Winning the Environmental Sustainability Crusade: Do Agricultural Development and Public Debt Mitigate Environmental Pollution in Nigeria?

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ABSTRACT

Although the literature has largely concentrated on a variety of factors that contribute to environmental pollution in Nigeria. It fails to recognize the influence of debt and agricultural development on the environment. Additionally, prior studies have employed CO2 emission to capture environmental degradation in their analyses. This study's purpose address the aforementioned gaps by analyzing the implications of public debt, and agricultural development on environmental degradation in Nigeria utilizing ecological footprint (a broad measure of pollution). The dynamic ordinary least squares (DOLS) method was used in this study to assess the influence of public debt and agricultural development on environmental pollution in Nigeria. The authors utilized time series data between 1981 and 2021. The results showed that population, agricultural development, public debt (domestic and external debt) and financial development reduce environmental pollution in Nigeria thereby promoting environmental sustainability while trade openness and energy consumption escalate environmental pollution though the effect of the latter was insignificant. The study made some policy suggestions to rejig the nation's environment

Keywords – Agricultural development, Public debt, Environmental pollution, Nigeria

INTRODUCTION

Human-induced climate change is probably the most significant concern for humanity due to environmental deterioration (Dimnwobi et al., 2021; Carrera and Vega, 2022). In recent decades, the concentration of atmospheric greenhouse gases (GHG), primarily carbon dioxide (CO2) has increased dramatically, Intergovernmental Panel on Climate Change (IPCC, 2021). Because they endanger biodiversity, climate stability and economic expansion, the factors and sectors that influence GHG emissions have drawn a lot of political and academic attention (Kwakwa, 2021; Carrera and Vega, 2022; Khalid et al., 2022). Among the ecological polluters, agricultural activities have a range of negative environmental effects (Kwakwa et al., 2022; Zafar et al., 2022). For instance, as noted by the Food and Agriculture Organization (FAO) report in 2017, due to increased food production, most forest cover has been trespassed, groundwater supplies have been exhausted as well as the destruction of biodiversity. The same report equally noted that the annual utilization of dirty fuels in the sector sends billions of tonnes of GHGs into the environment resulting in environmental deterioration (FAO, 2017). As per the statistics from the World Bank (2021a), agricultural activities currently account for 19-29% of overall GHG emissions. If there are no quick interventions, that proportion might significantly increase as other sectors cut their emissions. Analogously, Parajuli et al. (2019), Usman et al. (2021), Yasmeen et al. (2021), and Alavijeh et al. (2022) have identified agricultural activities as a major environmental pollution emitter in most economies. According to Kwakwa et al. (2022), the negative environmental impact of agricultural activities tends to be greater in developing economies than in their developed counterparts. Another driver of environmental pollution is public debt. Public debt-driven economic expansion may lead to higher energy consumption and consequent environmental degradation (Carrera & Vega, 2022). This is particularly true if investments are made in industries with high GHG emission rates, such as real estate, construction and manufacturing, or if the energy consumed as a result of increased economic activity is concentrated in sources with high emission levels, such as fossil fuel. Bese et al. (2021a), Bese et al. (2021b) and Carrera and Vega (2022) documented that public debt degrades the environment in diverse economies.

The decision of this study to focus on Nigeria is contingent on these justifications. First, statistics from the World Bank (2021b) show that carbon dioxide emission in the nation has significantly increased between 1990 (72,770kt) and 2019 (115,280kt). Such a trend does not bode well for a nation aiming to become a low-carbon economy (Dimnwobi et al., 2022a; Dimnwobi et al., 2022b). If these trends continue, they could hurt attempts to achieve most of the SDGs by 2030 (Alhassan, 2021). Despite contributing less to global GHG emissions, Nigeria remains one of the most climate-vulnerable nations. This is owing to the nation's reliance on rain-fed agriculture and insufficient infrastructure, which results in low agricultural production, poverty and severe food insecurity (Dimnwobi et al., 2017; Nwokoye et al., 2017; Nwokoye et al., 2019; Nwokoye et al., 2022). Second, relative to other African nations, Nigeria has relatively high levels of agricultural greenhouse emissions (Okorie & Lin, 2022). According to the 2019 Nigeria greenhouse factsheet, total greenhouse emissions in the country in 2014 were 492.44 million metric tons of CO_2 equivalent accounting for 1.01% of the world's GHG emissions (USAID, 2019). The nation's agricultural activities account for 51.2% of Nigeria's GHG emissions. Agricultural GHG emissions have steadily increased over time. Permanent agricultural activities are carried out on 6.5 million hectares of the nation's overall arable land area of around 34 million hectares. Roughly 23.36% of Nigeria's GDP is currently contributed by the agricultural sector, employing about 35% of Nigerians (World Bank, 2021b). Until the advent of crude oil in 1956, the sector was the largest contributor to national output and revenue (Che et al., 2020; Ekesiobi & Dimnwobi, 2020; Nwokoye et al., 2020; Azolibe et al., 2022; Okorie & Lin, 2022). Third, as of June 2022, Nigeria's total debt stock is 103.312 billion dollars with domestic debt and external debt contributing to US$63.248 billion and US$40.064 billion respectively (DMO, 2022). Despite the debt amnesty granted to the country by the Paris Club in 2005, the nation's debt stock has grown significantly generating discussion on its effects on the economy. Expectedly, the country's public official has defended these borrowings stating that it is critical in providing basic infrastructures, funding carbon mitigation initiatives and attaining most of the SDGs by 2030.

This study provides several significant contributions to the literature. First**,** this research is a pioneering endeavour to examine the effects of public debt, agricultural development and environmental quality in the literature. Second, unlike previous studies that have employed external debt in assessing the debt-environment nexus, this study uniquely decomposes public debt into internal and external debt. This segmentation is critical because they are the principal sources of the nation's debt stock. For instance, as per the Nigeria Debt Management Office, as of June 2022, domestic debt represents 61.22% of the nation's total debt. Third, prior studies have employed CO_2 emission to capture environmental degradation. This indicator, however, ignores the multifaceted nature of environmental degradation (Dimnwobi et al., 2021; Ehigiamusoe et al., 2022). The ecological footprint is used in this study to depict environmental changes because this metric is a more comprehensive and accurate picture of environmental pressures. Fourth, differing from prior studies which disregard econometrics-related issues such as reverse causality, simultaneity, potential endogeneity and serial correlation, this study employed a robust technique that tackles these issues. Specifically, we employed the dynamic ordinary least squares (DOLS) as the study's main estimation technique, while employing the duo procedures of the fully modified OLS (FMOLS) and the canonical cointegration regression (CCR) to validate our results. Lastly, this inquiry is more than just an empirical exercise; the outcome will help Nigeria develop and implement a far-reaching national climate change policy.

The remainder of our paper is divided as follows: Section two contains related prior inquiries, while Section three presents the methodological approach. The empirical outcome is reported and discussed in section four while Section 5 provides the conclusion as well as policy prescriptions.

LITERATURE REVIEW

The review of literature is divided into two categories: The first strand focuses on the influence of agricultural development on environmental degradation while the other category is on the implications of debt stock on environmental pollution.

2.1. Agricultural development and environmental degradation

Raihan and Tuspekova (2022a) applied dynamic ordinary least squares (DOLS) to Mexican data between 1990 and 2019 and reported that agricultural productivity lowers environmental pollution thereby enhancing environmental quality. Likewise, a similar outcome was obtained by Raihan and Tuspekova (2022b) using the same analytical technique and data from Nepal. In a similar study in Kazakhstan from 1996 to 2020, Raihan and Tuspekova (2022c) revealed that environmental quality is enhanced by agricultural productivity. Raihan and Tuspekova (2022d) highlighted that environmental pollution is significantly increased by expanding agricultural land in Peru. In a related study of Brazil between 1990 and 2019, Raihan and Tuspekova (2022e) discovered that Brazilian agricultural development contributes to environmental deterioration by raising CO2 emissions.

In a study of Bhutan between 1980 and 2020, Rehman et al. (2022) applied the ARDL and discovered that crop productivity and cropland usage have a positive connection with ecological damage. Kwakwa et al. (2022) applied the ARDL to unearth the influence of agricultural development on environmental pollution in Ghana between 1971 and 2018 and the study reported that agricultural development may be harmful to the environment because it is related to higher carbon emissions. Likewise, in Bangladesh, Raihan et al. (2022a) confirmed that environmental degradation is increased by agricultural productivity. Focusing on India between 1970 and 2018, Zafar et al. (2022) documented that agricultural development is beneficial to carbon reduction, whereas energy consumption harms the environment.

In Malaysia, Raihan et al. (2022b) discovered a positive link between agricultural land and environmental pollution, suggesting that expanding agricultural land causes environmental degradation. While Ali et al. (2021) discovered that agricultural innovation escalates environmental pollution in Nigeria, Kwakwa et al. (2020) confirmed that the production of aquaculture and livestock in Egypt degrades the environment. Based on China’s annual data, covering the years 1990 to 2016, Chandio et al. (2020) discovered that livestock and crop production significantly and positively affect environmental pollution. This implies that livestock and crop production causes carbon emissions in China to increase. A related study by Ullah et al. (2018) showed that Pakistan’s carbon emissions are highly influenced by agricultural machinery, cereal productivity, livestock production, and other crop production.

While the preceding paragraphs documented country-specific studies, the nexus between agricultural development and environmental pollution nexus has also been appraised in panel studies. For instance, focusing on the 15 most populated developing nations between 2004 and 2020, Alavijeh et al. (2022) highlighted that agricultural development has a substantial and positive influence on environmental pollution. Likewise, Yasmeen et al. (2021) revealed that agricultural production impairs environmental sustainability by increasing carbon emissions for 108 economies covering five regions between 1996 and 2015. In another study of seven South Asian economies between 1995 and 2017, Usman et al. (2021) highlighted that agricultural development considerably contributes to environmental deterioration, indicating that the sector hurts environmental quality. Using data from 14 African economies from 1990 to 2013, Sarkodie et al. (2019) discovered that environmental pollution is reduced by agricultural development. In BRICS nations between 1990 and 2014, Balsalobre-Lorente et al. (2019) confirmed that agricultural activities harm the environment. Analogously, Parajuli et al. (2019) and Adedoyin et al. (2021) disclosed that carbon emissions are increased by agricultural development in 86 nations and seven emerging economies respectively. Appiah et al. (2018) employed the FMOLS and DOLS to unearth the environmental pollution effects of agricultural production in emerging economies between 1971 and 2013 and the study reported that the production of livestock and crops both considerably contributes to the increase of environmental pollution.

In summary, the contradictions in the literature presented show that the agriculture-environmental pollution nexus is not conclusive in the extant literature. Furthermore, these studies used many proxies to assess environmental pollution ranging from carbon emission and deforestation. Analogously, various proxies are employed as agricultural development indicators ranging from agricultural value-added, crop yield, livestock production, and agricultural land expansion among others. However, the subject has received little attention in the Nigerian literature, hence this research closes the knowledge gap and offers crucial perspectives on the subject for Nigeria.

2.2. Public Debt and Environmental Degradation

In a study of 78 economies from 1990 to 2015, Carrera and Vega (2022) appraised the implications of external debt on ecological deterioration and discovered that external debt impairs the environment. Using data from 50 economies from diverse regions of the world, Zhao and Liu (2022) conclude that environmental degradation was positively influenced by the total debt-to-GDP ratio. In a recent study of Turkey between 1970 and 2016, Be?e and Friday (2022) confirmed that environmental pollution and external debt have an inverted U relationship.

For BRICS economies between 1990 and 2019, Sadiq et al. (2022) discovered that external debt protects the environment. Akam et al. (2021a) used data from 33 heavily indebted poor countries from 1990 to 2015 to appraise the implications of external debt on the environment and reported that environmental pollution is not increased by external debt. Akam et al. (2021b) arrived at a similar outcome while using data from South Africa, Algeria, Nigeria, and Egypt (SANE) nations between 1970 and 2018. Bese et al. (2021a) explored the influence of foreign debt on carbon emissions in China between 1978 and 2014 and highlighted a significant positive influence of external debt on environmental pollution. Bese et al. (2021b) assessed the influence of foreign debt on various kinds of emissions in India from 1971 to 2012 and confirmed the positive and significant influence of external debt on emissions of carbon dioxide, solid fuel use, gaseous fuel and methane. On the other hand, Katircioglu and Celebi (2018) discovered that external debt had no substantial environmental impact in Turkey between 1960 and 2013.

The literature shows that limited studies exist on the debt-environment nexus. However, most of these have utilized external debt to proxy a country's debt stock. However, we departed from the studies by disaggregating Nigeria's debt stock into external and domestic sources. These decompositions are crucial because Nigerian governments have mainly relied on these sources to fund carbon mitigation initiatives.

METHODOLOGY

3.1. Empirical modelling

This study utilizes the stochastic impacts of regression on population, affluence, and technology

(STIRPAT). The framework is expressed as;

$$I = \alpha P^{\beta 1} A^{\beta 2} T^{\beta 3} \mu \qquad (1)$$

Where I is the environmental impact captured with the ecological footprint (EFP), P is the population (POPG) pressure captured with the population growth rate, and A is the affluence captured with agricultural development (AD), which considerably adds to Nigeria's income level and T is the technology which is captured using trade openness (TO). Also, α is the constant, β1, β2 and β3 are the respective estimated parameters of population, affluence and technology and μ is the error term. As noted by Ahmed et al. (2020), the STIRPAT model can be modified by adding additional variables to the three explanatory variables. Following Kwakwa et al. (2021) and Kwakwa et al. (2022), the current STIRPAT model was expanded to include domestic debt (DOMD), external debt (EXTD), energy consumption (EC) and financial development (FD) because of the influence of these variables on the environmental degradation. As such, equation (1) becomes:

$$EFP = \alpha POPG^{\beta 1} .AD^{\beta 2}.TO^{\beta 3}.EXTD^{\beta 4}.DOMD^{\beta 5}.EC^{\beta 6}.FD^{\beta 7}. \mu \qquad (2)$$

Where $\beta^4 - \beta^7$ are additional parameters to be estimated

Logging the variables, we obtain equation 3 as

$$EFP = \alpha + \beta_1 POPG + \beta_2 AD + \beta_3 TO + \beta_4 EXTD + \beta_5 DOMD + \beta_6 EC + \beta_7 FD + \mu \qquad (3)$$

3.2. Data Description

The analysis makes use of annual time-series data collected primarily from the Central Bank of Nigeria, the World Bank and the Global Footprint Network Database. The period of the study is between 1981 and 2021 and this periodicity is contingent on data availability. The dependent variable of this inquiry is environmental degradation which is measured with the ecological footprint. The choice of this proxy is because the ecological footprint is a reliable tool for assessing the environmental pressures put on the ecosystem by human consumption and waste absorption. Since human activities affect the ecological atmosphere and degrade the quality of the water and land, it has been suggested that ecological footprint is a broad-based measure of environmental impairment (Dimnwobi et al., 2021; Ehigiamusoe et al., 2022). Public debt and agricultural development are the independent variables of the study. In alignment with Adedoyin et al. (2021), Alavijeh et al. (2022), Zafar et al. (2022) and Kwakwa et al. (2022), we utilized agricultural value-added to measure agricultural development. Similarly, owing to the peculiarity of the Nigerian environment and debt structure, we disaggregated public debt into internal and external debt. These decompositions are crucial because Nigerian governments have mainly relied on these sources to fund carbon mitigation initiatives. In line with recent literature (Dimnwobi et al., 2021; Alavijeh et al., 2022, Raihan and Tuspekova, 2022a,b,c., Zafar et al., 2022 and Kwakwa et al., 2022), we utilized four control variables namely energy consumption, financial development, population and trade openness. These variables are documented in Appendix 1.

3.3. Econometric Estimation Techniques

3.3.1. Unit Root Tests

To avoid spurious regression, the study tests for the stationary states of our time series data using both Philip Peron (PP) and Augmented Dickey-Fuller (ADF) unit root tests. In this study, the unit root test was utilized to guarantee that no variable surpassed the order of integration, as well as to validate the usage of the DOLS method over the conventional cointegration approach.

3.3.2. ARDL bounds test for cointegration

The study adopts an ARDL (Autoregressive Distributed Lag) bound test to co-integration to capture the long-run link between the variables. This is necessitated by the order of integration from the unit root test. This approach has several advantages over the other methods of co-integration. First, it is suitable when a series is integrated into different orders. Second, it is extremely reliable, particularly for a small sample size. Third, it provides an accurate prediction of the long-term model. Hence, the ARDL bounds testing method is expressed as:

$$LEFP)_{\mathrm{t}} = \alpha_0 + \alpha_1 (LEFP)_{t-i} + \alpha_2 (LPOPG)_{t-i} + \alpha_3 (LAD)_{t-1} + \alpha_4 (LTO)_{t-1} + \alpha_5 (LEXTD)_{t-1} + \alpha_6 (LDOMD)_{t-1} + \alpha_7 (LEC)_{t-1} + \alpha_8 (LFD)_{t-1} \sum_{i=1}^{q} \beta_1 \Delta(LEFP)_{t-i} + \sum_{i=0}^{q} \beta_2 \Delta(LPOPG)_{t-i} + \sum_{i=0}^{q} \beta_3 \Delta(LAD)_{t-i} + \sum_{i=0}^{q} \beta_4 \Delta(LTO)_{t-i} + \sum_{i=0}^{q} \beta_5 \Delta(\mathrm{LEXTD})_{t-i} + \sum_{i=0}^{q} \beta_6 \Delta\,(\mathrm{LDOMD}) + \sum_{i=0}^{q} \beta_7 \Delta(\mathrm{LEC})_{t-i} + \sum_{i=0}^{q} \beta_8 \Delta(\mathrm{LFD})_{t-i} \ \ \mathrm{v} \quad (4)$$

where Δ is the first difference operator and q is the optimum lag length, α_0 is the intercept while v is the error term. The null hypothesis is;

H_0: $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = \alpha_6 = \alpha_7 = \alpha_8$ while the alternative hypothesis is:

H_1 : $\alpha_1 \neq \alpha_2 \neq \alpha_3 \neq \alpha_4 \neq \alpha_5 \neq \alpha_6 \neq \alpha_7 \neq . \alpha_8$

Equation 4 is used to test whether cointegration exists or not. To account for the short-run linkage, the estimated ARDL model's error correction term is expressed as;

$$LEFP)_{\mathrm{t}} = \alpha_0 + \sum_{i=1}^{q} \beta_1 \Delta(LEFP)_{t-i} + \sum_{i=0}^{q} \beta_2 \Delta(LPOPG)_{t-i} + \sum_{i=0}^{q} \beta_3 \Delta(LAD)_{t-i} + \sum_{i=0}^{q} \beta_4 \Delta(LTO)_{t-i} + \sum_{i=0}^{q} \beta_5 \Delta(\mathrm{LEXTD})_{t-i} + \sum_{i=0}^{q} \beta_6 \Delta\,(\mathrm{LDOMD}) + \sum_{i=0}^{q} \beta_7 \Delta(\mathrm{LEC})_{t-i} + \sum_{i=0}^{q} \beta_8 \Delta(\mathrm{LFD})_{t-i} + \gamma \mathrm{ECT} + \mathrm{v} \quad (5)$$

3.3.3. Dynamic Ordinary Least Square (DOLS)

We adopted Dynamic Ordinary Least Square (DOLS) which was propounded by Stock and Watson (1993). DOLS is a co-integrating technique used to estimate the long-run relationship between dependent and series of explanatory variables. The DOLS is unique as it overcomes endogeneity, sample bias and autocorrelation problems. Thus after establishing cointegration among the variables, we estimated DOLS of long-run association using equation (6);

$$Y_{\mathrm{t}} = \alpha + bX_{\mathrm{t}} + \sum_{i=-\mathrm{k}}^{i=k} \theta\, \Delta X_{t+1} + e \qquad (6)$$

3.3.4. Fully Modified Ordinary Least Square (FMOLS) and Canonical Cointegration Regression (CCR*)*

To verify the robustness of the DOLS approach, we deployed FMOLS and CCR. The objective is to ascertain the accuracy of the DOLS results. The FMOLS model developed by Phillips and Hansen (1990), is

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commonly used to determine long-run elasticity coefficients and it addresses endogeneity issues, serial correlation, and omitted variable bias. FMOLS employs the non-parametric technique and is appropriate for small sample sizes since it generates unbiased, consistent, and efficient estimates. Park (1992) developed CCR, a cointegrating model with only the stationary component, and this approach is based solely on the stationary component of a data transformation. The CCR approach is based on a normal distribution. Thus we use FMOLS and CCR to also estimate the long-term elasticity as shown in equation 6.

RESULTS AND DISCUSSION

4.1. Descriptive statistics

Table 1 is the result of the summary statistics of all the variables used in our model. The findings indicate that DOMD has the highest average value of 3594.827, followed by EXTD (2311.984) and then EC (734.989) and TO (32.711). EFP has the lowest average value of 1.132. The probability values of most of the variables are higher than a 5% level of significance which shows that the parameters are normally distributed except for EXTD, DOMD and FD.

Table 1: Summary of statistics

Variables	EFP	POPG	TO	EXTD	DOMD	EC	FD
Mean	1.134	1.320	32.711	2311.984	3594.827	734.989	9.375
Median	1.120	1.250	34.182	648.810	1016.970	721.814	8.234
Maximum	1.370	2.110	53.277	15855.23	19242.56	848.064	19.625
Minimum	0.960	7.54405	9.135846	2.330000	11.19000	671.9070	4.957522
Std. Dev.	0.093753	4.04091	12.23624	3497.686	5162.039	52.04889	3.545440
Skewness	0.449466	0.386784	-0.44746	2.342756	1.536557	0.645728	1.049445
Kurtosis	3.031845	1.964246	2.324071	8.358841	4.246979	2.227230	3.676940
Jarque-Bera	1.382199	2.854958	2.148685	86.56330	18.78994	3.869434	8.308626
Probability	0.501025	0.239913	0.341522	0.000000	0.000083	0.144465	0.015697
Sum	46.49900	5.410	1341.164	94791.33	147387.9	30134.57	384.3859
Sum Sq. Dev.	0.351588	6.530	5989.019	4.890	1.070	108363.5	502.8059
Observations	41	41	41	41	41	41	41

Source: Authors Computation

4.2. Correlation between the variables

Table 2 shows the correlation result of the dependent and explanatory variables. From the outcome, we observed a positive correlation between dependent and independent variables. Also, there is no linear dependency between dependent and independent variables as none of the explanatory variables correlates with the dependent variable. This is so because none has a value up to 0.8 in its association with the dependent variable.

Table 2: Correlation Test

Variables	LEFP	LPOPG	LAD	LTO	LEXTD	LDOMD	LEC	LFD
LEFP	1.0000							
LPOPG	0.4358	1.0000						

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L AD	0.4073	0.3873	1.0000					
LTO	0.5847	0.5396	0.6644	1.0000				
LEXTD	0.376	0.8314	0.6753	0.6977	1.0000			
LDOMD	0.4845	0.9886	0.4663	0.6078	0.8648	1.0000		
LEC	0.3635	0.9271	0.1652	0.3858	0.7162	0.8846	1.0000	
LFD	0.4131	0.826	0.2537	0.3367	0.5481	0.8153	0.7199	1.0000

Source: Authors Computation

4.3. Results of unit root tests

The outcome of both ADF and PP unit root tests in Table 3 reveals that all the variables except POPG were not stationary at levels but became stationary after differencing them once. This shows an integration of the variables in mixed orders [I(1) and I(0)]. This outcome is suitable for using the ARDL bound test to check for the long-run relationship among the variables.

Table 3: Unit Root Tests

Variables	Augmented Dickey-Fuller (ADF) test		Philips-Perron (PP) test	
	Levels	First Difference	Levels	First Difference
LEFP	-1.571	-6.334***	-1.631	-6.333***
LPOPG	-0.709	-4.436***	1.254	-4.042***
LAD	-3.188**	-6.442***	-3.424**	-5.168***
LTO	-1.875	-7.562***	-1.875	-7.575***
LEXTD	-1.491	-4.864***	-2.5	-4.864***
LDOMD	-1.507	-4.699***	-2.063	-4.699***
LEC	-0.037	-6.170***	0.947	-6.640***
LFD	-1.613	-5.863***	-1.396	-10.581***

Source: Authors Computation. Note: **p < 0.05, ***p < 0.01.

4.4. Results of ARDL bounds test

The ARDL bounds test for co-integration which conforms to the series stationary properties is presented in Table 4. The results of the ARDL bounds test validate the existence long-run equilibrium relationship among the variables as the F-value is higher than the critical lower and upper limits at 10%, 5%, 2.5%, and 1%. Hence, we proceed to DOLS estimation.

Table 4: Bound Test Cointegration Result

F-bounds test		Null Hypothesis: No levels of relationship		
Test statistic	Value	Significance	I (0)	I (1)
Value of F -statistic	6.098706	10%	1.92	2.89
K	7	5%	2.17	3.21
		2.5%	2.43	3.51
		1%	2.73	3.9

Source: Authors Computation

4.5. DOLS Result

The result of the DOLS (see Table 5) revealed that all things being equal, the long-run coefficients of AD, POPG, EXTD, DOMD and FD are statistically significant and negative at 1% and 5% significant levels. This means that a 1% increase in POPG, AD, DOMD, EXTD and FD will lead to a 0.463%, 0.863%, 0.321%, 0.125% and 0.460% reduction in EFP respectively. This finding indicates that the above-named variable reduces environmental pollution in Nigeria.

The study discovered that public debt (domestic and external debt) reduces environmental pollution in Nigeria thereby promoting environmental sustainability. This indicates that Nigerian authorities utilize public debt in funding environmental protection and clean energy projects. Our study complements Sadiq et al. (2022) while conflicting with Bese et al. (2021a); Bese et al. (2021b) and Carrera and Vega (2022). This study documented that agricultural development protects Nigeria's environment. Agriculture productivity is linked to rising incomes, which stimulates demand for greener products. Similarly, the productivity of the agriculture sector prevents the extension of agriculture into forested regions thereby encouraging forest preservation and reducing environmental deterioration (Alhassan, 2021). The outcome shows that sustainable practices which enhance outputs without putting a strain on forest resources have been widely utilized in the Nigeria agricultural sector and our results align with Sarkodie et al. (2019); Raihan and Tuspekova (2022c) and Zafar et al. (2022).

Although population growth is expected to accelerate economic expansion, the depletion of natural resources and deforestation could degrade the environment but our outcome documented that population growth reduces environmental pollution. The possible explanation for this result is contingent on the fact that being one of the most populous economies of the world, Nigeria has been introducing several interventions to guarantee that population growth does not hamper the nation's chances of attaining sustainable development. Another possible explanation for this outcome is that population growth promotes innovations and this outcome matches Ibrahiem (2016); Appiah et al. (2018); Ahmed et al. (2019); Ibrahiem and Hanafy (2020). Financial development enhances Nigeria's environmental sustainability by lowering environmental pollution. A plausible explanation for this outcome is that the development of the financial sector makes credit available to firms and households enabling them to obtain energy-efficient appliances for their production and consumption activities respectively. The outcome corroborates Sheraz et al. (2021) and Kwakwa et al. (2022) for 20 economies and Ghana respectively. Our outcome on the reducing effect of financial advancement on environmental pollution in Nigeria is unsurprising given that the nation's financial sector has been environmentally conscious hence making credit facilities accessible to households and firms in the country to acquire sustainable energy. This outcome is partly supported by a recent inquiry in Nigeria by Dimnwobi et al. (2022a) and Somoye et al. (2022) which discovered that financial development stimulates the production and consumption of renewable energy in Nigeria.

However, the coefficients of TO are positive and significant at a 1% level of significant showing that the openness of the country's economy adds to pollution in the long run. Our outcome shows that environmental pollution increased with trade openness demonstrating the laxity of Nigeria's environmental policies. The results validate the pollution haven hypothesis, which contends that free trade forces developing economies to loosen environmental restrictions to lure foreign businesses to set up in their respective nations, thereby deteriorating the environment. The obtained outcome aligns with Kwakwa (2020); Coskuner et al. (2020); Alhassan (2021) and Dimnwobi et al. (2021).

The coefficient of EC on the other hand shows a positive but insignificant association with EFP in the long run. This outcome is expected given that Nigeria is energy-poor and traditional and fossil fuels are predominant in the country. This outcome aligns with prior studies of Raihan and Tuspekova (2022c); and

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Zafar et al. (2022). The insignificant effect of energy consumption on environmental pollution could be a gradual shift to energy efficiency and sustainable technologies following the introduction of the "National Renewable Energy and Energy Efficiency Policy (NREEEP)" in 2015 (Omoju et al., 2020; Dimnwobi et al., 2022b).

Considering, the R^2 and adjusted R^2 values as diagnostics tests which are 0.9865 and 0.9286 respectively, it can be seen that around 99 per cent of the changing variance of the dependent variable may be explained by independent factors. Additionally, the F-statistic demonstrates that the estimated DOLS regression is supported by the independent and dependent variables. With a p-value of 0.0004, the F-statistic indicates that the linear link in the model is statistically significant. The DOLS technique's outputs are a nearly perfect match to the data, as seen by the root means square error (RMSE) score of 0.02452, which is close to zero and non-negative.

Table 5: DOLS Results

Dependent variable: LEFP				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LPOPG	-0.46266	0.575587	-4.27852	0.0037
LAD	-0.86301	0.141339	-6.10599	0.0005
LDOMD	-0.32114	0.069285	-4.63506	0.0024
LEXTD	-0.12533	0.03623	-3.45938	0.0106
LTO	0.10886	0.031016	3.509756	0.0099
LFD	-0.45983	0.125444	-3.66561	0.008
LEC	0.831922	0.658904	1.262583	0.2472
C	4.887473	3.925926	1.244922	0.2532
R-squared	0.986508			
Adjusted R-squared	0.928685			
S.E. of regression	0.023371			
Long run variance	0.000147			
F-statistic	1619.937			
Prob (F-statistic)	0.0004			
Root mean square error (RMSE)	0.02452			

Source: Authors Computation

4.6. Robustness check

We adopted the FMOLS and CCR techniques to check for the robustness of the DOLS method and the results are presented in Table 6. The FMOLS and CCR results do not significantly differ from the DOLS results. The FMOLS and CCR output validates the negative and significant coefficients of POPG, AD, EXTD, and DOMD except for FD which was positive. Also, both FMOLS and CCR techniques established the positive coefficients of TO and EC with EC being significant only. Additionally, the R^2 and adjusted R^2 values from FMOLS and CCR estimation showcased the model's goodness of fit.

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Table 6: Results of FMOLS and CCR: Dependent variable LEFP

	FMOLS		CCR	
Variables	Coefficient	Probability	Coefficient	Probability
POPG	-0.5323*(0.3021)	0.0483	-0.6368*(0.331)	0.0642
AD	-0.0117**(0.105)	0.0157	-0.0440**(0.136)	0.0498
DOMD	-0.0398**(0.060)	0.0037	-0.059**4(0.068)	0.0134
EXTD	-0.054***(0.016)	0.0025	-0.0588***(0.020)	0.0068
TO	0.0656** (0.0388)	0.1012	0.0907**(042)	0.0417
FD	0.0063(0.060)	0.9176	0.0057(0.081)	0.9439
EC	0.3489**(0.539)	0.018	0.4812**(0.648)	0.0297
C	-7.3786**(3.667)	0.0532	-7.8798*(4.249)	0.0735
R-squared	0.986508		0.598976	
Adjusted R-squared	0.928685		0.478669	
S.E. of regression	0.023371		0.061645	

Note: *, ** and *** denote significant at 1%, 5% and 10% levels respectively. Values in parenthesis signify the standard errors

Source: Authors Computation

4.7. Diagnostic Tests

In this study, we carried out some diagnostics tests such as heteroscedasticity, normality, and serial correlation analysis and the outcome is represented in Table 7. Hence our model shows normality and the absence of serial correlation and heteroscedasticity.

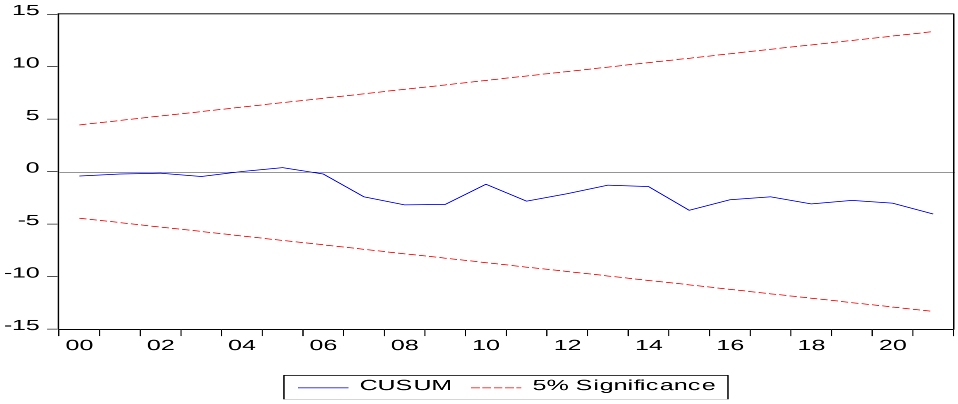
Table 7: The results of diagnostic tests

Diagnostic tests	Coefficient	p-value	Decision
Jarque-Bera test	2.1271	0.1213	Residuals are normally distributed
Breusch-Godfrey LM test	4.30764	0.2278	No serial correlation exits
Breusch-Pagan-Godfrey test	3.558481	3.558481	No heterosce dasticity exists

Source: Authors Computation

For the stability test, we estimated recursive tests of the cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMQ) and observed that the residuals' values remain within the confidence intervals, confirming the model's stability.

Figure 1: The plot of CUSUM (critical bounds at 5% significance level)



Source: Authors Computation

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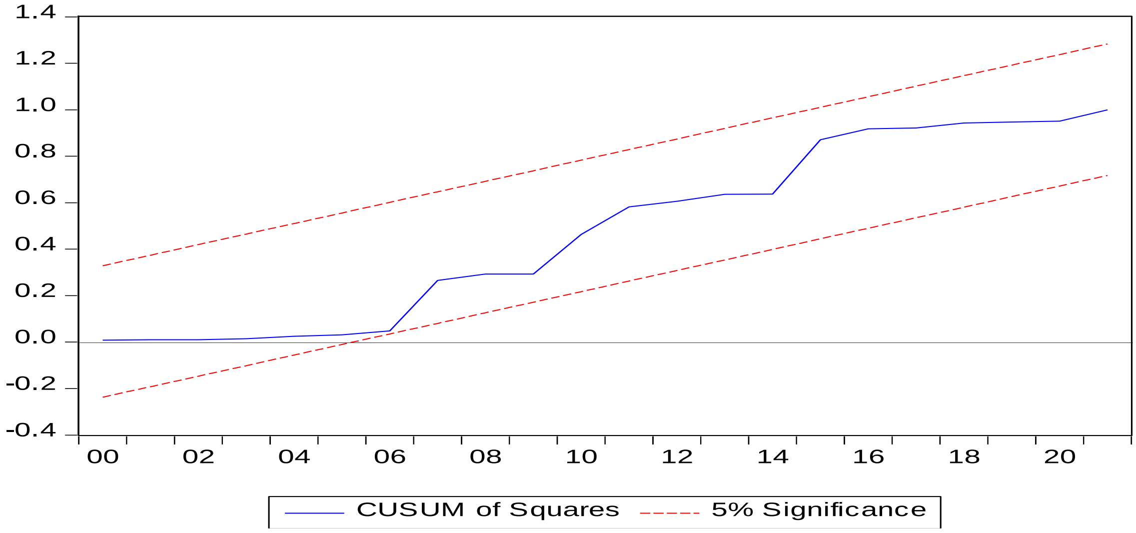
Figure 2: The plot of CUSUMQ (critical bounds at 5% significance level)



Source: Authors Computation

CONCLUSION AND POLICY IMPLICATIONS

Among policymakers and researchers, the environmental externalities of public debt and agricultural development have grown extremely contentious. To guide environmental policymakers and contribute to the ongoing debate, the study appraises the influence of public debt and agricultural development on environmental pollution in Nigeria between 1981 and 2021. The study applied both the ADF and PP tests to ascertain the stationarity of the variables. The study utilized the DOLS as the main estimation technique while the FMOLS and CCR were utilized for robustness checks. The outcome of the study shows that population, agricultural development, public debt (domestic and external debt) and financial development reduce environmental pollution in Nigeria thereby promoting environmental sustainability while trade openness and energy consumption escalate environmental pollution though the effect of the latter was insignificant.

Taking into account the findings, the study made several policy prescriptions. This study recommends that Nigerian policymakers create efficient measures to deepen environmental sustainability by boosting agricultural productivity. Enhanced initiatives are required to improve agricultural production by utilizing contemporary agro-based techniques, including disease-resistant and high-yield arrays of crops and sustainable land administration, as well as motivating farmers to forego conventional farming techniques in favour of more modern practices. Besides, the output of the agricultural sector can be significantly improved with the assistance of cutting-edge agricultural machinery and the accessibility of high-quality seeds as well as other sustainable practices. By implementing low-carbon and organic farming techniques, sustainable agriculture has the potential to reduce ecological damage while enhancing carbon sequestration. To increase the production of agriculture over time, the government should stimulate the utilization of efficient energy infrastructure and assist farms in making the switch to sustainable energy sources. The utilization of clean energy should be encouraged by the government because it mitigates environmental pollution while also increasing agricultural yield. Providing grants for the use of sustainable energy in the agricultural sector would increase the sector's competitiveness in global markets while reducing pollution. To achieve carbon neutrality, irrigation techniques can be changed to renewable energy sources from non-renewable ones. Analogously, to ensure sustainable agriculture and reduce pollution, the utilization of pesticides and fertilizer must be limited and priority must be given to green production. Moreover, increasing investment in agriculture in Nigeria through deepening international collaboration would help to minimize agricultural emissions while enhancing agricultural output in Nigeria.

The study highlighted that public debt reduces environmental degradation in Nigeria. To sustain this momentum, governments at all levels in the country should ensure that borrowed money is directed towards the acquisition of sustainable energy. Also, incentives should be given to industries that utilize clean production techniques while taxing firms that employ dirty fuels for the harmful externalities they generate. Put differently, the pursuit of energy-efficient production methods in the various industries in Nigeria is necessary as this is essential to making sure that Nigeria transitions to a low-carbon economy to secure the nation's sustainable development.

This study focuses on the symmetric effect of public debt and agricultural development on environmental degradation, Future research can explore the asymmetric effect of investigated regressors on environmental pollution. Analogously, future studies could improve the literature by utilizing different control variables.

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APPENDIX

Data Summary

Variables	Measurements	Sources
Ecological Footprint (EFP)	Global hectares per capita	Global Footprint Network Database
Domestic Debt (DOMD)	Billions of naira	Central Bank of Nigeria (2021)
External Debt (EXTD)	Billions of naira	Central Bank of Nigeria (2021)
Agricultural development (AD)	Agriculture, forestry, and fishing, value added (% of GDP)	World Bank (2021b)
Population Growth (POPG)	Annual (%)	World Bank (2021b)
Energy consumption (EC)	Kg of oil equivalent per capita	World Bank (2021b)
Financial development (FD)	Domestic credit to the private sector (% of GDP)	World Bank (2021b)
Trade openness (TO)	% of GDP	World Bank (2021b)

Source: Authors Computation