Journal of Sustainable Development in Africa (Volume 27, No.1, 2025)
ISSN: 1520-5509
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THE IMPACT OF FOREIGN DIRECT INVESTMENT ON CARBON EMISSIONS IN NIGERIA.

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ABSTRACT

The study not only examines the impact of foreign direct investment on carbon emissions but also tests the contingency effects of income level on the relationship between them. Employing annual data series from 1980 to 2022 in Nigeria, the study uses dynamic ordinary least squares and Markov-switching techniques to achieve the objectives. The results from dynamic OLS show that foreign direct investment increases carbon emissions. However, from Markov regime switching results, the effect of foreign direct investment on carbon emissions depends on the phase. Without an interaction term, foreign direct investment reduces carbon emissions in the low/repression phase. With an interaction term foreign direct investment increases carbon emission in the expansion phase. Therefore, policymakers need to consider the economic condition in the formulation of foreign direct investment policies that will assist in reducing pollution in Nigeria. The policies of improved credits and increased trade openness must encourage the adoption of low-carbon and environmentally friendly technologies that will facilitate an attainment of the same or even higher output at lower carbon emissions in the country and thereby contribute to the achievement of sustainable development goals (SDG 13).

Keywords: Foreign direct investment, pollution haven, pollution halo, carbon emissions, Markov regime switching, Nigeria

INTRODUCTION

In the past two decades, a broad consensus in the literature is that foreign direct investment plays a critical role in the process of development. Foreign direct investment (fdi) is associated with rapid economic growth, an industrialization process, employment generation, and improved standards of living in the recipient country. The various channels through which fdi impact the development and growth of the recipient country include capital accumulation in the host country, leading to the incorporation of new inputs and technologies into the production function; improved efficiency of the locally-owned host country's firms through demonstration and contract effects and technological upgrading; and hence, diffusion even without significant physical capital accumulation in the start-up, managerial contracts, marketing, licensing agreements, and joint ventures. Other channels are: increased productivity engendered by increased competition and increased exports by the host country.

For these reasons, there was an intense campaign for increased fdi inflows, especially to the developing countries. Sequel to this development, fdi inflows to developing countries continue to grow. For example, the developing countries' global share of fdi increased up to 72% in 2019 in spite of the emergence of the coronavirus (COVID-19). Developing countries' fdi inflows increased from $881 billion in 2021 to $910 billion in 2022 (UNCTAD 2023).

While foreign direct investment inflows to developing economies continue to grow with the potential benefits noted above, their ecological environmental consequences for the host countries are debated worldwide. To this end, theoretical literature has given three perspectives on the link between foreign direct investment and carbon emissions. The first perspective argues that the inflows of fdi to developing countries are as a result of lax environmental regulations, and thus, increased fdi inflows will engender environmental degradation and thus sustainable economic development in the host economies. This view is rooted in the pollution haven hypothesis propounded by Walter and Ugelow (1979), which argues that multinational firms faced with strict environmental management regulations, policies, and enormous compliance costs for production activities in their home countries tends to locate and/or relocate environmentally damaging production activities to resource-rich developing countries with lax environmental regulations. The second view argues that FDI inflows to developing countries enhance environmental quality. The argument is that FDI inflows bring technological improvement to the host country, and hence, better environmental quality (Zarsky 1999, Kim and Adilov 2012, Zhu et al. 2016, Eskeland and Harrison 2006). Abbasi and Riaz 2016). This view is referred to as the pollution halo hypothesis. The third perspective opines that fdi inflow has no relation with carbon emissions. This is referred to as the neutrality hypothesis.

Extensive empirical literature on the relationship between fdi and carbon emissions has yielded competing results, bringing to the fore the complexity in the fdi-carbon emissions and the need for more empirical studies on the relationship. In explaining the complexity of the empirical outcomes, Wang et al. (2022) argue that the level of income could affect the fdi-carbon emissions relationship. It is argued that countries with higher levels of income are likely to receive environment-friendly technologies, and thus, less carbon emissions. One of the arguments is that higher-income countries tend to adopt environmental regulations and various measures to reduce the use of fossil fuels, suggesting that income level affects the stringency of a country's environmental policies. The obverse is the case with low-income countries. In other words, countries with low income become pollution havens for foreign firms, where fdi deteriorates environmental quality, thereby compromising sustainable economic development. The above reasoning suggests testing the contingency effect of income level on the FDI-carbon emissions relationship for Nigeria as against most existing studies that theorize and test only the direct effects of income level.

Therefore, this study is an attempt to fix the perplexity of empirical outcomes on foreign direct investment-carbon emissions nexus in the case of Nigeria. Specifically, we investigate whether foreign direct investment and carbon emissions co-move in the long run, estimate the impact of foreign direct investment on carbon emissions, and check whether income moderates the relationship between fdi and Co2 emissions. To achieve the objectives above, the study analyzes data from Nigeria over 1980-2022, employing dynamic ordinary least squares (DOLS) and Markov regime-witching (MSM) estimation techniques.

The remainder of the paper is structured thus: Section 2 provides the empirical review. In section 3, we describe the data and methodology. The empirical results are provided in section 4. In section 5 is the discussion of the findings. The last section provides the conclusions.

EMPIRICAL LITERATURE

Several studies have probed the nexus between Co2 and fdi with divergent results/findings. Mostly, their findings are dependent on the countries studied and the estimation techniques employed. Some of these results confirmed the pollution haven hypothesis for many countries (see, for example, Cole 2004, Jiang 2015, Opoku and Boachie 2020, De Pascale et al., 2020, Nasir et al., 2019). Likewise, many other studies have provided findings in support of the pollution halo hypothesis, including Kim and Adilov 2012, Bao et al. 2011, Zugravu-Soilita 2017, Solarin and Al-Mulali 2018, and Demena and Afesorgbor 2020). Finally, few studies found no relationship between foreign direct investment and carbon emissions, supporting the neutrality hypothesis (Lee 2013). For brevity, Table 1 provides a highlight of some existing studies on the fdi-Co2 emissions nexus.

Although many existing studies have investigated the link between Co2 emissions and fdi, only a few existing empirical studies focused exclusively on Sub-Saharan Africa. These include Acheampong (2019), Maji et al. (2016), Adams and Opoku (2020), Opoku et al. (2021), Mahmood et al. (2019), and Opoku and Boachie (2020). Adams and Opoku's (2020) study for 22 SSA using the system GMM corroborates the pollution haven hypothesis, while Opoku and Boachie (2020) for 36 African countries using the PMG validate pollution haven. Similarly, Opoku et al. (2021) for 22 SSA countries confirm the pollution halo hypothesis. Country-specific cases by Mahmood et al. (2019) and

Maji et al. (2016) for Egypt and Nigeria, respectively confirm the pollution halo theory. Likewise, Odugbesan and Adebayo's (2020) for Nigeria. However, Solarin et al. (2017) for Ghana confirm the pollution haven hypothesis.

TABLE 1
Summary of empirical studies on fdi-Co2 emissions

STUDIES	COUNTRIES	PERIOD	METHOD	SUPPORTING HYPOTHESIS
Peng el al. (2016)	Provincial Chinese Data	1982-2012	SUR, Panel VAR OLS	Mixed results. Some pollution haven and few pollution halo.
Maji et al. (2016)	Nigeria	1971-2011	ADRL, VECM	Halo Pollution
Behera and Dash (2017)	South and Southern Asia.	1979-2017	Non-Linear TVAR Non-Linear TVECM	Pollution Haven
Abdouli and Omri (2021)	Mediterranean Panel.	1990-2013	DMOLS, DOLS.	Pollution Haven
Khan and Ahmad (2021)	Combined developed and developing countries.	2000-2020	DOLS, GMM, FMOLS	Pollution Haven
Jiang (2015)	28 Chinese Provinces	1997-2012	Fixed Effect (FE)	Pollution Haven
Adams and Opoku (2020)	22 SSA Countries	1995-2014	System GMM	Pollution Halo
Bakhsh et al (2017)	Pakistan	1980-2014	38LS	Pollution Halo
Kim and Adilov (2012)	164 countries	1961-2004	OLS	Pollution Halo
de Pascale et al. (2020)	36 OECD Countries	2000-2017	POLS, DOLS, FE, RE	Pollution Haven
Gorus and Aslan (2019)	9 MENA countries	1980-2013	DOLS	Pollution Haven
Huang et al. (2019)	30 Chinese Provinces	1997-2014	Quantile	Pollution Halo.
Salahuddin et al. (2018)	Kuwait	1980-2013	ARDL, VECM, Granger Causality	Pollution Haven
Liu et al (2018)	285 Chinese cities	2003-2014	Spatial panel	Pollution Halo
Wang et al (2022)	67 Countries	1990-2019	PTRE	Pollution Haven
Zakaria and Bibi (2019)	5 South Asian Countries.	1985-2015	FE	Pollution Halo
Ashraf el al. (2022)	GCC Countries	1999-2016	Non-Linear ARDL	Pollution Haven
Solarin et al. (2017)	Ghana	1980-2012	Cointegration, ARDL	Pollution Haven
Shahbaz et al. (2018)	France	1955-2016	Bootstrapping ARDL	Pollution Haven
Shahbaz et al. (2019)	United States	1965-2016	ARDL	Pollution Haven

Zhang and Zhang (2018)	China	1982-2016	ARDL	Pollution Haven
Zhu et al. (2016)	ASEAN-5 Countries	1981-2011	Panel quantile regression	Pollution Halo
Acheampong (2019)	46 SSA Countries	2000-2015	System GMM	Mixed Outcomes
Khan and Ozturk (2021)	88 Developing Countries.	2000-2014	System GMM	Pollution Haven
Singhania and Saini (2021)	21 Developing Countries	1990-2016	System GMM	Pollution Haven
Balsalobre-Lorente et al. (2019)	MINT Countries	1990-2013	Pedroni cointegration, FMOLS, DOLS.	Pollution Haven
Seker et al. (2015)	Turkey	1974-2010	ARDL, Granger Causality	Pollution Haven
Ozmen and Bali (2024)	BRICS	1992-2020	Smooth Quartile Regression (SIV-QR)	Pollution Haven
Khan et al. (2023)	108 Developing countries	2000-2016	P-VECM	Pollution Haven
Opoku et al. (2021)	22 SSA Countries	1995-2014	System GMM	Pollution Halo
Odugbesan and Adebayo (2020)	Nigeria	1981-2016	Linear ARDL Non-linear ARDL FMOLS, DOLS.	Pollution Halo

METHODOLOGY

Data and Data Sources

The study utilizes annual data from 1980 to 2022 for the estimation of the model. The variables employed in our analysis are carbon emissions (Co2), foreign direct investment (fdi), trade openness (top), ratio of private sector credit to GDP (cpp), energy consumption (lent), per capita income (pci), oil price (oip), population density (pde), urbanization (urb), per capita income squared (pci^2) and an interaction variable, namely the product of foreign direct investment and per capita income (fdi*pci). Data employed are sourced from the World Development Indicators database (World Bank). The price of oil (US$ per barrel) is sourced from the BP Statistical Review of World Energy. All the variables employed are in natural logarithmic form. The definitions of variables and the sources of data are presented in Table 2.

Table 2
Definition of Variables and Data sources

Variables	Definition of variables and sources of data
cpp	credit to the private sector. Source: CBN Statistical Bulletin (2023)
oip	price of oil (US $ per barrel). Source: BP Statistical Review of World Energy (2023)
lent	energy consumption. Source: World Development Indicators (2023)
urb	urbanization. Source: CBN Statistical Bulletin (2023 edition)
Co2	carbon emissions (millions metric tons). Source: World Development Indicators (2023).
pci	per capita income.
top	trade openness. Export plus imports over GDP
fdi	foreign direct investment
pde	population density

Model Specification

In this study, we use a variant of Dietz and Rosa's (1994) Stochastic Impacts by Regression of Population, Affluence, and Technology (STIRPAT) model incorporating explicitly fdi as an argument. Two models are specified. Model 1, the basic model, incorporates the main independent variables. Model 2 extended the model 1 by including the interaction term. The two models explicitly stated are:

$$Co2_t = (fdi_t, top_t, cpp_t, lent_t, pci_t,) \quad (1)$$

$$Co2_t = (fdi_t, top_t, cpp_t, lent_t, pci_t, oip_t, fdi_t*pci_t) \quad (2)$$

Equations (1) and (2) are stated explicitly as:

$$Co2_t = \alpha_0 + \alpha_1 fdi_t + \alpha_2 ltop_t + \alpha_3 cpp_t + \alpha_4 ent_t + \alpha_5 pci_t + \alpha_6 oip_t + \varepsilon t \quad (3)$$

$$Co2_t = \alpha_0 + \alpha_1 fdi_t + \alpha_2 ltop_t + \alpha_3 cpp_t + \alpha_4 ent_t + \alpha_5 pci_t + \alpha_6 oip_t + \alpha_7 fdi_t*pci_t + \varepsilon t \quad (4)$$

where *Co2* is carbon emissions, cpp denotes private sector's credit to GDP ratio, fdi is foreign direct investment, top is trade openness, pci is per capita income, lent represents energy consumption, oip denotes price of oil, fdi*pci represents the product of per capita income and foreign direct investment, and ε denotes the residual. The effects of the other variables, namely population density (pde), urbanization (urb), and per capita income squared (pci^2) are examined in our estimation.

Estimation Techniques

In estimating equations (3) and (4), the dynamic ordinary least squares (DOLS) and Markov switching regime[1] estimation techniques are employed. Next, we proceed to apply the Johansen-Juselius (1990) cointegration test[2]. To identify which variable is endogenous (weak) or exogenous (strong), we introduce the Vector Error Correction Model (VECM). However, as the VECM can only show the absolute exogeneity or endogeneity of a variable but not the relative endogeneity or exogeneity, we proceed to generate the variables' variance decompositions (VDCs) through which the latter is determined. Next, we generate the impulse response functions (IRFs) to find the impact of shocks to one variable on others. This assists in ascertaining not just the magnitude of the response but also the normalization duration.

EMPIRICAL RESULTS

The descriptive statistics and pairwise correlations of the data series are shown in Tables 3 and 4, respectively. From Table 3, per capita income has the highest mean, while the ratio of the private sector's credit to GDP has the lowest. Co2 emissions and the private sector's credit to GDP ratio have the lowest values compared to other variables. This suggests that cpp and Co2 series are steady from 1980-2022. The coefficient of correlation of the independent variables is less than 0.7, thus ruling out the likelihood of multicollinearity between the independent and dependent variables (see Table 4). The pairwise correlation results reveal that all the independent variables are negatively related to Co2 emissions.

TABLE 3
Descriptive statistics

Variable	Co2	fdi	top	cpp	lent	pci
Mean	0.605	1.457	32.306	0.115	682.639	31581.80
Standard Deviation	0.170	1.525	12.616	0.058	85.933	42209.87
Minimum	0.326	0.010	9.140	0.059	333.973	137.59
Maximum	0.928	5.790	53.280	0.0247	798.63	129397.0

[1] The beauty of using Markov Switching Regime technique as additional estimation technique is that it permits the coefficients of the regression and the variances to be regime- or state dependent (Reboredo, 2010). Moreover, the results of MSM will serve as robustness check for the findings from the dynamic OLS.
[2] This technique compared with the Engle and Granger approach is not only capable of observing the existence of more than one cointegration in the system but also provides the certainty of cointegration.

TABLE 4

SPEARMAN rank Correlation

Variable	Co2	fdi	top	cpp	lent	pci
Co2	1.000					
fdi	-0.303	1.000				
top	-0.251	0.479	1.000			
cpp	-0.094	0.218	0.025	1.000		
lent	-0.387	0.310	0.361	0.543	1.000	
pci	-0.279	0.176	0.253	0.838	0.661	1.000

Results of unit root test

The results of the unit roots are shown in Table 5 for level and first difference using PP and ADF. In both cases, stationarity is established for all the variables at first difference. Having established that the variables are I(1), we employed the Johansen-Juselius (1990) cointegration test to ascertain if there is at least one linear combination of these variables that is I(0). The results of the trace and λ-max tests are as shown in Table 6. The results indicate that the null hypothesis of no co-integration is rejected using either λ-max or trace test statistics. In both cases, the results established one cointegration only.

TABLE 5

Unit root results

	ADF		PP	
Serial Name	Level	First Difference	Level	First Difference
Co2	-2.095	-4.211***	-2.149	-6.261***
fdi	-1.979	-5.225***	-4.505	-9.245***
top	-1.863	-4.801***	-2.400	-8.104***
lent	-2.242	-3.231**	-2.271	-7.356***
cpp	-0.893	-5.620***	-0.799	-5.838***
pci	-1.686	-3.049**	-1.182	-2.944**
oip	-0.904	-4.988***	-0.942	-6.234***
pde	-0.882	-4.316***	-0.570	-8.890***
urb	-1.771	-5.147***	-2.088	-8.883***

TABLE 6

Co-interpretation results (including a constant) r being the number of co-interpretation rating vectors.

Null	Alternative r	λ-max	CV (95%)	Trace	CV (95%)
0	1	46.794	40.078	100.020	95.754
≤*1*	2	18.049	33.877	53.227	69.819
≤2	3	15.935	27.584	35.177	14.856
≤3	4	10.856	21.132	19.242	29.797
≤4	5	5.608	14.264	8.386	15.495
≤5	6	2.778	3.841	2.778	3.841

Although the variables are cointegrated, it is not clear which ones are endogenous or exogenous. Hence, we present the results of the VECM through which the variables included in the model are classified into either endogenous (weak) or exogenous (strong). The error correction term (ecm_{t-1}) lagged one period constitutes the focal point for the identification. The error term is the speed of adjustment that assists in knowing how long it takes to revert back to equilibrium when there is a shock to the adjustment variable. The outcomes are shown in Table 7.

TABLE 7
Vector Error Correlation Estimate for Variables

$ecm_{(-1)}$	Coefficient	T-Ratio (prob)	Significant	Result
ΔCo2	-0.233	-2.228**	Significant	Endogenous
Δfdi	-0.666	-2.343**	Significant	Endogenous
Δtop	-0.026	-0.464	Not significant	Exogenous
Δlent	-2.701	-3.464***	Significant	Endogenous
Δcpp	-0.004	-0.331	Not significant	Exogenous
Δpci	0.016	2.012**	Significant	Endogenous

As revealed in Table 7, four variables are endogenous: carbon emissions (Co2), foreign direct investment (fdi), energy use (lent), and per capita income (pci) are endogenous as the coefficients are significant. The other variables, namely the ratio of the private sector's credit to GDP (cpp) and trade openness (top) are not significant and thus exogenous. The main inference from this finding is that a shock to any of the endogenous variables will produce a significantly strong impact on the exogenous variables. Despite knowing the variables that are endogenous and exogenous using VECM, it is incapable of determining the relative degree of a variable's exogeneity and endogeneity. Hence, the recourse to variance decompositions (VDCs) of the variables. Essentially, any variable whose variance depends on its own past innovation rather than the innovations from other variables is the most exogenous variable. The VDCs for 3, 6, and 9 periods are presented in Table 8. The variable with the highest rank is the leading variable and becomes the immediate target variable. As revealed in Table 8, foreign direct investment (fdi) is the most exogenous. This is followed by energy use (lent), while the ratio of the private sector's credit to GDP (cpp), and trade openness (top) followed as third and fourth, and carbon emissions (Co2) and per capita income (pci) as fifth and sixth, respectively. The high exogeneity of foreign direct investment (fdi) can be attributed to the critical role it plays in the economy through capital accumulation, human capital augmentation, increased efficiency of local firms, technological change, and increased exports in the host country.

TABLE 8
Orthogonalized Variance Decomposition

Variable	Horizon	Co2	fdi	top	cpp	lent	pci	Total
Co2	3	77.224	1.134	4.850	3.288	5.862	7.643	100
fdi	3	2.547	80.052	2.287	3.342	1.679	10.094	100
top	3	2.253	5.359	78.218	5.065	8.938	0.173	100
cpp	3	1.687	1.998	1.416	78.317	16.379	0.203	100
lent	3	9.790	24.114	7.099	1.475	53.837	3.685	100
pci	3	4.947	14.493	1.795	2.985	59.312	16.467	100
Exogeneity		77.244	80.052	78.218	78.317	59.312	16.467	
RANK		4	1	3	2	5	6	
Co2	6	40.548	9.348	4.105	2.805	36.501	6.693	100
fdi	6	5.022	47.365	2.989	2.317	36.919	5.388	100
top	6	9.123	2.528	52.759	1.304	32.691	1.595	100
cpp	6	3.729	10.431	4.061	56.461	21.333	3.984	100
lent	6	11.790	15.202	4.511	0.849	61.774	5.875	100
pci	6	6.719	7.761	12.972	3.402	46.117	23.030	100
Exogeneity		40.548	47.365	52.759	56.461	61.774	23.030	
RANK		5	4	3	2	1	6	
Co2	9	23.938	19.761	7.510	1.963	39.829	6.999	100
fdi	9	5.607	49.877	4.193	2.381	30.170	7.772	100
top	9	5.822	16.458	35.625	1.246	33.528	7.320	100
cpp	9	7.195	14.710	6.397	19.525	47.620	4.552	100
lent	9	8.391	18.818	8.238	1.595	55.732	7.226	100
pci	9	6.629	16.187	10.952	1.797	48.628	16.167	100
Exogeneity		23.938	49.877	35.625	19.525	48.268	16.167	
RANK		4	1	3	5	2	6	

Exogeneity order: fdi ⇒ lent ⇒ cpp ⇒ top ⇒ co_2 ⇒ pci

Furthermore, we generate the impulse response functions to ascertain not just the magnitude of each variable's response but also to know how long it takes the process to normalize. Figs. 1, 2, and 3 show the charts for periods of 10, 20, and 30 years. A shock to the endogeneity variable, namely per capita income, has a profound effect on the exogenous variables. As revealed in Figs.1-3, carbon emissions, energy use, the private sector's credit to GDP ratio, foreign direct investment, and trade openness respond relatively fast to a perturbation in per capita income. The same applies to the rest of the variable's shocks, with shorter responses and normalization being more visible when impulses over 20-30 years.

Fig, 1: Plot of Impulse Response Functions (IRFs) for 10 periods

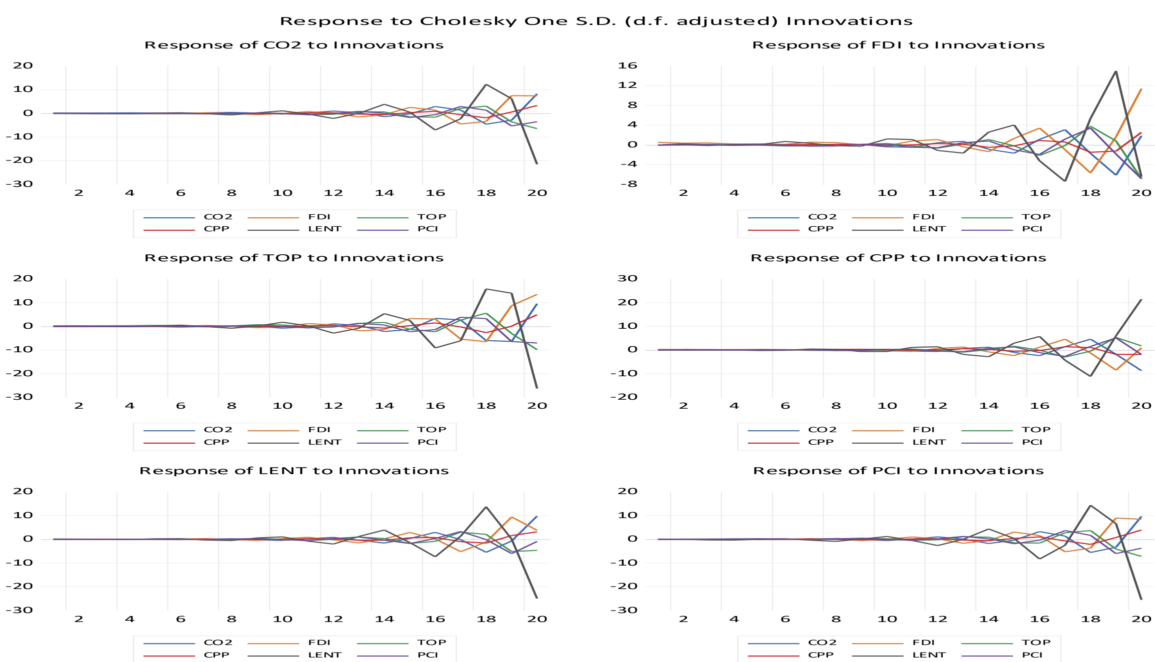


Fig. 2: Plot of Impulse Response Functions (IRFs) for 20 periods

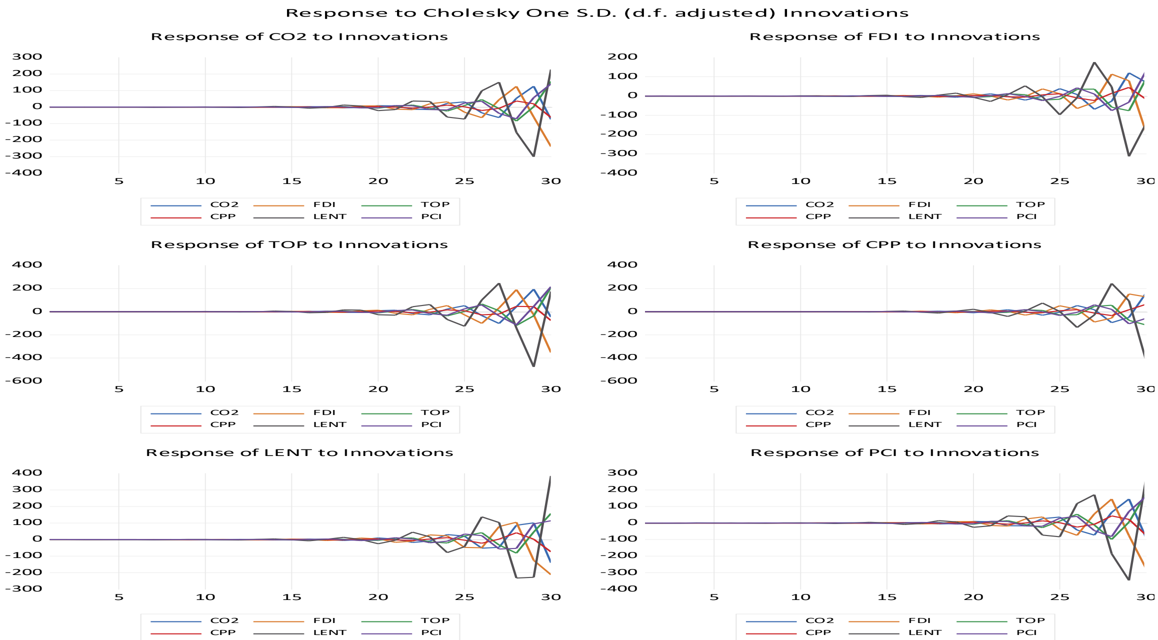


Fig. 3: Plot of Impulse Response Functions (IRFs) for 30 periods

Results of dynamic OLS

To ascertain the effect of foreign direct investment on carbon emissions, equation 2 is estimated using the DOLS estimation technique. The outcomes are presented in Table 10. Models 1-5 are outcomes where the interaction term is excluded, while models 6-8 include the interaction term. From columns 1-6, foreign direct investment has an insignificant positive relation with carbon emissions except in column 1, where it is significant. In column 1, a percentage (1%) increase in foreign direct investment causes carbon emissions to increase by 0.546%. In contrast, the relationship turns negative, though insignificant, when the interaction variable fdi*pci is included in models 7-8. For other variables, trade openness has a significant negative association with carbon emissions, except in model 5, where it is positive and insignificant. This implies that trade openness reduces carbon emissions. The results reveal a negative association between carbon and the ratio the private sector's credit to GDP, except in model 4, where it is positive and significant. While energy use has a negative and significant link with carbon emissions, the association between per capita income and carbon emissions is significantly positive. Using model 1 as a lead, a 1% increase in energy use and per capita income causes carbon emissions to reduce by 8.083% and increase by 0.28%, respectively. The variable population density is negative, meaning that population density reduces carbon emissions, while the price of oil is positive except in model 4, where the coefficient is negative and significant. The interaction of foreign direct investment and per capita income has no significant effect on carbon emissions, suggesting that income plays no significant moderating role in the relationship between foreign direct investment and carbon emission nexus in Nigeria.

Table 10
DOLS with CO2 as Dependent Variable

Var	1	2	3	4	5	6	7	8
C	52.865***	-4.592	-0.816	62.278**	22.281	71.380***	28.050	-0.465
	(13.757)	(29.226)	(2.305)	(21.531)	(17.198)	(22.891)	(35.114)	(2.224)
fdi	0.546***	0.581*	0.014	0.499	0.133	0.692	-12.813	-0.098
	(0.0167)	(0.332)	(0.081)	(0.360)	(0.275)	(0.490)	(20.204)	(0.288)
top	-0.910***	-1.086***	-0.449**	-1.364**	0.314	-0.702***	-1.422***	-0.508***
	(0.209)	(0.329)	(0.188)	(0.584)	(0.528)	(0.231)	(0.437)	(0.182)
cpp	-0.298	-0.057	-0.466*	2.459***	-1.079	-0.735***	-1.095**	-0.433**
	(0.270)	(0.494)	(0.257)	(0.639)	(0.907)	(0.211)	(0.530)	(0.253)
lent	-8.083***	1.535	-0.141**	-3.205	-7.271*	-11.231***	-4.488	-0.152
	(2.151)	(4.797)	(0.058)	(2.290)	(4.701)	(3.567)	(5.336)	(0.330)
pci	0.280***	-0.455	0.041	1.824**	-0.377	0.340***	0.392***	0.059
	(0.045)	(0.799)	(0.058)	(0.809)	(0.500)	(0.036)	(0.080)	(0.056)
pci^2		0.019						
		(0.046)						
pde				-16.067**				
				(6.22)				
oip			0.379**	-2.642***	0.635			0.316**
			(0.125)	(0.553)	(0.471)			(0.142)
urb					5.977			
					(5.470)			
pci*fdi						0.013	2.069	0.018
						(0.040)	(3.662)	(0.032)
R^{-2}	0.7404	0.7558	0.7612	0.7928	0.8054	0.8071	0.7059	0.7712

Note: The figures in bracket are the error terms

Markov- Regime Switching results

To verify the constancy of the coefficients reported in Table 10 over the study period, we re-estimate our model using a Markov regime-switching technique (MSM). Table 11 presents the results of the estimation. There are two sections, A and B, in the table. Section A comprises three columns, 1-3. Column 1 is the normal DOLS estimation. Columns 2-3 represent the two regimes, namely 1 and 2, of the MSM estimation of column 1. The B section is similar to A, except for the inclusion of the interaction variable. Essentially, section A is a regime-switching analysis of the 3rd column of Table 10, while section B is the 8th column of Table 10. In Section A, the effect of foreign direct investment is different for both regimes. The MSM results as shown in Table 11 reveal that foreign direct investment reduces carbon emissions in Regime 1 of the model without an interaction term (Model A) and Regime 2 of the model with an interaction term (Model B). However, foreign direct investment increases carbon emissions in Regime 1 of the model with an interaction term (Model B). In line with the results from the DOLS, the coefficient of the interaction variable (fdi x pci) is not significant for both regimes. One major finding from MSM results is that when economic phases/conditions are considered, the relationship between fdi and carbon emissions is significantly positive in Regime 1 and negative in Regime 2. If we differentiate Co2 with respect to fdi, the overall impact of fdi on Co2 can be compared.

With respect to regime 1, we calculate the overall impact as:

Co2 = 0.285 + (-0.034*pci)

Substituting 0.100 for pci

Co2 = 0.285 + (-0.034*-0.100)

Co2 = 0.285 + 0.0034

Co2 = 2.2884

For regime 2

Co2 = -0.109 + (0.010*pci)

Substituting 0.034 for pci

Co2 = -0.109+ 0.010*0.034

Co2 = -0.109+0.00034

Co2 = -0.1087

From the computation above, the total effect of fdi on Co2 emissions with the inclusion of the interaction variable in the model is 0.2884 for regime 1 and -0.1087 for regime 2. Two main inferences can be drawn for the results. One, the effect of fdi on carbon emissions is regime dependent. Two, income has a very insignificant moderating effect on the relationship between foreign direct investment and carbon emissions.

As regards other variables in MSM results, trade openness reduces carbon emissions in both regimes, supporting the results from DOLS. The ratio of the private sector's credit to GDP reduces carbon emissions in Regime 1 of the model without an interaction term (Model A) and Regime 2 of the model with an interaction term (Model B). However, the ratio of the private sector's credit to GDP increases carbon emissions in Regime 2 of the model without an interaction (Model A) and Regime 1 of the model with an interaction term (Model B). Energy use reduces carbon emissions in both regimes, in line with the DOLS results. Per capita income reduces carbon emissions in Regime 2 of the model without interaction term and Regime 1 of the model with an interaction term (Model B). Oil price increases carbon emissions in both models with and without an interaction term, though the coefficient is significant in some phases.

Table 11

Results of the Markov Regime-Switching Model

Section	A			B		
Variable	Normal	Regime 1	Regime 2	Normal	Regime 1	Regime 2
C	-0.816	2.564**	-1.775**	-0.465	1.833**	-2.505**
	(2.305)	(0.957)	(0.864)	(2.224)	(0.892)	(1.008)
fdi	0.014	-0.034**	0.041	-0.098	0.285**	-0.109**
	(0.081)	(0.016)	(0.038)	(0.288)	(0.146)	(0.047)
top	-0.449**	-0.081*	0.393**	-0.508**	0.301***	-0.109**
	(0.188)	(0.044)	(0.137)	(0.182)	(0.100)	(0.044)
cpp	-0.466*	-0.398***	0.298**	-0.433*	0.307**	-0.394***
	(0.257)	(0.087)	(0.114)	(0.253)	(0.110)	(0.096)
lent	-0.141**	-0.170***	-0.237**	-0.152	0.217**	-0.158***
	(0.058)	(0.037)	(0.094)	(0.330)	(0.086)	(0.039)
pci	0.041	0.021	-0.116***	0.059	-0.100***	0.034
	(0.058)	(0.021)	(0.026)	(0.056)	(0.026)	(0.022)
oip	0.379***	-0.027	0.0282	0.316**	0.315***	-0.054
	(0.125)	(0.039)	(0.055)	(0.142)	(0.049)	(0.045)
fdi*pci				0.018	-0.034	0.010
				(0.032)	(0.118)	(1.541)
R^{-2}	0.76			0.77		

Note: The figures in bracket are the error term

Next, we identify the nature of the two regimes. First, from the transition matrix for Model A in Table 12, the probability that it remains in regime 2 given that the economy is already in regime 2 is 86%. In contrast, the probability that at time t-1, it remains in regime 1 is 93%. However, for Model B shown in Table 13, the probability that it remains in regime 2 given that the economy is already in regime 2 is 92%, while the likelihood that it remains in regime 1 given that the economy is already in regime 1 is 86%.

TABLE 12
Transition Probabilities A

	Regime 1	Regime 2
Regime 1	0.93	0.07
Regime 2	0.14	0.86

TABLE 13
Transition Probabilities B

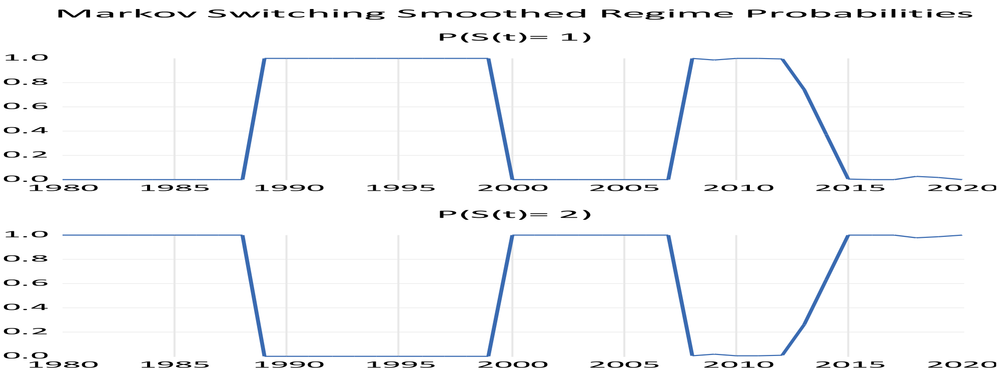
	Regime 1	Regime 2
Regime 1	0.86	0.14
Regime 2	0.08	0.92

As shown in Table 14, the expected durations for Model A in regimes 1 and 2 is 14.00 and 6.9 years, respectively. For Model B, the expected durations for regimes 1 and regime 2 are 7.26 and 13.45 years, respectively.

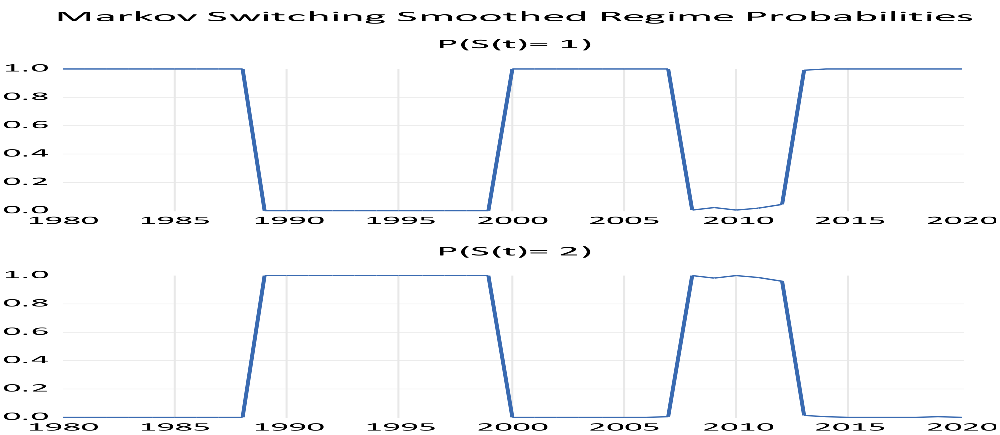
Table 14
Expected Duration

Regime	Model A	Model B
Regime 1	14.00	7.26
Regime 2	6.90	13.25

Next, from the transition probabilities, we try to observe the time duration (regime classification) of smoothed probabilities. Figs. 4A1 and 4A2 represent regime identification with regards to Model A, while Figs. 4B1 and 4B2 give smoothed probabilities for Model B. As revealed in Fig. 4A1, Regime time points are 1990-1998 and 2008-2012. Thus, the only way to characterize regime 2, is the obverse of regime 1. A look at Fig. 4B1 and 4B2 reveal that regime 1 time points are 1988, 2000, 2007, and 2013, while for regime 2, they are 1990-1999 and 2008-2012. Comparing the regime points for Models A, and B, we observe the significant similarities between regime 1, Model A and regime 2, Model B. Likewise for Regime 2 of Model A, and Regime 1 of Model B. It is interesting to know some realizations of the Nigerian economy that correspond to Regimes 1 and 2 of Model A. The period 1990-1998 was characterized by internal insurrection (1990 coup d'état), political unrest following the cancellation of the 1993 general elections, and the NLC strike of 1994. Besides, the period witnessed external shocks such as the Gulf War in the Middle East, the decline in oil prices, and the Global financial crisis of 2007/2008. In the same way, the period 2001-2012 witnessed both economic crises and downturns. The period was also characterized by external factors such as the Great Recession.



Figs. 4A1 and 4A2: The Smoothed Probabilities for Regimes 1 and 2 of Model A.



Figs. 4B1 and 4B2: The Smoothed Probabilities for Regimes 1 and 2 of Model B.

We present the graphical representation of MSM diagnostic tests of Models A and B as shown in Figs. 5 and 6, respectively. The two figures are quite similar and clearly show that the residuals form random plots around the line that passes through point zero, thereby satisfying the requisite condition for making the model Best, Blue, and Unbiased Estimates (BLUE). Consequently, the residuals must be normally distributed with a mean of zero.

Model A

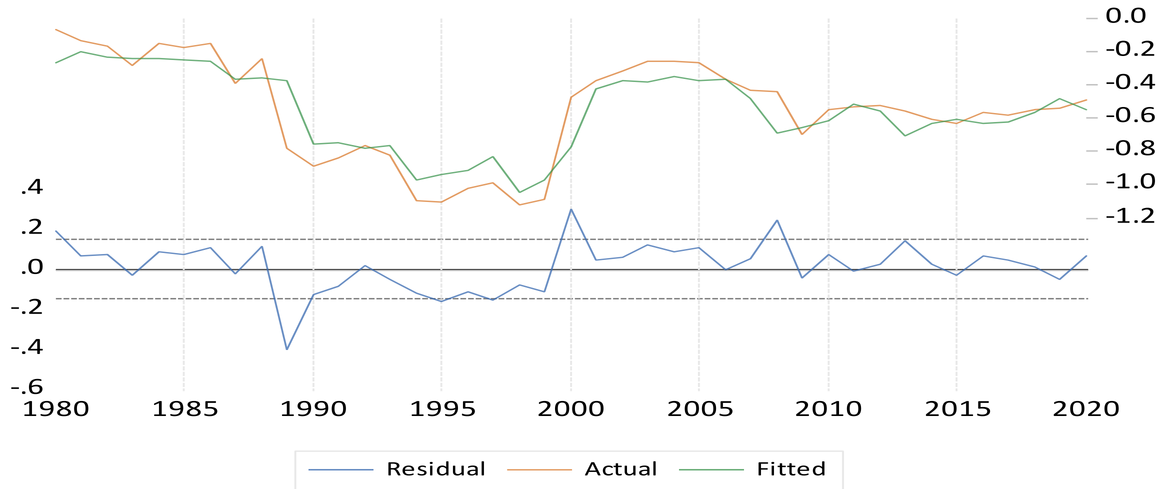


Fig. 5: Plot of residuals, actual, and fitted values of Model A

Model B

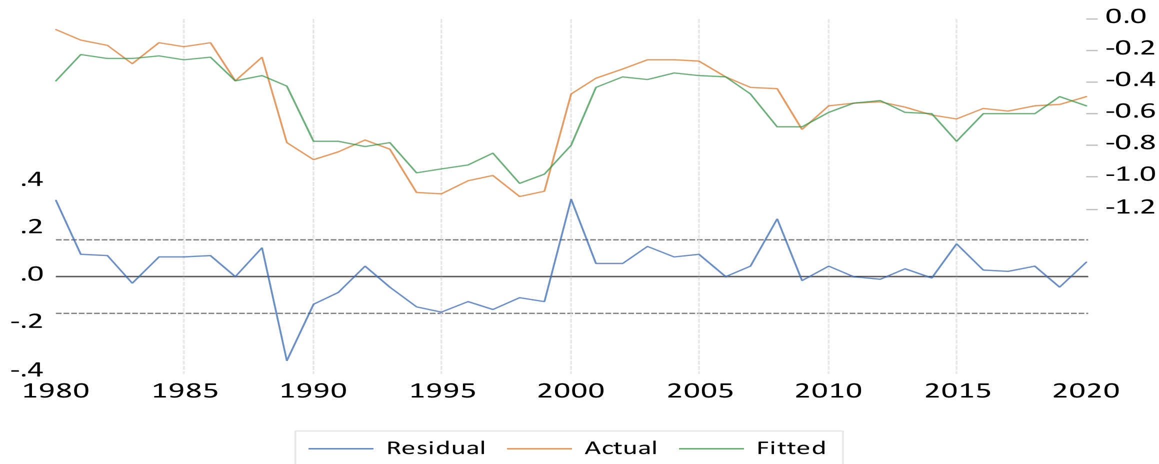


Fig. 6: Plot of residuals, actual, and fitted values of Model B

Discussion of Findings

The Johansen-Juselius (1990) cointegration test shows that the variables of the model are cointegrated, implying that the foreign direct investment on carbon emissions trends together in the long run, showing that the link between the two has a theoretical basis. Moreover, our results show that foreign direct investment is the most exogenous variable amongst the variables employed; hence, it can be targeted by policymakers in the country. Also, being the most exogenous variable shows that the foreign direct investment inflows are determined by external factors that are beyond the control of policymakers in Nigeria. For example, the economic climate of the foreign direct investment-sending countries is critical to the volume of foreign direct investment into the host countries. This factor is beyond the control of foreign direct investment host countries. Even internal factors such as insurgencies, corruption, and the like that have a significant impact on foreign direct investment are, to a reasonable extent, difficult to control in Nigeria.

Using DOLS estimation, fdi standalone increases carbon emissions. This tends to support the pollution haven hypothesis[3]. In the developing economies, it is contended that the scale effects of foreign direct investment tend to dominate the technique effects. Consequently, fdi will boost economic activities, thereby precipitating natural resources' depletion and environmental degradation (Antweiler et al. 2001). In this case, sustainable development will be adversely affected. However, our result contradicts the findings of a few other studies that reported a negative link between Co2 emissions and foreign direct investment (see Rafique et al. 2020, Odugbesan and Adebayo 2020). Trade openness is inversely related to Co2 emissions, suggesting that opening up the economy for trade will assist in reducing Co2 emissions. This result supports the findings of Boamah et al. (2023), and Karedia et al. (2021). However, the outcome contradicts the results of Jabli et al. (2019), Zeng et al. (2019), and Khan et al. (2023). The possible reason for this finding could be that increased openness allows developed countries to shift their clean industries and more effective technology practices to the country and thus reduce Co2 emissions. This development will enhance sustainable development given the fact that carbon emissions pose serious challenge to sustainable development by causing climate change on a worldwide scale.

The results equally reveal that financial development, measured as private sector's credit to GDP ratio, is negative. This result corroborates the findings of Jalil and Feridun (2011). This finding suggests that more credit to the private sector may lead to the adoption of environment-friendly technologies and more effective technology management practices in the economy. Meanwhile, the results contradict the findings of Broni et al. (2020), and Taghavee et al. (2016). Energy use is inversely associated with CO2 emissions. This means that energy consumption reduces Co2 emissions. Our result is inconsistent with the findings of Broni et al. (2020) and Khan et al. (2023). Per capita income is directly related to Co2 emissions. The result supports a large body of literature showing that increased economic activities adversely impact the quality of the environment (Solarin et al. 2017, Xie et al. 2019, Khan et al. 2023). This finding corroborates the 'affluence effect', as increasing economic activities lead to increased production with adverse effects on the environment. (Wang et al. 2016, Abid 2017, Mahmood et al. 2019, Khan et al. 2023). However, the finding contradicts the results of Adewuyi and Awodumi (2017) and Zubair et al. (2020).

The coefficient of urbanization is positive, consistent with Omri et al.'s (2015) but not significant. Oil prices are positively linked with carbon emissions, meaning that increased oil prices lead to increased carbon emissions. This result, however, contradicts the findings of Mahmood et al. (2019) and Attala et al. (2018). The finding should not come as a surprise, since over the years, the oil price has been massively subsidized in Nigeria. The domestic price of oil is far below the international price; thus, even when the domestic price is increased, it has little or no effect on energy use. This simply suggests that under the present oil-subsidized regime, the energy price policy may be ineffective as a policy for reducing carbon emissions in Nigeria.

From the Markov regime-switching results, foreign direct investment reduces carbon emissions in Regime 1 of the model without the interaction variable (Model A) and in Regime 2 of the model with the interaction term (Model B). In contrast, foreign direct investment increases carbon emissions in Regime 1 of the model with the interaction term (Model B). This seems

[3] A large number of studies have laid credence to PHH in developing countries (see the works of Solarin et al. (2017, Khan and Ozturk 2021, Khan et al. 2023)

to suggest that the effect of foreign direct investment on carbon emissions depends on the economic phase or condition in the country. With respect to MSM Model A, the regime 1 time points are 1990-1998 and 2008-2012. In model A, Regime 1, foreign direct investment enhances environmental quality because it reduces Co2 emissions. The reverse is the case in Regime 2, though the coefficient is not significant. As for the outcomes of MSM in Model B, foreign direct investment worsens the environment because foreign direct investment increases carbon emissions, while for Regime 2, it improves the environment. For Model B, Regime 1 time points are 1988, 2000, 2007, and 2013. However, for Regime 2, the time points are 1990-1999 and 2008-2012.

CONCLUSION

The objectives of the paper are to firstly, determine the long run co-movement of fdi and Co2 emissions, secondly, estimate the effect of foreign direct investment on carbon emissions, and thirdly, check whether income moderate the relationship between foreign direct investment and carbon emissions. The paper employs DOLS and MSM estimation techniques to achieve the above-stated objectives over 1980-2022.

The results confirm a long-run relationship between carbon emissions and foreign direct investment. The results from DOLS show that foreign direct investment increases carbon emissions and thus sustainable development. However, when business cycles or economic conditions are considered, the effect of foreign direct investment on carbon emissions depends on the economic conditions. It reduces carbon emissions in Regime 1 of the model without the interaction term and Regime 2 in the model with an interaction term. Contrariwise, foreign direct investment increases carbon emissions in Regime 1 of the model with the interaction term. Furthermore, the results show that trade openness helps to reduce carbon emissions. Also, the ratio of the private sector's credit to GDP enhances environmental quality as it reduces carbon emissions. The results equally reveal that energy use assists in reducing carbon emissions. The results show that per capita income increases carbon emissions in Nigeria, thus supporting the 'affluence effect' hypothesis.

The implications of the findings are that firstly, the economic conditions must be taken into consideration when formulating fdi policies that will reduce Co2 emissions in Nigeria. Secondly, the policy of trade liberalization needs to be pursued vigorously, as trade openness reduces carbon emissions. However, this must be accompanied by strict enforcement of all environmental regulations designed to control carbon emissions. Thirdly, there is a need for policymakers to promote the development of the financial sector. In particular, efforts must be geared towards making more credit available to the private sector to enable them to procure environmentally friendly equipment that will help reduce carbon emissions. This is particularly important considering the fact that increased economic activities tend to hurt the environment. Policymakers must promote the adoption of low-carbon emissions technologies that will facilitate the attainment of the same or even higher output level with lower carbon emissions in the long run. This is important because the achievement of lower carbon emissions will lead to sustainable development in the country.

This current study has examined the nexus between aggregate foreign direct investment and carbon emissions in Nigeria. However, there is a need to ascertain whether the types of foreign direct investment namely oil fdi, manufacturing fdi among others, have the same effects on carbon emissions in Nigeria.

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