_2 at the current period is 1.455122, which is below the threshold of 2. This implies that the null hypothesis, which states that there is no significant relationship between CO_2 emissions and PY, cannot be rejected. The general rule is that if the t-statistic exceeds 2, the null hypothesis can be rejected; otherwise, it must be retained.

This conclusion is further supported by the probability value, which must be ≤ 5% for statistical significance. Given that the p-value for CO_2 is 0.1557, which exceeds the 5% threshold, the null hypothesis cannot be rejected. Consequently, CO_2 emissions do not exhibit a meaningful or statistically significant impact on PY in the current period.

However, when considering CO_2 emissions lagged by one period [CO_2 (-1)], the t-statistic is 2.582779, which exceeds the threshold of 2. This suggests that the null hypothesis of no significant relationship between CO_2 emissions and PY can be rejected. Thus, there is a strong long-run association between lagged CO_2 emissions and PY. The result is further validated by its statistical significance, as indicated by a p-value of 0.0147, which is below the 5% threshold.

In the short run, CO_2 emissions exhibit a t-statistic of 1.4551, which remains below 2, indicating that the null hypothesis cannot be rejected. This suggests that CO_2 emissions do not have a statistically significant impact on PY in the short term. The finding is further reinforced by a p-value of 0.1557, confirming its statistical insignificance.

5.7. Discussion of Findings

Throughout the analyzed period, there exists an opposite relationship between CO_2 emissions and PY. CO_2 presents a positive significant relationship with PY during the long run after being lagged by one period. The analysis suggests serious attention needs to be directed at CO_2 emission reduction because they greatly affect PY. Ang (2007) in France discovered that CO_2 emissions in metric tons significantly impacted PY according to his research. The research by Shahbaz et al. (2016) demonstrates that CO_2 emissions create a direct Granger-causal relationship with PY and vice versa in Bangladesh together with Egypt. Ozturk and Acaravci's (2010) research diverges from this study because they established CO_2 emissions lacked a significant influence on PY throughout Turkey and the emissions did not cause GRase of PY. The Sustainable Development Goals by the United Nations have established worldwide objectives to remove CO_2 emissions entirely before 2025 (Gao et al., 2021). The research demonstrates that CO_2 emissions and PY possess a mutual influence pattern in Nigeria according to Rafindadi (2016).

6. Conclusion

The study evaluated Nigeria's CO_2 emissions and private investment link through cointegration examinations using dynamic causality analysis techniques. The analyzed period revealed that CO_2 produced negative effects on PY. An analysis using CO_2(-1) demonstrates that a one-period lagged CO_2 variable shows a positive significant relationship with PY in the long-term perspective. The study demonstrates that CO_2 and PY establish a dual-causational connection which proves that their relationship functions in both directions.

The study demonstrates that CO_2 creates negative impacts on Nigeria's PY during the short-term period which supports the dual-directional CO_2-PY relationship. When CO_2 is time-lagged by one period it produces a positive statistical relationship with PY that becomes significant.

Based on the observed negative CO_2 effect on PY the authors suggest Nigerian authorities should establish plans for clean energy transformation from non-renewable to renewable power platforms. Such transformations represent the necessary foundation to avoid PY decreases which eventually lead to CO_2 reduction levels.

Policy decisions require striking an equilibrium between ecosystem preservation and productive output results because the analysis indicates CO_2 produces positive impacts on PY with statistical significance in delayed periods. An energy conservation policy that focuses on energy efficiency needs implementation by the government to prevent the deterioration of PY while lowering carbon dioxide emissions. Time enables the reduction of CO_2 per person while maintaining continued PY and better environmental outcomes by consuming less energy to yield equal outputs.

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