International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2025, 15(1), 513-518.

Carbon Dioxide Emissions from Energy Consumption, Foreign Direct Investment and Economic Growth in Nigeria: A Multivariate Causal Analysis

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Received: 10 July 2024 **Accepted:** 05 December 2024 **DOI:** https://doi.org/10.32479/ijeep.18118

ABSTRACT

The relationship among Nigeria's CO_2 emissions, foreign direct investment inflows, and economic growth was examined in this study. The data period examined is from 1990 to 2020. The data is obtained from the World Bank's online database and adopted the VECM-based Granger causality technique. Results showed a feedback relationship between FDI inflows and CO_2 emissions as well as a unidirectional causal relationship from economic growth to CO_2 emissions. The information offered by these empirical studies will help policymakers develop effective economic policies.

Keywords: CO_2 Emissions, Foreign Direct Investment Inflows, Economic Growth, VECM-Based Granger Causality, Nigeria
JEL Classifications: L16, Q13, Q43

1. INTRODUCTION

One of the most significant trends in the modern global economy has been the globalization of manufacturing. This is due to the fact that the globalization trend has removed several obstacles to cross-border capital movements. The main change has been the sharp rise in foreign direct investment (FDI). Economic growth is boosted by increased output brought on by FDI, notably in the real sector of the host country. However, FDI inflows are also seen as a factor that might result in Carbon Dioxide (CO_2) emissions (see pollution haven hypothesis in Copeland and Taylor, 1994). Greater CO_2 emissions are also associated with increased economic growth. For instance, as the process of economic growth progresses, more energy would be needed. This means that using fossil fuels to provide energy for industry and other types of economic activity might eventually result in larger CO_2 emissions. Therefore, it is essential to comprehend the causal links between FDI inflows, economic growth, and CO_2 emissions.

Although FDI inflows, economic growth, and CO_2 emissions have all been thoroughly studied in the economic literature, but the findings are inconsistent (Aremo and Ojeyinka, 2018; Bardi and Hfaiedh, 2021; Latief et al., 2021; Liu and Lee, 2020; Mwakabungu and Kauangal, 2023; Nupehewa et al., 2022; Owusu, 2020; Radmehr et al., 2021; Sabharwal, 2019; Wang, 2018; Zubair et al, 2020). Unfortunately, however, the majority of these previous researches have focused solely on nations in Asia and Latin America. There is little research on African countries, especially those like Nigeria where a sizable amount of FDI inflows is concentrated. Nevertheless, some of the few studies that have examined the connections among FDI inflows, economic expansion, and CO_2 emissions in Nigeria have only used a bivariate framework (Danladi and Akomolafe, 2013), which could reveal causality when it does not actually exist or could incorrectly detect the direction of causality, leading to incorrect conclusions (Lütkepohl, 1982). Still, some of these scanty studies on Nigeria (Aremo and Ojeyinka, 2018) have incorporated energy use as a variable in their models. However, because energy use and CO_2 emissions are strongly correlated (Pereira and Pereira, 2010), this might lead to multicollinearity problems and inaccurate conclusions. Others, however, have only shown the long-run connection, ignoring the short-run causation among CO_2 emissions, FDI inflows, and economic progress (Zubair et al., 2020).

Our objective is to study the direction of causation among CO_2 emissions, FDI inflows, and economic growth in Nigeria in both the short and long periods using a multivariate model with all pertinent variables incorporated in a single equation. The study will add to the sparse body of empirical research that has been done on the topic in Africa. The remaining discussions are divided into four parts. In part 2, the prior literature is examined in brief. Part 3 presents the model and methodology employed in this investigation. Part 4 presents the empirical findings. The research comes to a conclusion in Section 5.

2. THEORETICAL AND EMPIRICAL ISSUES

2.1. Theoretical Issues

Theoretically, FDI inflows are a significant source of finance that support domestic investment, provide new employment possibilities, and are frequently linked to the advancement of technology transfer, all of which help economic growth (Ajayi, 2005). According to neoclassical theory, FDI inflows raise the quantity of capital per individual, which promotes economic growth. However, it does not result in long-term economic growth due to the declining returns on capital. On the other hand, the endogenous approach contends that FDI inflows have an impact on long-term elements like human capital and research and development. According to several theoretical studies (Lucas, 1988; Rebelo, 1991; Romer, 1986; 1993), FDI inflows can support host country growth in a variety of ways. FDI can influence higher capital accumulation in the host country, enhanced efficiency of local companies, and their exposure to intense competition (Aitken et al., 1997; Blomstrom and Kokko, 1998).

Theoretically, however, economic literature contends that FDI inflows could harm the environment (Grossman and Krueger, 1991), but the host nations' economic prosperity might compensate the environmental harm. This implies that host nations will endure increased pollution and environmental deterioration as economic expansion accelerates. Grossman and Krueger (1991) proposed three mechanisms for trade, economic expansion, and environmental protection. First, the scale effect, one of the processes, is detrimental to ecology. As more FDI flows into a country, industrial production increases, which might cause pollution and environmental deterioration. Second, FDI inflow provides an additional benefit and may be environmentally friendly. Modern technologies may be used by plants to increase productivity. FDI and commercial openness can therefore aid in enhancing environmental quality. The economic impact, which motivates residents to seek environmental change and, as a result, improves environmental quality, is the final phase that increases employment and income in the host nation. In contrast to Grossman and Krueger (1991) view, theoretical researches (Copeland and Taylor, 1994), however, argued that foreign investors favour making investments in emerging nations with lenient environmental rules. For instance, polluting businesses in affluent nations may think about relocating to less developed countries to save money on the costs of domestic abatement measures. Because these less developed nations lack the resources to engage in economic growth, polluting industries thrive there, which is known in economic theory as the "pollution haven hypothesis." According to Porter and Van der Linde (1995), which is in line with Grossman and Krueger (1991), rising nations begin to enact stronger environmental regulations to protect the environment from deterioration when economic growth rises as a result of FDI inflows. This is also termed as "pollution haloes hypothesis" in economic theory.

2.2. Empirical Evidence

Sabharwal (2019), focusing on MINT nations, demonstrated how economic growth Granger spurred FDI in Turkey and Nigeria. But, Okumoko et al. (2018) demonstrated a unidirectional Granger link from FDI to Nigeria's economic expansion. According to Gokmen's Granger causality findings from Gokmen (2021), FDI was the main force behind economic growth in Turkey, which was in agreement with Okumoko et al. (2018). However, Mwakabungu and Kauangal's (2023) showed a unidirectional Granger causation connecting Tanzania's economic development to FDI influx. However, the empirical results of Nupehewa et al. (2022) demonstrated that FDI and economic growth are causally related in both directions, both globally and in the Asian region. Owusu (2020), who used a multivariate Granger-causality technique to identify a significant bidirectional causal link between FDI influx and economic development in Namibia, corroborated these findings. Contrarily, Nupehewa et al. (2022) discovered that the causality is unidirectional in the American region. According to Nupehewa et al. (2022), a non-directional causation was discovered in the regions of Europe, Oceania, the Mediterranean, and Africa. Wang (2018) used the Granger causality test to examine the relationship between CO_2 emissions and economic growth in industrialized and developing countries, and the results showed that CO_2 emissions cause economic growth in underdeveloped countries while economic growth causes CO_2 emissions in developed countries. However, Radmehr et al. (2021) who focused on EU nations found a bidirectional causal relationship between CO_2 emissions and economic growth.

Aremo and Ojeyinka (2018) look at the causative relationships amid CO_2 emissions, FDI inflows, energy consumption, and economic development in Nigeria. Results from the VECM Granger causality technique show that FDI and CO_2 emissions are causally related in a single direction. Still concentrating on Nigeria, Zubair et al. (2020) use the Toda Yamamoto causality model on Nigeria's data. The results show that FDI and CO_2 emissions are causally related in both directions. In a comparable study, Latief et al. (2021) found a one-way relationship between economic growth and CO_2 emissions for the SAARC countries. CO_2 emissions are a direct result of economic growth. However, the findings of a causality research conducted by Bardi and Hfaiedh (2021) on MENA countries revealed a short term, unidirectional causal relationship between economic growth and CO_2 emissions as well as between CO_2 emissions and FDI. However, FDI and CO_2 emissions have a bidirectional causal link over the long term. Using the Granger causality test, Dahal et al. (2023) examined the connection between Nepal's industrial sector production, economic growth, and CO_2 emissions. The findings demonstrated that CO_2 emissions are not the primary source of Nepal's economic growth. But economic growth results in CO_2 emissions. The unexpected result is that CO_2 emissions in the Nepalese environment are not increased by the industrial sector's output. However, according to Gyamerah and Gil-Alana's (2023), economic expansion does not immediately increase CO_2 emissions.

3. THE MODEL AND METHODOLOGIES

3.1. The Model

To look at how FDI, economic growth, and CO_2 emissions are related, we use a Cobb-Douglas production function. Energy consumption and foreign direct investment are included as extra production variables in the production function, suggesting that private capital stock, labour, FDI, and energy consumption are all essential for output or economic growth (Omri et al., 2014). Consequently, the production function is described as

$$Y = AK^{\alpha} L^{\beta} F^{\gamma} E^{\phi} e^{\varepsilon} \tag{1}$$

In this equation, Y stands for economic growth, A for total factor productivity, K for private capital stock, F for foreign direct investment, L for labour force, E for energy consumption, and ε for error. Where α, β, ϒ and ϕ which are related to private capital stock, labour, foreign direct investment, and energy consumption, respectively, are the production elasticities.

However, information from the literature suggests that energy use and CO_2 emissions are directly correlated, with E equal to bCO_2 (Pereira and Pereira, 2010). Equation (1) changes when this is taken into consideration.

$$Y = AK^{\alpha} L^{\beta} F^{\gamma} (\mathrm{bCO_2})^{\phi} e^{\varepsilon} \tag{2}$$

$$Y = A\mathrm{b}^{\varphi} K^{\alpha} L^{\beta} F^{\gamma} \mathrm{CO}_2^{\varphi} e^{\varepsilon} \tag{3}$$

Equation (3) is divided by labour force (L), and using the supposition that the production function has constant returns to scale, we arrive at

$$Y/L = Ab^{\phi} (K/L)^{\alpha} (L/L)^{\beta} (F/L)^{\gamma} (CO_2/L)^{\phi} e^{\varepsilon} \tag{4}$$

$$Y/L = Ab^{\phi} (K/L)^{\alpha} (F/L)^{\gamma} (CO_2/L)^{\phi} e^{\varepsilon} \tag{5}$$

Equation (5) is then specified in log (l) to make it estimable

$$1(Y/L) = 1(Ab^{\phi}) + 1(K/L)^{\alpha} + 1(F/L)^{\gamma} + 1(CO_2/L)^{\phi} + 1e^{\varepsilon} \tag{6}$$

$$1(Y/L) = 1(Ab^{\phi}) + \alpha 1(K/L)^{\alpha} + \gamma 1(F/L)^{\gamma} + \varphi 1(CO_2/L) + \varepsilon \tag{7}$$

Assume $1(Ab^{\phi}) = a$, then

$$\mathrm{l}(Y/L) = a + \alpha\,\mathrm{l}(K/L) + \gamma\,\mathrm{l}(F/L) + \varphi\,\mathrm{l}(\mathrm{CO_2}/L) + \varepsilon \tag{8}$$

where (Y/L) stands for per capita GDP, (K/L) for per capita private capital stock, (CO_2/L) for per capita CO_2 emissions and (F/L) for per capita FDI. Equation (8) is then changed to values in growth, since unlogged data may indicate significant consequences but logged data may not show any indication of causality (Roberts and Nord, 1985).

$$gy_t = \alpha + \alpha gK_t + \gamma gF_t + \phi g\mathrm{CO}_{2t} + \varepsilon_t \tag{9}$$

The growth rates of GDP per capita, private capital stock, FDI, and CO_2 emissions are represented by the symbols gY, gK, gF, and gCO_2, respectively. To estimate Equation (9), we use annual data from 1990 to 2020 due to limited data on CO_2 emissions. Using data from the World Bank's World Development Indicators (WDI), the $gY = y$, $gK = k$, $gF = f$, and $gCO_2 = c$ were obtained. SeeTable A1 (Appendix) for measurement and sources of data.

3.2. Methodologies

To estimate Equation (9), a system of autoregressive distributed lag (ARDL) models was first developed to establish long term links (cointegration) among variables due to the fact that the ARDL technique can handle both the I(0) and I(1) variables (Abanikanda et al., 2023; Ogunjumo, 2024; Ogunjumo et al., 2024; Ogunjumo et al., 2023; Onabote et al., 2023). We must verify that there are no I(2) variables, though. We used the Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) unit roots to test the stationarity of variables since they are considered appropriate in the literature (Adebayo et al., 2020; Ogunjobi et al., 2021; Onabote et al., 2021). Once cointegration thas been shown, variables must have unidirectional or bidirectional causation (Omri et al. 2014; Owusu, 2020). We then formulated a vector error correction Granger causality model from the ARDL models (Omri et al., 2014; Owusu, 2020), which is written as follows

$$\begin{pmatrix} \Delta y_t \\ \Delta k_t \\ \Delta f_t \\ \Delta c_t \end{pmatrix} = A_0 + \sum_{i=1}^{p} A_i \begin{pmatrix} \Delta y_{t-i} \\ \Delta k_{t-i} \\ \Delta f_{t-i} \\ \Delta c_{t-i} \end{pmatrix} + \lambda \begin{pmatrix} ECT_{1t-1} \\ ECT_{2t-1} \\ ECT_{3t-1} \\ ECT_{4t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \end{pmatrix} \tag{10}$$

Where ECT_{1t-1}, ECT_{2t-1}, ECT_{3t-1}, and ECT_{4t-1} are lagged error correction terms derived from the long run relationships, since bound test findings revealed four cointegration relationships when y, k, f, and c are handled as dependent variables. As a consequence, the significance of the coefficient of error correction components is used to calculate the long run causality using the t-test statistic. The F statistic for the first differenced lagged independent variables is used to determine the direction of short run causation between the variables. Strong causality arises from the interaction of both short and long term causes.

Table 1: Descriptive statistics

Statistics	*c*	*f*	*k*	*y*
Mean	2.2	2.7	4.6	1.3
Median	2.7	2.4	4.8	1.8
Maximum	72.4	10.8	21.3	30.3
Minimum	−41.5	−1.1	−7.4	−15.4
Std. Dev.	21.0	2.1	5.4	7.3
Skewness	0.9	1.7	0.3	0.8
Kurtosis	4.9	6.8	1.1	7.4
Jarque-Bera	13.3	47.5	3.2	41.6
Observations	43	43	43	43

Source: Author's Computation

Table 2: Unit root test results

Variables	Constant ADF test	Constant, trend ADF test	Remarks	Constant PP test	Constant, trend PP test	Remarks
y	−5.5*	−6.1*	I(0)	−5.6*	−6.1*	I(0)
k	−5.1*	−5.7*	I(0)	−5.3*	−5.7*	I(0)
f	−3.6*	−3.9*	I(0)	−3.5*	−3.8*	I(0)
c	−6.7*	−6.7*	I(0)	−6.8*	−6.8*	I(0)

The symbols ***,** and * imply significance levels of 1%, 5%, and 10%, respectively

Source: Author's Computation

4. EMPIRICAL RESULTS

The distinctive descriptive statistics of the data employed are first assessed before looking at the aim of this investigation. Skewness, kurtosis, and Jarque-Bera statistics are used to describe the sample distribution, whereas the mean, median, greatest as well as lowest values are used to describe sample statistics. Table 1 displays the descriptive statistics for the data utilized in the inquiry. The data spans the years 1990 through 2020 and is all presented in annual format. Given that their mean and median values lie between the series' highest and lowest values, the descriptive statistics reveal that all of the series have a respectable amount of consistency. Additionally, the standard deviation demonstrated that the actual data for the series do not considerably deviate from the mean value. Additionally, Table 1 shows that all distributions are normal since the Jarque-Bera statistics value for each variable is higher than the value of kurtosis. The closeness between the mean and median values for these data sets lends more evidence in favour of the hypothesis of normalcy. The likelihood that data in a series are normally distributed increases with the proximity of the mean and median values. The next step is to examine the properties of the variables in order to avoid erroneous regression.

According to the unit root test results in Table 2, all of the variables are stationary in their level forms. The series are therefore referred to as being of order zero (I[0]) integrated. The autoregressive distributed lagged model (ARDL) fits the research well to assess if there is a long run relationship that has to be taken into account in the econometric assumption by testing for cointegration between per capita GDP growth, per capita private capital stock growth, per capita FDI growth, and per capita CO_2 emissions growth rates.

The estimated F-statistic from the bound tests is much greater than the Pesaran et al. (2001) lowest critical value, as shown in Table 3. When the growth rates of per capita GDP, private capital stock, foreign direct investment, and CO_2 emissions are taken into account as dependent variables, we find four cointegration linkages. This suggests that there are enduring connections between the variables in Nigeria.

The Granger causality test may be applied after the cointegration of the four variables. In this study, the VECM-based Granger causality test of Engle and Granger was used. The results of a VECM causality test among CO_2 emissions, foreign direct investment, and economic expansion are shown in Table 4. According to the short term findings provided in Table 4 (panel A), there is unidirectional Granger causation flowing (1) from economic growth to CO_2 emissions and (2) from economic growth

Table 3: Panel (A): Bounds test results

Variables	K	Computed F-statistic	Remarks
$F(y\|k\,f\,c)$	3	8.2***	Reject H_0
$F(k\|y\,f\,c)$	3	6.5***	Reject H_0
$F(f\|k\,y\,c)$	3	4.1**	Reject H_0
$F(c\|k\,f\,y)$	3	9.7***	Reject H_0

***,** and * denotes statistical significance at 1%, 5%, and 10% levels respectively

Source: Author's Computation

Panel (B): F-Table

K	10% I(0)	10% I(1)	5% I(0)	5% I(1)	1% I(0)	1% I(1)
3	2.7	3.7	3.2	4.3	4.2	5.6

Source: Pesaran et al. (2001)

Table 4: The VECM Granger causality findings (only the variables of interest were reported)

Panel (A)

Variables	Short-term causality Δc	Short-term causality Δf	Short-term causality Δy	Long-term causality ECT_{t-1} t-statistics
Δc	-	0.65637	4.14447*	−4.22134*
Δf	0.00090	-	2.84614***	1.848360**
Δy	0.10552	1.29487	-	0.271629

At the 1, 5, and 10% levels, respectively, ***, **, and * demonstrate significance

Source: Author's Computation

Panel (B)

Variables	Strong causality *c*	Strong causality *f*	Strong causality *y*
c	-	20.50325*	17.99228*
f	5.23814**	-	4.51190
y	0.44588	1.54069	-

*,** and *** show significance at 1, 5 and 10% level respectively

Source: Author's Computation

to foreign direct investment. There is no proof that the variables are causally correlated in both directions. These results are at odds with the short term findings of Danladi and Akomolafe (2013), who found no connection between economic expansion and FDI or economic expansion and CO_2 emissions in Nigeria. Long term results suggest that economic growth and foreign direct investment Granger cause CO_2 emissions and that, in turn, economic growth and CO_2 emissions Granger cause foreign direct investment, as shown in Table 4 (panel A). The long term findings of Zubair et al. (2020) and Aremo and Ojeyinka (2018), which came to the conclusion that there is no causality among economic growth and FDI or economic growth and CO_2 emissions in Nigeria, are likewise in conflict with these findings. However, our analysis supports Zubair et al. (2020) in their conclusion that FDI and CO_2 emissions are causally related in both directions.

In Nigeria, it may be possible to reduce CO_2 emissions without sacrificing economic growth in the medium or long term since changes in economic growth often come before changes in CO_2 emissions, not the other way around. To lessen the negative consequences of foreign direct investment anticipated by the pollution haven hypothesis, strong environmental measures must be implemented. The results also imply that economic expansion is crucial in luring foreign direct investment, which implies that the nation should concentrate on enhancing institutional quality and other traits that have been shown to positively influence economic development. Additionally, the results in panel B of Table 4 demonstrate that the variables have strong causal relationships. The results show a one-way causal relationship between economic growth and CO_2 emissions. Additionally, there is a bidirectional causal link between foreign direct investment and CO_2 emissions.

5. CONCLUSION AND POLICY IMPLICATIONS

Very few studies have scrutinized the connections among FDI inflows, economic expansion and CO_2 emissions in Nigeria; however, these studies rely on a bivariate framework, which may lead to the incorrect discovery of causality, or they have included the variable of energy consumption in the model, which may cause the problem of multicollinearity because energy consumption and CO_2 emissions are highly correlated. We sought to determine whether there was a causative relationship among CO_2 emissions, FDI inflows, and economic expansion in Nigeria from 1990 to 2020 using a VECM-based (multivariate framework) Granger causality technique. According to the short term facts, our results show that there is unidirectional Granger causality flowing (1) from economic growth to CO_2 emissions and (2) from economic growth to foreign direct investment. We thus reject a number of earlier studies that contend that there is no causal connection between economic expansion and FDI inflows or between economic growth and CO_2 emissions in the Nigeria. Furthermore, the findings show that (1) foreign direct investment and economic growth Granger cause CO_2 emissions and (2) CO_2 emissions and economic growth Granger cause foreign direct investment over the long term. Additionally, the strong causal links test also demonstrates a bidirectional causal relationship between foreign direct investment and CO_2 emissions in addition to a unidirectional causal relationship between economic expansion and emissions of CO_2.

The empirical results suggest that reducing CO_2 emissions in Nigeria would be feasible without having a detrimental long or short term impact on economic growth. Strong environmental policies must be put in place, by the government and policymakers in Nigeria, to mitigate the harmful effects of foreign direct investment predicted by the pollution haven hypothesis. The empirical results also reveal that economic growth is crucial for luring foreign direct investment, which suggests that the nation should concentrate on enhancing institutional quality and other factors that have been shown to have a positive influence on economic growth.

6. ACKNOWLEDGMENT

The authors would like to thank Landmark University, Omu-Aran, Nigeria for providing the article's publication fee.

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APPENDIX

Table A1: Measurement and sources of data

Variables	Measurement	Source(s) of Data
Growth rate of GDP per capita	Growth rate of GDP per capita (constant Local currency)	Author's computation from WDI
Growth rate of private capital stock Per capita	Growth rate of gross fixed capital formation per capita (constant Local currency)	Author's computation from WDI
Growth rate of FDI inflows Per capita	Growth rate of FDI net inflows per capita	Author's computation from WDI
Growth rate of CO_2 emissions per Capita	Growth rate of CO_2 emissions per capita (Metric Tons)	Author's computation from WDI