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Article

Revisiting the pollution-haven vs. porter hypotheses: Empirical evidence from Nigeria

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Abstract: Since the 1970s, the role of trade liberalization and foreign direct investment in promoting environmental sustainability has been a hot topic in academics. While some research supports the Porter hypothesis, others support the pollution-haven hypothesis. Accordingly, this study aims to determine whether the pollution haven hypothesis holds by examining how trade openness and foreign direct investment affect Nigeria's environmental sustainability for the period of 1981 to 2021. By deploying the dynamic ordinary least square (DOLS) estimation technique, the study outcomes indicate that trade openness and foreign direct investment have a negative and significant long-term effect on Nigeria's greenhouse gas emissions. Therefore, the results of this study support the Potter hypothesis, which holds that emerging nations become centers of advanced and cleaner technology as a result of trade liberalization and foreign direct investment. As a result, the study suggests that the Nigerian government should support 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 in this field. Furthermore, there should be 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
JEL Codes: F18; F21; P33

1. Introduction

The impact of trade liberalization and foreign direct investment on environmental sustainability has been hotly debated since the 1970s [1]. While some researchers support the Porter Hypothesis (PH), others argue for the Pollution Haven Hypothesis (PPH). The debate intensified in the 1990s as a result of the establishment of organizations that promoted trade openness, including the World Trade Organization (WTO), the United Nations Conference on Environment and Development (UNCED), the Uruguay Round of the General Agreement on Tariffs and Trade, and the North American Free Trade Agreement (NAFTA) [2]. The school of thought that supported the pollution haven hypothesis claimed that because developed countries have strict environmental regulations, developing countries, which are known for their lax environmental policies, become hubs for pollution from trade and foreign direct investment. In the meantime, the school of thought that supports the Porter Hypothesis contends that stringent environmental regulations in developed nations benefit developing nations through trade liberalization and foreign direct investment as these

nations become the destination for cleaner, more advanced technology that preserves the environment.

By definition, foreign direct investment (FDI) is the process through which a national investor acquires a sizable share in a company operating in another nation. Foreign direct investment, as opposed to stock market investments, concentrates on long-term investments in companies where the investor actively manages the business and owns at least 10% of the company's shares [3]. Conversely, trade openness quantifies the proportion of a nation's GDP that comes from its total imports and exports. Trade openness is essential for capital accumulation, knowledge transfer, and the diffusion of technology from industrialized to developing nations. Similarly, FDI plays an important role in stimulating the economic growth of a country through capital provided by international investors. FDI inflow promotes economic growth since it can increase the stock of real capital, enhance knowledge and technology transfer, and widen global commercial networks [4]. Over the last ten years, Nigeria has seen a notable decline in trade openness and foreign direct investment despite the crucial role that FDI and trade openness play in the prosperity of developing nations. **Figure 1** below illustrates how Nigeria's foreign direct investment (FDI) fell sharply after reaching an all-time high in 2011. Similarly, **Figure 2** below demonstrates that since reaching its peak in 2007, trade openness has been steadily declining.

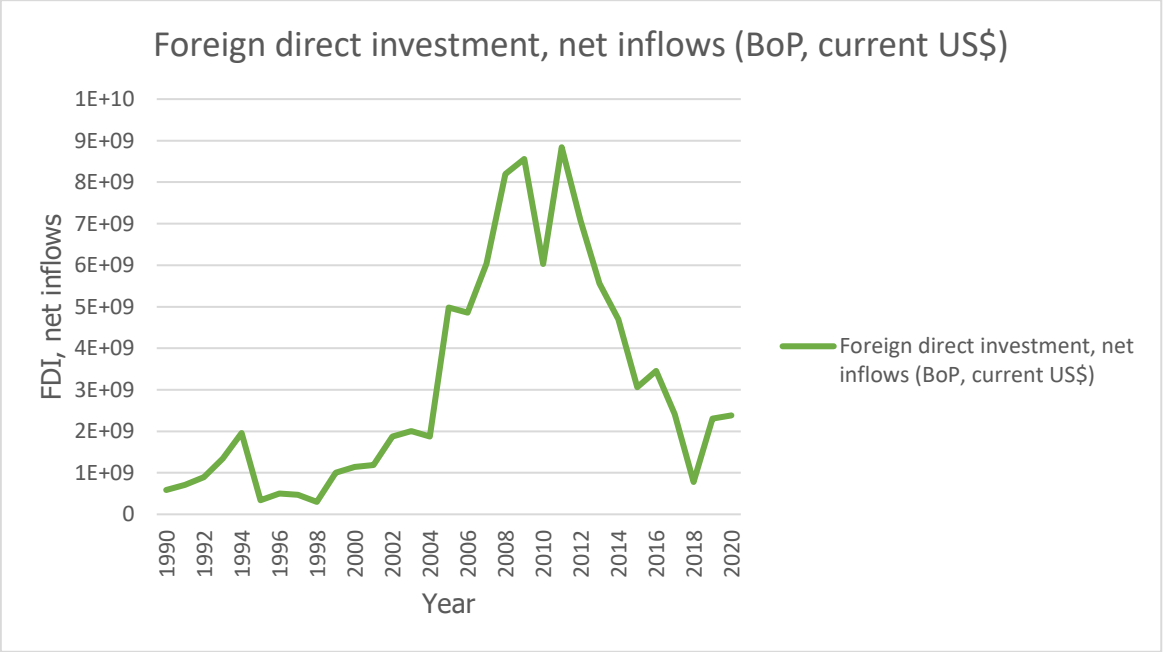

Figure 1. Foreign direct investment inflow in Nigeria.

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

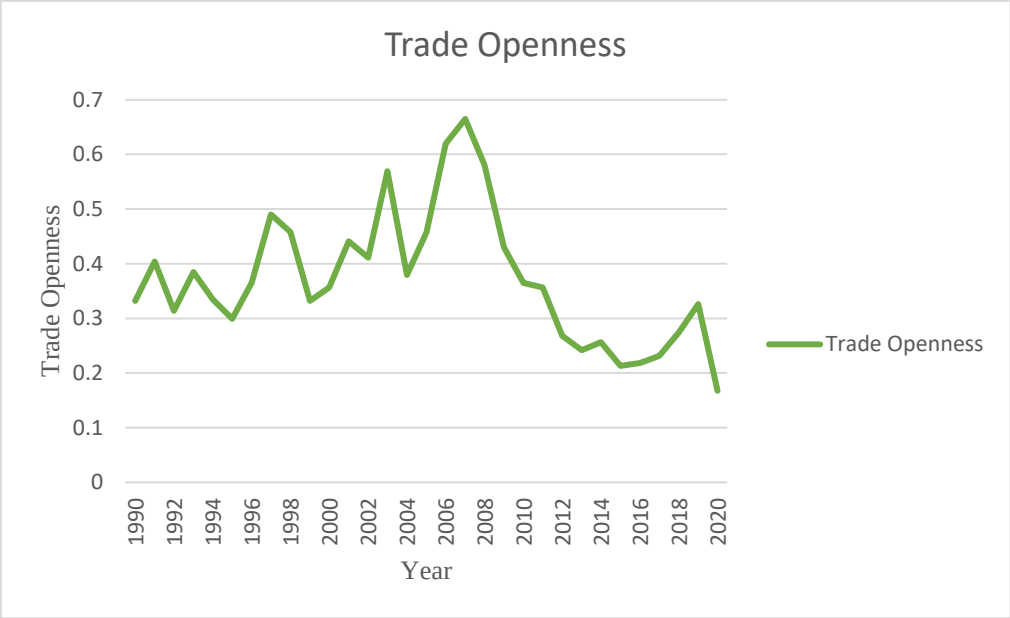

Figure 2. Trade openness in Nigeria.
Source: Authors' construct using data from World Development Indicators (WDI)

Research has yielded varying conclusions about the impact of foreign direct investment (FDI) and trade openness on environmental sustainability. Copeland and Taylor [5] submit that because of trade liberalization, companies that manufacture polluting goods have shifted from developed nations with strict environmental policies to developing nations with lax environmental regulations. This is because the comparative cost of pollution in these nations is less expensive. This movement turns emerging nations into sanctuaries—"pollution havens"—for polluting companies that manufacture noxious products. This perspective is supported by Riti et al [6], using the Auto Regressive and Distributed Lag (ARDL) model, validated the existence of the pollution haven hypothesis in Nigeria. The study's conclusions indicate that FDI inflow has a positive impact on Nigeria's CO_2 emissions. However, it is necessary to note that the reliance on aggregate national data may suffuse more nuanced regional or sectorial variations. For instance, Ayadi et al [7] also found evidence supporting the pollution haven hypothesis in Nigeria, while Ekesiobi [8] reported a more complex finding, suggesting the presence of the Porter hypothesis in Nigeria in the short run but a long-run pollution haven effect in Nigeria. Singhania and Saini [9] highlighted the importance of financial development and institutional quality in bridging the gap between FDI and environmental sustainability. The study suggests that institutional quality can facilitate the inflow of environmentally friendly technologies in the receiving country. Similarly, Yan et al [10] demonstrate that capital market liberalization leads to a substantial increase in the variability of ESG ratings across firms, suggesting a complex relationship between market openness and corporate sustainability practices. Hence, it is important to consider the dynamic impact of policy and institutional changes on the effectiveness of FDI on environmental sustainability, especially in developing countries like Nigeria.

According to the Federal Environmental Protection Agency (FEPA), Nigeria is fully dedicated to implementing the National Environmental Policy, which is designed to achieve sustainable development to address the environmental difficulties it faces.

The policy's objectives include the preservation of natural resources and the protection of the environment [11]. Also, Nigeria unveiled the National Renewable Energy and Energy Efficiency Policy (NREEEP) in 2015. This initiative hopes to reach a capacity of over 23 GW for renewable energy by 2030. Nigeria approved a National Action Plan in 2019 that included several emission-reduction initiatives. The strategy is centered on lowering methane emissions from natural gas transportation and oil production leaks. Furthermore, 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 [12]. However, 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.

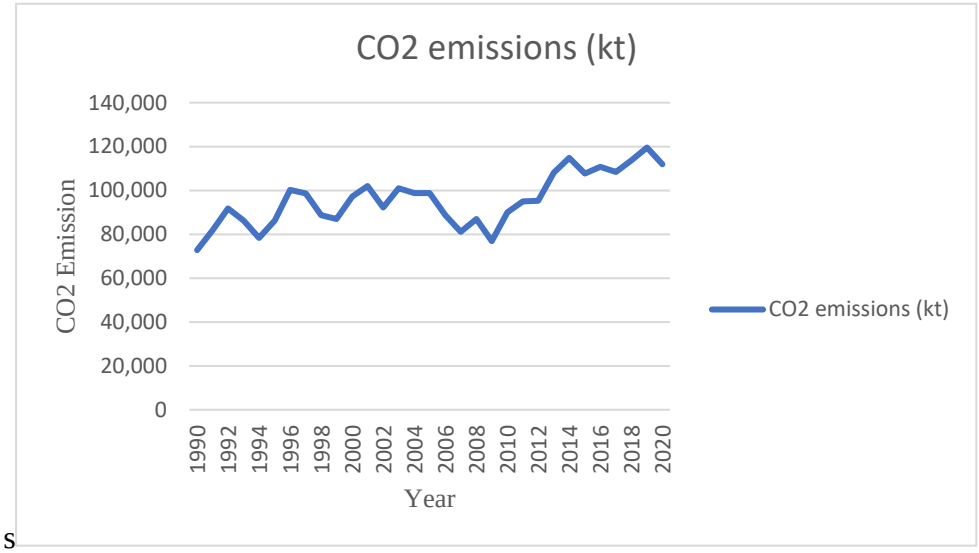

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Figure 3. CO_2 emission in Nigeria.
Source: Authors' construct using data from World Development Indicators (WDI)

In light of this unfavorable tendency, this study aims to add to the empirical discussion regarding the major impact that trade openness and foreign direct investment have on Nigeria's environmental sustainability within the context of the pollution haven hypothesis. The novelty of this study lies in its specific focus on the most recent decade of data for Nigeria—a period marked by significant fluctuations in FDI and trade openness, as presented in **Figures 1** and **2**. By focusing on more up-to-date data and employing a dynamic methodological approach, this study explicitly analyzes the evolving nature of the environmental impacts of trade openness and FDI in Nigeria. The remainder of this paper is organized as follows: Section 2 discusses the literature review, Section 3 examines the methodology, Section 4 presents the results and discussion, while Section 5 concludes and provides policy recommendations.

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. We shall investigate what principles they uphold.

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 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 [13]. 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 [14].

Meanwhile, trade openness measures the proportion of a nation's GDP that comes from its total imports and exports. According to the United Nations [15], 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 influences the environment through economic growth [16]. 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 to maintain their quality of life, environmental sustainability will follow.

Furthermore, foreign direct investment (FDI) is the process through which a national investor acquires a sizable share in a company operating in another nation [3]. 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.

2.1. Trade openness theories

2.1.1. Comparative advantage theory

David Ricardo proposed this theory in 1817 in the Principles of Political Economy and Taxation. According to the notion, a nation ought to focus on producing and exporting the commodities and services that have the lowest opportunity costs. In other words, a nation ought to focus on producing commodities and services in which it possesses a comparative advantage over its peers. David Ricardo used this argument to refute the protectionist Corn Law of Great Britain, which prohibited the importing of wheat between 1815 and 1846. David Ricardo highlighted the advantages of trading with one another while arguing in favor of free trade.

2.1.2. Heckscher-Ohlin model

Eli Heckscher first proposed this hypothesis in 1919, and his student Bertil Ohlin developed it in 1933. The theory states that countries should export goods for which they have an abundance of the resources needed for production and import goods for which their domestic resources are limited. For example, nations possessing an abundance of labor should prioritize exporting labor-intensive goods and importing capital-intensive goods, whereas nations possessing an abundance of capital should prioritize exporting capital-intensive goods and importing labor-intensive goods.

2.2. Foreign direct investment theories

2.2.1. Market imperfections theory

Market imperfection theory is also known as market failure theory. The theory states that market imperfection attracts foreign direct investment. Market imperfections occur when the market violates the assumption of perfect competition as described by neoclassical economists. The primary assumption of the neoclassical economist is that the market will efficiently allocate resources. When this proves to be untrue, the market is said to have failed. Market imperfection can be a result of the number of buyers or sellers, heterogeneity of products, barrier to entry, and information asymmetry, among others.

2.2.2. Eclectic paradigm (OLI framework)

This theory was developed by British economist J.H Dunning. The theory explains the attractiveness of making foreign direct investments from the perspective of ownership, location, and internalization. The theory assumes that companies are more likely not to proceed with foreign direct investment if they can acquire the service needed for production internally and at a lower cost.

2.3. Environmental sustainability theories

2.3.1. Sustainable development theory

This theory was popularized by the Brundtland Commission's "Our Common Future" in 1987. According to the theory, long-term well-being can be achieved through striking a balance between economic growth, social justice, and environmental sustainability. The theory opposes the traditional approach to development, which often leads to economic imbalance, social injustice, and environmental degradation. Sustainable development theory proposes a more holistic approach to development, which encompasses social justice, economic growth, and environmental sustainability.

2.3.2. Ecological modernization theory

Ecological modernization is an approach that believes that environmental problems can be resolved through political, economic, and technological means in a given institutional framework, power structure, and continued economic growth [17]. According to the theory, the modernization of the political institution towards making the economy environmentally friendly and the transformative role of technology, innovation, and market dynamics is imperative in addressing environmental issues.

2.4. Empirical literature

2.4.1. Time series outcomes

Solarin et al [18] investigated the existence of the pollution haven hypothesis in Ghana by employing the autoregressive distributed lag (ARDL) model. The study's findings reveal that the pollution haven hypothesis is not present in Ghana. In a different study, Zubair et al [19] utilized the autoregressive distributed lag (ARDL) model to investigate the relationship between GDP, FDI, capital, and carbon emission in Nigeria. According to the study findings, GDP, FDI, and capital reduce carbon emissions in Nigeria. Similarly, Usman and Manap [20] investigated the influence of FDI and activities of multinational companies on sustainability in Nigeria by employing the autoregressive distributed lag (ARDL) model. The study's finding shows that foreign direct investment negatively influences carbon emissions in Nigeria.

Furthermore, the effect of international trade and foreign direct investment on carbon emissions in Nigeria was studied by Ekesiobi [8]. Using the autoregressive distributed lag (ARDL) model, the study found that foreign direct investment and international trade had a long-term positive impact on carbon emissions. The study did find, however, that short-term carbon emissions are adversely impacted by international trade and FDI. By employing the autoregressive distributed lag (ARDL) model, Riti [6] examined the relationship between FDI, manufacturing output, and environmental pollution in Nigeria. According to the findings of the study, the pollution haven hypothesis exists in Nigeria. In another study, Yakubu and Musah [21] employed the fully modified least squares (FMOLS) model to investigate the relationship between FDI and environmental pollution in Ghana. The study finding validates the pollution haven hypothesis in Ghana.

In a more recent study, Shen [22] explored the nexus between climate investment, green finance, and sustainable development in China using the coupled coordination model. The study's findings indicated that climate investment, when coupled with green finance, promotes sustainable growth. However, the effectiveness of these mechanisms varies across different regions, highlighting the need for proper climate investment and environmental policies. Other studies that also adopted a time series approach to investigate the FDI nexus with other macroeconomic variables and found diverse results include [23–29].

2.4.2. Panel outcomes

Singhania and Saini [9] employed the generalized method of moments (GMM) and system-generalized methods of moments (Sys-GMM) to investigate the interplay between foreign direct investment, institutional quality, and environmental degradation in 21 developing and developed nations. The study found the presence of a pollution haven hypothesis in developing nations.

Furthermore, Gharnit [30] investigate the relationship between FDI and carbon emission in 54 African countries by employing dynamic panel analysis. The study findings validate the presence of the pollution haven hypothesis. Halliru et al [31] investigated the existence of the pollution haven hypothesis in ECOWAS countries. The study employed the pooled mean group (PMG) estimation method and found the existence of the pollution haven hypothesis in the selected countries.

In a different study, Nathaniel et al [32] examined if the pollution haven hypothesis is present in coastal Mediterranean countries by utilizing quantile panel data analysis. The study's findings show that the pollution haven hypothesis does not hold in coastal Mediterranean countries. In another study, Orji et al [23] employed the pooled least squares and the fixed and random effects model to investigate the relationship between FDI and CO_2 emission in 41 African countries. The study found the absence of the pollution haven hypothesis. Similarly, Bouzahzah [33] employed the panel autoregressive distributed lag (PARDL) model to investigate the relationship between FDI and CO_2 emission in 40 African countries. The study also found the absence of the pollution haven hypothesis. Tiba and Belaid [34] investigated the relationship between foreign direct investment, trade openness, and environmental sustainability in 27 African countries. The study employed the Common Correlated Effects Mean Group (CCE-MG) model and found that foreign direct investment and trade openness reduce environmental pollution. Similarly, Abbas et al [35] investigated the connection between foreign direct investment (FDI), energy consumption, and institutional governance in the reduction of greenhouse gas emissions in a panel of Asian countries and found that foreign direct investment has a significant moderating role in the nexus between energy consumption and greenhouse gas emissions. In particular, the study highlighted that FDI inflows enhance the reduction of GHG emissions. Other studies that also adopted a panel approach to investigate the FDI nexus with other macroeconomic variables and found diverse results include [36–39].

Summarily, the majority of the studies reviewed (among others, see Zubair et al [19]; Yakubu and Musah [21]; and Riti et al [6]) focused on examining the relationship between FDI and environmental sustainability. Meanwhile, a few studies Ekesiobi et al [8] have jointly looked into the effect of FDI and trade openness on environmental sustainability in Nigeria. As a result, this study employs both FDI and trade openness as the core independent variable to validate the existence of the pollution haven hypothesis in Nigeria. Additionally, the majority of studies on 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) is employed. To the best of empirical 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.

3. Methodology

3.1. Model construction

This study hinges on the pollution haven hypothesis, which states that global openness to trade and foreign direct investment has led to the creation of "pollution havens", which are countries with less stringent environmental laws. As a result of their weak environmental regulations and lower compliance costs, pollution-intensive industries relocate to these countries. The influx of polluting industries leads to higher

natural energy consumption, potentially increasing the levels of greenhouse gas emissions.

On this background, following similar studies [1,20] this article proposes the following model to investigate the relationship between FDI, trade openness, and total greenhouse gas emissions in Nigeria:

$$LTGE = f(FDI, TOP, FFE, LPOP).$$

where:

LTGE = Log of total greenhouse gas emission, FDI = Foreign direct investment, TOP = Trade openness, FFE = Fossil fuel energy consumption, LPOP = Log population.

Total greenhouse gas emissions and population are logged due to the large scale of the dataset, which may be positively skewed and might deviate from the normal distribution. Consequently, these extreme values can be difficult to model and interpret. The log form of the variable presents a more direct interpretation in which a one-unit change in the independent variable leads to a percentage change in the dependent variable [40].

3.2. Econometric strategy

In order to achieve the objective of this study, a multivariate framework is employed. This involves the Dynamic Ordinary Least Squares (DOLS) method, following the approach developed by Saikkonen and Stock and Watson. The DOLS technique is selected for its ability to provide reliable estimates even with limited data, as well as its effectiveness in addressing potential endogeneity and autocorrelation when variables exhibit different orders of integration. This is achieved by incorporating both past and future values of the independent variables, effectively mitigating bias caused by feedback effects and serial correlation. The DOLS model can be specified as follows:

$$LTGE_t = \alpha_0 + \beta_1 FDI_t + \beta_2 TOP_t + \beta_3 FFE_t + \beta_4 LPOP_t + \beta_5 \Delta FDI_t + \beta_6 \Delta TOP_t + \beta_7 \Delta FFE_t + \beta_8 \Delta LPOP_t + \beta_9 \Delta FDI_{t+1} + \beta_{10} \Delta TOP_{t+1} + \beta_{11} \Delta FFE_{t+1} + \beta_{12} \Delta LPOP_{t+1} + \beta_{13} \Delta FDI_{t-1} + \beta_{14} \Delta TOP_{t-1} + \beta_{15} \Delta FFE_{t-1} + \beta_{16} \Delta LPOP_{t-1} + v_{t..}$$

where:

β_1, β_2, β_3, and β_4 = 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}, and β_{16} = Nuisance Parameters.

Δ and v_t = Difference operator & Error term, respectively.

3.3. Data sources and variable descriptions

This study will focus on and be limited to the borders of Nigeria. The dataset for this analysis covers the period 1981–2021. Data on total greenhouse gas emissions, foreign direct investment, trade openness, fossil fuel energy consumption, and population were sourced from the World Bank World Development. Outlined in **Table 1** below are the operational descriptions of the respective variables:

Table 1. Variables description and sources of Data.

Variables	Description	Unit	Data Source
Total Greenhouse Gas Emissions (TGE)	It includes emissions from sectors like energy, industry, agriculture, land use, and waste. This variable standardizes the measurement of various greenhouse gases by converting them to their equivalent warming potential relative to CO_2.	Measured in metric tons of carbon dioxide equivalent (CO_{2e})	World Development Indicator Database
Foreign Direct Investment (FDI)	Foreign Direct Investment (FDI) represents the net flow of capital into a country, specifically to gain a sustained controlling interest in a business operating within that economy. This typically involves an investor acquiring at least 10% of the voting shares. FDI encompasses various financial components, including equity investments, reinvested profits, and other long-term and short-term capital, as reflected in a nation's balance of payments.	Measured in billions as a percentage of GDP	World Development Indicator Database
Trade Openness (TOP)	This reflects the degree to which a country participates in international trade and is commonly measured as the sum of exports and imports of goods and services, expressed as a percentage of Gross Domestic Product (GDP).	Measured in billions as a percentage of GDP	World Development Indicator Database
Fossil Fuel Energy Consumption (FFE)	Fossil fuel energy consumption measures the amount of energy derived from fossil fuels, such as coal, oil, and natural gas, expressed as a percentage of total energy consumption.	Measured as a percentage of total energy consumption	World Development Indicator Database
Population (POP)	Population refers to the total number of people living within a defined geographic area at a specific point in time.	Measured in millions	World Development Indicator Database

4. Empirical results

4.1. Descriptive statistics

To provide a foundational understanding of the data employed in this analysis, this section presents descriptive statistics, which offer a concise summary of the key characteristics of each variable, including measures of central tendency, dispersion, and shape. **Table 2** below presents a preliminary overview of the dataset before the subsequent findings of the study are further discussed.

Table 2. Descriptive statistics.

Statistic	TGE	FDI	TOP	FFE	POP
Mean	271,984.70	1.476171	0.404839	19.50043	1.33×10^8
Median	263,368.00	1.087951	0.364938	18.95003	1.26×10^8
Maximum	332,247.00	5.790847	1.067601	22.84479	$2.13\ E \times 10^8$
Minimum	233,668.60	0.183822	0.162482	15.85414	75,175,387
Std. Dev.	24,471.20	1.235819	0.181654	1.538227	41,471,452
Skewness	0.9373	1.766764	1.600965	0.301549	0.374437
Kurtosis	2.87172	6.193077	6.214836	2.740056	1.924503
Jarque-Bera	6.031405	38.74765	35.17036	0.736799	2.934071
Probability	0.049011	0.00000	0.00000	0.691841	0.230608
Sum	11,151,374	60.52301	16.59841	799.5177	5.46×10^9
Sum Sq. Dev.	2.40×10^{10}	61.08993	1.31993	94.64569	6.88×10^{16}
Observations	41	41	41	41	41

Source: Authors' compilation from EViews' output.

Table 2 provides a summary of the data used in this study, covering 41 observations. It presents key descriptive statistics for the dataset employed in this study. The mean values indicate the average levels for each variable. For instance, the average TGE is approximately 271,984.70. The median, which represents the middle value, is close to the mean for all of the variables, suggesting that the data is relatively symmetrical and not influenced by outliers. This implies that the observations for each variable are generally clustered around the average during the observation period. The skewness values indicate the shape of the data distribution, and all the variables observed are positively skewed. The Jarque-Bera statistic and its associated probability are used to test for normality. In this case, TGE, FDI, and TOP have probability values below 0.05, suggesting that their distributions are not normally distributed. FFE and POP have probability values above 0.05, suggesting that their distributions are normally distributed. The table also provides the minimum and maximum values, showing the range of observations—the difference between the highest and lowest values in the dataset. The standard deviation, which measures the dispersion of the data, is also presented, indicating the variables have some variations.

4.2. Unit root test

To assess the stationarity of the variables, this study employs the Augmented Dickey-Fuller (ADF) test, outlined in **Table 3** below. Stationarity refers to the stability of a variable's mean and variance over time. The Augmented Dickey-Fuller test will be applied to find the unit root in this study. The proposed hypothesis will be:

H_0: The variable is not stationary.

H_1: The variable is stationary.

If the ADF test statistic exceeds the critical value at the 5% significance level, the null hypothesis of non-stationarity is rejected.

Table 3. 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
FFE	−6.537480	−2.938987	0.0000	I(1)	Stationary
LPOP	−3.002233	−2.963972	0.0461	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 3** above, show that, except for FDI and TOP, which are stationary at levels, i.e., I(0), others became stationary after differencing them once, i.e., I(1). Regardless of this mix of integration orders, the Johansen co-integration test in section 4.2 below revealed at least one cointegrating vector, confirming the existence of a long-run relationship among the variables. This further justifies the use of the DOLS model. It is also worth noting that an ARDL bounds test approach could also be adopted in this context. Nevertheless, given the established co-integration through the

Johansen co-integration test, the use of the DOLS model remains a robust and appropriate technique for the estimation of the long-run coefficients in this study.

4.3. Co-integration test

To determine the presence of long-run relationships among the variables, this study employs the Johansen co-integration test. Co-integration analysis assesses whether variables exhibit a stable equilibrium relationship over time, rather than simply moving together due to short-term fluctuations. The underlying hypotheses are as follows:

H_0 = There is no stable long-run relationship.

H_1 = There is a stable long-run relationship.

If both the trace and Max-eigenvalue tests indicate the presence of at least one co-integrating equation at the 5% significance level, the null hypothesis of no co-integration is rejected.

Decision: From **Tables 4** and **5**, the results indicate the presence of at least one co-integrating equation, as both the trace and Max-eigenvalue statistics exceeded their respective critical values in at least one instance. Consequently, the null hypothesis of no co-integration is rejected at the 5% significance level, suggesting a long-term relationship among the variables. This implies the variables tend to move together over time.

Table 4. Johansen co-integration test results (trace).

Hypothesized No. of Co-Integrating Equation	Eigenvalue	Trace Statistic	0.05 Critical Value	*P*.Value
None*	0.780850	104.6305	69.81889	0.0000
At most 1	0.372007	45.42856	47.85613	0.0831
At most 2	0.320921	27.28477	29.79707	0.0949
At most 3	0.258365	12.19105	15.49471	0.1480
At most 4	0.013600	0.534041	3.841466	0.4649

Trace test indicates 5 co-integrating eqn(s) at the 0.05 level. * denotes rejection of the hypothesis at the 0.05 level.

Table 5. Johansen co-integration test results (Max-eigenvalue).

Hypothesized No. of Co-Integrating Equation	Eigenvalue	Trace Statistic	0.05 Critical Value	*P* Value
None *	0.780850	59.20193	33.87687	0.0000
At most 1	0.372007	18.14380	27.58434	0.4832
At most 2	0.320921	15.09372	21.13162	0.2824
At most 3	0.258365	11.65701	14.26460	0.1242
At most 4	0.013600	0.534041	3.841466	0.4649

The Max-eigenvalue test indicates 3 co-integrating eqn(s) at the 0.05 level. * denotes rejection of the hypothesis at the 0.05 level.

4.4. Estimation result

In **Table 6**, the DOLS result demonstrates that in the long run, foreign direct investment (FDI) reduces total greenhouse gas emissions by an average of 2.29%. As a result, while controlling for all other variables, an increase in foreign direct investment will result in a 2.29% reduction in Nigeria's overall greenhouse gas

emissions. This finding aligns with the Porter Hypothesis, which posits that stringent environmental regulations in developed nations can benefit developing nations through trade liberalization and FDI, as these nations become destinations for cleaner, more advanced technology. The likely explanation for this result is that FDI facilitates the inflow of foreign capital and, consequently, cleaner, more sophisticated environmental preservation technology. This finding is consistent with findings from Zubair, Samad, and Dankumo [20] and Usman and Manap [21], which also revealed that FDI contributes to environmental sustainability in Nigeria. This, however, contrasts with studies that found Pollution Haven effects, such as Riti et al [6], Ayadi et al [7], which suggested that FDI increases CO_2 emissions in Nigeria due to lax environmental policies. By intuition, this result suggests that there are improvements in Nigeria's policy environment, possibly due to initiatives like the National Renewable Energy and Energy Efficiency Policy (NEP) and the Climate Change Act of 2021, which may be enabling FDI to bring in cleaner technology. Furthermore, channeling FDI into green projects, as supported by green finance initiatives [22], could reinforce the outcome of the Porter Hypothesis in Nigeria. However, it is crucial to temper optimism, as simply increasing FDI is not a panacea. As Yan et al. [10] suggest, firms' environmental performance can diverge with liberalization, underscoring the importance of accompanying measures like robust environmental regulations and incentives.

Table 6. DOLS regression result.

Variable	**Coefficient**	**Std. Error**	***t*-Statistic**	***P*-Value**
FDI	−0.022897	0.007699	−2.973969	0.0072
TOP	−0.251174	0.073146	−3.433888s	0.0025
FFE	0.013410	0.005604	2.393216	0.0261
LPOP)	0.214210	0.024771	8.647615	0.0000
C	8.841666	0.496504	17.80783	0.0000
R-squared	0.914230	Adjusted R-squared		0.848881
F-statistic	13.99003	Prob(*F*-statistic)		0.00000
Durbin-Watson stat	2.049125			
Diagnostic Tests	Test Statistic		*P*-Value	
Heteroscedasticity Test (Breusch-Pagan-Godfrey Test)	13.54057		0.6329	
Autocorrelation Test (Breusch-Godfrey Serial Correlation LM Test)	3.146883		0.2073	
Specification Bias Test (Ramsey-Reset Test)	1.491638		0.2362	
Normality Test (Jarque-Bera Test)	1.008721		0.603892	

Source: Researcher's construct from EView's output.

Similarly, trade openness (TOP) has a long-run coefficient of −0.251174 and is statistically significant at a 5% significance level. As a result, holding other variables constant, a percent increase in TOP decreases total greenhouse gas emissions by 25.1174% on average. This finding is consistent with findings from Sun et al [40], who found that trade openness reduces environmental pollution in Nigeria. The most plausible explanation for this is that trade liberalization provides Nigeria with the opportunity to import cleaner energy sources.

In contrast, fossil fuel energy consumption upsurges total greenhouse gas emissions in Nigeria. The result from DOLS in **Table 6** shows that, on average, a percentage increase in fossil fuel energy consumption will increase total greenhouse gas emissions by about 1.34%, holding other variables constant. This explains the high rate of dependency on fossil fuel as the primary energy source for Nigeria's manufacturers and consequently the upsurge in total greenhouse gas emission in Nigeria. This finding aligns with Kojo and Paschal's [41] findings, who discovered that fossil fuel energy consumption contributes positively to environmental pollution in Nigeria.

Furthermore, an increase in population also influences GHG emissions positively. **Table 6** shows that in the long run, a percent increase in population will result in a 21.42% increase in total greenhouse gas emissions on average, holding other variables constant. This finding aligns with Schneider's [42] findings, which discovered that the population contributes positively to environmental pollution in Nigeria. Intuitively, the demand for manufactured consumer goods also grows as the population grows. As a result, fossil fuel consumption, a necessary input in the production process, grows. This leads to an increase in greenhouse gas emissions that contribute to environmental degradation.

The results of the diagnostic test show that the model is accurately specified, there is no serial correlation or heteroscedasticity, and the error term has a normal distribution.

4.5. Parameter stability test (CUSUM test)

The CUSUM test result shown in **Figure 4** 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.

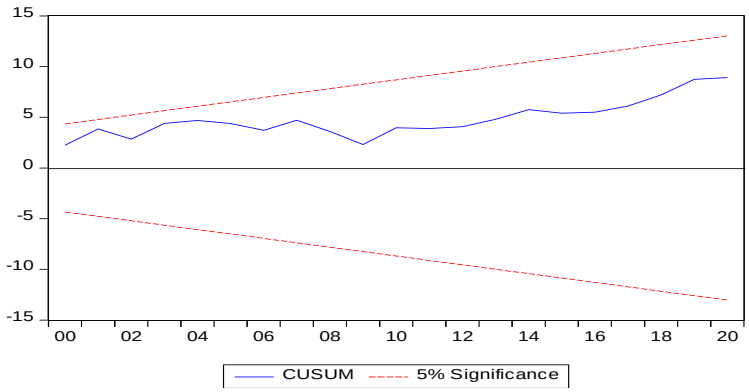

Figure 4. CUSUM plots for stability test.

5. 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 its impact on a nation's ability to preserve its environment. Hence, the purpose of this study is 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 show that trade openness and foreign direct

investment have a negative and significant long-term effect on Nigeria's greenhouse gas emissions. Therefore, the results of this study support the Potter hypothesis, which holds that emerging nations become centers of advanced and cleaner technology as a result of trade liberalization and foreign direct investment.

Consequently, given the findings of this study, which indicate that fossil fuel energy consumption increases total greenhouse gas emissions, this report suggests that the Nigerian government strongly supports the creation of compressed natural gas (CNG) stations and the switch to CNG-powered vehicles. Furthermore, to leverage the effect of FDI bringing in cleaner technology, as reinforced by the Porter hypothesis, the Nigerian government should actively promote investment in the green energy industry by offering tax holidays and other benefits to companies operating in this field. By attracting climate-focused investment and financing, Nigeria can solidify the positive environmental impact of FDI. Given the significant positive impact of population growth on greenhouse gas emissions, alongside the urgency of combating climate change, a widespread public education campaign on the threats posed by global warming is necessary in Nigeria. This is particularly vital because controlling emissions is not solely related to trade and FDI but also requires a well-rounded plan that tackles domestic factors.

This study contributes valuable insights to the ongoing debate regarding trade openness, foreign direct investment, and environmental sustainability. However, certain limitations should be acknowledged. The single-country focus restricts the generalizability of the findings; therefore, future research could adopt a comparative approach, examining a panel of countries with varying levels of economic development and environmental regulation. Moreover, given the significant impact of population growth on greenhouse gas emissions, public education campaigns addressing global warming are crucial alongside policies targeting trade and FDI.

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