The Economic Research Guardian – Vol. 13(2)2023
Semi-annual Online Journal, www.ecrg.ro
ISSN: 2247-8531, ISSN-L: 2247-8531
Econ Res Guard 13(2): 100-110

Carbon Emission, Energy Consumption, Trade Openness, and Sectoral Output in Nigeria

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Abstract
Using ARDL estimation technique, this study investigated the cointegrating relationship among carbon emission, energy consumption, trade openness and sectoral output in Nigeria over the period 1990-2021. The ARDL bound test showed the existence of long run relationship among carbon emission, energy consumption, trade openness and sectoral output. The findings indicated that energy consumption and trade openness have significant positive effects on carbon emission in the short and long run. The estimates revealed that output expansion in the agricultural, industrial and service sectors have significant positive impacts on carbon emission in the short and long run. The result, however, indicated that the service sector has the greatest positive effect on carbon emission. Further estimates showed that foreign direct investment and financial development have negative impacts on carbon emission. The study recommends that energy-efficient technologies that reduce carbon emissions should be adopted while expanding output in all the sectors.

Keywords: Carbon emission, Energy consumption, Sectoral output, Trade openness, Nigeria

JEL classification: Q13, Q43, Q56

Received: 29 November 2023; Received in revised form: 20 December 2018; Accepted: 21 December 2023

1. Introduction

Nigeria has the highest carbon (CO_2) emission among the West African countries; Nigeria's CO_2 emission rate increased from 95.8849Mt in 2016 to 112.103Mt in 2021, representing a rise by 16.9 per cent. Hence, Nigeria ranks among the top 5 polluting countries in Africa. However, Nigeria is a low-income country, seeking to industrialize and expand foreign trade so as to promote economic growth, generate income and improve the societal welfare. These economic objectives necessitate expansion of output in various sectors of the economy and impel increasing and intensive use of energy, fossil fuels and extraction of natural resources. Studies have shown that expansion of output in the various sectors of the economy, increasing use of energy and extraction of natural resources contribute to carbon dioxide (CO_2) emission and environmental degradation (see Kwakwa et al., 2020). This study investigates the inter-relationship among carbon (CO_2) emission, energy consumption, trade openness and sectoral output in Nigeria.

Previous studies that investigated the drivers of CO_2 emissions in Nigeria have largely considered the effects of energy use, financial development and growth. For instance, Akpan & Akpan (2012) and Alege et al. (2016) examined the links between CO_2 emissions, energy consumption and growth in Nigeria. Yahaya et al. (2021) evaluated the effects of financial development on carbon emission in Nigeria. These existing studies only considered aggregate growth which masked the contributions of different sectors' output to CO_2 emission. Our study is related to Kwakwa (2023) who investigated sectoral output and carbon emission in a panel of 32 African countries. However, Kwakwa (2023) does not consider the heterogeneity of different countries. Nigeria is predominantly an agrarian society trying to industrialize and expand output in its industrial and tertiary sectors in order to promote growth and societal welfare. What can be the effects of these economic objectives on quality of the Nigerian environment?

The environmental Kuznets curve (EKC) hypothesis shows the nexus between growth and environmental degradation. The EKC hypothesis posits an inverted U-shaped relationship between growth and environmental degradation, implying that environmental pollution rises at an early of economic growth but later declines. A number of empirical studies have tested the validity of EKC hypothesis (see Baek, 2015). In recent time, a strand of studies have disaggregated growth to evaluate the contributions of each sector to environmental degradation. The evidence show that agricultural, industrial and service sectors output contribute differently to CO_2 emissions (see Kwakwa, 2023). Thus, the gap that this study fill is to decompose the aggregate output and evaluate each sector's contribution to CO_2 emission in Nigeria. Further, given the objective of trade expansion, the study also evaluates the effects of trade openness on CO_2 emission in Nigeria. Empirical studies have shown that trade openness impact CO_2 emission in developing countries (see Shahzad et al., 2017).

We contribute to the existing literature in two respects. First, we disaggregate output in the economy into sectors- agricultural, industrial, and services. This enables us to evaluate the contribution of each sector's output to CO_2 emissions in Nigeria. Low-income countries, like Nigeria, attempt to overcome economic backwardness by galvanizing growth in the industrial and service sectors. Rapid growth in these sectors lead to higher consumption of fossil fuels and energy that cause more CO_2 emission (see Rahman and Kashem, 2017). Second, we evaluate the effects of trade openness on CO_2 emission in an economy depending on imported intermediate inputs to produce domestic output and promoting exports to stabilize its foreign exchange markets. Studies have shown that foreign trade may impact CO_2 emissions in developing countries (see Hossain, 2011).

Table 1 presents the descriptive statistics of variables employed in the study. Energy has the lowest mean value with the highest standard deviation, indicating some degree of variability. The FDI has the highest mean value, demonstrating high FDI inflow over the sample period. The variable with the highest coefficient of variation (CV) is energy and the lowest are agriculture and services. The CV is computed as the ratio of standard deviation to mean measure; it is used to compare relative volatility among the variables. The highest CV implies that energy is the most volatile variable while agriculture and services are the least volatile variables. Three of the variables are positively skewed while three are negatively skewed.

Table 1 - Descriptive statistics

Variable	Mean	Std. dev.	Min	Max.	Skewness	Kurtosis	CV
CO_2	4.14	0.29	3.77	4.66	0.66	1.97	0.07
Energy	0.02	0.31	-0.4	0.55	0.59	1.88	15.5
Openness	3.59	0.24	3.03	3.98	-0.61	2.99	0.07
Agriculture	3.18	0.14	3.00	3.61	1.05	4.18	0.04
Industry	3.33	0.19	2.90	3.63	-0.11	2.52	0.06
Services	3.83	0.14	3.57	4.09	-0.04	2.25	0.04
FDI	21.42	1.01	19.52	22.90	-0.21	1.95	0.05
Fin develop	7.50	2.16	3.51	10.28	-0.28	1.76	0.28

The remaining chapters are structured as thus: Section 2 reviews related literature; section 3 is for the data and method; section 4 analyses the results while section 5 draws the conclusion

2. Literature review

The EKC hypothesis shows the adverse effects of growth on degradation of the environment at the early stage of economic development. Some extensions of the EKC hypothesis have identified international trade as one of the vital factors impacting environmental quality. Grossman & Krueger (1991) underscored that trade has three types of effect on the environment- scale effect, composition effect and technology effect. The scale effect shows that trade increases output and consequently increases environmental pollution (see Dinda, 2004). Composition effect suggests that through trade, developing countries attract pollution intensive industries which contribute to environmental degradation (see Copeland & Taylor, 2005). Finally, technology effect demonstrates that trade introduces new technology which improves the environmental quality. Empirical findings on the effect of trade on CO_2 emission have been mixed. Shahzad et al. (2017) found that trade openness increases CO_2 emission in Pakistan. Dou et al. (2021) concluded that trade openness positively contribute to CO_2 emission in China, Japan and South Korea. Ho & Iyke (2019) found that trade increases CO_2 emission in the short run but decreases it in the long run in the Central and Eastern European countries. Karedla et al. (2021) found that trade openness reduces CO_2 emission in India.

As an extension of EKC hypothesis, a strand of literature has evaluated the contributions of various sectors to CO_2 emission and environmental degradation. The findings, however, have been divergent. Considering agricultural sector's impacts on CO_2 emission, some studies report positive effects while others found negative effects. For instance, Alavijeh et al. (2022) concluded that growth in the agricultural sector increases carbon emissions in populous developing countries. Udemba (2022) showed that agricultural output increase CO_2 emission in Nigeria. Shah et al. (2022) concluded that agricultural output increase emission in BRICS countries. Kwakwa et al. (2022a) found that agricultural sector increases CO_2 emission in Ghana. In contrast, Raihan and Tuspekova (2022a) reported that agricultural growth reduces CO_2 in Kazakhstan. Adekoya et al. (2022) found a negative effect of agriculture on CO_2 in resource-rich African countries. Raihan and Tuspekova (2022b) revealed that agricultural expansion reduced CO_2 in Turkey. Also, Raihan et al. (2023) reported that the expansion of agricultural sector reduces carbon emissions in Thailand. Authors have attributed the negative effects of agricultural sector on CO_2 emissions to practices such as minimum tillage, which reduces the usage of fossil fuel usage and the adoption of energy-efficient methods for their operations.

Similarly, evidence on the effects of industrial output on CO_2 emission is also mixed. For example, Azam et al. (2023) found that industrial activities positively impact CO_2 emissions in OPEC member countries. Kwakwa (2022a) concluded that industrial growth has positive impacts on CO_2 emissions in Ghana. Raihan and Tuspekova (2022) revealed that industrial growth has positive effects on CO_2 emissions in Turkey. Song et al. (2022) concluded that CO_2 emissions rises with industrialization in Korea. On the other hand, Elfaki et al. (2021) revealed that industrial growth reduces CO_2 emissions among ASEAN + 3 economies. Studies that reported positive effect of industrial sector on CO_2 emissions attributed it to high-energy intensity of the sector.

Findings on the impacts of service sector on CO_2 emissions are also divergent. Butnar and Llop (2011) reported that service sector increases CO_2 emissions in Spain. Martínez and Silveira (2012) revealed that growth in the service sector led to a rise in energy consumption and CO_2 emissions in Sweden. Gan et al. (2022) revealed that service sector's growth positively contributes to CO_2 emissions in China. However, Martínez (2013) found that the service sector reduced CO_2 emissions in Sweden. Ali et al. (2022) found a negative relation between service sector growth and CO_2 emissions in Pakistan. Nwani et al. (2022) found that the service sector has a negative impact on CO_2 emissions in African countries. Wang et al. (2022) revealed that digital service in China reduces CO_2 emissions. The mixed evidence for the service sector could be due to the extent that it dominates the economy of the country.

A number of studies have investigated the multi-dimensional nexus among carbon emission, energy consumption and growth. For example, Saibu and Jaiyeola (2013) reported positive impacts of oil production and growth on CO_2 emissions in Nigeria. Zubair et al. (2020) showed that FDI, GDP and capital reduce carbon emission in Nigeria. Tiwari (2011) found that energy consumption generates economic growth and also has positive effect on CO_2 emission in India. Khobai and Roux (2017) obtained a cointegrating relationship among growth, energy consumption and CO_2 emissions in South Africa. Rahman and Kashem (2017) revealed a long run cointegration among CO_2 emissions, energy consumption and industrial growth in Bangladesh.

The above review shows that existing studies have largely focused on the effects of aggregate growth on CO_2 emissions. The few studies that disaggregated growth have only considered the sectors separately (see Alavijeh et al., 2022; Kwakwa, 2022a; Gan et al., 2022). The gap that this study seeks to fill is to evaluate each sector's contribution to CO_2 emission in an agrarian society trying to accelerate growth and development through expansion of output in its industrial and tertiary sectors while pursuing food security.

3. Data and method

This study employed time-series annual data over the period 1990 to 2021. The variables include energy consumption, trade openness proxy as the sum of exports and imports as a ratio of GDP, agriculture, industry and services contributions to GDP, foreign direct investment (FDI) and financial development proxied by domestic credit to the private sector. The data were sourced from the World Bank Development Indicator (WDI), Central Bank of Nigeria, and the U.S. energy information administration. Data for carbon emission were sourced from the U.S. energy information administration. The functional form of the model is specifies as:

$$CO_2 = \text{f (Energy consumption, Openness, agriculture, Industry, Service, FDI, Fin. dev)} \quad (1)$$

The autoregressive Distributed Lag (ARDL) technique by Pesaran and Shin (1999) and Pesaran et al. (2001) is employed to investigate the short and long run dynamics among the variables. ARDL is applied due to its flexibility, provision of unbiased for long run relationship and long run parameters and its capability to adequately address autocorrelation and endogeneity problems (see Rahman and Kashem, 2017). The econometric form of the model is stated as:

$$lCO_{2t} = \gamma_1 + \gamma_2 lEnergy_t + \gamma_3 lOpenness_t + \gamma_4 lAgricsect_t + \gamma_5 lIndustsect_t + \gamma_6 lServsect_t + vZ_{it} + \mu_t \quad (2)$$

where $lAgricsect_t$ represents the agricultural sector, $lIndustsect_t$ is the industrial sector, and $lServsect_t$ denotes the service sector, γ_1 is the intercept; $\gamma_2, \gamma_3, \gamma_4, \gamma_5$, and γ_6 are the coefficient of explanatory variables and μ_t is the stochastic term. Z_{it} denotes the control variables such as foreign direct investment (FDI) and financial development.

4. Results

4.1. Unit root tests

Table 1 presents the unit root tests results. The Augmented Dickey Fuller (ADF) and Phillips Peron (PP) were applied for the stationarity tests. The estimates show that the variables are of different order of integrations, providing justification for the application of ARDL (see Pesaran et al., 2001; Pesaran & Shin, 1999).

Table 2 - Unit root test results

Variable	Intercept		Trend & Intercept	
	Level	1st difference	Level	1st difference
Augmented Dickey Fuller (ADF)				
lCO_2	-0.787	-6.438***	-2.396	-6.411***
$lenerg$	-0.951	-6.695***	-2.564	-6.642***
$lopen$	-2.915*	-6.118***	-3.119	-5.997***
$lagric$	-1.794	-6.136***	-3.405*	-6.188***
$lindustry$	-2.015	-5.854***	-3.791**	-6.033***
$lservices$	-1.386	-4.006**	-1.971	-3.861**
$lFDI$	-2.129	-6.1***	-3.229	-6.159***
$lfindev$	-2.392	-4.006***	-0.810	-4.662***
Phillips-Peron (PP)				
lCO_2	0.687	-6.48***	-2.481	-6.430***
$lenerg$	-0.827	-6.798***	-2.644	-6.773***
$lopen$	-2.955*	-8.635***	-3.099	-9.297***
$lagric$	-2.218	-5.420***	-1.994	-5.642***
$lindustry$	-1.82	-5.699***	-1.937	-8.231***
$lservices$	-1.515	-4.063***	-2.713	-4.005**
$lFDI$	-1.633	-6.057***	-1.457	-6.098***
$lfindev$	-2.45	-3.965**	-0.846	-4.635**

Note: ***, **.and * indicate that the series is stationary at 1%, 5% and 10% level of significance

4.2. ARDL estimates

The ARDL method is employed to examine the short and long run dynamics among the variables. ARDL is preferred to the traditional cointegration technique given its flexibility, provision of unbiased for long run relationship and long run parameters and its capability to adequately address autocorrelation and endogeneity problems (see Rahman and Kashem, 2017). Our approach is similar to Shahbaz et al. (2013), Rahman and Kashem (2017) and Zubair et al. (2020). Our ARDL model is specified as:

$$\Delta CO_{2t} = \beta + \sum_{i=1}^{n} \theta_1 \Delta CO_{2t-1} + \sum_{i=1}^{n} \theta_2 \Delta Energy_{t-1} + \sum_{i=1}^{n} \theta_3 \Delta Openness_{t-1} + \sum_{i=1}^{n} \theta_4 \Delta Agric_{t-1} + \sum_{i=1}^{n} \theta_5 \Delta Industry_{t-1} + \sum_{i=1}^{n} \theta_6 \Delta Service_{t-1} + \sum_{i=1}^{n} \theta_7 \Delta FDI_{t-1} + \sum_{i=1}^{n} \theta_8 \Delta Findev_{t-1} + \delta_1 CO_{2t-1} + \delta_2 Energy_{t-1} + \delta_3 Openness_{t-1} + \delta_4 Agric_{t-1} + \delta_5 Industry_{t-1} + \delta_6 Service_{t-1} + \delta_7 FDI_{t-1} + \delta_8 Findev_{t-1} + \varepsilon_t \quad (3)$$

In eq. (2), the short run effects are captured by the estimates assigned to the first-differenced variables and long run effects are represented by the estimates of $\delta_2 - \delta_6$ normalized on δ_1. To examine the existence of long run relationship and joint significance of lagged variable, the F-test is applied. The hypotheses are stated as: $H_0: \delta_0 = \delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = 0$

$$H_1: \delta_0 \neq 0;\ \delta_1 \neq 0;\ \delta_2 \neq 0;\ \delta_3 \neq 0;\ \delta_4 \neq 0;\ \delta_5 \neq 0;\ \delta_6 \neq 0 \quad (4)$$

If the computed F-statistics is greater than the upper bound critical value, the null hypothesis of no cointegration is rejected. In contrast, if the F-statistics is below the lower bound critical value, the null hypothesis is not rejected. However, if the computed F-statistics falls between the upper and lower critical bound value, the test is inconclusive.

4.3. Discussion of results

The ARDL bound test are reported in Table 3. The computed F-stat of 14.956 is greater than the upper critical bound value at 5% significant level and other levels, confirming the existence of cointegration among the variables over the sample period.

Table 3 - Bound test result

	Pesaran	
Critical values	Lower $I(0)$	Upper $I(1)$
1%	2.73	3.9
5%	2.17	3.21
10%	1.92	2.89
F-stat	14.956	

Table 4 and 5 present the estimates for short and long run relationship. The results show that energy consumption has significant positive impact on CO_2 emission in the short and long run. This indicates that energy consumption contributes to a rise in CO_2 emission. This is in line with the results by Kwakwa (2020). Also, the results reveal that trade openness has significant positive effect on CO_2 emission in the short and long run. This implies that openness increases CO_2 emission in Nigeria, reinforcing the pollution haven hypothesis. This conforms to the findings by Shahzad et al. (2017).

For sectoral contributions, the results reveal that all the 3 sectors' output have significant positive impacts on CO_2 emission in the short and long run. This suggests that expansion of output in agriculture, industry and services contributes to environmental degradation by increasing the level of CO_2 emission in Nigeria. The positive impact of agriculture on CO_2 emission can be attributed to deforestation occasioned by expansion of cropland area and excessive use of fertilizers (see Kwakwa, 2022a). Similarly, the positive effects of industry and services on CO_2 emission can be attributed to increased energy and fossil fuel consumption to expand output in these sectors. The estimates reveal that the service sector has the greatest impact on CO_2 emission both in the short and long run. Further, the results show that FDI has significant negative effects on CO_2 emission in short and long run. This is similar to the findings by Zubair et al. (2020). Lastly, the estimates reveal that financial development has insignificant negative effect in the short run but significant negative impact on CO_2 emission in the long run.

Table 4 - Short run estimate: Dependent variable: $\Delta lnCO_2$

Independent variables	Coefficient	Standard error	t-ratio
$\Delta lenergy$	0.960***	0.024	40.881
$\Delta lenergy(-1)$	-0.079*	0.034	-2.294
$\Delta lopenness$	0.131***	0.026	4.98
$\Delta lopenness(-1)$	-0.013	0.02	-0.649
$\Delta lagric$	0.322**	0.095	3.387
$\Delta lagric(-1)$	-0.483**	0.103	-4.68
$\Delta lindustry$	0.208*	0.092	2.255
$\Delta lindustry(-1)$	-0.41**	0-1	-4.134
$\Delta lservices$	0.646**	0.146	4.429
$\Delta lservices(-1)$	-0.74**	0.163	-4.533
$\Delta lfdi$	-0.027**	0.006	-4.774
$\Delta lfdi(-1)$	-0.017*	0.008	-2.139
$\Delta lfindev$	-0.02	0.017	-1.156
$\Delta lfindev(-1)$	0.117	0.021	5.531
ECM	-0.919***	0.049	-18.709

$R^2 = 0.998;\ \bar{R}^2 = 0.995;$

Table 5 - Long run estimates: Dependent variable: $lnCO_2$

Independent variables	Coefficient	Standard error	t-ratio
$lenergy$	1.246***	0.05	24.889
$lopen$	0.139**	0.045	3.086
$lagric$	0.993***	0.187	5.316
$lindust$	0.765**	0.18	4.239
$lserv$	1.981***	0.346	5.721
$lfdi$	-0.022*	0.008	-2.623
$lfindev$	-0.057***	0.01	-5.74
$Constant$	-3.3693	2.6447	-1.274

$$R^2 = 0.997;\ \bar{R}^2 = 0.993; F-stat = 106.8;\ (\chi^2_{LM}) = 0.02\ ; (\chi^2_{R}) = 0.43; (\chi^2_{N}) = 0.37; (\chi^2_{H}) = 0.18$$

4.4. Diagnostic tests

To examine the robustness and stability test of our model, we employ the cumulative sum of recursive residuals (CUSUM) and cumulative sum of recursive residuals of squares (CUSUMSQ) tests (see Pesaran & Pesaran, 1997). If the CUSUM and CUSUMSQ plots remain within the 5 per cent critical bound, it signifies the parameter constancy and model stability. Figures 1 and 2 show that the plots of the residuals lie within two pairs of straight lines at a 5% critical bound, confirming the model stability.

Figure 1 - CUSUM

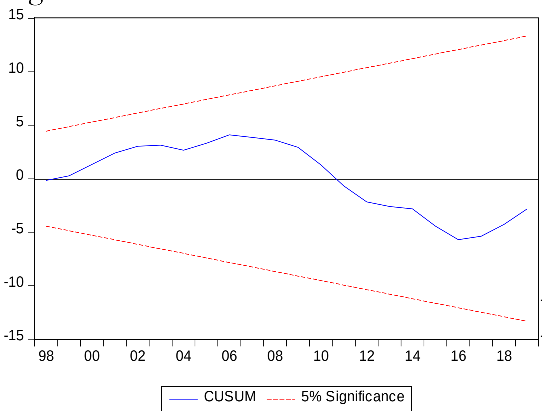
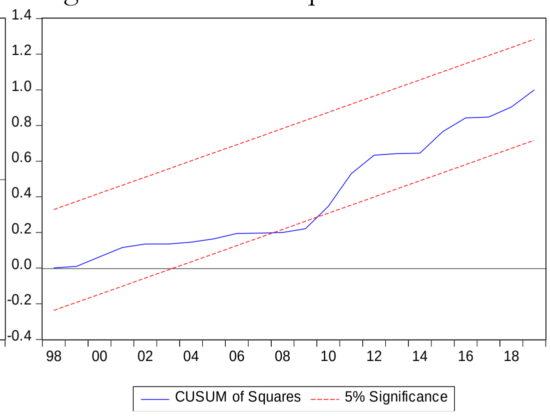


Figure 2 - CUSUM Square



5. Conclusion

Using ARDL test, this study investigated the cointegrating relationship among CO_2 emission, energy consumption, trade openness and sectoral output in Nigeria, over the period 1990-2021. The study is important to evaluate the contributions of each sector to environmental degradation in Nigeria. The estimates revealed an existence of long run relationship among CO_2 emission, energy consumption, trade openness and sectoral output. The findings show that energy consumption and trade openness contribute positively to CO_2 emission in the short and long run. Moreover, the estimates suggest that the 3 sectors – agriculture, industry and services - have significant positive effects on CO_2 emissions. The service sector, however, has the highest impact on CO_2 emission both in the short and long run. Lastly, the results indicate that FDI and financial development reduce CO_2 emissions. The results have some policy implications. Given that Nigeria is a low-income country which needs to expand output in all the sectors and trade so as to feed its large population, generate employment, promote growth and reduce poverty, an instant reduction in CO_2 emission may increase hunger, reduce growth, increase unemployment and aggravate the poverty rate. However, continuous CO_2 emission, which causes environmental degradation, is harmful to sustainable development in the long run. Given this dilemma, this study recommends that the government should adopt energy-efficient production technological methods in all the sectors and implement sustainable development policies that integrate climate risk options and adaptations while promoting growth and productivities in all the sectors.

This study has its limits. It is limited to 3 sectors; it did not decompose the sectors into sub-sectors to examine each contribution to carbon emission. Further research should decompose each sector into sub-sectors to compare and evaluate which sub-sector really contributes significantly to environmental degradation.

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