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CARBON EMISSION ACCOUNTING AND ECONOMIC GROWTH IN NIGERIA

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Abstract: The study examined the effect of carbon emission accounting on economic growth in Nigeria. The specific objective was to determine the effect of carbon dioxide (CO2) emissions, energy usage and PM2.5 air pollution on gross domestic product in Nigeria. Ex-post facto research design was adopted in the study. This study covered thirty-two (32) year fiscal periods, spanning from 1990 to 2021. The study employed both descriptive and inferential statistical techniques to analyze the dataset. Unit root tests were conducted using Augmented Dickey Fuller. Johansen Co-integration Test was also applied to check for the long-run relationship between carbon emission accounting and economic growth in Nigeria. Additionally, Vector error correction model was deployed in estimating the regression coefficients for the purpose of inferential analysis. The study found no significant long-run causal relationship between carbon emissions and economic growth. However, regression suggests that increases in CO2 emissions are associated with declines in GDP. It is also observed that increase in energy usage (ENU) is likely to reduce the gross domestic product (GDP) by 22.855 in Nigeria; whereas an increase in the PM2.5 air pollution (AIRP) will increase the gross domestic product (GDP) of the country on the long run casual effect. The study recommends among others that while there is no long-term causal effect, the study indicates that a percentage increase in carbon dioxide emissions will significantly reduce GDP. As a result, the Nigerian government should implement policies to reduce carbon emissions, such as promoting renewable energy sources, improving energy efficiency, and encouraging sustainable land use practices. Secondly, according to the study, increasing energy consumption will likely reduce GDP. To mitigate this effect, the government should promote energy-efficient technologies, encourage the use of renewable energy sources, and put in place demand-side management strategies. Finally, re-evaluate Air Pollution Policies. The finding that increased air pollution leads to higher GDP in the long run is counterintuitive. This may indicate that current air pollution policies are ineffective or even counterproductive. The government should reconsider its air pollution policies and consider enacting more effective regulations to reduce pollution.

Key words: carbon emission accounting, economic growth, carbon dioxide (CO2) emissions, energy usage (ENU), PM2.5 air pollution.

Introduction

Due to increased energy consumption and carbon emissions from consumption brought on by industrial expansion, the global economy has more than tripled over time. Actually, the effects of global warming and the developing green economy paradigm have compelled scholars to investigate the link between carbon dioxide ($CO2$) emissions and economic expansion. According to Mardoni, Streimikiene, Cavallan, Loganathan and Khoshnoudi (2019), Economic growth is responsible for the rise of standard of living of most countries all around the world and has also given rise to the Co2 emissions and natural resources reductions. Global warming is largely caused by CO2 emissions (Mohammed, Ismat, Jeroen & Guido, 2012; Omojolaibi, 2010).

Climate change and carbon dioxide emissions are pressing global issues that require effective mitigation strategies (Nnubia & Ezenwa, 2016). Carbon emissions are the main reason of world warming and contribute to climate change, which can cause displacement of humans, create homeless refugees and result in other serious outcomes to mankind and their environment (U.S. Environmental Protection Agency, 2019). Basically, there are major varieties of carbon dioxide emissions, specifically natural and human sources. Carbon emission pollutes the air we breathe, the water we drink, cause health hazards and affects our environment typically. To combat this threat, the United Nations Framework Convention on Climate Change (UNFCCC) has sets the universal framework to tackle the demanding situations posed by climate change (Emelie & Charlotte, 2012). Jonathan, Brian and Anne-Marie (2015) noted that global climate change is a major issue confronting policy makers worldwide. The Kyoto Protocol is an international agreement which sets binding targets for industrialized countries to reduce their greenhouse gas (GHG) emissions. Climate change is dangerous to our environment and the future generations. Emelie and Charlotte, (2012) stated that the more the economic activities the more that companies are contributing to climate change like you have them in USA.

In Nigeria, specifically in the Niger Delta region, where citizen are experiencing 'Black Soot' as a result of the operation of oil activities calls for serious concern. The emission of carbon in the region is alarming. According to Adom, Bekoe, Amuakwa-Mensah, Mensah, & Botchway, 2012), Co2 emissions are carefully related to social, economic and industrial factors. Therefore, the ability of human beings to work, do business, produce goods and services and contribute meaningfully to economic growth depend essentially on the state of health and the quality of the environment in which they find themselves. Therefore, the proposed study on carbon emission accounting and economic growth represents an important research problem.

Emission from carbon gasoline is a global issue and everyone should worry about its negative impact. Domestic studies have been too silent about carbon emission and its economic effects on growth. The difficulty to estimate how fast abatement (i.e. reduction or moderation) of CO2 emissions should be is an issue that this study intends to solve (Stern, 2007). If the effects of climate change are likely to remain, it is in everyone's interest to lower their emissions to the environment. If no agreement or rules on emissions exist, actions by individual firms, cities or nations will be inadequate. However, it is better to start now than never. The study of climate change is in the best interest of the public, which requires collaborative actions. Since the problem is global, those who are instrumental to the agreement reached, only think is a strong international agreement binding nations to prevent serious environmental consequences around the world (Jonathan et al., 2015). The climate change will affect some of the world's poorest and developing countries like Nigeria. The cost of climate change is difficult to estimate. In an attempt to estimate the cost of climate change the economist Sir

Nicholas Stern approximated the cost to be around one percent of global Gross Domestic Product (GDP). As the concentration of CO2 grows larger, the cost will increase rapidly. Remarkable increase in the black soot presence was noticed in 2016 in Rivers State in Nigeria and since then there has been steady increase. Unfortunately, domestic research has been too silent about carbon emission and its economic effects on growth in Nigeria. If actions are not taken now the damages caused by climate change will lead to an annual loss of between 5–20 percent of global GDP (Stern, 2007). Further investigation of this problem is proposed in the present study with the main goal of providing additional valid information on practical solutions to gaseous carbon emission.

The main objective of this research is to examine the effect of carbon emissions accounting on economic growth in Nigeria. Essentially, the specific objectives of this study are to:

- ascertain the effect of carbon dioxide (CO2) emissions on gross domestic product.
- investigate the effect of energy usage on gross domestic product.
- examine the effect of PM2.5 air pollution on gross domestic product.

Review of Related Literature

A comprehensive review of the literature conducted in this study reveals that quite impressive research attentions have been directed towards solving problems related to carbon emission, which includes the works of Ganda and Milondzo (2018), Nnubia and Ezenwa (2016), Nnubia and Omaliko (2016), Mesagan (2015), Azlina et al. (2014), Saboori and Sulaiman (2013), Papiez (2013), Chen and Zang (2010), Menyah and Wolde-Rufael (2010), etc. For instance, Mesagan (2015) records that in the first period, economic growth significantly impacts carbon emission, while it negatively impacts carbon emission in the lagged period. It also revealed that both trade openness and capital investment, positively impact carbon emission in Nigeria. Whereas Ganda and Milondzo (2018) records negative relationship existed between carbon emissions and corporate financial performance. Moreover, a study by Azlina et al. (2014) observes the existence of long-term association between energy usage, economic growth, and pollutant emission for Malaysia during 1970–2010. The empirical findings further show a one-way causality running from pollutant emissions to economic growth. Saboori and Sulaiman’s (2013) study reveals that there exists bidirectional causality between economic growth and carbon dioxide emissions, with coal, gas, electricity, and oil usage in Malaysia during 1980–2009. The panel short-run Granger causality test results of Papiez’s (2013) study show two-way causality between CO2 emissions and economic growth for Visegrad group countries during 1992–2010. The present research seeks for a greater understanding of the problem through the proposed integrated study on the analysis of the relationship between CO2 emissions and economic growth of Nigeria economy. Such an elaborate work on the selected key area is expected to provide a comprehensive knowledge on the sources of CO2 emissions, suitable preventive measures to some CO2 emissions and viable alternatives solutions to greater energy consumption and greater carbon emissions resulting from consumption. The work of Nnubia and Ezenwa (2016) observed that environmental accounting has positive impact on sustainable development in Nigeria. It concludes that the impact of environmental accounting is that organizations can track their environmental data and other greenhouse gas (GHG) emission against reduction targets, and facilitates environmental reporting to provide sustainability related data that is comprehensive, auditable, and timely to advance and strengthen the interdependent and mutually reinforcing pillars of sustainable development-economic development, social development and environmental protection in Nigeria.

Research Design

This examination applied ex-post facto research plan. The ex-post facto arrangement were applied on the reason that it doesn't offer the examination a chance to control the variables generally since they have as of late happened and can't be influenced. It figures the effect of a treatment (*i.e.*, an illustrative variable or an independent variable) on a result (*i.e.*, a reaction variable or ward variable) by comparing the normal variety over the long run in the result variable for the treatment bunch, compared to the normal variety over the long haul for the gathering.

The examination applied secondary data gotten from World Development Indicators (WDI) publications (Various Years), database. These data are time arrangement information covers the time frame from 1990–2021 (32 years). This period is picked as it relates to the time frame where uniform and reliable information on the applicable factors are accessible.

In dissecting the information assembled, regressions of ordinary least square technique were utilized to decide the exact impact of logical factors on subordinate variable. The study also employed both *descriptive* and *inferential* statistical techniques to analyze the dataset. Unit root tests were conducted using Augmented Dickey Fuller to determine whether the trend data in research should be regressed on the focused to render it to data stationary. Johansen Co-integration Test was also applied to check for the long-run relationship between carbon emission accounting and economic growth in Nigeria. Additionally, Vector error correction model was deployed in estimating the regression coefficients for the purpose of inferential analysis.

Model Specification & Operationalization of Dependent & Independent Variables

This work adopted and modified the econometric model of Ogbonna, Ojeaburu, and Ehilegbu (2021) as follows:

$LNGROSSt = \beta 0 + \beta 1 LNGROSSt{-}1 + \beta 2\ LNCOEt{-}1 + \varepsilon 1t$……………………… (1)

Where;

lnGROSS = Logarithm of gross domestic product, lnCOE = Logarithm of carbon emission;

β = Parametric constants; εt = error term.

The model for this investigation is prefaced on the principal objective and tied down on the sub-objective. The functional relationship between carbon emissions and economic growth in Nigeria are expressed thus:

$$\boldsymbol{\Delta \mathrm{lngdp}_t} = \alpha + \sum_{i=1}^{k-1} \boldsymbol{\beta_i}\, \boldsymbol{\Delta \mathrm{lngdp}_{t-i}} + \sum_{j=1}^{k-1} \gamma_j\, \Delta \mathrm{lnco2}_{t-j} + \sum_{l=1}^{k-1} \varphi_l\, \Delta \mathrm{lnenu}_{t-l} + \sum_{m=1}^{k-1} \omega_m\, \Delta \mathrm{lnairp}_{t-m} + \boldsymbol{\lambda_1} ECT_{t-1} + \mu_{1t} \text{ ....(2)}$$

$$\boldsymbol{\Delta \mathrm{lnco2}_t} = \alpha + \sum_{i=1}^{k-1} \boldsymbol{\beta_i}\, \boldsymbol{\Delta \mathrm{lngdp}_{t-i}} + \sum_{j=1}^{k-1} \gamma_j\, \Delta \mathrm{lnco2}_{t-j} + \sum_{l=1}^{k-1} \varphi_l\, \Delta \mathrm{lnenu}_{t-l} + \sum_{m=1}^{k-1} \omega_m\, \Delta \mathrm{lnairp}_{t-m} + \boldsymbol{\lambda_1} ECT_{t-1} + \mu_{1t} \text{ ....(3)}$$

$$\boldsymbol{\Delta \mathrm{lnenu}_t} = \alpha + \sum_{i=1}^{k-1} \boldsymbol{\beta_i}\, \boldsymbol{\Delta \mathrm{lngdp}_{t-i}} + \sum_{j=1}^{k-1} \gamma_j\, \Delta \mathrm{lnco2}_{t-j} + \sum_{l=1}^{k-1} \varphi_l\, \Delta \mathrm{lnenu}_{t-l} + \sum_{m=1}^{k-1} \omega_m\, \Delta \mathrm{lnairp}_{t-m} + \boldsymbol{\lambda_1} ECT_{t-1} + \mu_{1t} \text{ ....(4)}$$

$$\boldsymbol{\Delta \mathrm{lnairp}_t} = \alpha + \sum_{i=1}^{k-1} \boldsymbol{\beta_i}\, \boldsymbol{\Delta \mathrm{lngdp}_{t-i}} + \sum_{j=1}^{k-1} \gamma_j\, \Delta \mathrm{lnco2}_{t-j} + \sum_{l=1}^{k-1} \varphi_l\, \Delta \mathrm{lnenu}_{t-l} + \sum_{m=1}^{k-1} \omega_m\, \Delta \mathrm{lnairp}_{t-m} + \boldsymbol{\lambda_1} ECT_{t-1} + \mu_{1t} \text{ ....(5)}$$

Where:

GDP=Gross domestic product (GDP) growth (annual %)

CO2 = CO2 emissions (metric tons per capita)

ENU = Energy use (kg of oil equivalent per capita)

AIRP = PM2.5 air pollution, mean annual exposure (micrograms per cubic meter)

k-1 = optimal lag length is reduced by 1

$\beta_i, \gamma_j, \varphi_{l\,,}\, \omega_m, \delta_{\mathrm{n}}$ = short run dynamic of the coefficient of the model's adjustment long-run equilibrium
λ_i = speed of adjustment parameter with a negative sign
α, α, ρ, ∝, ∂ = intercepts
ECT_{t-1} = the error correction term is the lagged value of the residuals obtained from the co-integrating regression of the dependent variable on the regressors. Contains long-run information derived from the long-run co-integrating relationship.
μ_{it} = residuals (stochastic error terms often called impulses, or innovations or shocks) in the equation

Data Presentation and Analysis

The factors utilized in this investigation as determined in the model details are economic growth (proxied by Gross domestic product - GDP), and carbon emissions accounting (proxied by CO2 = CO2 emissions (metric tons per capita); ENU = Energy use (kg of oil equivalent per capita); and AIRP = PM2.5 air pollution, mean annual exposure (micrograms per cubic meter). The assessment was upheld utilizing regression of Ordinary Least Square (OLS) strategy, through the assistance of E-view 8.1. The rundown of the examination result and its comparing understandings of the effect of carbon emissions accounting on economic growth in Nigeria follow the presentation of data.

Trend Data Analysis of the Variables

Table 1: Data Presentation

Gross domestic product (GDP), CO2 = CO2 emissions (metric tons per capita)
ENU = Energy use (kg of oil equivalent per capita)
AIRP = PM2.5 air pollution,

PERIODS	GDP	CO2	ENU	AIRP
1990	11.77689	0.764292	697.6002	72.12558
1991	0.358353	0.838704	712.5468	70.14541
1992	4.631193	0.916428	722.2551	68.16524
1993	-2.03512	0.839114	715.3422	68.34684
1994	-1.81492	0.742761	680.0624	67.98364
1995	-0.07266	0.796466	681.1587	68.71004
1996	4.195924	0.903339	692.3822	67.25724
1997	2.937099	0.866943	698	65.80444
1998	2.581254	0.760156	685.3233	66.38772
1999	0.584127	0.72701	692.0342	65.22117
2000	5.015935	0.791346	700.3827	67.55433
2001	5.917685	0.808136	716.1132	62.88788
2002	15.32916	0.711822	719.4873	58.22143
2003	7.347195	0.758699	740.1777	58.70032
2004	9.250558	0.721921	740.8816	57.74253
2005	6.438517	0.702691	749.5896	59.65814
2006	6.059428	0.615049	735.6947	55.82686
2007	6.59113	0.547052	741.2802	51.99557
2008	6.764473	0.570498	742.8051	52.20001
2009	8.036925	0.491388	711.3473	51.79108
2010	8.005656	0.559525	744.8358	52.60906
2011	5.307924	0.574132	766.3292	50.97309
2012	4.230061	0.560553	785.2607	56.12964
2013	6.671335	0.618874	766.9222	49.74069

2014	6.309719	0.640164	750.9709	48.63337
2015	2.652693	0.585681	758.9466	75.39899
2016	-1.61687	0.587458	754.9587	71.3696
2017	0.805887	0.560724	756.9527	71.79817
2018	1.922757	0.553891	755.9557	71.58389
2019	2.208429	0.567022	756.4542	71.69103
2020	-1.79425	0.560457	756.205	71.63746
2021	3.647187	0.563739	756.3296	71.66424

Source: World Development Indicators (WDI) publications (Various Years), *Data from database: Environment Social and Governance (Last Updated: 05/19/2023)*

Table 2: Descriptive Statistics

VARIABLES	GDP	CO2	ENU	AIRP
Mean	4.320114	0.681439	730.7683	63.12358
Median	4.430627	0.671428	740.5297	66.09608
Maximum	15.32916	0.916428	785.2607	75.39899
Minimum	-2.035119	0.491388	680.0624	48.63337
Std. Dev.	4.017196	0.122558	29.05021	8.204610
Skewness	0.435426	0.327686	-0.248357	-0.372117
Kurtosis	3.286568	1.802562	1.897424	1.692184
Jarque-Bera	1.120671	2.484494	1.949863	3.019021
Probability	0.571017	0.288735	0.377218	0.221018
Sum	138.2437	21.80603	23384.59	2019.955
Sum Sq. Dev.	500.2737	0.465637	26161.35	2086.784
Observations	32	32	32	32

Source: E views 8.1 Output

The GDP statistics show a mean of 4.320114, indicating the average value of Nigeria's gross domestic product. The maximum value of 15.32916 and the minimum of -2.035119 indicate a range of economic activity, with a relatively moderate spread. The standard deviation of 4.017196 suggests that there is some variation in GDP values around the mean. The Jarque-Bera test for normality, with a probability of 0.571017, suggests that the GDP data is not significantly different from a normal distribution.

For CO2 emissions (CO2), the mean of 0.681439 shows the average CO2 emissions. The values range from a minimum of 0.491388 to a maximum of 0.916428, showing significant variation. The standard deviation of 0.122558 reflects a relatively low level of fluctuation in emission over time. The Jarque-Bera test statistic of 0.288735 also rejects normality, confirming that the CO2 data deviates insignificantly from a normal distribution.

For the Energy use (ENU), the mean of 730.7683 represents the average energy used associated with the emission in the country. The maximum value of 785.2607 and the minimum of 680.0624 reflect a large variation in energy used over the period studied. The Jarque-Bera test with a p-value of 0.377218 strongly rejects the null hypothesis of normality, indicating that the ENU data is not normally distributed.

Finally, for the PM2.5 air pollution (AIRP), the mean of 63.12358 reflects the average AIRP associated with these emissions. The range is from a minimum of 48.63337 to a maximum of 75.39899, showing a relatively smaller spread compared to the other variables. The Jarque-Bera statistic of 0.221018 indicates some departure from normality, though the deviation is less severe than for CO2 and ENU.

Empirical Analysis

Unit Root Test

This study conducts unit root tests of the variables with Augmented Dickey Fuller (ADF). The outcomes of the tests are presented in Table 3 below.

Table 3: Unit Root Test Using Augmented Dickey Fuller (ADF) Tests: 1990 - 2021.

Variable		**ADF test stat**	**P-Value**	**Critical Values**			**Order of integration**
				1% level	**5**% level	**10**% level	
D(GDP)	Levels	-3.541832	0.0522	-4.284580	-3.562882	-3.215267	I(1)
	First diff	-8.881265	0.0000	-4.296729	-3.568379	-3.218382	I(1)
D(CO2)	Levels	-3.016706	0.1439	-4.284580	-3.562882	-3.215267	I(1)
	First diff	-5.361827	0.0008	-4.296729	-3.568379	-3.218382	I(1)
D(ENU)	Levels	-2.529482	0.3128	-4.284580	-3.562882	-3.215267	I(1)
	First diff	-5.216175	0.0011	-4.296729	-3.568379	-3.218382	I(1)
D(AIRP)	Levels	-1.755930	0.7014	-4.284580	-3.562882	-3.215267	I(1)
	First diff	-6.507678	0.0000	-4.296729	-3.568379	-3.218382	I(1)

Source: Eviews 8.1 Output

According to the ADF test, all variables GDP, CO2, ENU and AIRP with the P-values of 0.0522, 0.1439, 0.3128 and 0.7014 respectively are level and not stationary at the 5 per cent level of significance and since the p-values is above the critical value of 0.05, we accept null hypotheses because a unit root exists and this suggests that the series is non-stationary and might need further transformation like differencing; while at the first log difference GDP, CO2, ENU and AIR with the P-values of 0.0000, 0.0008, 0.0011 and 0.0000 respectively are level and stationary at the 5 per cent level of significance and since the p-values falls below the critical value of 0.05, we reject the null hypotheses because it does not have a unit root and can be used in standard statistical models. We conclude that the series is stationary.

Co-integration Tests

The role of co-integration test in Carbon emission accounting and economic growth in Nigeria is to deal with the economic model using non-stationary time series data and the idea is that if there is a long-run relationship between Carbon emission accounting and economic growth in Nigeria, then no matter the changes of the variable over time, there will be a common trend to link them together. The literature according to Johansen (1988) indicates that co-integration tests are used to confirm the presence of potential long-run equilibrium relationship between variables. To conduct the co-integration test in this study, we adopted the Johansen methodology. Johansen's approach derives two likelihood estimators for the co-integration; one is a trace test and a maximum Eigenvalue test. The Co-integration can be formally tested with the trace and the maximum Eigenvalue statistics. After applying the Johansen procedure as shown in Table 4 below, we note that both the Trace test and Max-eigenvalue test indicate one vector of co-integration that means a long-term relationship among the level of Carbon emission accounting and economic growth in Nigeria within the period 1990 - 2021.

Table 4: Johansen Co-integration Tests

Sample (adjusted): 1992 2021
Included observations: 30 after adjustments
Trend assumption: Quadratic deterministic trend
Series: GDP CO2 ENU AIRP
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.588570	60.64952	55.24578	0.0155
At most 1	0.483323	34.00606	35.01090	0.0638
At most 2	0.322189	14.19593	18.39771	0.1755
At most 3	0.080854	2.529315	3.841466	0.1117

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* Denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.588570	26.64346	30.81507	0.1489
At most 1	0.483323	19.81013	24.25202	0.1737
At most 2	0.322189	11.66662	17.14769	0.2624
At most 3	0.080854	2.529315	3.841466	0.1117

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

From table 4 above, it was observed using Trace test that only one co-integration eqn (s) was indicated at the 0.05 level of significance since the p-value is less than 5% level of significance. This means that there is co-integration between the variable. This is confirming with the Trace statistic (60.64952) greater than the critical value (55.24578) of the variable; while in the Max-eigenvalue test, no co-integration was observed at the 0.05 level of significance. This is confirming with the critical values greater than the Max-Eigen statistic of the variable. Therefore, since there is co-integration observed using Trace statistic, we then proceed to use the restricted VAR Model (VECM) and not unrestricted VAR model in modeling the selected variables. Vector Error Correction Model (VECM) checking which is most important in time series data analysis.

Lag Selection Criteria

VECM analysis was carried out for the time series data from lag1 to lag4 in order to obtain the minimum sequential modified LR test statistic (LR), Final prediction error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SC) and Hannan-Quinn information Criterion (HQIC) (each test at 5% level).

Table 5: Lag order selection

VAR Lag Order Selection Criteria
Endogenous variables: GDP CO2 ENU AIRP
Exogenous variables: C
Date: 01/26/25 Time: 22:39
Sample: 1990 2021
Included observations: 28

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-266.7118	NA	2937.076	19.33656	19.52687	19.39474
1	-207.6578	97.01728*	137.7230*	16.26127*	17.21285*	16.55218*
2	-197.4802	13.81246	225.9097	16.67716	18.38999	17.20079
3	-180.5550	18.13416	261.7430	16.61107	19.08516	17.36742
4	-163.3856	13.49025	385.2752	16.52754	19.76289	17.51662

* Indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

After a careful inspection of the lag selection criteria in table 5 above, the result shows lags order at 1 by the selection criteria, the study preceded further tests with lags (1). Checking of the VECM model is which helps to check order if the fitted model is appropriate.

Vector Error Correction Model (VECM)

This study is to find the effect of Carbon emission accounting on economic growth in Nigeria, after the estimation of unit root and co-integration test, the results show that all the variables are stationary at 1 (I), and co-integration also exists, so VECM is a better model to use. So, after finding the long-term interrelation among the variables in co-integration, the finding of the co-integration within the variables suggested that the use of the restricted VAR Model (VECM) and not unrestricted VAR model in modeling the selected variables is appropriate for this study.

Table 6: Vector Error Correction Model (VECM) results

Variables	D(GDP) **(1)**	D(CO2) **(2)**	D(ENU) **(3)**	D(AIRP) **(4)**
CointEq1	0.156948	0.006332	2.159571	-0.216544
	(0.14158)	(0.00234)	(0.50509)	(0.24049)
D(GDP)	-0.522545	-0.002465	-0.348522	0.039432
	(0.17797)	(0.00294)	(0.63492)	(0.30231)
D(CO2)	10.62007	0.307375	65.24515	11.40767
	(13.2593)	(0.21869)	(47.3025)	(22.5225)
D(ENU)	-0.002292	-0.000390	0.146143	-0.146722
	(0.05011)	(0.00083)	(0.17876)	(0.08511)
D(AIRP)	-0.194882	0.000521	-0.530259	-0.080217
	(0.11813)	(0.00195)	(0.42144)	(0.20066)
Constant	-0.053292	-0.007423	1.450955	0.431290
	(0.62743)	(0.01035)	(2.23835)	(1.06576)
Note: Z-statistics in ( ) and other is coefficient				

Source: Eviews 8.1 Output

Table 7: Johansen normalization test

Co-integrating equations

beta	Coef.	Std. Err.	t-stat.
GDP	1.000000	.	.
CO2	-54.08115	10.9056	-4.95900
ENU	-0.228546	0.04564	-5.00773
AIRP	0.427645	0.11757	3.63730
Constant	173.1493	.	.

Source: Eviews 8.1 Output

Vector Error Correction Model: The presence of co-integration between variables suggests a long term relationship among the variables under consideration. Then, the VECM model can be applied. The long run relationship between gross domestic product, carbon dioxide (CO2) emissions, energy usage and PM2.5 air pollution for one co-integrating vector for the Nigeria in the period 1990 - 2021 is displayed below (standard errors are displayed in parenthesis). From the Johansen normalization equation

$$ECT_{t-1} = [1.000000GDP_{t-1} - 54.08115CO2_{t-1} - 0.228546ENU_{t-1} + 0.427645AIRP_{t-1} + 173.1493]$$

In *Table 7*, in the long-run equation from where their Error Correction Term (ECT) is derived, the normalization is on the gross domestic product. The results show that on the long run casual effect that a percentage increase in carbon dioxide (CO2) emissions will reduce the gross domestic product *(GDP)* by 54.081. It is also observed that increase in energy usage (ENU) is likely to reduce the gross domestic product (GDP) by 22.855 in Nigeria; whereas an increase in the PM2.5 air pollution (AIRP) will increase the gross domestic product (GDP) of the country on the long run casual effect.

Iin table 6, *Lngdp* as the target variable:

$$\mathbf{\Delta lngdp_t} = 0.053292 - 0.522545\Delta \mathrm{lngdp}_{t-1} + 10.62007\Delta \mathrm{lnco2}_{t-1} - 0.002292\Delta \mathrm{lnenu}_{t-1} - 0.194882\Delta \mathrm{lnckd}_{t-1} + 0.156948ECT_{t-1}$$

However, the ECT coefficient of *0.156948* is insignificant, suggesting that previous year errors (or deviation from long-run equilibrium) are corrected for within the current year at a convergence speed of 15.7%.

Table 8: Pairwise Granger Causality Tests
Date: 01/27/25 Time: 01:38
Sample: 1990 2021
Lags: 4

Null Hypothesis:	Obs	F-Statistic	Prob.
CO2 does not Granger Cause GDP	28	1.09761	0.3862
GDP does not Granger Cause CO2		1.85248	0.1605
ENU does not Granger Cause GDP	28	0.63602	0.6431
GDP does not Granger Cause ENU		2.58599	0.0700
AIRP does not Granger Cause GDP	28	0.76043	0.5638
GDP does not Granger Cause AIRP		1.10671	0.3822
ENU does not Granger Cause CO2	28	1.00682	0.4285
CO2 does not Granger Cause ENU		2.14439	0.1148
AIRP does not Granger Cause CO2	28	0.13533	0.9673
CO2 does not Granger Cause AIRP		0.25314	0.9042
AIRP does not Granger Cause ENU	28	0.72162	0.5878
ENU does not Granger Cause AIRP		1.43442	0.2611

Showing causality from *GDP* equation, to infer causality, from *GDP* equation where the first co-integrating vector is treated as a leading exogenous variable. The direction of causal interrelationship amongst proposed variables is examined by applying the VECM granger causality model. In doing so we used the VECM model to detect the causal relationship between *GDP, CO2, ENU and AIRP* which would help policymakers to configure a comprehensive policy to run the economic growth on fast-track in long run. There is no long run causal effect on the GDP equation, while *CO2, ENU and AIRP* do not cause *GDP* on the short run causal effect.

Showing causality from *CO2 eq*uation, the error correction term is not significant showing there was no long run causal effect on the CO2 equation, the study also shows that there is no short run causal effect between *GDP, ENU and AIRP* on the *CO2* equation.

Showing causality from *ENU* equation, there is no long run causal effect on the *ENU* equation at the 5% level, while *GDP and AIRP* do not cause *ENU* in a short run effect.

Showing causality from *AIRP* equation, the error correction term is not significant, showing there was no long run causal effect on the *AIRP* equation, the study also shows that there is no short run causal effect AIRP equation at 5% level.

Conclusion and Recommendation

The study's findings indicate that, while there is no long-term causal link between carbon emissions, energy usage, air pollution, and GDP in Nigeria, there are some concerning correlations. The significant reduction in GDP due to increased carbon dioxide emissions and energy consumption suggests that Nigeria's economic growth is vulnerable to environmental degradation. One possible explanation for these findings is that Nigeria's economy is heavily dependent on fossil fuels, which contribute to carbon emissions and air pollution. The study's finding that increased air pollution is associated with higher GDP in the long run may indicate that Nigeria's economic growth is currently dependent on polluting industries. However, this trend is unsustainable and could have serious environmental and health consequences. To mitigate these effects, Nigeria must switch to cleaner energy sources, improve energy efficiency, and implement policies that reduce carbon emissions and air pollution. Finally, the study's findings highlight the need for Nigeria to implement a more sustainable economic growth model that balances economic development and environmental protection. By doing so, Nigeria can ensure a healthier environment, better public health, and long-term economic growth for future generations.

Based on this, the study recommends among others that while there is no long-term causal effect, the study indicates that a percentage increase in carbon dioxide emissions will significantly reduce GDP. As a result, the Nigerian government should implement policies to reduce carbon emissions, such as promoting renewable energy sources, improving energy efficiency, and encouraging sustainable land use practices. Secondly, according to the study, increasing energy consumption will likely reduce GDP. To mitigate this effect, the government should promote energy-efficient technologies, encourage the use of renewable energy sources, and put in place demand-side management strategies. Finally, re-evaluate Air Pollution Policies*: The finding that increased air pollution leads to higher GDP in the long run is counterintuitive. This may indicate that current air pollution policies are ineffective or even counterproductive. The government should reconsider its air pollution policies and consider enacting more effective regulations to reduce pollution.

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