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Impact of poverty, population density, and trade openness on deforestation: fresh evidence from Nigeria

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Abstract. Using time series data from 1981 to 2015, this study examines the impact of poverty, population density, and trade openness on deforestation in Nigeria, and it tests the presence of the environmental Kuznets curve (EKC) hypothesis. The results of an autoregressive and distributed lag (ARDL) bounds testing approach to cointegration indicate that poverty, population density, and trade openness all have a significant positive impact on deforestation. The estimated result also suggests that deforestation and income per capita in Nigeria have an inverted U-shaped relationship. Hence, it supports the EKC hypothesis for deforestation in Nigeria. It implies that when income per capita increases, deforestation experiences an increasing trend up to a certain point, after which it reverts with a continuous increase in income per capita. As a recommendation, policy options that would alleviate poverty, control population upsurge, and restrict timber export would be vital in reducing deforestation in the country.

1. Introduction

International organisations, conservationists, and researchers are concerned about deforestation. The most cited contributors are agriculture, logging, urbanisation, population, and poverty. Several further links are mentioned in the literature [1-5]. However, for this study, we focus on the impacts of population density, poverty, and trade openness, on deforestation in Nigeria.

The world's forest area has continuously declined over the last 25 years due to human activities [6]. [7] reports that out of the world's total land area, only about one-third was covered by forests in 2010, amounting to about 4 billion hectares, and it was the same in 2018 [8]. People may depend on forests due to proximity and poverty [9]. This dependency causes deforestation. Deforestation today occurs more often in developing nations in tropical regions [9]. From 2010 to 2020, Africa's annual net loss of forests was 3.9 million hectares [10]. The 2015 Global Forest Resources Assessment (GFRA) report puts Nigeria’s annual deforestation rate at 2.7% for 1990-2000, 3.7% for 2000-2010, and 5% for 2010-2015 [6]. According to this data, Nigeria has the largest annual forest loss from 2010–2015.

Poverty, population growth, and export logging drive deforestation in Nigeria. Forest pressure will remain with a national poverty headcount ratio of 46% [11]. The poor rely on wood fuel due to exorbitant kerosene, gas, and electricity rates.

Nigeria's population is growing [11] and is projected to be 239 million and 440 million [12]. It ranks 7th in the world [11]. The overpopulated areas undergo environmental degradation when the land cannot support the population [13].

Rosewood demand from China increased illegal harvesting in Nigeria's natural forests. Rosewood-rich Nigerian states deforest extensively as China imports 45% of its rosewood from Nigeria [14].

Using the EKC hypothesis, this study examines poverty, population density, trade openness, and deforestation relationship. The Environmental Kuznets Curve (EKC), named after Simon Kuznet (1955), postulates that early income growth affects the environment but reverses later, generating an inverted U curve. Previous studies on EKC reported mixed results hence the need for further investigation into Nigeria's deforestation. This study adds to the literature by adding poverty, population density, and trade openness in Nigeria's deforestation model. This has never been done, especially in Nigeria.

2. Literature Review

The study of deforestation can hardly be complete without evaluating the EKC theory. [15] investigated the EKC hypothesis in Pakistan during 1980-2013 using deforestation to proxy environmental degradation. Their study supports EKC for deforestation in Pakistan. Likewise, [16] used a meta-analysis to determine if EKC for deforestation theory is endangered. Using 69 research and 547 estimations, they discovered a tipping point after 2001 and argued that the EKC theory would continue to hold until alternative theories emerge.

According to [17], policy approaches focused at protecting ecological services must consider the role of poor people in clearing forests, whether they degrade or conserve them. Poorer areas remove woods faster and vice versa. Similarly, [18] found that poverty reduction saves forests. Though [19] suggests that small increases in the incomes of the poorest may not stop deforestation.

Population and deforestation in developing countries remain interlinked, [20] said. Population growth boosts the conversion of forests to agriculture in African, Asian, and Latin American countries, according to [21]. Since most rural residents depend on agriculture for survival, deforestation should increase with population expansion.

Poverty, population, and the environment are often intertwined, leading to environmental degradation through deforestation [22].

3. Research Methodology

Using 1981-2015 time-series data for Nigeria, we analyse the EKC link between income and deforestation. To our knowledge, only [5, 23] have studied EKC and deforestation in the country. Other research on EKC in Nigeria employed CO2 emission to proxy environmental degradation [24].

The study employed forest area (% of land area) to proxy deforestation, while income is proxied by GDP per capita (2010 US$), poverty headcount at $1.90 a day in 2011 Purchasing power parity for the poverty indicator, trade (as a % of GDP) for trade openness, while population density is the population expansion index. The World Bank's World Development Indicators (WDI) database provided all of the data.

3.1 Model Specification

This study extends [25] 's, log-linear model. The log-linear specification offers consistent empirical results [30]. The equation for this study is modelled as follows:

$$lnDF_t = \alpha_0 + \alpha_1 lnY_t + \alpha_2 lnY_t{}^2 + \alpha_3 lnPV_t + \alpha_4 lnPD_t + \alpha_5 lnTO_t + \mu_t \qquad (1)$$

Where DF stands for deforestation, Y stands for income per capita, Y^2 is the square of income, PV is the poverty indicator, PD represents the population density, TO represents trade openness, and μ_t is the error term. We expect α_1 to be positive ($\alpha_1 > 0$), while we expect α_2 to be negative ($\alpha_2 < 0$) and form an inverted U-curve, which satisfies the EKC hypothesis. If $\alpha_2 > 0$, then we have a U-shaped curve, and If it is statistically insignificant, it suggests a monotonic expansion in the relationship between deforestation and per capita income [26]. The signs for α_3, α_4 and α_5 are expected to be positive. [25] supports including poverty variable. [27] adds population density. FAO supports trade openness in [14].

Given its many benefits over more traditional cointegration methods like those presented in [28-31] we opted for the ARDL methodology given in [32]. This method can simultaneously estimate long- and short-run models with fewer degrees of freedom, and it can estimate cointegration and models without a unit root test. Recent ARDL research in different countries includes [26], [33], [34], and [25]. Below is the long-run relationship equation:

$$\Delta lnDF_t = \varphi_0 + \sum_{i=1}^{n} \varphi_{1i}\,\Delta lnDF_{t-i} + \sum_{i=0}^{n} \varphi_{2i}\,\Delta lnY_{t-i} + \sum_{i=0}^{n} \varphi_{3i}\,\Delta lnY_{t-i}^2 + \sum_{i=0}^{n} \varphi_{4i}\,\Delta lnPV_{t-i} + \sum_{i=0}^{n} \varphi_{5i}\,\Delta lnPD_{t-i} + \sum_{i=0}^{n} \varphi_{6i}\,\Delta lnTO_{t-i} + \delta_1 lnDF_{t-1} + \delta_2 lnY_{t-1} + \delta_3 lnY_{t-1}^2 + \delta_4 lnPV_{t-1} + \delta_5 lnPD_{t-1} + \delta_6 lnTO_{t-1} + \mu_t \quad (2)$$

Bounds testing uses Fisher (F) or Wald-statistics. If the F-Statistic is above the critical limit, there can be no cointegration and the order of integration cannot be validated. A unit root test is required if the F-statistic is below the critical limit [32, 35-37]. This study employs [36] rather than [32] for the bounds test. This is based on the approach by [38] and [26]. Before estimating the short-run and long-run models, we utilised Akaike Information Criterion (AIC) to select lags. The ECM is constructed in the following manner:

$$\Delta lnDF_t = \varphi_0 + \sum_{i=1}^{n} \varphi_{1i}\,\Delta lnDF_{t-i} + \sum_{i=0}^{n} \varphi_{2i}\,\Delta lnY_{t-i} + \sum_{i=0}^{n} \varphi_{3i}\,\Delta lnY_{t-i}^2 + \sum_{i=0}^{n} \varphi_{4i}\,\Delta lnPV_{t-i} + \sum_{i=0}^{n} \varphi_{5i}\,\Delta lnPD_{t-i} + \sum_{i=0}^{n} \varphi_{6i}\,\Delta lnTO_{t-i} + \eta ECM_{t-1} + \mu_t \quad (3)$$

The ECM measures equilibrium readjustment speed. Diagnostic and stability tests evaluate ARDL bounds testing's fit. It checks for serial correlation, model specification, normality, and heteroscedasticity. The ARDL parameter stability is tested with CUSUM and CUSUMSQ.

4. Results and Discussion

We utilised the Augmented Dickey-Fuller test and compared it to the Philips-Perron test to verify if the variables had unit roots, which is common with time series data. Table 1 shows unit root test results. The results show that all the variables are stationary at either level or at first difference. Hence the study can proceed to estimate the long-run relationship. The estimated result for the long-run relationship among the variables is shown in Table 2. The cointegration result (Table 2) reveals the computed F-statistic is 4.12, which is exceeds the upper critical bound in the Narayan table at significance level of 5% level. Hence, the null hypothesis of no cointegration is rejected, indicating the existence of a long-run relationship.

Table 1. Unit root tests' results

	ADF		pp		
Variable	Intercept	Intercept & Trend	Intercept	Intercept & Trend	Decision
lnDF	-27.024***	-33.324***	-9.600***	-16.270***	

Δ lnDF	-48.365***	-55.079***	-37.023***	-36.151***	S
lnY	0.986	-1.863	0.587	-1.860	
Δ lnY	-4.288***	-5.133***	-4.246***	-5.108***	S
lnY^2	0.511	-2.075	0.239	-2.074	
Δ lnY^2	-4.341***	-4.930***	-4.325***	-4.880***	S
lnPV	-2.218	-2.925	1.373	-2.340	
Δ lnPV	-5.141***	-5.122***	-5.460***	-5.714***	S
lnPD	4.480***	-1.214	33.660***	9.407***	S
Δ lnPD	-0.530	-4.094**	5.401***	-6.113***	S
lnTO	-0.4083	-3.257	-0.418	-3.371	
Δ lnTO	-5.565***	-5.727***	-5.615***	-5.901***	S

Note: ***, ** and * denotes significance at 1%, 5% and 10% levels. Δ is the difference operator. S stands for stationary.

Table 2. ARDL cointegration test.

Bounds test result	F-Statistic	Lag	Level of Sig.	Unrestricted intercept without trend	
				I(0)	I(1)
$lnDF_t = f(lnY, lnY^2, lnPV, lnPD, lnTO)$	4.12	2	1	3.74	5.06
			5	2.86	4.01
			10	2.45	3.52

Note: F-statistic is greater than the upper bounds at 1%, 5% and 10%, indicating cointegration among variables.

The long-and short-run results of the ARDL model are presented in Table 3 alongside the fully modified ordinary least squares (FMOLS) result as a robustness check. All the explanatory variables are significantly related to deforestation in the short and long-run.

The signs of income coefficients and its squared form validate an inverted U-shaped Kuznets curve. All things being equal, when per capita income increases by 1%, deforestation will increase by 1.87 %. The negative sign of income squared corroborate a decrease in deforestation as income levels increase and are sustained. This result is similar to the result by [19]. The finding is also similar to the results of [39], [15], and [5], but negates the finding of [21] and [40] for Africa and Latin America, and Malaysia respectively.

Similarly, the study finds that poverty and deforestation are positively related in Nigeria, in the short-run and long-run. It indicates that deforestation in Nigeria increases with high poverty levels. This result is supported by the findings of [17] and [18].

Table 3. Long-run and short-run models' results.

Dependent Variable =lnDF				
Long-run and short-run results			FMOLS results	
	Coefficients	T-ratio (*p*-values)	Coefficients	T-ratio (*p*-values)
Long-run coefficients				

lnY	1.871	3.499(0.001) ***	1.556	2.329(0.026) **
lnY^2	-0.226	-3.765(0.000) ***	-0.221	-2.780(0.009) ***
lnPV	1.784	4.569(0.006) ***	1.753	-3.443(0.001) ***
lnPD	1.481	2.932(0.000) ***	1.873	3.015(0.005) ***
lnTO	0.026	2.291 (0.031)**		
Short-run coefficients				
Δ lnY	3.337	3.307(0.025) **		
Δ lnY^2	-0.405	-3.529(0.001) ***		
Δ lnPV	3.182	4.190(0.000) ***		
Δ lnPD	2.641	2.783(0.009) ***		
Δ lnTO	0.092	2.304 (0.011)**		
ECM (-1)	-0.783	-4.889(0.000) ***		

Note: ***, ** and * denotes significance at 1%, 5% and 10% levels.

The result reveals that increasing population will intensify deforestation in the short and long run, as a 1% increase in population density increases deforestation by 2.64% and 1.48%. This finding corroborates [39], but contradicts [28] 's finding in sub-Saharan Africa. Trade openness has a positive and significant coefficient in the short and long run. It means that exporting timber products promotes deforestation in Nigeria. This finding agrees with FAO in [23].

Additionally, in line with theory, the error correction term's coefficient is noticeably negative and lower than one. The coefficient of the ECM also shows that 78% of change from the long-run equilibrium is restored within a year. The ECM term measures the speed with which it readjusts to the long-run equilibrium after the model is shocked.

We performed the FMOLS analysis to verify the robustness of the long-run results. The FMOLS estimator is an asymptotically unbiased estimator which has the power to deal with endogeneity problems associated with most estimators. All the variables were significant at 1%, except for income which is significant at 5%. According to [36], If the robustness of the results is a concern, utilising more than one estimator is imperative.

Table 4. Diagnostic tests' results.

Test Statistics	LM Version	F Version
A: Serial correlation	6.103(0.098)	0.981(0.137)
B: Functional form	1.105(0.000)	1.222(0.000)
C: Normality	Not applicable	Not Applicable
D: Heteroscedasticity	14.029(0.372)	1.081(0.428)

Note: ***, ** and * denotes significance at 1%, 5% and 10% levels.
A: Lagrange multiplier test of residual serial correlation
B: Ramsey's RESET test using the square of the fitted values
C: Based on a test of skewness and kurtosis of residuals using Jarque-Bera
D: Breusch-Pagan-Godfrey test based on the regression of squared residuals on squared fitted values

The results of the diagnostic tests are reported in Table 4. The results indicates that the p-values for all the diagnostic tests exceed the 5% significance level. It indicates that there is no serial correlation nor heteroscedasticity, and that the errors are distributed normally. we ran a stability test with the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMSQ), as shown in Figures 1 and 2, respectively. The critical bounds at the 5% level of significance are shown by the two parallel straight lines. The line within the critical bounds, which represents the results of the short-run and long-run analyses, suggests that the coefficients of our error correction model provide a good model fit. Hence, our model is consistent, stable, and reliable enough for policymaking.

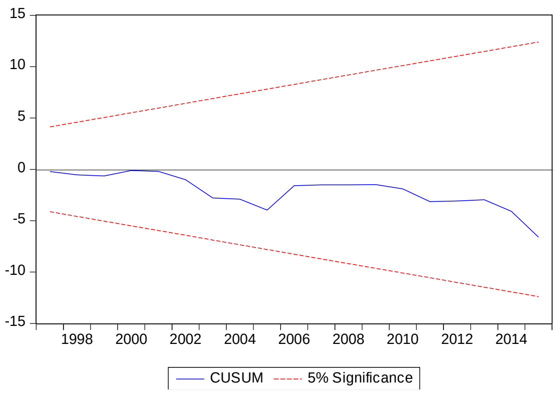

Figure 1. Plot of cumulative sum of recursive residuals.

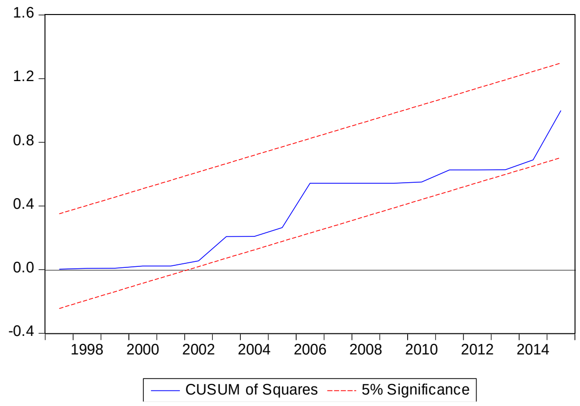

Figure 2. Plot of Square of cumulative sum of recursive residuals.

5. Conclusion and Policy Implications

This research examined poverty, population density, and trade openness to validate the EKC hypothesis on deforestation in Nigeria. To accomplish this, we used an approach to the cointegration model called the ARDL bounds test that was established by [32].

The study's results suggest that deforestation in Nigeria is affected positively by poverty, population density, and trade openness. It implies that poverty, population density, and trade are the significant contributors to deforestation in Nigeria. The result also validates that there is EKC for deforestation in the country.

To reduce deforestation, policymakers must improve poverty alleviation programmes including conditional cash transfers and N-power [41]. New poverty-reduction initiatives are also suggested due to the country's rising poverty, which causes deforestation. Current population control policies are weak and ineffectual. According to the 2006 census [42], the birth rate drives population growth. Policymakers must address population growth problems. Finally, measures targeting international trade rules in timber products should be examined and emphasised. Reducing forest clearance for timber production will help slow deforestation.

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