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Environmental management amidst energy use, urbanization, trade openness, and deforestation: The Nigerian experience

Solomon Prince Nathaniel[1] | Festus Victor Bekun[2]

[1]Department of Economics, University of Lagos, Akoka, Nigeria

[2]Faculty of Economics Administrative and Social Sciences, Istanbul Gelisim University, Istanbul, Turkey

Correspondence
Solomon Prince Nathaniel, Department of Economics, University of Lagos, Akoka, Nigeria.
Email: nathaniel_solomon21@yahoo.com

This study empirically explores the linkage between urbanization and deforestation while controlling for the role of energy consumption, trade openness, and economic growth within recent data from 1971 to 2015. To do this, we employed the vector error correction-Granger causality approach and Pesaran's autoregressive distributed lag cointegration technique. The Bayer–Hanck cointegration test establishes an equilibrium relationship among the variables. Results reveal that economic growth, energy consumption, and urbanization have a significant impact on deforestation in Nigeria, thereby reducing the quality of the environment. Short- and long-run unidirectional casualty flows from urbanization to deforestation. Therefore, policies for reducing deforestation and enhancing environmental sustainability for growth and development were suggested.

1 | INTRODUCTION

Nature does not need us. We actually need nature. For the past few decades, the necessity for biological diversity to be maintained for continued human existence has emerged as a critical global issue. The need for conservation, management, and sustainable use of the world's flora and fauna, as well as the environment, is a matter of utmost importance. The importance of the environment to human existence cannot be overemphasized. This position has been advocated by the United Nations Convention on Climate Change alongside the 2015 Paris Agreement as they implore countries to keep mean temperature increase well below 2°C by the end of the century. The Agreement further commits countries to reduce the temperature rise to below 1.5°C so as to achieve minimum greenhouse gas emission in 2020. Unfortunately, the world depends on crude oil, natural gas, coal, and fossil fuels whose reserves are finite (Bildirici & Özaksoy, 2016).

Biomass is an organic matter that is renewable over time. Wood remains the largest biomass energy source. Wood constitutes about 87% of the total biomass energy, which includes forest residues, yard clippings, wood chips, animal dung, sawdust, charcoal, and so forth. Wood energy is achieved by using lignocellulosic biomass as fuel. Both wood and wood-based products are used by businesses, households, and industries (Food and agricultural organization [FAO], 2010). Nigeria is rich in biomass resources because it has a good environment and geography that supports the growth of almost all crops. The country has kilometers of forest areas but is depleting them at a faster rate than they are being created. Woody biomass energy consumption in Nigeria has expanded rapidly over the years. Saad and Bugaje (2016) attributed this expansion to poverty, availability and cost, and cultural factors. No matter where we live, the forests make our life possible. Forests are a key source of biodiversity, and when a forest is lost anywhere, people feel it everywhere.

The deforestation rate in Nigeria is accelerating. The resilience of the ecosystem has diminished due to overgrazing and poor land tenure system. Deforestation has implication for desertification. Nigeria lost about 409,700 ha of forest every year between 1990 and 2005 (FAO, 2005). This keeps the annual deforestation rate at 2.38% and 35.7% of forest cover lost. Nigeria's forest cover is less than 6%, which is far below the 26% recommended by Food and Agricultural Organization. The deforestation rate in Nigeria was the highest in the world in 2005 (FAO, 2005). This statistic represents a danger for the nation and stakeholders alike. Ibrahim, Iheanacho, and Bila (2015) attributed the causes of deforestation in Nigeria to fuelwood consumption, forest product for export, round wood consumption, and area of food crop production. Nigeria's economy has growth potential given its antecedent in the last decades. The country's openness to trade has been greeted with an increase in energy demand. However, all these have a negative impact on the environment.

Nigeria's economy relies on agriculture and, to a large extent, on crude oil (Okunola, Nathaniel, & Festus, 2018). Urbanization has also

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been on the increase in Nigeria. Increase urbanization, which creates the need for more agricultural land, and population explosion are causing deforestation in the country. Due to a high rate of deforestation, Nigeria was far behind the World Bank's Millennium Development Goal of 6% increase in forest area by 2015. Deforestation is also responsible for the country's various natural disasters in recent years, as its activities trigger other forms of a natural disaster like a desert encroachment. A good example was the 2012 flooding that killed about 363 people and displaced 2.1 million others (National Emergency Management Agency, 2012). National Emergency Management Agency further alerted that the country would face more of such natural disasters if deforestation persist. Forest are useful because they react sensitively to climate change, and they also produce wood for fuel (FAO, 2014). The environment can be well preserved by ending deforestation, which will curb global warming. Reducing emission from deforestation will benefit lower income nations in terms of agricultural expansion and economic growth (Doupe, 2014). Therefore, deforestation, urbanization, population, energy consumption, and openness to trade are factors that should be closely monitored and controlled to protect the biodiversity, curtail the negative impact of climate change, and entrench environmental sustainability in Nigeria. Agriculture is the major driver of deforestation (FAO, 2014). Thus, this necessitates the inclusion of agricultural land as a percentage of the total land area as a proxy for deforestation.

Against this background, we empirically explore the nexus of energy use, trade flow, economic growth, urbanization, and deforestation in Nigeria. Unlike other related studies, this study adds to the existing literature, especially those from Nigeria, by incorporating urbanization as a potential determinant of environmental degradation in Nigeria. Thus, we seek to advance the frontiers of knowledge on the following fronts: (a) Given that Nigeria is a fast emerging economy, people tend to move from rural areas that are less developed to the urban cities to provide for their livelihood. In order to cater to the population explosion (in urban cities), agricultural lands are either been cleared to build houses for accommodation or industries to cater to the ever-growing unemployed army. Hence, the inclusion of urbanization as one of the variables could degrade the environment. (b) Economic episodes offer structural break dates in time series data especially our focus data series due to the implementation of economic policies (e.g., Structural Adjustment Program in 1986). These structural breaks are enough to change the unit root results, causality, and the effect of each of the variables on the dependent variable. Hence, structural break unit root tests, which were not considered (especially for studies in Nigeria), are employed. (c) The Bayer and Hanck (2013) recent cointegration test and Pesaran's autoregressive distributed lag (ARDL) bounds test were utilized while controlling for possible structural breaks over the period examined.

The layout of our study is given as follows: Section 2 discusses previous studies. Section 3 dwells on the econometric modelling. Section 4 focuses on data and discussions of results. The conclusion is highlighted with relevant policy framework emanating from the study in Section 5.

2 | REVIEW OF EXISTING STUDIES

Environmental sustainability is not only an interdisciplinary issue but is also well discoursed in both secular and academic spheres, more so among economists and environmentalist. Kuznets (1955) researched on long-run income inequality and income growth to ascertain how the disparity in income reacts to economic growth. From his findings, income inequality rises at the early trajectory of income rise, however, after some point (maximum point), income inequality experiences a diminishing return. In the late 1990s, a similar relationship that linked environmental quality with real income was discovered and referred to as the environmental Kuznets curve (EKC). Over the years, especially of recent, various scholars have explored the theme under consideration using carbon emission as an indicator of environmental degradation (see, e.g., Ahmad, Du, Tian, & Wang, 2018; Tang & Tan, 2015; Antonakakis, Chatziantoniou, & Filis, 2017; Ben, Kais, Mohammad, & Rahman, 2017; Bretschger, 2017; Yang & Zhao, 2014; Wang, Chen, & Kubota, 2016; Sebri & Ben-Salha, 2014; Zhu, Duan, Guo, & Yu, 2016; Aklin, 2016; Apergis & Ozturk, 2015; Sadat & Alom, 2016; Begum, Sohag, Abdullah, & Jaafar, 2015; Yaduma, Kortelainen, & Wossink, 2015; Heidari, Katircioğlu, & Saeidpour, 2015; Sinha, 2015; Adusah-Poku, 2016; Al-Mulali, Saboori, & Ozturk, 2015; Flores, Flores-Lagunes, & Kapetanakis, 2014; Boutabba, 2014; Salahuddin & Gow, 2014; Baek & Kim, 2013; Behera & Dash, 2017; Chakravarty & Mandal, 2016; Dogan & Turkekul, 2016; Pandey & Mishra, 2015; Sadorsky, 2014; Shahbaz, Loganathan, Muzaffar, Ahmed, & Jabran, 2015; Shahbaz, Solarin, & Ozturk, 2016; Twerefou, Adusah-Poku, & Bekoe, 2016; Zhang, Wang, & Wang, 2017) ignored deforestation.

Furthermore, in recent times, studies have been extended to explore the link between selected macroeconomic variables and deforestation for environmental degradation. For instance, Maji et al. (2017) used the ARDL model as estimation technique to explore the interaction of income level with energy use, population, and deforestation for the quality of the environment in Nigeria. Empirical findings reveal an inverse relationship between income and deforestation whereas a positive relationship was observed in both the long and short run for population and deforestation. However, no significant impact was seen in the case of energy consumption; there is no short run and cointegration evidence. Their results suggest that higher income can reduce deforestation and improve environmental quality in Nigeria. The population increase was the major cause of deforestation and environmental degradation.

Coulibaly (2017) examined how macroeconomic policies affect deforestation in Côte d'Ivoire from 1960 to 2015. The study did not only attribute to the depletion of forest to agricultural practices but also noted that the agricultural sector is very important for the economy inasmuch as it generates revenue and employment opportunities. The simple regression result suggested a negative relationship between population growth and deforestation in Côte d'Ivoire.

Shahbaz et al. (2015) explored the EKC for Pakistan with deforestation as an indicator of environmental degradation. The ARDL bounds test confirmed the existence of a cointegration relationship of the interest variables, whereas the vector error correction (VECM)-

Granger causality test detected feedback causality from income level (gross domestic product [GDP]) to energy consumption for Pakistan. The study affirms that the EKC hypothesis for Pakistan as a negative impact of economic growth on deforestation is observed in the long run. Waheed, Chang, Sarwar, and Chen (2018) carried a similar study for Pakistan but used CO_2 emissions as an indicator of environmental degradation. The study affirmed that forest reduces environmental degradation, same as renewable energy. They were able to show that forest planting can yield efficient result in emission reduction than renewable energy.

Faria and Almeida (2016) investigated how trade flow has affected deforestation in the Brazilian Amazon at the level of the municipality. The study combined standard econometrics with spatial econometrics to capture the socio-economic interactions in 732 municipalities. From their findings, a direct relationship was observed between openness to trade in the Amazon and deforestation on one hand, and a significant positive relationship between GDP and deforestation on the other. Zambrano-Monserrate, Carvajal-Lara, Urgilés-Sanchez, and Ruano (2018) investigated factors encouraging deforestation in five European countries for the period 1974–2013 relying on the ARDL technique. Findings revealed that agricultural export does not contribute to deforestation. This finding totally contradicts that of Leblois, Damette, and Wolfersberger (2017) who focused on developing countries and concentrated on the perceived factors that could be responsible for the incessant rate of deforestation. Apart from validating other determinants, agricultural trade was found to be the major driver of deforestation. These differences in findings could be attributed to discrepancies in the level of development and the methodologies used by the authors. Combes, Delacote, Motel, and Yogo (2018) utilized secondary data spanning 2001–2012 to examine if excess to credit and public spending can drive deforestation in developing countries. This was a paradigm shift from related studies. However, both variables turned out to be key drivers of deforestation.

Choumert, Combes Motel, and Dakpo (2013) through a meta-analysis of 69 studies, offering 547 estimations, examined the authenticity of the EKC for deforestation. The study revealed why the EKC results differ for different countries. Also, a turning point was discovered after the year 2001. They, however, concluded that the EKC story will continue as long as there are no theoretical alternatives. Considering the importance of institutions, Culas (2007) examined the impact of institutional factors on deforestation across Africa, Latin America, and Asia. The EKC relationship for deforestation was established for Latin American countries. The study showed the key roles that institutions can play in terms of minimizing the adverse effects of deforestation. Strengthening institutional factors, enacting viable environmental policies, and instituting property rights were identified as factors that could reduce deforestation across the three regions. Before Culas (2007) and Bhattarai and Hammig (2001) had earlier investigated how income growth could encourage deforestation in a panel of 66 countries, which consist of Africa, Asia, and Latin America. Their findings revealed that income significantly increases deforestation in the three regions considered for the study. Just like the study of Culas (2007), efficient and effective governance and reliable political institutions were suggested as factors that could help minimize deforestation. Both studies, however, arrived at a similar conclusion that institutional structure affects deforestation. Other studies that concentrated on tropical deforestation and income include Copeland and Taylor (2004), López and Galinato (2005), DeFries, Rudel, Uriarte, and Hansen (2010), Panayotou (2016), and Rudel (2013).

Maji and Habibullaha (2015) investigated the relationship between openness to trade and deforestation in Nigeria between 1981 and 2011. Population, energy use, and trade were used as control variables. From the ARDL result, trade flow and economic growth had an indirect but significant relationship with deforestation, suggesting that both variables will not only reduce deforestation but also promote environmental quality in Nigeria. The population was the only variable that promotes deforestation in the long run, whereas the impact of energy use was not significant.

Alola and Alola (2018) applied the ARDL technique on data spanning 1995 to 2014 and discovered that tourism development and agricultural land usage promote the use of renewable energy in 16 Coastline Mediterranean Countries. Alola (2019a) discovered that immigration, trade, and monetary policy are the main hurdles to environmental sustainability in the United States. Alola (2019b) examined the determinants of environmental degradation in the United States adopting applying quarterly data spanning 1990:Q1–2018:Q2. The ARDL estimates revealed a positive relationship between migration and CO_2 emissions, with trade policy exacting a significant impact on CO_2 emissions only in the short run. Saint Akadiri, Alola, and Akadiri (2019) investigated the role of income, tourism, and globalization on environmental quality in Turkey from 1970 to 2014. Findings suggest that real income and tourists' arrivals contribute about 0.625% and 0.129% to environmental degradation, respectively. Alola, Yalçiner, Alola, and Saint Akadiri (2019) discovered that the consumption of renewables can actually abate environmental degradation in three European countries (Germany, France, and the United Kingdom). A feedback causality was also found between renewable energy and CO_2 emissions.

Ogunwale (2015) analysed the current deforestation status in Nigeria, with the aim of assessing the possibility of it depleting the green environment. Questionnaire and interviews were used to test the participation of household in the six geo-political zones, pertaining their contributions to deforestation. From the empirical findings, poverty, awareness, and lack of enforcement were highlighted as factors that drive deforestation. This study was carried out at the zonal levels. Therefore, generalizing the findings of this study may not be free from bias.

Though there are a few studies on deforestation in Nigeria, all such studies are either regional based (Enaruvbe & Atafo, 2016; Odihi, 2003; Ogbuene, 2010; Mustapha, Bzugu, Ali, & Abdullahi, 2012) or suffer from omitted variable case (Maji et al., 2017; Maji & Habibullaha, 2015). The current study focuses on Nigeria and uses recent annual time series data with a more robust econometrics technique. As highlighted earlier, most previous studies focused on either cross-section analysis of (lower income, middle income, higher income, or a combination of the three) or regional analysis, but this study concentrates on Nigeria. This study will examine how urbanization influences deforestation, which was ignored by similar studies (Ahmed, Shahbaz, Qasim, & Long, 2015; Faria & Almeida, 2016; López & Galinato, 2005; Maji, 2017; Maji & Habibullaha, 2015; Mustapha et al., 2012; Rudel, 2013).

3 | ECONOMETRIC MODELLING AND ESTIMATIONS

We tried to explore the linkage between urbanization and deforestation for environmental quality in Nigeria. Following the works of Maji (2017) and Ahmed et al. (2015), with little modification to accommodate the impact of urbanization, the current study lead equation is rendered below:

$$D_t = f(U_t, G_t, E_t, T_t, P_t). \quad (1)$$

From Equation (1), D_t is deforestation (used to measure environmental degradation), G_t represents growth, E_t is energy consumption, T_t indicates trade openness, P_t stands for population density, and U_t denotes urbanization. In order to reduce skewness in the data, we transform Equation (1) into a log-linear functional form, as shown in Equation (2):

$$lnD_t = \phi_0 + \phi_1 lnU_t + \phi_2 lnG_t + \phi_3 lnE_t + \phi_4 lnT_t + \phi_5 lnP_t + \varepsilon_t. \quad (2)$$

From Equation (2), ϕ_0 is the intercept of the model. ϕ_1,ϕ_2,ϕ_3,ϕ_4,and ϕ_5 are the partial slope coefficients to be estimated, whereas ε_t is the stochastic term. After the stationarity test for the interest variables is examined, we proceed with the Pesaran, Shin, and Smith (2001) bounds testing methodology. However, other techniques exist, the preference of ARDL methodology includes the following: (a) it avoids the problem of endogeneity; (b) apart from being suitable, it also provides robust results for smaller data sets; (c) it has the ability of simultaneously computing both the short-run and long-run results, and (d) it can be used when variables are strictly $I(0)$,$I(1)$ or a combination of both; and (e) the stationarity of a variable(s) may not even be a problem. The ARDL technique can still be applied by taking the difference of $I(2)$ variable and then using it in the model (Ahmad & Du, 2017).

The dynamic ARDL approach for the model is given as

$$\Delta Y = \alpha_0 + \alpha_1 t + \gamma_1 y_{t-1} + \sum_{i=1}^{k} \phi_1 \upsilon_{it-1} + \sum_{j=1}^{r} \varphi_j \Delta Y_{t-j} + \sum_{i=1}^{N} \sum_{j=1}^{P} \xi_{ij} \Delta \upsilon_{it-j} + \delta D_t + \varepsilon_t. \quad (3)$$

The null hypothesis of no cointegration is given as $H_0: \tau_1 = \tau_2 = \tau_3 = \tau_4 = \tau_5 = \tau_6 = 0$ against $H_1: \tau_1 \neq \tau_2 \neq \tau_3 \neq \tau_4 \neq \tau_5 \neq \tau_6 \neq 0$. The *F* statistics critical value will determine the presence or otherwise of cointegration. The decision rule applies that if the *F* statistics estimated is greater than the upper boundary value, H_0 is rejected. If otherwise, we do not reject. However, in a situation where the *F* statistics lies between the upper and lower bound limits, our decision will remain inconclusive (see Narayan, 2004; Narayan, 2005; and Pasaran et al., 2001, for more details).

To further buttress the cointegration analysis, the novel methodology of Bayer and Hanck (2013) gives a more efficient result. The test comprises several individual test statistics such as the Boswijk (1995), Banerjee, Dolado, and Mestre (1998), Engle and Granger (1987), and Johansen (1991) tests. The Fisher equation is provided as

$$EG-JOH = -2[ln(\rho_{EG}) + (\rho_{JOH}), \quad (4)$$

$$EG-JOH-BO-BDM = -2[ln((\rho_{EG}) + (\rho_{JOH}) + (\rho_{BO}) + (\rho_{BDM}). \quad (5)$$

ρ_{BDM}, ρ_{BO},ρ_{JOH},and ρ_{EG} are the test probability. When variables are cointegrated, there is a need to carry out a causality analysis to underpin directional flow of causality. The VECM-Granger causality technique is considered most appropriate because of its ability to reveal both short- and long-run causality between D_t,U_t,G_t,E_t,T_t,and P_t. The VECM-Granger causality equation is provided as

$$(1-L)\begin{bmatrix} LnD_t \\ LnU_t \\ LnG_t \\ LnE_t \\ LnT_t \\ LnP_t \end{bmatrix} = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \\ \beta_6 \end{bmatrix} + \sum_{i=1}^{p}(1-L)\begin{bmatrix} \beta_{11i}\beta_{12i}\beta_{13i}\beta_{14i}\beta_{15i}\beta_{16i} \\ \beta_{21i}\beta_{22i}\beta_{23i}\beta_{24i}\beta_{25i}\beta_{26i} \\ \beta_{31i}\beta_{32i}\beta_{33i}\beta_{34i}\beta_{35i}\beta_{36i} \\ \beta_{41i}\beta_{42i}\beta_{43i}\beta_{44i}\beta_{45i}\beta_{46i} \\ \beta_{51i}\beta_{52i}\beta_{53i}\beta_{54i}\beta_{55i}\beta_{56i} \\ \beta_{61i}\beta_{62i}\beta_{63i}\beta_{64i}\beta_{65i}\beta_{66i} \end{bmatrix} \times \begin{bmatrix} LnD_{t-1} \\ LnU_{t-1} \\ LnG_{t-1} \\ LnE_{t-1} \\ LnT_{t-1} \\ LnP_{t-1} \end{bmatrix} + \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \varepsilon_{t1} \\ \varepsilon_{t2} \\ \varepsilon_{t3} \\ \varepsilon_{t4} \\ \varepsilon_{t5} \\ \varepsilon_{t6} \end{bmatrix}.$$

$(1 - L)$ is the difference operator, and ECT_{t-1} is the lagged value of the error term. ε_{it} represents the stochastic term with the asymptotic assumption of being normally independently identically distributed, that is, N~iid (0,1). For instance, urbanization does not Granger

TABLE 1 Descriptive statistics

Variables	lnD	lnU	lnG	lnE	lnT	lnP
Mean	4.539	17.243	7.413	6.747	3.817	4.721
Median	4.269	17.283	7.411	6.542	3.877	4.726
Maximum	18.276	18.276	7.849	15.863	4.404	5.292
Minimum	3.948	16.157	7.048	6.361	3.060	4.142
SD	2.099	0.633	0.245	1.391	0.365	0.341
Skewness	6.436	–0.089	0.218	6.451	0.518	–0.029
Kurtosis	42.639	1.832	1.663	42.757	2.286	1.837
Observations	45	45	45	45	45	45

Source: Authors' computation.

cause deforestation if $\beta_{12,i} \neq 0\forall_i$, whereas $\beta_{21,i} \neq 0\forall_i$ indicates that deforestation Granger causes urbanization.

4 | DATA, EMPIRICAL RESULTS, AND DISCUSSION

This section renders the discussion of empirical simulations. Our study relies on recent annual time series data. Data for the study were retrieved from the World Bank indicators (2017) from 1971 to 2015.

TABLE 2 Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) stationarity results (without break dates)

	Level	First difference
Variables	KPSS	KPSS
lnD	0.126***	0.129
lnU	0.180**	0.084
lnG	0.208**	0.098
lnE	0.131***	0.132
lnT	0.147**	0.078
lnP	0.154**	0.115

Note. Mackinnon (1996) one-sided *P*-value is reported. Models with intercept and trend were reported for all test statistics.
Source: Authors' computation.
*Signifies 0.10 rejection level.
**Signifies 0.05 rejection level.
***Signifies 0.01 rejection level.

TABLE 3 Zivot and Andrews test (with break dates)

	Level		First difference	
Name of series	*t* statistics	Break years	*t* statistics	Break years
lnD	−1.8784(1)	1981	−5.3456(1)*	1997
lnU	−5.0179(1)	1981	−5.0796(1)***	1991
lnG	−3.2222(1)	1986	−7.1539(1)**	1988
lnE	−1.4688(1)	1995	−5.2727(1)*	2008
lnT	−3.2853(1)	2008	−10.4843(1)**	1985
lnP	−5.5721(1)	2008	−16.7118(1)***	1997

Note. Values in brackets sign depict optimum lag length for test construction.
Source: Authors' computation.
*Denotes 0.10 rejection level.
**Denotes 0.05 rejection level.
***Denotes 0.01 rejection level.

Table 1 shows the mean, median, maximum, minimum, skewness, kurtosis, and the standard deviation of the variables. From the results, urbanization and population density are negatively skewed, whereas deforestation, trade openness, energy consumption, and economic output are positively skewed. All variables show obvious dispersion from their means over the sampled period.

Stationarity traits of the interest variables are considered as the next step for our study. This is essential to avoid the spurious regression trap and avoid *I*(2) variable(s). Tables 2 and 3 report the unit root tests. Both tests are in harmony as they both suggest that all variables are *I*(1).

However, ZA test reports structural break dates as seen in Table 3. Coincidentally, the structural break years resonate with major events/episodes in Nigeria. For instance, in the 1980s, the country witnessed several economic regimes especially the major economic switch of 1986 associated with the introduction of the Structural Adjustment Program. The study also captured the Lehman Brothers' crash of 2008 that rock the world.

Prior to the estimation of the cointegration test, the need for appropriate lag selection is crucial before estimation of cointegration analysis. On this premise, the unrestricted VAR is estimated for the most parsimonious and efficient model. The Schwarz information criterion is selected as most parsimonious due to its high explanatory power seen in Table 4. Subsequently, we estimated the Bayer–Hanck test for cointegration. Results are shown in Tables 5 and 6.

The results from Table 5 affirm relationship that suggests equilibrium among the interest variables. The cointegration status is confirmed by the rejection of the null hypothesis at a 1% significance level for each of the fitted models.

To further give credence to the cointegration analysis, the ARDL bounds test result reported in Table 6 corroborate the outcomes of Bayer and Hanck in Table 5. Thus, our study makes the claim that there is a sort of comovement among the variables.

Table 7 reports the ARDL results. The estimated model is robust with 16% convergence speed to its equilibrium path. We find that urbanization impacts deforestation positively and significantly at 1% and 5% in the long and short run, respectively. If urbanization increase by 1%, deforestation will increase by 3.001% and 3.320%, respectively, in both time frame. The movement of people from rural areas in search of “greener pastures” into cities comes at a cost. As it tends to reduce environmental quality. As earlier mentioned, rural areas in Nigeria, like any other developing country, are grossly underdeveloped. As a result, encouraging rural–urban migration in turn degrades

TABLE 4 Parsimonious VAR order of lag selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	80.605	NA	1.15e-09	−3.552	−3.304	−3.462
1	513.922	722.196	7.14e-18	−22.472	−20.734	−21.836
2	611.710	135.040	4.19e-19	−25.414	−22.187	−24.231
3	713.458	111.438*	2.47e-20*	−28.546*	−23.829*	−26.817*

Abbreviations: AIC, Akaike information criterion; FPE, final prediction error; HQ, Hannan Quinn information criterion; LR, means sequential modified LR statistic; SIC, Schwarz information criterion. *indicates possible lag length.
Source: Authors' computation.

TABLE 5 Bayer–Hanck test analysis

Fitted model	EG-JOH	EG-JOH-BO-BDM	Cointegration
lnD = f (*lnU*,*lnG*, *lnE*,*lnT*,*lnP*)	55.383***	72.446***	Yes
lnU = f (*lnD*,*lnG*, *lnE*,*lnT*,*lnP*)	55.522***	80.331***	Yes
lnG = f (*lnD*,*lnU*, *lnE*,*lnT*,*lnP*)	55.407***	56.230***	Yes
lnE = f (*lnD*,*lnU*, *lnG*,*lnT*,*lnP*)	55.394***	77.126***	Yes
lnT = (*lnD*,*lnU*, *lnG*,*lnE*,*lnP*)	56.073***	113.177***	Yes
lnP = f (*lnD*,*lnU*, *lnG*,*lnE*,*lnT*)	55.529***	110.825***	Yes
1% critical value	15.701	29.850	
5% critical value	10.419	19.888	

Source: Authors' computation.
*Denotes 0.10 rejection level.
**Denotes 0.05 rejection level.
***Denotes 0.01 rejection level.

the environment. This situation portrays danger considering the fact that wood is mostly used as fuel by most rural and urban dwellers. Even the construction of houses involves the use of wood. Development factors (like social amenities) are the main cause of urbanization. The provision of these amenities will minimize the upward surge of urbanization in Nigeria.

The impact of economic growth (GDP) on deforestation was positive in the short run but negative and significant at 1% in the long-run period. Other determinants held constant; a 1% increase in economic growth is connected with an increase in deforestation with a magnitude of 3.052% in the short run and 0.072% decrease in deforestation in the long run. This suggests that the impact of economic activities is more intense on environmental quality in the short run, but in the long run, the positive effect of growth on deforestation diminishes, thus suggesting that growth trajectory improve the quality of the environment on the long-term basis.

Our findings are contradictory with Maji and Habibullaha (2015) who noted that economic growth is negatively linked to deforestation in both time periods but in line with Ahmed, Liu, et al., (2018) who discovered a similar relationship for Pakistan. The positive impact of population density on deforestation gives credence to the earlier claim that population increase reduces environmental quality. This is similar to the findings of Adams, Adom, and Klobodu (2016), Ahmed and Long (2012), Maji and Habibullaha (2015), Ahmed, Liu, et al. (2018), Aboagye (2017), Ali, Abdullah, and Muhammad (2017), and Kwakwa, Arku, and Aboagye (2014). But the impact of population density on environmental quality remains insignificant in both periods this is indeed revealing. Nigeria is the most populous country in Africa, but its population does not harm the environment in any way.

Further empirical revelation shows the inverse relationship between trade openness and deforestation in both time frame (short and long run). The above insight is suggestive, that is, openness to trade reduces deforestation thereby improving environmental quality. Also, Nigeria's openness to trade has not harmed the environment in any way. A 1% increase in trade openness is expected to reduce deforestation by 0.039% and 0.0074% in the short and long run, respectively. However, just like population density, the impact of trade openness is not significant. Further analysis reveals that energy intensification fuels deforestation as a 1% increase in energy consumption will increase deforestation by 1.504% in the short run and 1.503% in the long run.

TABLE 6 ARDL estimation

Bounds test	Diagnostic test					
Fitted regression	Lag length	Break dates	*F* statistics	Normality	ARCH	RESET
lnD = f (*lnU*,*lnG*,*lnE*, *lnT*,*lnP*)	1,1,1,1,1,1	1981	9.816	1.071	0.195	4.106
lnU = f (*lnD*,*lnG*, *lnE*,*lnT*,*lnP*)	1,0,2,0,2,2	1981	9.191	1.915	0.689	0.339
lnG = f (*lnD*,*lnU*,*lnE*, *lnT*,*lnP*)	1,1,2,0,1,0	1986	2.214	0.396	0.708	0.674
lnE = f (*lnD*,*lnU*,*lnG*,*lnT*,*lnP*)	1,2,1,0,1,1	1995	8.895	3.919	0.521	0.461
lnT = (*lnD*,*lnU*,*lnG*,*lnE*,*lnP*)	1,1,0,0,1,2	2008	6.95	1.317	0.519	0.484
lnP = f (*lnD*,*lnU*,*lnG*,*lnE*,*lnT*)	1,0,0,0,1,0	2008	4.111	0.662	0.201	0.122
Significance level	Lower bound			Upper bound		
1.00%	3.06			4.15		
5.00%	2.39			3.38		
10.00%	2.08			3		

Source: Authors' computation.
*Denotes 10% significance rejection level.
**Denotes 5% significance rejection level.
***Denotes 1% significance rejection level.

TABLE 7 ARDL regression analysis (short and long run dynamics)

Independent variables	Explained variable: *lnD* Coefficients	Standard error	*t* statistics
Short-run coefficients			
lnU	3.320**	1.235	2.688
lnG	3.052***	0.751	4.064
lnE	1.504*	0.003	378.017
lnT	−0.039*	0.023	−1.713
lnP	3.377*	1.92	1.759
ECMt-1	−0.163***	0.025	−6.621
R^2	0.567		
F statistics	15.414***		
Long-run coefficients			
lnD(−1)	0.858*	0.134	6.411
lnU	3.001***	1.489	2.015
lnG	−0.072***	0.038	−2.281
lnE	1.503*	0.005	302.5
lnT	−0.074**	0.022	−0.002
lnP	0.657	0.852	0.77
Constant	4.102	3.859	−1.062
R^2	0.998		
F statistics	176.13***		
Diagnostic tests			
Test	Statistics	*P*-value	
Serial correlation	1.098	.346	
ARCH	1.737	.195	
White	2.222	.042	
Ramsey	4.106	.115	

Source: Authors' computation.
*Indicates rejection level of significance of 0.10.
**Indicates rejection level of significance of 0.05.
***Indicates rejection level of significance of 0.01.

The short-run result is intuitive with the long-run outcome, indicating that energy consumption increases deforestation and reduces environmental safety in both periods. This is worrisome considering the fact that energy consumption/demand and economic development are two sides of a coin; the absence of one inadvertently queries any claim in the true existence of the other. This finding further lay claims to the fact that Nigeria is a growing economy; therefore, energy consumption is also expected to be on the increase, but the increase in energy consumption influences the environment negatively. Energy consumption in Nigeria is largely non-renewable. Non-renewable energies create environmental havoc (Destek & Sarkodie, 2019; Feron et al., 2019; Hanif, Raza, Gago-de-Santos, & Abbas, 2019; Nathaniel, 2019; Nathaniel et al., 2019; Nathaniel & Iheonu, 2019; Wang & Dong, 2019). On the flipside, renewable energies are clean (Baloch, Mahmood, & Zhang, 2019; Hassan, Xia, Khan, & Shah, 2019) and low in emissions (Bekun, Alola, & Sarkodie, 2019; Bekun Bekun, Emir, & Sarkodie, 2019; Maji & Sulaiman, 2019; Nguyen & Kakinaka, 2019; Destek & Sarkodie, 2019).

Traditional regression does not imply a causal interaction between variables; thus, the need for causality test is crucial given the inherent policy implication(s) that can be gleaned from such directional causality flow (Table 8).

To examine the directional flow of causality between the variables under consideration, this study leverages on the VECM-Granger methodology. Empirical evidence shows convergence in the long run among the variables as revealed by their respective error correction terms. The results reveal both short- and long-run unidirectional causality between urbanization and deforestation, and trade openness and population density. Furthermore, one way, Granger causality was observed running in the short run from urbanization to trade openness and population density. In the same fashion, one way, Granger causality is seen in the short run from economic growth to population density. Strikingly, in both long and short run, we observed causality nexus of trade openness, deforestation, economic output, energy

TABLE 8 Results of VECM causality analysis

Dependent variable	Direction of causality: Short run						Long run
	lnD_{t-i}	lnU_{t-i}	lnG_{t-i}	lnE_{t-i}	lnT_{t-i}	lnP_{t-i}	ECT_{t-1}
Δ*lnD*	—	0.224 (0.801)	0.176 (0.840)	0.293 (0.749)	0.125 (0.884)	0.051 (0.950)	−6.962 (0.789)
Δ*lnU*	3.494** (0.049)	—	2.414 (0.114)	2.391 (0.116)	3.809** (0.039)	4.280** (0.028)	−0.059** (0.041)
Δ*lnG*	1.157 (0.334)	2.195 (0.136)	—	0.898 (0.422)	0.477 (0.627)	4.361** (0.026)	−0.554 (0.366)
Δ*lnE*	0.436 (0.652)	0.243 (0.787)	0.202 (0.819)	—	0.156 (0.857)	0.075 (0.928)	−5.694 (0.742)
Δ*lnT*	5.195** (0.015)	2.762* (0.086)	3.193* (0.062)	2.863* (0.079)	—	3.277* (0.058)	−4.022** (0.033)
Δ*lnP*	0.647 (0.534)	0.853 (0.440)	0.533 (0.594)	0.533 (0.594)	0.915 (0.416)	—	−0.000 (0.317)

Note. Numbers in bracket indicate probability values.
Source: Authors' computation.
*Denotes rejection level at either 0.10.
**Denotes rejection level at either 0.05.
***Denotes rejection level at either 0.01.

consumption, and population density. However, among the variables examined for this study, no feedback Granger causality was observed.

Subsequently, Chow forecast test is estimated in order to investigate the joint significance of our study break (structural) dates over the considered period. Interestingly, the break dates reflect major political and economic happenings and episodes.

Table 9 of this study confirms the Structural Adjustment Program of 1986 as a major economic transformation in Nigeria. Furthermore, the major political transition of 1999 from the military to a democratic regime was also captured by the study. Not left out is the Global Financial Crisis that struck the mortgage market and translated into worldwide economic contraction and financial stress. All mentioned dates were jointly significant as reported by our study, which was appropriately modelled in the methodology. To conclude the study, apart from being free from serial correlation and heteroscedasticity, the fitted model is also well specified.

These tests, suggested by Brown, Durbin, and Evans (1975), were used to examine the stability of the model. Figures 1 and 2 render the cumulative sum and the cumulative sum of squares tests, and both tests affirm the model stability indicating that the residuals are within 5% critical bonds. This suggests that the coefficients of the model are stable and reliable for policy constructions.

TABLE 9 Results of Chow forecast

	Value	*df*	Probability
Chow forecast test from 1986 to 2015			
F statistics	11.105	(30, 9)	.000
Likelihood ratio	163.713	30	.000
Chow forecast test from 1999 to 2015			
F statistics	18.181	(17, 22)	.000
Likelihood ratio	122.008	17	.000
Chow forecast test from 2008 to 2015			
F statistics	36.064	(8, 31)	.000
Likelihood ratio	104.976	8	.000

Source: Authors' computation.

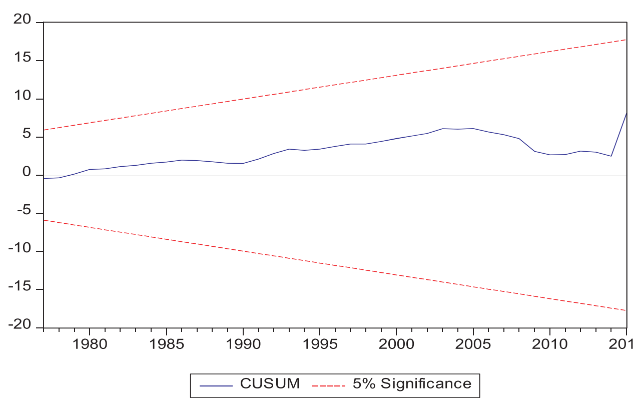

FIGURE 1 CUSUM stability test. CUSUM, cumulative sum

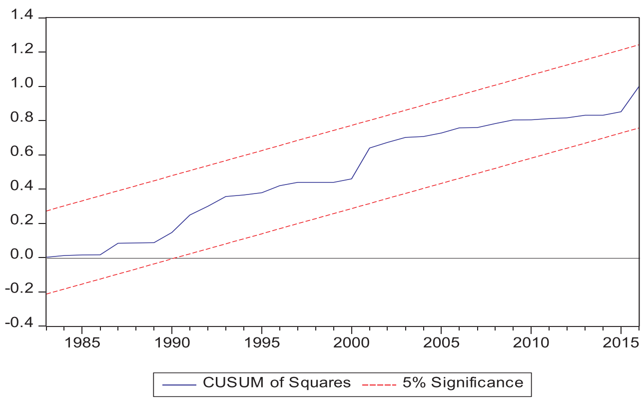

FIGURE 2 Cumulative sum square stability test. CUSUM, cumulative sum

5 | CONCLUDING COMMENTS, RECOMMENDATION, AND POLICY DIRECTION

We focus on exploring the nexus between urbanization and deforestation while accounting for the impact of trade flow, energy, and population on environmental management in Nigeria. In order to achieve robust results, we employed the VECM-Granger causality test, Bayer–Hanck cointegration test, and the ARDL bounds test approach as estimation techniques. Empirical revelation shows that economic growth, energy consumption, and urbanization possess statistical and significant effect on deforestation in both time periods. Suggesting that energy consumption and growth contribute to environmental degradation in Nigeria. This outcome is indicative to government administrator, energy, and environmental administrators that formulate and design energy strategies/regulations. This is an indication that Nigeria energy source is not renewable.

Therefore, there is need to diversify its energy portfolio especially at a time of global environmental consciousness for cleaner energy sources as strengthened by the studies of Balsalobre-Lorente, Shahbaz, Roubaud, and Farhani (2018), Emir and Bekun (2018), and Shahbaz, Zeshan, and Afza (2012). The Lagos State Government has taken the right step in this regard by encouraging its inhabitants to plant three trees whenever one is brought down. Empirical findings showed that population density impacts negatively on the environment. Therefore, population control policy will be sacrosanct to preserve the biodiversity and ensure environmental sustainability which is at the front burner of the Sustainable Development Goal.

Urbanization arises mainly from inequality in development factors. These development factors include household income, access to amenities, and provision of infrastructures (Al Shueili, 2015). Therefore, the provision of the needed infrastructures and amenities in the rural areas will help in mitigating the upward surge in urbanization and the anomaly associated with it.

ORCID

Solomon Prince Nathaniel https://orcid.org/0000-0001-7623-9526

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AUTHOR BIOGRAPHIES

Solomon Prince Nathaniel is a PhD scholar (Advance Stage) at the University of Lagos, Akoka, Nigeria. He lectures economics at the Lagos State University, Badagry Campus, Nigeria. He has shown his expertise in Energy and Environmental Economics by publishing in top ranked journals in the field. Such journals include; Science of The Total Environment, Environmental Science and Pollution Research, Geojournal, etc.

Festus Victor Bekun holds a PhD in energy and environmental economics. Currently serves as a faculty member at Istanbul Gelisim University, Istanbul, Turkey. His articles appear in top tier energy and environmental journals like Science of The Total Environment, Energy Policy, Energy and Environment, Environmental Science and Pollution Research, among others.

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APPENDIX A

Johansen cointegration test

No. of Cointegration Equations	Maximum Eigen value	Trace test
None	0.752003***	114.7272***
At most 1	0.608945***	95.27566***
At most 2	0.697243***	138.2893***
At most 3	0.945261**	139.4536**
At most 4	0.139445	5.471984
At most 5	0.001821	3.841466

Both tests (Trace and Maximum Eigen value) indicate at most 3 cointegrating eqn(s) at the 0.05 level. *** and ** show 0.01% and 0.05% significance levels respectively.

Source: Authors computation.