Pollutant Emissions and Economic Growth in Nigeria: A Comparative Analysis of Carbon Emissions from Gaseous, Liquid and Solid Fuel Consumption

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Abstract

This research study analyses the growth effects of carbon emissions from alternative fuel consumption by investigating how carbon emissions from gaseous, liquid, and solid fuel usage affect GDP growth in Nigeria from 1981 to 2020. Using the autoregressive distributed lag (ARDL) estimator, the result showed that there exists a long run relationship between the disaggregated carbon emissions and economic growth in Nigeria. The result reveals that carbon emissions from liquid fuel consumption have a negative impact on both short-term and long-term output growth. It implies that the price volatility, foreign exchange dependence, and environmental and health expenses associated with using liquid fuels have a detrimental effect on economic growth in the short run. The study also showed that carbon emissions from the burning of gaseous and solid fuels have direct and significant links with economic growth both in the short and long run. It means that the importance of adopting sustainable and low-carbon development pathways to ensure sustainable economic growth in Nigeria is highlighted by the fact that carbon-emitting fuels can contribute to short-term economic growth. On the policy front, a carbon tax or cap-and-trade scheme should be implemented to reduce carbon emissions. This will push industry and consumers to use cleaner energy sources and technologies and generate income for low-carbon infrastructure and research.

Keywords: Carbon emissions, gaseous pollution, liquid pollution, solid pollution, income growth.

1. Introduction

Economic growth refers to a rise in a country's production capacity and the production of more goods and services. Employment opportunities, tax money for public spending, lower debt, longer life expectancy, more investment, and breakthroughs in R&D are all positive outcomes of a flourishing economy. However, slow economic growth has negative effects on public services, such as inadequate health and education facilities, low savings and investment rates, high unemployment and poverty rates, an increase in public debt, and lower tax revenues than expected (Picardo, 2020). Growth in the economy, according to some academics (Jhingan, 2008), is a symptom of developed-world difficulties. Economic expansion has been acknowledged with contributing to rising living standards in industrialized countries (Jhingan, 2008). Schumpeter (1934) and Jhingan (2008) describe economic growth as a long-term process characterized by an increase in the rate of savings and population. Some have claimed that growth is independent of economic structure and instead is tied to the dynamics of change (Osadume and University, 2021). This disproves the claim that the issues of developing countries have little to do with economic progress. Developing economies, like Nigeria are also expanding.

Nigeria's Gross Domestic Product (GDP) saw periods of expansion, stagnation, and instability from 1986 through 2020. Also, the country's GDP grew at a rapid clip in the late 1980s, reaching 7.33% in 1988 (World Bank, 2022). However, the early 1990s saw a decrease, with several years even recording negative growth rates. Afterward, Nigeria's GDP growth steadily improved in the 1990s and early 2000s, with gains of between 2.95% and 9.50% during this time period (World Bank, 2022). As a result of policy changes, more oil was produced, and oil prices rose, economic performance improved during this time period. The global financial crisis, declining oil prices, and security concerns all had an impact on the economy of the country in the 2010s. As a result, GDP growth slowed, falling below 3% in several years. Recession hit the country in 2016, when GDP growth was -1.62% (World Bank, 2022). With a negative growth rate of -1.79%, the country's GDP shrank mostly due to disruptions in economic operations and falling oil prices (World Bank, 2022).

Carbon dioxide (CO_2) emissions are one of several elements that influence a country's economic development and growth. Without a question, Nigeria is one of SSA's leading carbon emitters. It is worth noting that despite having the lowest growth rates in SSA, Nigeria had the greatest CO_2 emissions. Excess carbon dioxide emissions and Nigeria's recent low growth rate may have unfavorable effects on the environment, economic outputs, and people's standard of life in the country (Abubakar and Abdullahi, 2022). Nigeria is still the region's greatest emitter of CO_2 despite its GDP growth rates being relatively low. Nigeria's CO_2 emissions rose by 9.2 percent from 2012 to 2014, from 119,008.82 to 130,130.67 million tons (International Energy Agency, 2018). The World Bank (2022) stated that Nigeria's 2019 CO_2 emissions are 115279.99 million tons. This figure is a 271.6% rise from 1990 values. Thus, the decline in economic growth may be related to the adverse effects of excessive CO_2 emissions, such as environmental degradation, low agricultural output, insufficient investment in agro-allied sectors, and poor citizen health.

Nigeria faces a difficult problem in the interplay between rising emissions of carbon dioxide and the country's expanding economy. Carbon emissions have been on the rise alongside Nigeria's expanding economy, which has been fueled by industrialization and rising energy demand. This raises serious environmental concerns and casts doubt on the long-term viability of Nigeria's economic growth. Thus, rising carbon emissions from gaseous, liquid, and solid fuel use endanger environmental sustainability and raise worries about the long-term implications for economic development in Nigeria as the country experiences rapid economic expansion. This study is to determine the impact of carbon emissions from the use of gaseous, liquid, and solid fuels on Nigeria's GDP growth between the years 1981 and 2020.

2. Literature Review

2.1 Conceptual Review

Economic growth can be defined as a rise in the quantum of economic commodities and services that are produced when comparing one time period to another. The growth of the economy can be measured either in nominal or real terms. The rate of increase in gross domestic product was used as the metric for measuring economic growth in this study. In addition, carbon emissions are the emissions that result from the combustion of fossil fuels (such as coal, natural gas, and oil). The combustion of gaseous, liquid, and solid fuels for the generation of thermal energy is the standard method for quantifying carbon emissions.

2.2 Theoretical Review

According to the Environmental Kuznets Curve theory proposed by Grossman and Krueger (1991), environmental degradation (including carbon emissions) is inversely related to economic expansion. At first, a growing economy causes a rise in carbon emissions. After a certain point, however, rising prosperity is linked to diminishing carbon emissions. The introduction of greener technologies and stricter regulations has led to this dramatic decrease. The Neo-classical growth theory proposed that the accumulation of physical and human capital, as well as technical advancement, is postulated to be the primary drivers of economic growth (Solow, 1956). This hypothesis proposes that rising economies are accompanied by rising energy consumption and carbon-intensive activities, and thus rising carbon emissions. However, innovation and the development of cleaner technologies can reduce the carbon intensity of economic activities, thanks to technical advancement (Solow, 1956). According to proponents of the decoupling idea, “green growth” need not be contingent on increasing fossil fuel consumption. It indicates that it is possible to achieve economic growth while lowering carbon emissions through increasing resource efficiency, technological breakthroughs, and sustainable behaviors (Wiedmann *et al*., 2013). This idea highlights the significance of divorcing economic growth from environmental degradation through sustainable development measures.

2.3 Empirical Review

The study identified only a small number of recent studies on the link between carbon emissions and economic growth in Nigeria. For instance, Musibau, Shittu, and Ogunlana (2021) employed a non-linear ARDL to investigate the relationship between environmental deterioration, energy consumption, and GDP development in Nigeria between 1981 and 2014. The results show that when GDP in Nigeria grows, so does CO_2 emissions. Zakari, Abdulkarim, and Umar (2022) use the ARDL bounds testing method to look at the effect of CO_2 emissions and financial development on economic expansion in Nigeria from 1981 to 2021. Long-run cointegration between CO_2 emissions, financial advancement, and production growth was found, according to the limits test for cointegration. The estimation demonstrates that increasing emissions contribute significantly to GDP growth in Nigeria.

Also, Olubusoye and Musa (2020) examined the Environmental Kuznets Curve (EKC) hypothesis in 43 African countries pooled into 3 income groups from 1980-2016 using the ARDL model, Mean Group (MG), and the Pooled Mean Group (PMG) model. Only 21% of the sample agrees with the EKC hypothesis; the remaining 70% disagree. This finding demonstrates that in the majority of nations (79%) economic growth leads to higher carbon emissions, while in a minority of countries (21%), economic growth leads to lower carbon emissions. The research found that as economic growth increased, emissions increased in the majority of African countries. Abubakar and Abdullahi (2022) analyze CO_2 emissions and GDP growth in Nigeria between 1980 and 2020, and they consider if the CO_2 emissions-GDP growth link depends on Nigeria's financial growth. Using the Autoregressive Distributed Lag estimate approach (ARDL), they discovered that a high level of accumulated pollution (carbon dioxide emissions) negatively affects long-term economic growth. Furthermore, there is minimal evidence that CO_2 emissions slow economic growth over the long run. Evidence suggests, however, that CO_2 emissions only have an economic affect when there is financial development, implying that CO_2 emissions only have an influence when there is financial development.

Olabanji and Adeolu (2020), for example, used the non-linear autoregressive distributed lag (NARDL) modeling technique to examine the effects of renewable energy consumption and CO_2 emissions on economic growth across the major oil-producing economies in Africa from 1980 to 2015. The results reveal that, with the exception of Algeria, the per capita consumption of petroleum and natural gas has an uneven effect on economic development and per capita carbon dioxide emissions. The results show a nonlinear relationship between the parameters in the specific situation of Nigeria. Between 1980 and 2019, Osadume, et al (2021) studied the effect of economic growth on carbon emissions in a number of different West African countries. The results suggest that in the short run, there is strong cointegration between economic development and carbon emission for the combined samples. Carbon emissions were found to increase by 3.11 percentage points for every one percentage point increase in economic growth.

Kohlscheen, Moessner, and Takáts (2021) conduct a panel analysis examining the effects of macroeconomic factors on carbon (carbon-dioxide) emissions, drawing on data from 121 nations between 1971 and 2016. Carbon emissions were found to increase with economic development, manufacturing activity, urbanization, and increasingly economic growth using dynamic panel regressions. Onofrei, Vatamanu, and Cigu (2022) use a panel data set to analyze the 2000–2017 dynamics of the connection between GDP growth and CO_2 emissions across the 27 EU member states. The DOLS method shows a statistically significant effect of economic growth on CO_2 emissions for both versions of estimators, revealing that on average, a 1% change in GDP leads to 0.072 change in CO_2 emissions, suggesting the existence of a long run cointegrating relationship between growth and CO_2 emissions in EU countries. The findings also highlight the importance of developing environmental policies that are able to cut emissions during times of economic expansion and show that higher income levels lead to increasing demand for environmental protection.

Nguyen, Pham, and Tram (2020) used data from 13 G-20 countries (including Argentina, Canada, China, France, Germany, Italy, Japan, Mexico, the Republic of Korea, Russia, Turkey, the United Kingdom, and the United States) over a 15-year period and found that only five factors (energy price, FDI, technology, spending on innovation, and trade openness) inhibit carbon emissions. Carbon emissions are not statistically confirmed to be a role in economic growth, while advances in information and communication technology and financial development are. Gao *et al.* (2021) combined the Logarithmic Mean Divisia Index model with the Cobb-Douglas production function to examine the emission driving force, particularly from an economic standpoint, and applied the Tapio decoupling model to analyze the decoupling status of provincial carbon emissions from its economic development. Economic growth was shown to be the dominant driver of emissions in most provinces, acting mostly through capital investment and total factor productivity.

Adedoyin et al. (2020) examine the relationships between GDP growth, pollutant emissions, and coal rent in BRICS from 1990 to 2014, taking into account the influence of confounders like regulatory quality. Using the pooled mean group (PMG) estimator, they found that coal rents have a significant but negative impact on CO_2 emissions for BRICS nations, in contrast to coal consumption. Moreover, carbon damage cost limitations on coal rents have a much larger and beneficial effect on CO_2 emissions than was originally anticipated. Increased regulation in the area of environmental and energy policy appears likely in light of the growth push by the BRICS countries and the need to reduce CO_2 emissions for green growth and sustainable development. Gonzalez-Sanchez and Martin-Ortega (2020) do a similar analysis for eleven countries in the Euro Area starting in the 1990s and find a positive correlation between emissions and GDP growth.

Zou and Zhang (2020) use a spatial Durbin model of the links among economic growth, energy consumption equation, and CO_2 emissions to analyze the dynamic relationship and spatial spillover among these effects in China, using panel data from 30 regions from 2000 to 2017. Carbon dioxide emissions have improved greatly as a result of economic expansion, and the degree of economic growth in China has become a positive driving force for emissions. However, cutting back on carbon dioxide emissions won't have a major impact on economic growth. Carbon dioxide emissions and energy consumption both rise and fall together. There is a negative spatial spillover impact on the carbon dioxide emissions of neighboring provinces and cities due to the correlation between energy consumption and carbon emissions. Using data that spans from 1960 to 2018, Rjoub*et al.* (2021) examine the connections between CO_2 emissions, GDP growth, and life expectancy in Turkey using a variety of statistical methods, including the Bayer-Hanck cointegration test, wavelet coherence, Fourier Toda-Yamamoto, and Breitung-Candelon frequency-domain spectral causality tests. We find a positive co-movement between life expectancy and CO_2 emissions and a positive correlation between life expectancy and GDP across multiple time scales, which is in contrast to the literature. We also find that CO_2 is causally related to life expectancy, that life expectancy is causally related to GDP in both directions, and that GDP has medium and long-run causal relationships with life expectancy.

Carbon emissions, energy consumption, and economic growth all have complex interrelationships, but Debone, Leite, and Miraglia (2021) conducted a thorough evaluation of the econometric models used to tear them apart. To address the issue, they searched through 776 citation records found in internet databases such Web of Science, SCOPUS, and Economics Papers. In the end, 182 publications from reputable journals were found to be suitable for further consideration. Among the many models they discovered, artificial neural networks, the STIRPAT model, and the Granger causality were the most frequently employed. Overall, the studied approaches may be deemed effective in examining the correlations between the investigated variables, stimulating dialogue about the critical need to invest in renewable energy sources, and enacting suitable legislation to mitigate CO_2 emissions.

2.4 Gaps in Literature

The quality of the reviewed papers' arguments and the approaches taken to answer the concerns it poses are indicative of its uniqueness. Through a disaggregated analysis of carbon emission factors (pollutants from the gaseous, liquid, and solid fuel consumption), this study sheds light on previously obscure relations in the literature of carbon emission and economic growth, specifically with regard to Nigeria. Previous literature on the topic largely fails to fully investigate this trend. Nigeria is endowed with a heterogeneous bounty of oil and natural gas. It would be helpful for Nigeria's overall energy use and management to have a better understanding of how different growth situations respond to variations in CO_2 emissions from gaseous, liquid, and solid fuel consumption. This research added to the body of knowledge on carbon emissions-induced development dynamics by drawing a broad conclusion about why countries with heavy consumption of fossil fuels tend to have weak economic performance. This research also investigates whether or not carbon emissions cause or are caused by Nigeria's poor economic growth and development.

3. Methodology

The theoretical framework of this study hinges on Foster's (1973) growth and pollution stock model, which demonstrates that a large pollution stock has an effect on long-term economic growth. It emphasized that increased CO_2 emissions reduce economic growth. The expansion process is accompanied by a number of externalities, including pollution and environmental difficulties. Considering the high value of the environment, a rise in economic activity may cause an increase in pollution and environmental degradation, making it less desirable (Foster, 1973). In developing this approach, inspiration was drawn from previous works such as Olubusoye and Musa (2020), Musibau, Shittu, and Ogunlana (2021), Abubakar and Abdullahi (2022), and Zakari, Abdulkarim, and Umar (2022). The study makes the assumption that higher levels of CO2 emissions are associated with higher levels of GDP. CO_2 emissions have a long-term effect on economic development, according to research by Musibau, Shittu, and Ogunlana (2021), Abubakar and Abdullahi (2022), and Zakari, Abdulkarim, and Umar (2022). Energy consumption (econ), gross fixed capital formation (gfcf), foreign direct investment (fdi), trade openness (topn), and domestic credit to the private sector (dcps) are also identified as major predictors of economic growth in the research. Olubusoye and Musa (2020), Musibau, Shittu, and Ogunlana (2021), Abubakar and Abdullahi (2022), and Zakari, Abdulkarim, and Umar (2022) all argue that the control variables are conceptually linked to economic growth. This leads to the following model specifications:

$$rgdp_t = \phi_0 + \phi_1 econ_t + \phi_2 co2_t + \phi_3 gfcf_t + \phi_4 fdi_t + \phi_5 topn_t + \phi_6 dcps_t + \mu_t \quad (1)$$

Where: *gdpg* is gross domestic product growth; *econ* denotes energy consumption; *co2*is a vector of carbon emissions from gaseous (*gco2*), liquid (*lco2*) and solid (*sco2*) fuel consumption as percentage of total carbon emission; *gfcf* is gross fixed capital formation to GDP; *fdi* denotes foreign direct investment to GDP; *topn* represents total trade to GDP; *dcps* is domestic credit to private sector to GDP; ϕ_0, ϕ_{1-6} are parameters; *t* is time; and μ is error term.

The impact of de-aggregated carbon emissions on economic growth in Nigeria is analyzed using annual data from 1981 to 2020. The World Development Indicators served as the sole data source for this study. Autoregressive Distributed lag (ARDL), first introduced by Pesaran and Shin (1999) and then refined by Pesaran, Shin, and Smith (2001), was used for this study. The ARDL method can be used whether the series is integrated in the 0th order (I(0)), 1st order (I(1)), or a mixed order (Zakari, Abdulkarim, & Umar, 2022). The technique can also be applied when working with limited sample sizes. In addition, the issue of missing data and autocorrelations is addressed using the ARDL method (Zakari, Abdulkarim, and Umar, 2022).

4. Results and Discussion

The descriptive statistics of the variables for the sampling periods are shown in Table 1. GDP growth is shown to average 3.03%, carbon emissions from gaseous, liquid, and solid fuel consumption to average

18.72%, 46.04% and 0.15% respectively. Additionally, average annual energy use was calculated at $731.98 per person. The averages for gross fixed capital creation (35.69%), domestic lending to the private sector (9.28%), foreign direct investment (1.50%), and trade (31.9%) as a share of GDP are as follows. Both the skewness and Kurtosis asymmetry tests indicate that the variables are not normally distributed, most likely as a result of policy shocks and other forms of economic instability.

Table 1: Descriptive statistics

Signs	Variables Description	Mean	Std. Dev.	Max.	Min.	Kurtosis	Skewness	Obs.
gdpg	GDP growth (annual %)	3.0263	5.4532	15.329	-13.128	1.8744	-0.8327	40
gco2	CO_2 emissions from gaseous fuel use (% of total)	18.719	7.9276	32.042	5.6618	-1.3219	0.2159	40
lco2	CO_2 emissions from liquid fuel use (% of total)	46.044	11.763	76.819	27.293	-0.2178	0.5386	40
sco2	CO_2 emissions from solid fuel use (% of total)	0.1467	0.1268	0.5299	0.0086	1.2580	1.3155	40
econ	Energy use (kg of oil equivalent per capita)	731.98	55.616	883.47	671.61	0.7929	1.2196	40
gfcf	Gross fixed capital formation (% of GDP)	35.694	19.207	89.386	14.169	1.0968	1.1069	40
dcps	Domestic credit to private sector (% of GDP)	9.2830	3.5405	19.626	4.9575	1.1661	1.1756	40
Fdi	Foreign direct investment, net inflows (% of GDP)	1.4957	1.2455	5.7908	0.1838	3.6290	1.7973	40
topn	Trade (% of GDP)	31.902	12.501	53.278	9.1358	-0.8025	-0.3198	40

Source: Author's computation (2023).

As shown in the correlation matrix shown in Table 2, GDP growth is positively correlated with carbon emissions from gaseous fuel use, but negatively correlated with carbon emissions from liquid and solid fuel consumption. Also, gross fixed capital formation is correlated negatively with GDP growth. There was a direct correlation between GDP growth and the following variables - energy consumption, domestic lending to the private sector, FDI, and trade openness, as seen in the table below. The control variables' correlation coefficients are also presented. Low levels of correlation suggest no multicollinearity is present. Therefore, the correlation findings are preliminary analysis until the suitable estimation method is used to confirm them by revealing the signs and magnitudes of the variables' parameters.

Table 2: Correlation matrix

	gdpg	*gco2*	*lco2*	*sco2*	*econ*	*gfcf*	*dcps*	*fdi*	*topn*
gdpg	1								
gco2	0.1685	1							
lco2	-0.0283	0.4023	1						
sco2	-0.3290	-0.4180	0.3120	1					
econ	0.0676	0.8750	0.4659	-0.3317	1				
gfcf	-0.6236	-0.7307	-0.1844	0.6241	-0.6395	1			
dcps	0.2591	0.7081	0.1561	-0.3681	0.5609	-0.6987	1		
fdi	0.1670	-0.0388	-0.1624	-0.2722	-0.1944	-0.1305	0.0702	1	
topn	0.5127	0.2567	-0.1855	-0.6849	0.0857	-0.5103	0.2044	0.3111	1

Source: Author's computation (2023).

Table 3 shows Augmented Dickey Fuller unit root estimator results. The estimated unit root results showed that carbon emissions from gaseous fuel usage, domestic credit to private sector, and foreign direct investment reject the stationary null hypothesis at 5% significant level. Thus, carbon emissions from gaseous fuel usage, private sector domestic credit, and foreign direct investment remain stationary at levels [I(0)]. However, GDP growth, carbon emissions from liquid and solid fuel use, energy usage per capita, gross fixed capital formation, and trade openness did not reject the null hypothesis at levels, indicating nonstationarity. First differential unit root estimations rejected the null hypothesis at I(1). The variables are I(1) integration.

Table 3: Unit Root Test (Augmented Dickey Fuller)

Signs	Variables Description	ADF Test		Remark
		Levels	1st Diff.	
gdpg	GDP growth (annual %)	-2.4718	-10.4507***	I(1)
gco2	CO2 emissions from gaseous fuel consumption (% of total)	-4.4953***	-	I(0)
lco2	CO2 emissions from liquid fuel consumption (% of total)	-2.7722	-7.5273***	I(1)
sco2	CO2 emissions from solid fuel consumption (% of total)	-2.5416	-7.7824***	I(1)
econ	Energy use (kg of oil equivalent per capita)	-1.0380	-6.3890***	I(1)
gfcf	Gross fixed capital formation (% of GDP)	-2.4606	-5.3194***	I(1)
dcps	Domestic credit to private sector (% of GDP)	-4.1104***	-	I(0)
fdi	Foreign direct investment, net inflows (% of GDP)	-3.7914***	-	I(0)
topn	Trade (% of GDP)	-1.9833	-4.5650***	I(1)

Source: Author's computation (2023).

The F-statistics estimate, which is indicative of cointegration, is presented in Table 4. In the table, the F-statistics of the normalized equations indicate that the null hypothesis of no long-run connection is rejected at the 5% significance level, since the estimated F-statistic of 9.1809 is larger than the upper critical bounds at the 1% significance level. This is due to the fact that, at a 1% level of significance, an F-statistic estimate of 9.1809 is larger than the upper critical bounds. As can be seen from the following computation, disaggregated carbon emissions and economic growth in Nigeria are related over the long run.

Table 4: Long-run relationship using ARDL bound test (2, 3, 3, 3, 3, 3, 2, 3, 3)

Test Statistic	Value	K
F-statistics (*gdpg* | *gco2 lco2 sco2 econ gfcf dcps fdi topn*)	9.1809	8
Critical Value Bounds		
Significance	**I0 Bound**	**I1 Bound**
10%	1.85	2.85
5%	2.11	3.15
2.5%	2.33	3.42
1%	2.62	3.77

Source: Author's computation (2023).

Table 5: Results of Estimated ARDL Model

Dependent Variable: GDP Growth (gdpg)				**Sample:** 1981 2020
Selected Model: ARDL (2, 3, 3, 3, 3, 3, 2, 3, 3)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Short-run estimates				
D(GDPG(-1))	-0.758411	0.051181	-14.81819	0.0007
D(GCO2)	-0.663731	0.060110	-11.04193	0.0016
D(GCO2(-1))	3.062384	0.155358	19.71175	0.0003
D(GCO2(-2))	2.029222	0.095859	21.16875	0.0002
D(LCO2)	0.121996	0.018355	6.646437	0.0069
D(LCO2(-1))	-0.773952	0.040329	-19.19084	0.0003
D(LCO2(-2))	-0.224030	0.018157	-12.33862	0.0011
D(SCO2)	18.81110	2.280920	8.247152	0.0037
D(SCO2(-1))	111.7751	4.853647	23.02910	0.0002
D(SCO2(-2))	-53.25039	3.299987	-16.13654	0.0005
D(ECON)	-0.296649	0.014471	-20.49886	0.0003
D(ECON(-1))	-0.348984	0.018979	-18.38815	0.0004
D(ECON(-2))	-0.199331	0.011859	-16.80880	0.0005
D(GFCF)	-1.399457	0.050341	-27.79940	0.0001
D(GFCF(-1))	0.759144	0.051921	14.62107	0.0007
D(GFCF(-2))	-0.124075	0.027670	-4.484054	0.0207
D(DCPS)	-0.305643	0.081255	-3.761516	0.0329
Δ(DCPS(-1))	0.927589	0.090077	10.29778	0.0020
Δ(FDI)	2.502251	0.175538	14.25474	0.0007
Δ(FDI(-1))	-2.504138	0.209537	-11.95083	0.0013
Δ(FDI(-2))	-2.753676	0.141289	-19.48961	0.0003
Δ(TOPN)	0.650459	0.035383	18.38312	0.0004
Δ(TOPN(-1))	0.813498	0.033375	24.37462	0.0002
Δ(TOPN(-2))	-0.118012	0.018190	-6.487583	0.0074
ECT(-1)	-0.118044	0.006159	-19.16341	0.0003
Long-run estimates				
GCO2	2.912631	0.504178	5.776996	0.0103
LCO2	-1.143258	0.170646	-6.699592	0.0068
SCO2	101.6216	18.64537	5.450231	0.0121
ECON	-0.240781	0.050087	-4.807271	0.0171
GFCF	-0.080637	0.108285	-0.744673	0.5105
DCPS	-1.745721	0.301261	-5.794719	0.0102
FDI	1.532059	0.524222	2.922540	0.0614
TOPN	0.206330	0.105881	1.948686	0.1465
C	172.5980	32.09142	5.378323	0.0126
Adj. R-squared	0.7872	**F-stat**		14.8069
D-Watson	2.1218	**Prob.(F-stat)**		0.0232
Diagnostic test				
Serial Correlation: 2.9667 [0.1927]		**Normality Test:** 1.6559 [0.4369]		
Functional Form: 1.4196 [0.4712]		**Heteroskedasticity Test:** 0.5206 [0.8546]		

Source: Author's computation (2023).

Table 5 displays the predicted short and long run ARDL outcomes. Since the estimator was given the Akaike Information Criterion as a default, it picked a value of three for the model to provide a respectable degree of freedom. The results of the short-run estimation also demonstrate the error-correction technique, a metric of the pace or intensity of adjustment. Adjustment-rate economic growth is shown to be sensitive to changes in the explanatory variables. We find that the ECT coefficient is significantly negative at the conventional threshold of significance. According to the ECT value (-0.1180), the model needed an adjustment speed of 11.8% to achieve long-run equilibrium after correcting the short-run disequilibrium.

Furthermore, GDP growth at lag one had a negative effect on current income growth, the short run estimate suggests. At a significance level of 5%, it was found that the short-run parameter of carbon emissions from gaseous fuel usage at delays one and two has a beneficial effect on variations in GDP growth. Income was also positively affected by carbon emissions from solid fuel use. But at delays 1 and 2, carbon emissions from liquid fuel consumption dampen economic expansion. GDP growth at the 5% level was negatively and considerably impacted by energy use. Overall, GDP growth is influenced favorably by trade openness and domestic lending to the private sector, and negatively by gross fixed capital formation and FDI.

Table 5 shows that the results of long-run estimations for the impact of changes in carbon emissions from gaseous and solid fuel consumption on GDP growth are positive and significant. As carbon emissions from liquid fuels increase or decrease, it has a negative effect on economic growth. The results suggest that changes of 1% in carbon emissions from gaseous, liquid, and solid fuel consumption result in changes of about 2.91%, -1.14%, and 101.6% in GDP growth, respectively. The results also show that long-term GDP growth is negatively affected by energy use, gross fixed capital formation, and domestic lending to the private sector. Except for gross fixed capital formation, all other variables are statistically significant at the 5% level. For every 1% increase in energy use, gross fixed capital formation, and domestic lending to the private sector, GDP growth slows by 0.24%, 0.08%, and 1.75%, respectively. The table, however, demonstrated that FDI and trade liberalization have a direct impact on GDP growth. Statistical significance (at the 5% level) indicates that the results are consistent with theoretical assumptions.

Increases of 1% in FDI and 1% in trade openness, respectively, would boost GDP growth by 1.53 and 0.21 percentage points, respectively.

In addition, the model's explanatory variables accounted for almost 78.72% of the overall variations in GDP growth, as indicated by the high Adjusted-R2 value (0.7872). The F-statistic of 14.8069 is statistically significant at the 5% level, further supporting the conclusion that the model is well-defined and meaningful. Durbin Watson's test for serial autocorrelation in the model yields a result of 2.1218, indicating that the model is free of serial autocorrelation. The estimated model is considered to be diagnostically sound as the serial correlation test shows no evidence of order 4 serial correlation in the error terms. Also, both the normality and heteroskedasticity tests accepted the null hypothesis at the 5% significance level. This creates the false appearance that the erroneous words are normally distributed. Likewise, the ARDL model passed the Ramsey RESET test's functional form test, demonstrating that it is correctly represented and not mis-specified. This finding provides further evidence that the ARDL model is reliable. Figures 1 and 2 show that the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMSQ) are both constants.

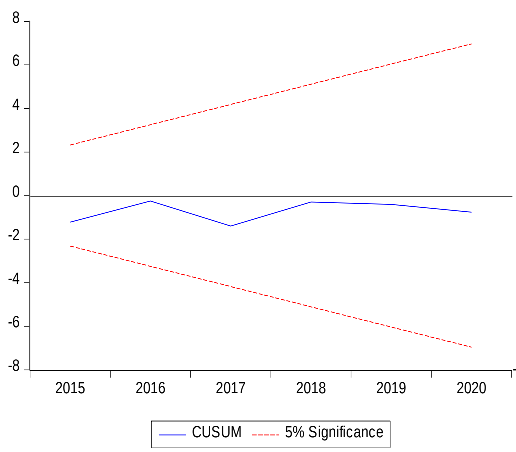

Figure 1: Cumulative Sum (CUSUM)

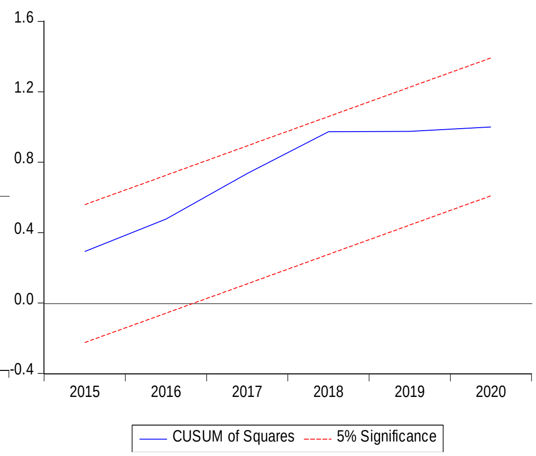

Figure 2: Cumulative Sum of Square (CUSUMQ)

5. Conclusion

This research looks at the links between disaggregated carbon emissions and economic growth in Nigeria from 1981 to 2020. It uses an ARDL bound estimate approach to analyze the dynamic effects of carbon emissions from the usage of gaseous, liquid, and solid fuels onGDP growth. The result reveals that carbon emissions from liquid fuel consumption have a negative impact on both short-term and long-term output growth. It seems to reason that the price volatility, foreign exchange dependence, and environmental and health expenses associated with using liquid fuels have a detrimental effect on economic growth in the short run. Transitioning to cleaner energy sources is crucial to Nigeria's long-term economic growth and resilience in the face of climate change implications, energy security concerns, international commitments, and the potential for technical innovation and job creation. Meanwhile, carbon emissions from the burning of gaseous and solid fuels, have direct and significant links with economic growth both in the short and long run. The importance of adopting sustainable and low-carbon development pathways to ensure sustainable economic growth in Nigeria is highlighted by the fact that carbon-emitting fuels can contribute to short-term economic growth. Also, the long-term implications, like environmental and health costs and the need to transition to cleaner energy sources are crucial.

On the policy front,a carbon tax or cap-and-trade scheme should be implemented to reduce carbon emissions. This will push industry and consumers to use cleaner energy sources and technologies and generate income for low-carbon infrastructure and research. Solar, wind, and hydroelectric power should be promoted by government policies and incentives. Clean energy infrastructure investment creates jobs, reduces carbon emissions, and boosts long-term economic growth. Also, clean technologies, energy storage, and carbon capture and storage require research and development. Government investment and private-sector collaborations can boost innovation, develop new businesses, and boost economic growth while decreasing carbon emissions. Finally, they should enforce and reinforce industry, power plant, and automobile environmental legislation and emission standards.

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