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TRADE OPENNESS, FOREIGN DIRECT INVESTMENT AND ENVIRONMENTAL SUSTAINABILITY NEXUS IN NIGERIA

OTWARTOŚĆ HANDLOWA, BEZPOŚREDNIE INWESTYCJE ZAGRANICZNE I RÓWNOWAGA ŚRODOWISKOWA W NIGERII

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Abstract

Subject and purpose of work: Although foreign direct investment has the potential to promote sustainable economic growth, research shows a troubling pattern: some countries that attract these investments become "pollution havens" for developed nations. On the other hand, various researchers are of the notion that FDI has the potential to promote sustainability if there are stringent environmental regulations. This has led to a serious debate between the "Pollution Haven" and "Porter" hypotheses. Accordingly, the purpose of this study is to determine which of these hypotheses holds, by examining the impact of trade openness and foreign direct investment on Nigeria's environmental sustainability.

Materials and methods: The variables of interest are total greenhouse gas emissions, foreign direct investment (FDI), trade openness, access to electricity, access to clean fuels and technology, and urban population. The Dynamic Ordinary Least Squares (DOLS) estimation technique was deployed in this study.

Results: The study's findings indicate that foreign direct investment (FDI) has a statistically significant negative long-run effect on Nigeria's overall greenhouse gas (GHG) emissions. This robust result, with a coefficient of -0.10478 and a probability of 0.0012, lends strong support to the Porter Hypothesis. While trade openness also exhibits a negative long-run association with GHG emissions, its effect was not found to be statistically significant, showing a coefficient of -0.00166 and a probability of 0.4122.

Conclusions: As a result, the report suggests that the Nigerian government supports the creation of compressed natural gas (CNG) stations and the switch to CNG-powered vehicles. The Nigerian government can also promote investment in the green energy industry by offering tax holidays and other benefits to companies operating in this field. Furthermore, there should be

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a widespread public education campaign on the threat posed by global warming and the necessity of planting trees to mitigate the effects of climate change and discourage tree-cutting.

Keywords: Trade, Environment, Foreign Direct Investment

Streszczenie

Przedmiot i cel pracy: Chociaż bezpośrednie inwestycje zagraniczne mają potencjał do promowania zrównoważonego wzrostu gospodarczego, badania pokazują niepokojący wzorzec: niektóre kraje, które przyciągają te inwestycje, stają się „rajami zanieczyszczeń" dla krajów rozwiniętych. Z drugiej strony, różni badacze są zdania, że BIZ mają potencjał do promowania zrównoważonego rozwoju, jeśli istnieją rygorystyczne przepisy dotyczące ochrony środowiska. Doprowadziło to do poważnej debaty między hipotezami „raju zanieczyszczeń" i „Portera". W związku z tym, celem niniejszego badania jest określenie, która z tych hipotez jest prawdziwa, poprzez zbadanie wpływu otwartości handlowej i bezpośrednich inwestycji zagranicznych na zrównoważony rozwój środowiskowy Nigerii.

Materiały i metody: Zmienne będące przedmiotem zainteresowania to całkowita emisja gazów cieplarnianych, bezpośrednie inwestycje zagraniczne (BIZ), otwartość handlowa, dostęp do energii elektrycznej, dostęp do czystych paliw i technologii oraz populacja miejska. W badaniu zastosowano dynamiczną technikę estymacji metodą najmniejszych kwadratów (DOLS).

Wyniki: Wyniki badania wskazują, że bezpośrednie inwestycje zagraniczne (BIZ) mają statystycznie istotny negatywny długoterminowy wpływ na ogólną emisję gazów cieplarnianych (GHG) w Nigerii. Ten solidny wynik, ze współczynnikiem -0,10478 i prawdopodobieństwem 0,0012, stanowi silne wsparcie dla hipotezy Portera. Podczas gdy otwartość handlowa również wykazuje ujemny długoterminowy związek z emisjami gazów cieplarnianych, jej wpływ nie okazał się statystycznie istotny, wykazując współczynnik -0,10478.

Wnioski: W rezultacie raport sugeruje, że rząd Nigerii wspiera tworzenie stacji sprężonego gazu ziemnego (CNG) i przejście na pojazdy napędzane CNG. Nigeryjski rząd może również promować inwestycje w branżę zielonej energii, oferując wakacje podatkowe i inne korzyści dla firm działających w tej dziedzinie. Ponadto należy przeprowadzić szeroko zakrojoną kampanię edukacyjną na temat zagrożeń związanych z globalnym ociepleniem i koniecznością sadzenia drzew w celu złagodzenia skutków zmian klimatycznych i zniechęcenia do wycinki drzew.

Słowa kluczowe: handel, środowisko, bezpośrednie inwestycje zagraniczne

1. Introduction

The alarming truth is that the Earth is suffering, with serious concerns about environmental degradation and the impact of foreign direct investment. Despite witnessing numerous technological advancements and groundbreaking innovations today, we continue to delay our commitment to environmental sustainability. Although foreign direct investment has the potential to promote sustainable economic growth, research shows a troubling pattern: some countries that attract these investments become "pollution havens" for developed nations, resulting in environmental harm when these investments are not properly managed. On the other hand, various researchers are of the notion that FDI has the potential to promote sustainability if there are well-designed and stringent environmental regulations. This has led to an ongoing debate – The Pollution-Haven (PH) versus the Porter Hypothesis (PHH), which offer opposing views on the nexus between foreign direct investment, trade liberalization, and environmental degradation. By definition, foreign direct investment (FDI) involves an investor acquiring a substantial ownership stake (typically 10% or more) in a company operating in another nation, implying active management involvement (Bilawal et al., 2014). Conversely, trade openness (TOP) measures a nation's propensity for international commerce, typically as the proportion of its GDP derived from total imports and exports (United Nations, 2023).

While trade liberalization can spur economic growth, which historically has been linked to increased resource consumption and pollution, proponents argue that as economies mature and citizens demand a cleaner environment, economic growth can eventually lead to improved environmental sustainability (Mahmood, Maalel, and Zarrad, 2019). In the global context, the empirical evidence on this debate remains largely inconclusive and often contradictory. Some studies, for instance, find support for the PHH, particularly in developing regions (Aliyu and Ismail, 2015; Gharnit et al., 2019; Duan and Jiang, 2021). Conversely, a significant body of research supports the Porter Hypothesis, indicating that FDI can be a conduit for cleaner technology transfer and improved environmental performance (Solarin et al., 2017; Wang et al., 2019). Andre et al. (2025) even theoretically confirm that stricter environmental policies can lead to a "win-win" scenario for green innovation.

Consequently, there is a dire need to empirically re-examine this critical debate within Nigeria, a prominent African economy facing significant environmental challenges amidst its pursuit of economic development. Nigeria's position as a major oil producer, its large and growing population, and its increasing integration into the global economy through trade and FDI make it an ideal case study for shedding light on these competing hypotheses. Prior research on Nigeria has explored the relationship between FDI, trade, and environmental pollution, but results have been mixed. For example, some studies confirm the PHH in Nigeria (Riti et al., 2016; Ekesiobi et al., 2022), while others find evidence for the Porter Hypothesis (Zubair et al., 2020; Usman and Manap, 2010). Similarly, findings on the environmental impact of trade openness in Nigeria have been inconsistent, with some indicating a reduction in pollution (Ado, 2021) and others showing a positive long-term impact on emissions (Ekesiobi et al., 2022).

Hence, this study adds to the existing body of literature on this subject matter by providing insights on whether Nigeria functions as a "pollution haven" or benefits from a "porter effect" from international economic engagement. To guide this investigation, the study explicitly tests two competing hypotheses: the Pollution Haven Hypothesis – (Foreign direct investment and trade openness lead to an increase in total greenhouse gas emissions in Nigeria), against the Porter Hypothesis – (Foreign direct investment and trade openness lead to a decrease in total greenhouse gas emissions in Nigeria).

In the past decade, Nigeria has experienced a significant downturn in both trade openness and foreign direct investment. As depicted in Figure 1, Nigeria's foreign direct investment saw a sharp decline subsequent to its peak in 2011. Concurrently, Figure 2 illustrates a consistent downward trajectory in trade openness since its high point in 2007.

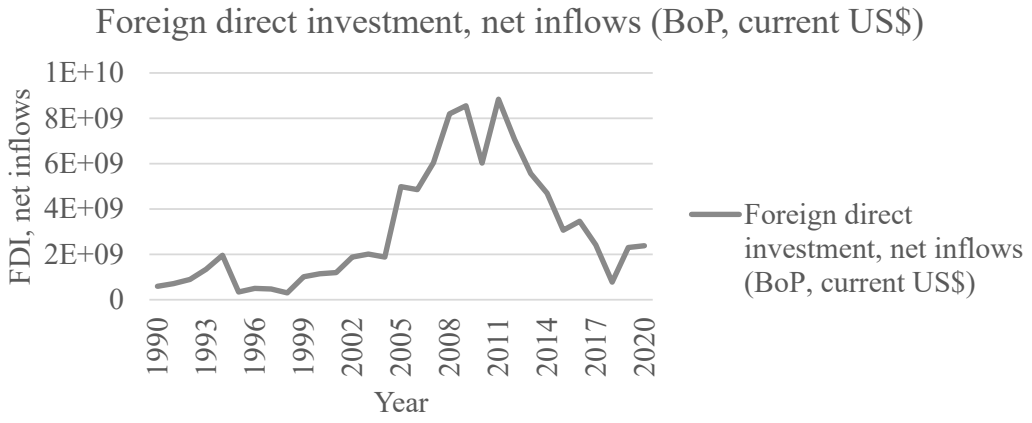

Figure 1. Foreign Direct Investment Inflow in Nigeria

Source: Authors' construct using data from World Development Indicators (WDI).

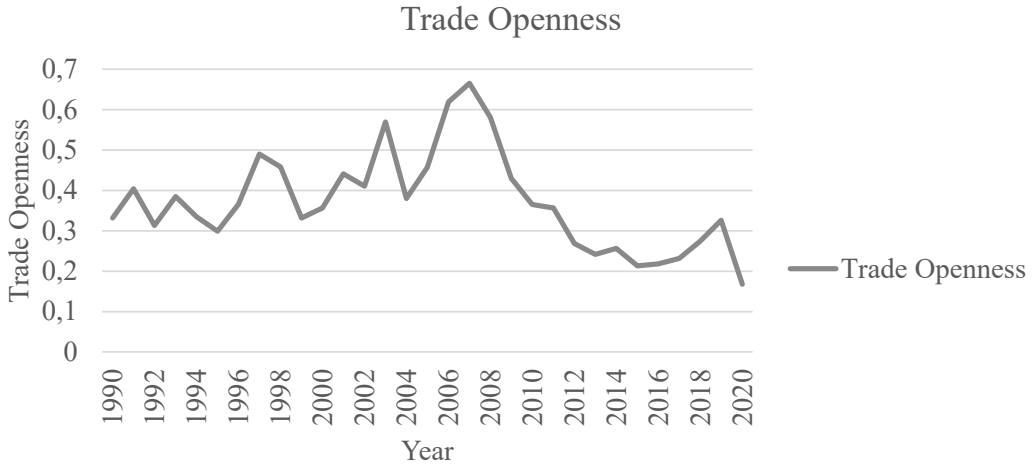

Figure 2. Trade Openness in Nigeria

Source: Authors' construct using data from World Development Indicators (WDI).

Recognizing these limitations, the Nigerian government has acknowledged the imperative to balance economic growth with environmental protection. The Federal Environmental Protection Agency (FEPA) noted that initiatives such as the National Environmental Policy, efforts to diversify the energy mix, and participation in international environmental agreements like the Paris Agreement signify a growing commitment to change the narrative from one of unchecked environmental degradation to one of sustainable development. In November 2021, Nigeria enacted the Climate Change Act, whose main goal is to reduce greenhouse gas emissions in the nation by establishing a framework that will allow for the achievement of net-zero emissions between 2050 and 2070 (Climate Action Tracker, 2023). However, the efficacy of these efforts remains a subject requiring rigorous empirical scrutiny. For instance, data from Figure 3 below demonstrates that Nigeria's carbon dioxide emissions reached an all-time high in 2019 following a decade-long upward trend. This means that despite these efforts, Nigeria still suffers from environmental degradation.

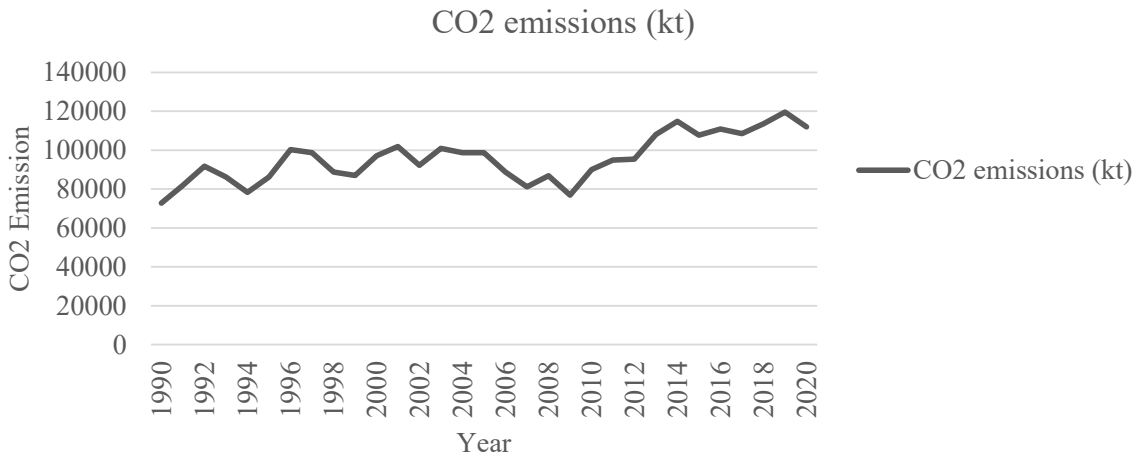

Figure 3. CO2 Emissions in Nigeria

Source: Author's construct using data from World Development Indicators (WDI).

Therefore, the need for a study like this is paramount. By effectively re-examining the Pollution-Haven versus Porter Hypothesis in the unique context of Nigeria, this research provides a timely and essential contribution to this ongoing debate.

2. Literature review

Three key concepts in the study are environmental sustainability, foreign direct investment, and trade openness. There are several appropriate definitions for each of these concepts.

Environmental sustainability refers to the ability to efficiently make use of the earth's resources and maintain the ecosystem for current and future needs. Environmental sustainability, according to Khan et al. (2021), is a conservation concept that emphasizes serving the needs of both current and future generations for resources and services without causing harm to the ecosystem that makes them available. Environmental sustainability encompasses both location-specific and global concerns. Whereas soil erosion, air pollution, and water pollution are among the location-specific concerns, greenhouse gas emissions and climate change are generally associated with global issues (Ghosh, Westhoff, and Debnath, 2019).

Meanwhile, trade openness measures the proportion of a nation's GDP that comes from its total imports and exports. According to the United Nations (2023), trade openness describes how a nation's economy is oriented (either inward or outward). It gauges a country's propensity to be open to commerce with other countries. Trade openness, according to Mahmood, Maalel, and Zarrad (2019), influences the environment through economic growth. Countries that open their borders to international trade see

a surge in demand for their commodities, which forces manufacturers to use a lot of polluting energy to produce enough items to meet demand. Nonetheless, the detrimental effects of economic expansion on environmental sustainability are not permanent. Eventually, as the economy grows and more people want a cleaner environment in order to maintain their quality of life, environmental sustainability will follow.

According to Bilawal et al. (2014), foreign direct investment (FDI) is the process through which a national investor acquires a sizable share in a company operating in another nation. In other words, foreign direct investment is the total amount of money coming into a country's economy from foreign investors. In contrast to investments in a country's stock market, foreign direct investment focuses on long-term investments in businesses where the investor holds at least 10% of the company's shares and is actively involved in the management of the business. The strength of the environmental policies in the host and receiving countries helps to understand how foreign direct investment affects the environment. Some researchers will contend that developing countries frequently become the home of dirty goods due to foreign direct investment and the strict environmental policies of advanced nations, while others will contend that, as a result, emerging countries will become a destination for clean technology.

A. Trade openness theories

The Comparative Advantage Theory (Ricardo, 1817) and the Heckscher-Ohlin Model (Heckscher, 1919; Ohlin, 1933) underscore how international trade can facilitate specialization and the exchange of goods and services based on relative efficiencies and factor endowments. These theories conceptually support the inclusion of Trade Openness (TOP) as a core independent variable in the empirical model of this study. Empirically, trade liberalization, as implied by these theories, can alter production structures and consumption patterns through the import of cleaner technologies or changes in industrial composition.

B. Foreign direct investment theories

The Market Imperfections Theory explains FDI as a firm's response to inefficiencies in external markets, leading to direct investment abroad. Dunning's Eclectic Paradigm (OLI framework) further elaborates on the conditions for FDI, considering Ownership, Location, and Internalization advantages. From an environmental perspective, these theories imply that FDI, being a direct investment involving management control and technology transfer, could bring specific environmental practices – either more polluting (PHH) or cleaner (Porter) – into the host economy.

C. Environmental sustainability theories

The Sustainable Development Theory (Brundtland Commission, 1987) and the Ecological Modernization Theory (Gibbs, 2016) provide the necessary theoretical context for environmental sustainability, represented by greenhouse gas (GHG) emissions in this study. Sustainable Development emphasizes a balance between economic and environmental goals. Ecological Modernization, with its focus on technological solutions and policy-induced innovation, directly informs the expectation that certain economic activities (for instance, cleaner FDI or access to clean technologies) could lead to reduced emissions.

Empirical literature

Several studies, both time-series and panel, suggest the existence of the Pollution-Haven Hypothesis. Riti et al. (2016) for Nigeria and Yakubu and Musah (2022) for Ghana, employing ARDL and FMOLS, respectively, found evidence supporting the PHH. Panel studies further reinforce this, with Aliyu and Ismail (2015) in 19 African nations, Singhania and Saini (2021) across 21 developing and developed nations, Gharnit et al. (2019) in 54 African countries, and Ayadi (2020) in 9 West African countries, all using various panel methods (pooled estimation, GMM, dynamic panel, PGMM), concluding that FDI significantly contributes to environmental degradation in developing regions. Ekesiobi et al. (2022) also found a long-term positive impact of FDI on carbon emissions in Nigeria.

Using a more diversified approach, Wang et al. (2019), using firm-level data in China (2011-2015), found compelling evidence that environmental regulations affect firm location choices, consistently confirming the Porter effect at the country level. Polluting firms in Eastern China, notably, preferred provinces with stringent environmental policies. This result remained robust even when addressing endogeneity and

using various model specifications. In a recent study, Andre et al. (2025), through a two-country, two-firm game theory model, demonstrated that a stricter environmental policy increases the likelihood of a "win-win" scenario where firms stay in the home country and invest in green technology. Emission taxes, in particular, were found to induce green investment under circumstances where standards might not. Furthermore, Duan and Jiang (2021), utilizing an inter-country inter-industry input-output database, concluded that Multinational Enterprises (MNEs) lead to pollution haven effects in both high-income and low-income economies. Their simulations showed that replacing MNE manufacturing with domestic counterparts could significantly reduce global CO2 emissions, suggesting MNEs contribute to a pollution haven effect along global supply chains

Conversely, several studies indicate that FDI either reduces or has no adverse effect on environmental pollution, aligning with the Porter Hypothesis. Solarin et al. (2017) found no evidence of PHH in Ghana using ARDL. For Nigeria, Zubair et al. (2020) and Usman and Manap (2010), both utilizing ARDL, revealed that FDI reduces carbon emissions or negatively influences them, promoting environmental sustainability. Panel studies by Nathaniel et al. (2020) in coastal Mediterranean countries (using quantile panel data) and Yakubu and Musah (2022) in 41 African countries (using pooled, fixed, and random effects) found the absence of the PHH. Bouzahzah (2022) also found no evidence of PHH in 40 African countries via PARDL. Tiba and Belaid (2020), using CCE-MG in 27 African countries, concluded that FDI reduces environmental pollution. Offering a more nuanced view, Lodi and Bertarelli (2022), analyzing German and Eastern European firm-level data, demonstrated that the eco-innovation induced by regulation can have either positive or detrimental effects on exporting propensity. Their study underscored the significant relevance of firm-level productivity, size, and geographical heterogeneity in shaping these outcomes.
Meanwhile, empirical findings on trade openness are also mixed. While Ado (2021) found that trade openness lowers environmental pollution in Nigeria (using ARDL), Tiba and Belaid (2020) similarly concluded that trade openness reduces environmental pollution in 27 African countries. However, Ekesiobi et al. (2022) indicated that international trade had a long-term positive impact on carbon emissions in Nigeria, despite a short-term negative impact.

3. Gaps in literature and value added

The majority of the studies reviewed (among others, see Zubair, Samad, and Dankumo (2020); Usman and Manap (2010); and Riti, Sentanu, Cai, and Sheikh (2016)) focused on examining the relationship between FDI and environmental sustainability. Meanwhile, a few studies (see Ado (2021) and Ekesiobi et al. (2022)) have jointly looked into the effect of FDI and trade openness on environmental sustainability in Nigeria. As a result, this study will employ both FDI and trade openness as the core independent variables to validate the existence of the pollution haven hypothesis in Nigeria. Additionally, the majority of studies pertaining to Nigeria employed the autoregressive distributed lag (ARDL) estimating approach. However, in this study, the dynamic ordinary least squares estimate method (which is more robust against endogeneity problems and serial correlation) will be employed. To the best of our knowledge, this is one of the few studies that made use of a more reliable measurement of environmental degradation (total greenhouse gas emissions) compared to the more restrictive measurement of GHG emissions by carbon emission used as a proxy for environmental degradation in other studies.

4. Methodology

This study will focus on and be limited to the borders of Nigeria. The data for this analysis, which focused on 1990 to 2023, was sourced from the World Bank World Development Indicators (WDI), World Integrated Trade Solution Database, and Our World In Data. The article proposes the following model to investigate the relationship between FDI, trade openness, and total greenhouse gas emissions in Nigeria:
LTGE = f (FDI, TOP, ATE, ATCT, UPOP)

Where:
LTGE = Log of Total greenhouse gas emission, FDI = Foreign direct investment, TOP = Trade openness, ATE = Access to electricity, ATCT = Access to clean fuels and technology, UPOP = Urban Population.
The use of Total Greenhouse Gas (GHG) Emissions is necessary in the context of this study because while carbon dioxide (CO_2) is a significant measure of environmental degradation, global warming is driven by a range of gases, including methane and nitrous oxide, which total GHG emissions capture. However, it is important to acknowledge that the data, while the best available, might have inherent approximations. Regardless, for a macro-level analysis focused on the broad implications of FDI and trade openness on environmental sustainability, this comprehensive measure is indispensable.

The central factors under investigation are Foreign Direct Investment (FDI) and Trade Openness, along with other key variables like Access to Electricity, Access to Clean Fuels and Technology, and Urban Population. Access to electricity (ATE) is a critical component, as increasing energy consumption is a major contributor to emissions. Its inclusion allows the study to capture the environmental impact of Nigeria's predominantly fossil fuel-based electricity supply, which could be a major driver of GHG emissions. Similarly, access to clean fuels and technology (ATCT) directly addresses efforts to mitigate emissions by shifting from polluting energy sources. Urban Population (UPOP) is incorporated to account for the environmental implications of demographic shifts and urbanization, which can influence energy demand, infrastructure development, and industrialization in ways that are distinct from FDI and trade openness. Moreover, if FDI primarily flows into already polluting sectors, it might more strongly support the Pollution Haven Hypothesis, and conversely, if it flows into cleaner or service sectors, its environmental effect could be different. This distinction is vital for a precise understanding of FDI's role in this ongoing debate.

Meanwhile, to achieve the objective of this study, this empirical study adopts a multivariate regression model. In order to obtain the long-run estimates, this study employs the Dynamic Ordinary Least Squares (DOLS) model, which was first put forth by Saikkomen (1992) and Stock and Watson (1993). By including leads and lags of the first difference of the exogenous regressors in the model, DOLS tackles the issues of endogeneity and Autocorrelation. The model's lags deal with the problem of Autocorrelation, while the leads deal with the endogeneity issue that results from a potential feedback effect. The DOLS model is well known for its robust features since it can be applied when the sample size is small and the model's variables are in a mixed order of I(0) and I(1). The DOLS model can be specified as follows:

$$LTGE_t = \alpha_0+\beta_1 FDI_t+\beta_2 TOP_t+\beta_3 ATE_t+\beta_4 ATCT_t+\beta_5 UPOP_t+ \beta_6 \Delta FDI_t+ \beta_7 \Delta TOP_t + \beta_8 \Delta ATE_t + \beta_9 \Delta ATCT_t +\beta_{10} \Delta UPOP+\beta_{11} \Delta FDI_{t+1}+\beta_{12} \Delta TOP_{t+1}+\beta_{13} \Delta ATE_{t+1}+\beta_{14} \Delta ATCT_{t+1} \beta_{15} \Delta UPOP_{t+1}+\beta_{16} \Delta FDI_{t-1}+\beta_{17} \Delta TOP_{t-1} +\beta_{18} \Delta ATE_{t-1}+\beta_{19} \Delta ATCT_{t-1} \beta_{20} \Delta UPOP_{t-1} +\mathcal{V}_t$$

Where:
β_1, β_2, β_3, β_4, and β_5 = Long-run co-efficient.
B_5, β_6, β_7, β_8, β_9, β_{10}, β_{11}, β_{12}, β_{13}, β_{14}, β_{15}, β_{16}, β_{17}, β_{18}, β_{19} and β_{20} = Nuisance Parameters.
Δ and $\mathcal{V}_t$ = Difference operator & Error term, respectively.

5. Empirical results

5.1 Unit root test

This test determines whether a variable's mean and variance have remained stable throughout time. That is, to determine whether or not the variable is stationary. The Augmented Dickey-Fuller test will be applied to find the unit root in this study. The proposed hypotheses will be:

H_0: The variable is not stationary.
H_1: The variable is stationary.

If the Augmented Dickey-Fuller statistics are greater than the 5% critical values, we must fail to accept the null hypothesis.

Table 1. Augmented dickey-fuller test for unit root

Variables	ADF test statistic	t-Statistic	P-value	Order of integration	Decision
LTGE	-6.415557	-2.938987	0.0000	I(1)	Stationary
FDI	-3.872159	-2.936942	0.0049	I(0)	Stationary
TOP	-4.133648	-2.936942	0.0024	I(0)	Stationary
ATE	-6.752313	-3.552973	0.0000	I(0)	Stationary
ATCT	-3.769303	-2.967767	0.0081	I(0)	Stationary
UPOP	-5.135253	-2.960411	0.0002	I(1)	Stationary

Source: Authors' construct using E-Views' output. Note: Test critical values at a 5% level of significance.

The DOLS model's flexibility in applying when its variables have mixed orders of I(0) and I(1) is one of its primary advantages. The results of the ADF's unit root test, shown in Table 1 above, indicate that, except for LTGE and UPOP, which became stationary after being differenced once, i.e., I(1), the others remained stationary in their level form, i.e., I(0).

5.2 Cointegration test

The co-integration test is a vital econometric tool used to assess the existence of long-term relationships between variables in a regression model. It helps to ascertain whether these variables move together in the long run, indicating a stable equilibrium relationship rather than short-term fluctuations. The Johansen co-integration will be deployed to examine if a long-run relationship exists between the variables. The proposed hypotheses are as follows:

H_0 = No Co-integration (There is no stable long-run relationship)
H_1 = Co-integration (There is a stable long-run relationship)

If the Trace and Max-eigenvalue tests indicate a cointegrating equation at the 0.05 level, we must fail to accept the null hypothesis.

Table 2. Johansen cointegration test results (trace).

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.736494	135.1369	95.75366	0.0000
At most 1 *	0.669032	92.45914	69.81889	0.0003
At most 2 *	0.606717	57.07565	47.85613	0.0054
At most 3	0.417698	27.21240	29.79707	0.0965
At most 4	0.257046	9.907913	15.49471	0.2879
At most 5	0.012423	0.400022	3.841465	0.5271

Source: Authors' construct using E-Views' output. Note: Test critical values at a 5% level of significance.

Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

Table 3. Johansen cointegration test results (max-eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.736494	42.67772	40.07757	0.0249
At most 1 *	0.669032	35.38349	33.87687	0.0328
At most 2 *	0.606717	29.86325	27.58434	0.0250
At most 3	0.417698	17.30449	21.13162	0.1581
At most 4	0.257046	9.507891	14.26460	0.2463
At most 5	0.012423	0.400022	3.841465	0.5271

Source: Authors' construct using E-Views' output. Note: Test critical values at a 5% level of significance.

Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

Decision: Based on the results in Table 2 and Table 3, we can conclude that there is at least one co-integrating equation, as evidenced by three instances where the trace and Max-eigenvalue statistics are below the critical value. Therefore, we fail to accept the null hypothesis at a 0.05 level of significance and infer that there exists a long-term relationship among the variables, indicating that they remain close to each other over time.

5.3 Estimation result

Table 4. DOLS regression result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
FDI	-0.10478	0.023475	-4.46353	0.0012
TOP	-0.00166	0.001944	-0.85574	0.4122
ATCT	-0.00224	0.007961	-0.28126	0.7842
ATE	0.022958	0.007211	3.183622	0.0098
UPOP	-0.04189	0.006837	-6.12593	0.0001
C	6.29057	0.089511	70.27717	0.0000
R-squared = 0.938575		**F Statistic** = 17.77220		
Adjusted R-squared = 0.815724		**Prob (f-stat)** = 0.0002		

Diagnostic Tests	Test Statistc	P-Value
Heteroscedasticity Test (Breusch-Pagan-Godfrey Test)	19.06869	0.5174
Autocorrelation Test (Breusch-Godfrey Serial Correlation LM Test)	1.314752	0.3209
Specification Bias Test (Ramsay Test)	0.008067	0.9304
Normality Test (Jarque-Bera (JB) Test)	0.381917	0.826167

Source: Authors' construct using E-Views' output.

Note: Test critical values at a 5% level of significance.

In Table 4 above, the DOLS result for foreign direct investment (FDI) demonstrates a statistically significant negative long-run relationship with total greenhouse gas emissions, with a coefficient of -0.10478. This indicates that, holding other variables constant, an increase in FDI leads to an average 10.478% reduction in Nigeria's overall GHG emissions. This finding strongly supports the Porter Hypothesis, refuting the notion of Nigeria as a "pollution haven." The observed is likely due to the transfer of more sophisticated environmental technologies and superior management practices from the investors' home countries. This is attributed to their drive to maintain global best practices, technological superiority, or even simply, their reputation. This result aligns with findings from Usman and Manap (2010) and Zubair, Samad, and Dankumo (2020), which also indicate FDI's contribution to environmental sustainability.

Trade openness (TOP) exhibits a long-run coefficient of -0.00166, suggesting a negative association with GHG emissions, but it is not statistically significant at the 5% level. Therefore, a definitive conclusion regarding this indicator's significant influence on total greenhouse gas emissions cannot be drawn from this model. However, according to the theoretical framework outlined in this study, trade liberalization can facilitate access to cleaner energy sources, more efficient machinery, and environmentally friendly products, potentially mitigating domestic emissions. The lack of statistical significance, contrasting with findings like Ado (2021), suggests that while the potential for cleaner technology transfer via trade exists, other dominant factors or insufficient utilization mechanisms might currently outweigh this effect in Nigeria.

Access to Electricity (ATE) shows a statistically significant positive long-run relationship with total greenhouse gas emissions, with a coefficient of 0.022958. This implies that a one percent increase in ATE leads to an average 2.3% increase in GHG emissions, holding other variables constant. This finding

highlights Nigeria's current electricity generation mix, which is predominantly fossil fuel-based. As more of the population gains access to this carbon-intensive grid electricity, the increased demand directly contributes to higher emissions. This underscores that while expanding electricity access is vital for development, its environmental impact will persist unless coupled with a rapid transition to renewable energy sources. This aligns with findings from Kojo and Paschal (2018), emphasizing the positive contribution of fossil fuel consumption to pollution in Nigeria.

Conversely, Access to Clean Fuels and Technology (ATCT) has a coefficient of -0.00224, but it is not statistically significant at the 5% level of significance. This indicates that, in the long run, and within the scope of this model, an increase in access to clean fuels and technology does not have a statistically measurable impact on reducing total greenhouse gas emissions in Nigeria. This lack of significance suggests that while efforts to promote cleaner alternatives exist, their widespread adoption and effective displacement of carbon-intensive fuels might be too limited. This study's result on the positive and significant effect of ATE on GHH emissions could counteract this relationship, given the challenges posed by the energy mix underpinning ATE. This points to the need for policies to focus not just on access but on facilitating the widespread transition to and use of these cleaner alternatives to effectively replace polluting energy sources.

Urban Population (UPOP) reveals a statistically significant negative long-run coefficient of -0.04189. This counter-intuitive finding, where a one percent increase in urban population is associated with a 0.04189% decrease in total GHG emissions, challenges conventional assumptions and Schneider's (2022) findings. This unique result warrants further investigation into Nigeria's specific urban development and environmental dynamics, which further research can explore.

The results of the diagnostic test show that the model is accurately specified, there is no autocorrelation or heteroscedasticity, and the error term has a normal distribution. While the diagnostic tests are satisfactory, potential omitted variables, for instance, unmeasured institutional frameworks or informal sector impacts, could present potential bias. In this regard, future studies could address these limitations by employing panel data analysis across multiple African countries and incorporating additional variables such as institutional quality, governance indicators, or more disaggregated data for FDI.

5.4 Parameter stability test (CUSUM test)

The CUMSUM test result shown in Figure 1 below shows that all of the model's coefficients are stable over time since they are below the 5% critical bounds. We can trust the model's result based on the stability test result.

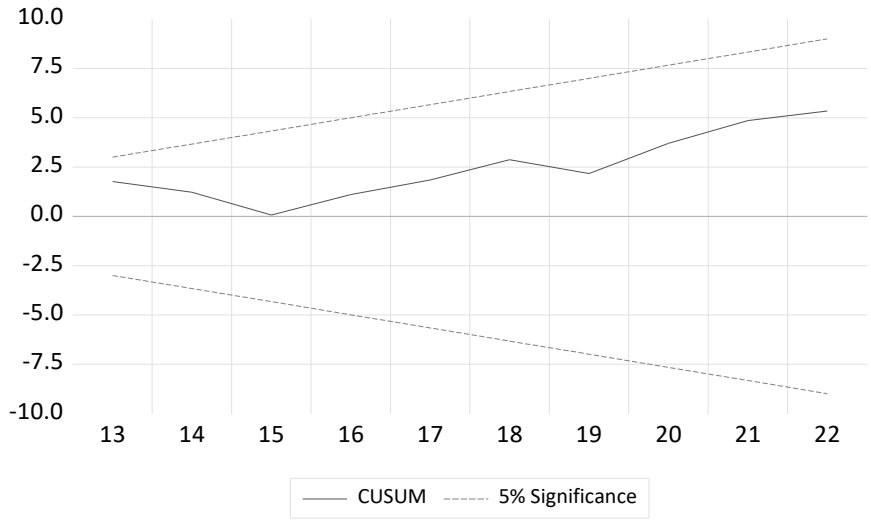

Figure 4. CUSUM Plots for Stability Test

Source: Made by the researchers.

6. Conclusion and recommendations

One major factor influencing a nation's economic growth is trade liberalization and foreign direct investment. Nonetheless, there is cause for concern regarding their impact on a nation's ability to preserve its environment, hence, the purpose of this study was to critically assess how trade openness and foreign direct investment affect Nigeria's environmental sustainability within the context of the pollution haven hypothesis.

The study's findings reveal a statistically significant negative long-run effect of foreign direct investment (FDI) on Nigeria's overall greenhouse gas (GHG) emissions. This result supports the Porter Hypothesis, which suggests that as developing nations like Nigeria attract FDI, they become centers for advanced and cleaner technology, leading to environmental improvements. While trade openness also exhibits a negative coefficient, its long-run effect on GHG emissions was not found to be statistically significant.

Beyond FDI and trade openness, the study's findings also highlight other important determinants of Nigeria's environmental sustainability. Access to electricity (ATE) shows a statistically significant positive effect on GHG emissions, underscoring the carbon-intensive nature of the nation's current energy generation mix. Conversely, access to clean fuels and technology (ATCT) did not show a statistically significant long-run impact on emissions. Interestingly, urban population (UPOP) demonstrates a statistically significant negative relationship with GHG emissions.

Consequently, the study recommends several policy interventions to leverage these findings for enhanced integration of FDI, while ensuring environmental sustainability in Nigeria. Given FDI's statistically significant role in reducing emissions, the Nigerian government should actively promote policies that attract sustainable foreign direct investment. This includes offering targeted tax holidays and other incentives for companies investing in green industries, renewable energy projects (e.g., solar, wind), and environmentally friendly manufacturing processes. The positive association between access to electricity and emissions necessitates a concerted effort to decarbonize Nigeria's power sector. This can be achieved by prioritizing investment in renewable energy generation and supporting the creation of infrastructure for cleaner alternatives, such as compressed natural gas (CNG) stations, and incentivizing the transition to CNG-powered vehicles. Although access to clean fuels and technology did not show a statistically significant impact, its negative coefficient implies potential. Therefore, efforts should be intensified to expand the adoption and effective utilization of clean fuels and technologies, ensuring they genuinely displace, rather than merely complement, polluting alternatives. Furthermore, recognizing the surprising negative association of urban population with emissions, policies should focus on promoting sustainable urban planning and development that maximizes efficiency gains from urbanization. Finally, a widespread public education campaign on the threat posed by global warming and the necessity of planting trees while discouraging deforestation is essential to foster a collective environmental consciousness and drive behavioral change at the grassroots level.

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