European Xtramile Centre of African Studies (EXCAS)

EXCAS Working Paper

WP/19/040

Does Agricultural Value Added Induce Environmental Degradation? Empirical Evidence from an Agrarian Country [1]

Forthcoming: Environmental Science and Pollution Research

Mary O. Agboola[a] & Festus V. Bekun[b,c,d]

[a]Finance and Banking Department, College of Business Dar Al Uloom University, 1 Mizan St., Al Falah, Riyadh 13314 Saudi Arabia.
Email: maryagboola@dau.edu.sa

[b]Eastern Mediterranean University, Northern Cyprus, via Mersin 10, Turkey
Email: festus.bekun@emu.edu.tr

[c]African Governance and Development Institute, Yaoundé, Cameroon

[d] European Xtramile Centre of African Studies, Liège, Belgium

1 This working paper also appears in the Development Bank of Nigeria Working Paper Series.

Research Department

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Mary O. Agboola & Festus V. Bekun

January 2019

Abstract

This study empirically investigates the agriculture-induced environmental Kuznets curve (EKC) hypothesis in an agrarian framework. Annual time series data from 1981–2014 was employed using Augmented Dickey–Fuller and the Phillips–Perron (PP) unit root test complemented by the Zivot and Andrews unit root test that accounts for a single structural break to ascertain stationarity properties of variables under consideration. For the cointegration analysis, an autoregressive distributive lag methodology and the recent novel Bayer and Hanck combined cointegration technique is employed. For the direction of causality, the Granger causality test is used as estimation technique. Empirical findings lend support for the long-run equilibrium relationship among the variables under consideration. This study also validates the inverted U-shaped pattern of EKC for the case of Nigeria, affirming that Nigeria remains at the scale-effect stage of its growth trajectory. Further empirical results show that foreign direct investment attraction helps mitigate carbon emissions in Nigeria. Based on these results, several policy prescriptions on the Nigerian energy mix and agricultural operations in response to quality of the environment were suggested for policymakers, stakeholders, and environmental economists that formulate and design environmental regulations and strategies to realise the Goal 7 of sustainable development goals (SDGs).

Keywords: Agriculture ecosystem, Energy consumption, Granger Causality, EKC, Nigeria.

JEL Classification: C32, Q1, Q4, Q5

1. Introduction

Environmental sustainability has been a priority of most if not all economies. The necessity for management, conservation, and sustainability of the world's flora and fauna is pertinent, especially considering the increasing global consciousness for friendlier and cleaner energy sources (Emir & Bekun, 2018). The 2015 Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) further strengthens this position. The agreement signed by 195 UNFCCC member countries as of March 2019 commits countries to deliberately maintain an increase in global mean temperature to an appreciable level below 2°C above the pre-industrial levels and to reduce temperature rise to 1.5°C; 20% reduction in greenhouse gas (GHG) emissions, 20% increase in renewable energy shares by consumption, and increase in energy efficiency leading to a 20% safe up of energy consumption. However, most economies still depend on natural gas, crude oil, coal, and fossil fuel as energy sources. Notably, most of these economies possess high reserves, or infinite amounts, of the aforementioned energy sources (Bildirici & Özaksoy, 2016).

The trajectory to economic growth has costs and implications. The bane of industrialisation is characterised by the trade-off between higher incomes and environmental pollution. The observed global depletion in the environment and pollution intensification is being enhanced by humanity's activities that aim for economic reward; unfortunately, many of these activities also result in environmental costs. Fossil fuel emissions rank topmost among environmental pollutants and are emitted through, for example, industrial gas flaring, transport, farming and agricultural production activities like bush burning, and deforestation. The consciousness of the high impact of the environmental costs of economic growth (national prosperity) has attracted more discourse among scholars, government administrators, and environmental and energy specialists, especially regarding sustainable development (Boluk & Mert, 2015).

Agriculture is often regarded as a panacea for sustainable economic growth in developed and developing economies. The physiocracy school of thought validates this claim (Higgs, 1897). The premise of the ideology is that agriculture is the only sector responsible for economic growth compared with other traditional schools of thoughts such as mercantilism is strengthen in the studies of (Bekun & Akadiri,2019; Sertoglu *et al.*, 2017). However, the path to how this translates into long-run economic prospect has been a concern for government administrators and all stakeholders. Nigeria is reputed to be an agrarian country with a substantial amount of arable land and agricultural export potential. The agricultural sector in Nigeria accounts for greater than 60% of gross domestic product (GDP), implying that the economy is heavily reliant on agriculture as its backbone (Olajide *et al*., 2012; Gokmenoglu *et al*., 2016).

The agricultural sector in most developing nations has been identified as a key determinant of national development [World Trade Organization (WTO) 2014, Food and Agricultural Organization (FAO), 2009]. This is achievable due to value-added chain in the production process. Furthermore, over the years, an increased demand for agricultural products has also been observed. This higher agricultural commodity demand results in greater energy consumption and higher GHG emissions, given that agricultural operations are mostly carried out in the primary sector and runs on non-renewable fuels sources especially in the case of developing countries (Gokmenoglu & Taspina,2018). Agriculture is one of the greatest contributors to global warming, generating nearly one- third of global anthropogenic greenhouse gas emissions (FAO, 2016).This trend has intensified, especially after the global food crises that occurred between 2006 and 2008. This is also resonated in the study of Ityavyar and Thomas (2012) that the root cause of environmental pollution in Nigeria is mainly as a results of man's interaction with nature (environment) for exploration to sustain livelihood in urban areas where industrial activities are prominent and in rural areas where primary activities like mining, agricultural operations thrives.

In a recent report from the Food and Agriculture Organization of the United Nation (FAO, 2016) shows that 21% of global Green house (GHG) emissions is from the Agricultural sector. Agriculture is rank second contributor to global total emitters of GHG emissions. Generally, GHG emissions are mainly from known agricultural operations like deforestation as it often practiced by peasant and commercial farmers (forest encroachment). The forest woods are burnt for cooking which also increase CO_2 emissions, soil, livestock emission and the use of fossil fuel based fertilizer. Further agricultural operations include bush burning, burning of biomass fuel energy. On the contrary, the (FAO, 2016) report also assert that the agricultural sector has huge prospect to decrease global total emission by 20% to overwhelming 60% in 2030 (Liu et al., 2017). This is attainable by decline in the highlighted activities earlier mentioned. For instance, reduction in forest encroachment activities rather rejuvenation of more hybrid verities of forest plants, fortifying management of livestock and fertilizer application to mitigate fossil fuel and adoption renewable energy technologies which are cleaner and more green.

Given the depleted environment from human activities like agricultural operation, A 2018 Health Effect Institute (HEI, 2018) report stated that Nigeria and ten other countries were ranked as having the most deadly ambient air in the world. That is, Nigeria has poor air quality that threatens human life as a result of vehicle emission of carbon mono oxide (CO) and carbon dioxide (CO2) fume from generators. These activities have resulted in negative health outcomes, such as: high maternal mortality rate and 150 deaths per every 100,000 persons resulting from pollution of atmospheric air. Rampant crop bush burning by peasant farmers to expedite the availability of land for an agricultural operation is another major source of pollution in Nigeria (Hamid *et. al*. 2010; Ityavyar &Thomas, 2012). The bush burning practices are prominent in Nigeria because most arable land has been crowded out by urbanisation and industrial activities. Thus, farmers cannot practice a bush fallowing farming system where the land is allowed to rest to regain fertility.

Based on the aforementioned contexts, this study attempts to explore the nexus among real income, the quadratic form of real income, and agriculture in the conventional environmental Kuznets curve (EKC) framework while controlling for trade openness, foreign direct investment, and energy consumption for the first time in Nigeria with recent time series data. This study attempts to investigate the contribution of agricultural activities to the environment performance in an agricultural dependent country like Nigeria were most of the nation's revenue accrue from agricultural sector. Furthermore, this study present a new course for environmental stakeholders and government administrators based on the outcome(s) of the study.

This study challenges the literature for the first time in Nigeria, despite that the theme has been investigated by Dogan, (2016) for the case of Turkey; notably Dogan, 2016 did not control for the variables in this study, which marks a distinct by scope. Furthermore, this study contributes to the energy literature on agriculture-induced environmental degradation, as Nigeria is majorly an agrarian state. Thus, this study is timely and relevant to ascertain the impact of agricultural activities on environmental quality.

Another novelty of this study is the methodological innovation in the accounting for a structural break in the methodological framework. A couple of economic contractions and policy/regime switches characterise the Nigerian economy as well. The structural adjustment program (SAP) implemented in 1980 is precisely the case of Nigeria in 1986, which also characterises most developing nations and emerging economies in the era of re-building their broken country. The Bretton Wood institutions such as the International Monetary Fund and World Bank imposed requisites, such as structural changes in the economic system such as liberalisation of the debtor country to free market system, as conditions for loan assessment. These structural changes are capable of interfering with our empirical results and were adequately modelled for by estimation techniques that other studies did not considered, Dogan, (2018) for China; Ullah et al., (2018) for Pakistan; and Dogan, (2016) for Turkey are case in point. Thus, to circumvent spurious analysis in the stationarity test beyond the traditional Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP), the study employed a Zivot and Andrews (1992) unit root that accounts for a single structural break. For cointegration analysis, a novel approach of combined Bayer and Hanck (2013) test complimented with the Pesaran *et al*, (2001) autoregressive distributive lag (ARDL) bounds test methodology in the presence of possible structural breaks was employed. The ARDL facilitated the simultaneous accounting for the long–short run dynamics among the dependent variable and the explanatory variables over the sampled period.

The remaining section of this study is structured as follows. Section 2 presents the literature review. Section 3 offers the materials and methods. Section 4 discusses the findings. Section five concludes and policy implication(s).

2. **Conceptual Framework and Literature Review**

2.1 **Conceptual framework**

The environmental Kuznets (EKC) hypothesis is conceptualised as the inverse nexus between per capita income level and environmental degradation. This nexus explains the inverse consequences on the trajectory of the economic growth path and environmental quality. This argument was asserted by Grossman (1955). This phenomenon is observed through three paths: the scale effect, composite effect and technique effect. The scale effect reflects the initial developmental stage of economies and resembles a pre-industrialisation stage because the emphasis is on economic growth relative to environmental quality (Shahbaz & Shina, 2018). The scale-effect stage is more eminent in the developing economies were the awareness on quality of the environment is low and most activities that foster economic growth are primary sector based mainly the mining, agriculture activities among others which in turn pollutes and deplete the quality of the environment. Regarding the second trajectory, the composite stage denotes industrialised economies, some sort of growth rate achieved, and environmental consciousness is awakened. This phenomenon is more common in emerging economies in the third tier in the technique stage, the stage where a decline in environmental degradation is observed because the turning point threshold has been achieved (Shahbaz & Sinha, 2018).This phenomenon is explained by the adoption of cleaner and friendlier technologies such as renewable energy sources. The developed economies that have crossed the pre-industrialisation and industrialisation stages to the post-industrialisation stage have made it to last stage of the EKC concept. Figure 1 further buttress the schematic of the conceptualisation of the EKC ideology.

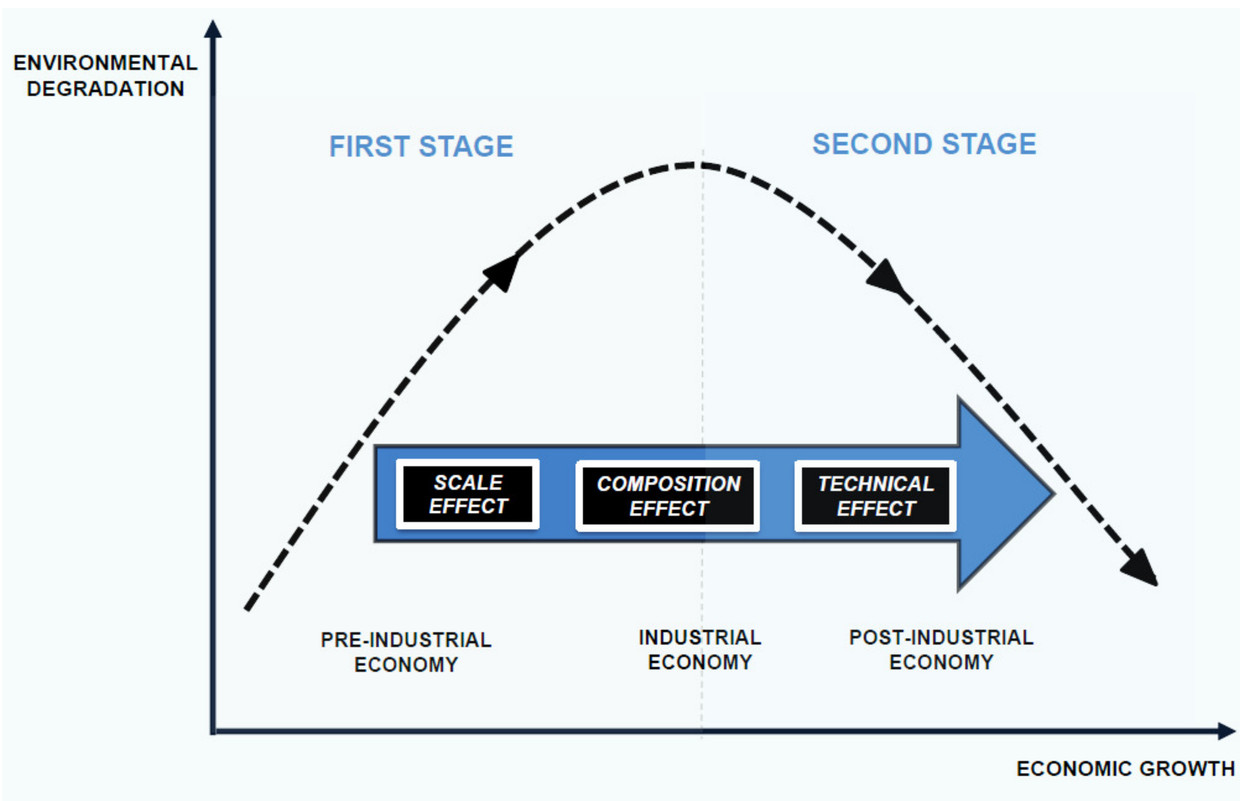


Figure 1: Schematic of EKC Conceptualization

2.2 Literature review

Environmental sustainability has been a priority for most if not all economies around the globe because of the world's global environmental consciousness regarding cleaner and friendlier ecosystems and renewable energy sources. This discourse was first discussed by Simon Kuznets

(1955), who asserted that a relationship exists between per capita income and inequality. His empirical investigation demonstrated an inverted U-shape pattern between both variables. This result implies that inequality increases to a certain threshold and then diminishes over time as income per capita increases over time. Environmental economists and energy practitioners have adopted this idea: they use the conceptualisation to investigate the relationship between per capita income and environmental quality.

The pioneering study in this regard was that of Grosssman & Krueger (1991), who investigated the possible impact of the environmental impacts of the North American Free Trade Agreement (NAFTA) on national income. Grosssman & Krueger (1991) conducted a novel investigation on the inverted U-shaped relationship. Inferences from Grosssman & Krueger (1991) imply that for countries at a low national income level, sulphur dioxide and smoke increases, whereas the opposite was observed in countries at a higher income level. Subsequently, more studies like Shafik & Bandyopadhyay (1992) were observed that investigated the theme. Shafik & Bandyopadhyay (1992) also corroborated the findings of Grosssman and Krueger (1991). Similarly, Panayotou (1993) examined the theme, and the findings reiterated the findings in the literature regarding the establishment of the EKC hypothesis pattern[2].

There exist a flourishing body of well documented studies on the themes after the seminal study of Grosssman and Krueger (1991) on the nexus between energy consumption and environmental degradation. A bulk of the empirical literature on the EKC hypothesis incorporated foreign direct investment, financial development, trade openness, urbanization, education, capital growth and more recently all dimensions of globalization (Kalmaz & Kirikkaleli, 2019; Katircioglu *et al.*, 2018, Balsalobre *et al.*,2018; Álvarez-Herranz, 2017; Sinha *et al.*,2017; Balsalobre & Shahbaz, 2016, Balsalobre & Álvarez-Herranz ,2016; Soni *et al.*,2013; Thamo *et al.*,2013). These studies all rendered insightful accounts of the effects of theses macro-economic variables and demographic variables on the EKC concept.

Following the antecedence of the seminal study of Simon Kuznets (1955) on the topical topic of tradeoff between income and environmental quality, several studies have cut across the country-specific, cross-country, or panel of countries' basis. However, the literature regarding this theme has

[2]Additional details regarding the survey on EKC hypothesis are available in the studies of (Kijima et al.,2010; Pasten&Figuerao,2012).

been flourishing; among these studies, Shahbaz *et al.* (2010) investigated the case of the Portuguese economy. The study examined the carbon–income nexus while controlling for urbanisation, energy consumption, and trade openness in a multivariate setting. The study confirmed EKC hypothesis for the Portuguese economy despite the strides to reduce or eliminate GHG.

The EKC hypothesis was also validated in the studies of Guangyue and Deyong (2011), for Chinese provinces in the eastern and western regions, the carbon emissions per capita increased as income increased, indicating that these regions in China remain in the scale-effect stage of their growth trajectory, where the increase in national output (GDP) overwhelms the necessity for the quality of the environment. This result aligns with the position of Balcilar et al. (2010): there is a strong correlation between energy consumption and economic growth. This regarding is observed in their study, which was conducted with a bootstrap non-Granger causality estimation approach for G-7 countries. Furthermore, in a study conducted for Pakistan by Shahbaz*et al.* (2012), the study joins the strands of studies that have corroborated the inverted U-shaped relationship between income and carbon emissions (environmental degradation). Furthermore, Shahbaz *et al.* (2012) observed that trade openness decreases environmental degradation in a study similar to that of the Romanian economy. Another study conducted by Shahbaz *et al.* (2013) investigated the case of Romania and explored the income–carbon emissions and confirms the pollution haven hypothesis.

In addition to the aforementioned studies, Tiwari *et al.* (2013) explored the theme while examining coal consumption as a source of environmental degradation and accounting for structural breaks in the Indian economy. The study's empirical evidence validates the EKC hypothesis for the Indian economy because coal consumption and economic growth spur a high flare of carbon emissions. The Granger causality test of the study also affirms the EKC hypothesis because one-way causality is observed from GDP to the consumption of coal. Katircioğlu *et al.* (2014) examined the income–carbon nexus and accounted for the role of a tourist destination. The study reveals that tourism induced economic growth though having environmental quality because a one-way Granger causality is observed in tourism development and CO_2 emissions. However, for panel of countries, Apergis (2016) conducted the EKC hypothesis for a bloc of 15 countries. The panel estimation validatesthat 12 countries out of the 15 countries possess the EKC hypothesis and offers different policy implications in that regard.

Over the years, researchers have augmented the conventional EKC framework to account for other important variables, such as the study of Gökmenoğlu and Taspina (2016), and examined the EKC hypothesis in Turkey while accounting for the role of foreign direct investment. Gökmenoğlu and Taspina (2016) validated that the pollution haven hypothesis holds in Turkey because foreign direct investment increases carbon dioxide emissions. The study further supports the position that the Turkish economy has a poor environmental consciousness, which is true given that Turkey remains at the scale stage on their path to economic growth. By contrast, Katircioğlu and Katircioğlu (2018) studied Turkey and investigated the conventional EKC hypothesis while controlling for urbanisation. The study could not trace the inverted U-shape relationship observed in the literature.

The conventional EKC framework has recently been augmented with several variables, namely, the energy variables electricity and energy consumption, because there is an obviously strong synergy between energy and economic growth. Thus, its implication on environmental quality is worth investigating through the EKC framework. Examples of such studies include Hamit-Haggar (2012), for the Canadian experience in the industrial sector, and Baek, (2015) forArctic countries, which further reinforce the validity of the EKC hypothesis for the investigated countries. Furthermore, other scholars have also augmented the traditional EKC framework with capital and labour, for example, Al-Mulali*et al.* (2015) in Vietnam and Chang (2015) for G7 and BRICS countries. Other researchers have also emphasised the implication of agricultural production on the conventional EKC framework. A phenomenon known as the agricultural-induced environmental degradation hypothesis was introduced in the energy economic literature. The most recent studies available in the literature include Ullah *et al.*(2018) for the case of Pakistan, Gokmenoglu and Taspina, (2018) a similar study for the case of Pakistan, Dogan (2018) for the case of China, and Dogan, (2016) for the case of Turkey. All the aforementioned studies have examined how agricultural production affects environmental quality.

3. Methodology

This section of this study dwells on the data selection, variables choice and econometrics procedure that is applied in the course of the study.

3.1 Data description and source

This study investigated the dynamic interaction between carbon dioxide emissions, real income, and the quadratic form of real income while controlling for foreign direct investment, energy consumption, and trade openness in the conventional EKC framework for the case of Nigeria, an agrarian country. The study data were retrieved from the World Bank Development Indicators database for the years

1981–2014, and the data had been collected annually. Real income and its quadratic form were measured by real gross domestic product constant 2010 US$ (GDP). Agriculture (AVA) was measured by a value-added (% of GDP). Trade openness (TO) was captured by export plus import (% of GDP), foreign direct investment (FDI) net inflow (% of GDP), carbon dioxide emissions (CO_2) in (Kt), and energy consumption (EU) measured as energy use (kg oil equivalent per capita).The span of the data was informed by the availability of CO_2data until 2014, and other is until 2017. To arrive at a balanced dataset and for the ease of estimations, the data span is from 1981–2014.

Table 1 Summary of the data description and unit of measurement.

Table 1: Summary of data description and Source

Variable Name	Code	Description	Source
Gross domestic product	GDP	Real income represented by gross domestic product constant (2010 USD$)	World Development Indicator (2018)
Agricultural value added	AVA	Agricultural value-added constant, (% of GDP)	World Development Indicator (2018)
Foreign direct investment	FDI	Measured at net inflow (GDP)	World Development Indicator (2018)
Carbon dioxide emissions	CO_2	Measured in Kt tones	World Development Indicator (2018)
Energy consumption	EU	Measured as energy use in Kg of oil equivalent per capita	World Development Indicator (2018)
Trade openness	TO	Considered as the ratio of import, export to share of GDP	World Development Indicator (2018)

Source: Authors compilation

3.2 Model specification construction

The functional relationship form for this study is rendered as

$$CO_2 = f(GDP, GDP^2, Z) \tag{1}$$

Equation (1) provides the basic conceptual framework for investigating the theme under consideration and is based on (Gökmenoğlu & Taspina, 2018). Equation (1) is augmented with agriculture to examine the agriculture-induced EKC for the case of Nigeria.This study uses agricultural value added as share GDP which previous studies like (Gokemnoglu and Taspina, 2018; Doğan, 2018, Ullah *et al.*,2018; Doğan,2016) adopted. This study further improves on Gökmenoğlu and Taspina (2018) for the case of Pakistan and a similar study by Shahbaz *et al.* (2014) for Tunisia. We incorporated control variables, such as FDI, trade openness, and energy consumption, captured in Z:

$$CO_2 = f(GDP, GDP^2 AVA, Z) \quad . \tag{2}$$

This study also circumvent for multicollinearity in the econometrics construction. To do this, we estimate two separate model that takes partial impact of each explanatory variables to avoid perfect collinearity which is a violation of the assumption of classical linear regression model (CLRM) and by extension compromise all analysis (Akadiri*et al.*,2019a; Akadiri *et al.*,2019b)

To arrive at homoscedasticity, we take the logarithm transformation determine the next explicit functional form:

$$LnCO_{2t} = \alpha + \beta_1 LnGDP_t + \beta_2 LnGDP_t^2 + \beta_3 LnEU_t + \beta_4 LnFDI_t + \beta_5 LnTO_t + \varepsilon_t \tag{3}$$

$$LnCO_{2t} = \alpha + \beta_1 LnAVA_t + \beta_2 LnEU_t + \beta_3 LnFDI_t + \beta_4 LnTO_t + \varepsilon_t \tag{4}$$

$$LnCO_{2t} = \alpha + \beta_1 GDP_t + \beta_2 GDP_t^2 + \beta_3 LnAVA_t + \beta_4 LnEU_t + \beta_5 LnFDI_t + \beta_6 LnTO_t + \varepsilon_t \; (5),$$

where α depicts intercept, and $\beta_{1,}\beta_2 \,....\beta_6$ are the partial slope parameter and ε_t represents the error terms that captured unobserved indicators that explains determinant of carbon emission not included in the fitted model above.

From our study fitted model it would make theoretical and empirical sense to expect the signs of $\beta_1 and \beta_2$ to be positive and negative respectively. If that the case, the study would validate the EKC hypothesis for Nigeria. Also, for β_3>0, this is on the premise that agricultural activities induce environmental pollution given the consumption of fossil fuels to power farm machinery. This also leads to $\beta_4 ......\beta_6$ which could be ambiguous in terms of unknown signs.

This study's empirical route follows four processes. First, a stationarity test through the conventional ADF, the PP unit root test, and the Zivot and Andrews (1992) stationarity test are conducted to determine the maximum order of integration and asymptotic traits of the variable under review.

Second, we explore the long-run properties of the variables with the novel methodology of (Bayer & Hanck, 2013) and conduct a robustness check using the ARDL methodology by Pesaran *et al.* (2001). Finally, we probe for directional flow of the variables with Granger causality approach.

3.3 Stationarity test

In times series econometrics analysis, the usual practice is to conduct a unit root/stationarity test to avoid the spurious regression trap. In the econometrics literature, well-documented tests, namely, ADF (1981) and—closely after—Phillips and Perron (PP), (1988) have advanced similar unit root tests through, for example, accounting for structural break. The aforementioned tests do not account for structural break dates in the presence of a possible break. Most traditional unit root test such as the ADF and PP have been criticised in the econometrics literature regarding a low power and size problem. Thus, both tests accept stationarity when the critical values are close and are prone to make either a type I or type II error. To circumvent the aforementioned shortcomings of the tests, this study takes advantage of the Zivot and Andrews (1992) unit root test that accounts for a single structural break. The equation is provided as follows:

$$\Delta Y_t = \alpha_1 + \alpha_2 t + \theta Y_{t-1} + \gamma DU_t + \sum_{i=0}^{k} \xi_i \Delta Y_{t-i} + \varepsilon_t \quad (6)$$

$$\Delta Y_t = \alpha_1 + \alpha_2 t + \theta Y_{t-1} + \phi DT_t + \sum_{i=0}^{k} \xi_i \Delta Y_{t-i} + \varepsilon_t \quad (7)$$

$$\Delta Y_t = \alpha_1 + \alpha_2 t + \theta Y_{t-1} + \gamma DU_t + \phi DT_t + \sum_{i=0}^{k} \xi_i \Delta Y_{t-i} + \varepsilon_t \quad (8)$$

Here, the dummy variable DU_t represents the shift that occurs at each point of the possible breaks in all three forms of model construction (intercept, trend, or intercept and trend). The ZA unit has a null hypothesis unit root, which implies $H0:\theta > 0$ against an alternative of stationarity of $H1:\theta < 0$. The rejection of the null hypothesis implies stationarity. Non-rejection depicts such series possess unit root properties.

3.4 Cointegration test

The next procedure after the establishment of stationary properties of the interest variable is to examine the long-run equilibrium relationship. If there exist any sort of co-movement, the economic literature has said that two or more series are cointegrated if there is a linear combination among the series. The literature has well-documented techniques in this regard, for example, Engle-Granger advanced by Engle and Granger (1987); Philips Ouliaris, (1990); and the system of equation cointegration test ofJohansen and Juselius, (1990) and Johansen, (1991). There is also a breed of cointegration tests that accounts for structural break, for example, Gregory and Hansen, (1996) and Maki, (2012) have accounted for multiple structural breaks.

All the aforementioned tests provide a diverse conclusion with varying null hypotheses of cointegration to no cointegration. The recently advanced, unique combined cointegration test of Bayer and Hanck, (2013) offered a more robust and reliable conclusion by incorporating different individual test statistics. The test is based on the Engle and Granger (1987), Johansen (1991), Boswijk (1995), and Banerjee (1998) tests. The Fisher version equation form of the test is given as follows:

$$EG - JOH = -2[\ln(P_{EG}) + (P_{JOH})] \qquad (9)$$

$$EG - JOH - BO - BDM = -2[\ln((P_{EG}) + (P_{JOH}) + (P_{BO}) + (P_{BDM}) \qquad (10),$$

where $P_{EG}, P_{JOH}, P_{BO} and P_{BDM}$ represent the different probabilities of the various individual cointegration tests.The Bayer and Hanck cointegration test hypothesis is a null hypothesis of no cointegration against an alternative hypothesis of cointegration.

3.5 ARDL methodology

We also conducted the ARDL bounds test to cointegration for robustness of the long-run equilibrium relationship between the variables under consideration. The ARDL bounds testing approach is used on the premise that it offers an efficient and robust estimate in cases of small sample size relative to other traditional cointegration tests. The ARDL bounds approach also distinct because it simultaneously reports the short-run and long-run dynamics of an estimated model and the corresponding error correction model term (ECT) that captures the speed of adjustment to equilibrium. Additionally, the test is very useful in case of an unknown order of integration among the series, that is, either an I(1) or I(0) series, but not an I(2) series. The model is estimated in the framework of the unrestricted error correction model, where all variables are taken as endogenous. The unrestricted error correction model (UECM) is estimates as follows:

$$\Delta Y = \mu_0 + \mu_1 t + \lambda_1 y_{t-1} + \sum_{i=1}^{N} \theta_1 v_{it-1} + \sum_{j=1}^{p} \gamma_j \Delta Y_{t-j} + \sum_{i=1}^{N} \sum_{j=1}^{P} \omega_{ij} \Delta V_{it-j} + \Psi D_t + \varepsilon_t \qquad (11).$$

Here, V_t represents vector, and D_t accounts for structural a break in the framework as an explanatory variable. The test hypothesis is a null of hypothesis of no cointegration with the bounds test, which is estimated using either the F statistics or the T statistics. The decision rule in the three scenarios available is notable. First, if the computed F statistics are greater than the upper bounds of the critical values, the report rejects the null hypothesis. Second, if the F statistics are within the lower and upper bounds, the decision is inconclusive. In the final case, the F statistics below the upper bounds do not reject the null hypothesis. The hypotheses for the bounds test are specified as follows:

$H_0: \phi_1 = \phi_2 = ... = \phi_{k+2} = 0$

$H_1: \phi_1 \neq \phi_2 \neq .... \neq \phi_{k+2} \neq 0.$

3.6 Granger causality methodology

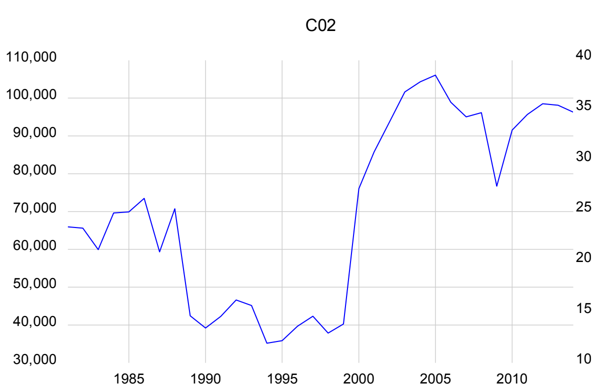
Conventional regression does not translate into causal interaction. Thus, it is pertinent to examine the causality flow among variables for policy direction. This is so, given the predictability power of the test. This study leverages the popular Granger causality test methodology among the variables under consideration. Generally, in the literature, when, for example, variable X Granger causes another, for example, Y, the meaning is that the variable X and its past realisation have a predictive power to forecast the outcome of variable Y, not only the historical variable of Y alone. For instance, a bivariate relationship between (X, Y) in a Granger causality test can be specified as follows:

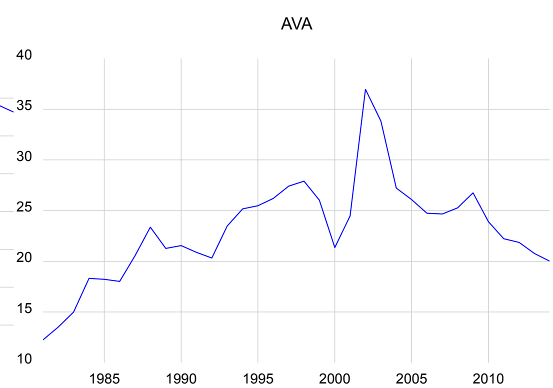
$$X_t = \gamma_0 + \gamma_1 X_{t-1} + \gamma_2 Y_{t-1} + \varepsilon_t \qquad (12)$$

$$Y_t = \gamma_0 + \gamma_1 Y_{t-1} + \gamma_2 X_{t-1} + \varepsilon_t \qquad (13)$$

4. Empirical Results Interpretation and Discussions

It is pertinent to analyse the trend analysis of variables in time series econometrics to attempt to understand how the variables fare. As such, we examined the visual plot of the variables under review (figure 2). It is conspicuous that the variables possess structural break dates that resonate significant economic episodes and events in our study area. Table 2 panel A renders the descriptive statistics of the variables under consideration with economic growth (real income) possess the highest average relative to the other variables. All observations show strong dispersion from their respective means, as revealed by the mean deviation. We also observe that all the series are normally distributed, as reported by the Jarque-Bera probability, with a failure to reject the null hypothesis of normality. Subsequently, at the bottom of Table 2, panel B renders the Pearson correlation matrix relationship between the variables that reports the pairwise relationships among the choice variables under consideration. We observe a statistical significant relationship between economic growth and carbon dioxide emissions (CO_2), energy consumption, agriculture and FDI. Table 2 (correlation matrix analysis) shows a statistical positive and weak association of 27% between agriculture and GDP which denote no one to one relationship or perfect collinearity between agriculture proxy and GDP in the fitted model thus, reveals no traits of multicollinearity in the current version of the study. This is in line with the previous studies of (Gokemnoglu and Taspina, 2018; Doğan,2018, Ullah *et al.*,2018; Doğan,2016). All the aforementionedinteractions has its implication. For instance the observed positive interaction between economic growth and CO_2 emission reveal that as Nigeria income level (economic growth) rises there is a trade-off for quality of the environment. The same implication holds for energy consumption. Furthermore, an inverse relationship is seen between trade openness and economic growth. These outcomes are insightful and quit revealing for policy and decision makers in our study area. To validate the established relationships, further econometrics empirical analyses are conducted in the course of this study.





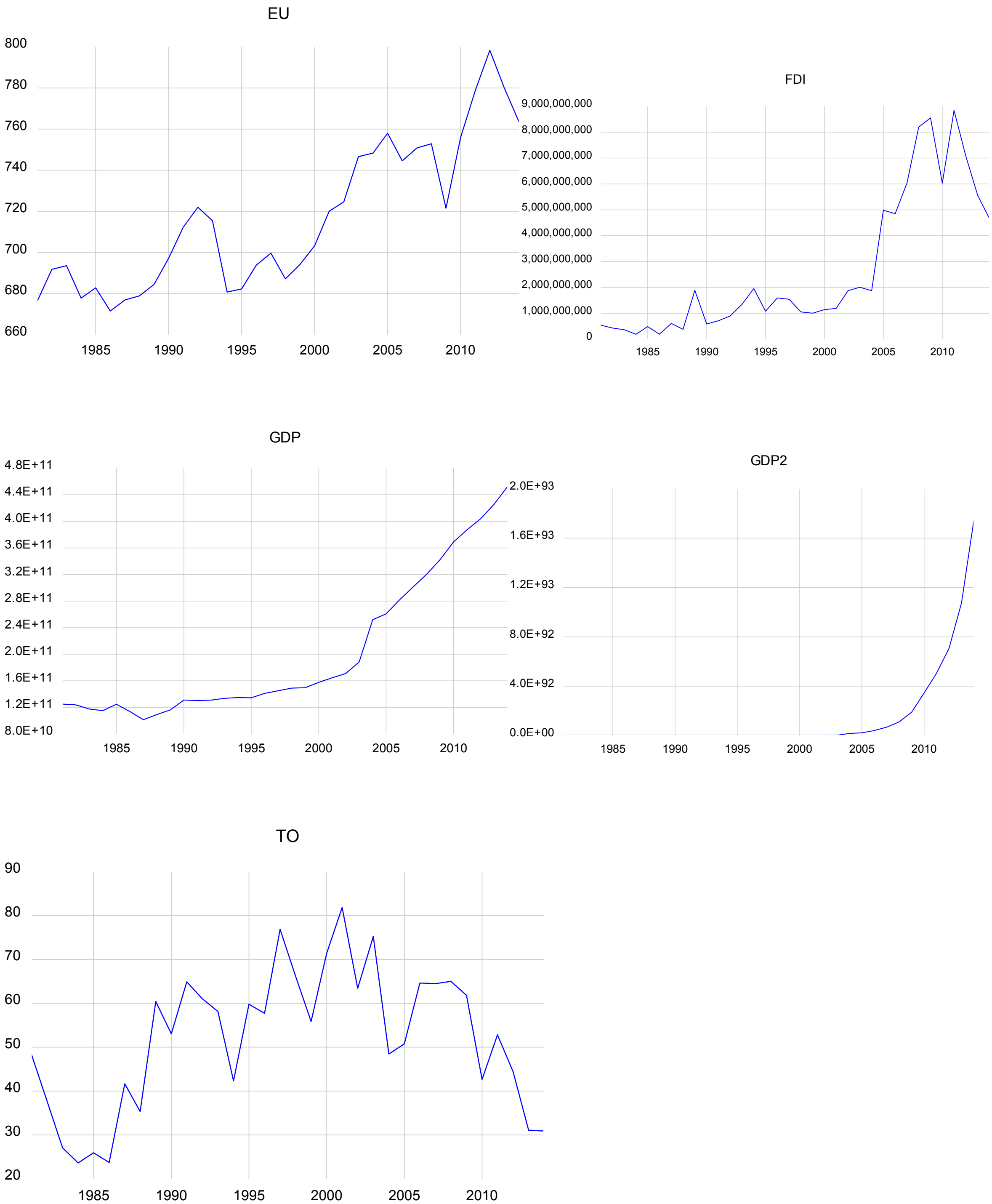


Figure 2: Level plot of Variables under Consideration

Table 2: Descriptive statistics

Panel A	LNC02	LNGDP	LNEU	LNAVA	LNFDI	LNTO
Mean	11.0970	25.9187	6.5734	3.1156	21.1459	3.8972
Median	11.1608	25.7126	6.5621	3.1541	21.0873	3.9967
Maximum	11.5718	26.8376	6.6825	3.6100	22.9027	4.4044
Minimum	10.4688	25.3425	6.5095	2.5047	19.0581	3.1616
Std. Dev.	0.3793	0.4722	0.0492	0.2263	1.1112	0.3491
Skewness	-0.3440	0.7147	0.5219	-0.6180	0.0061	-0.7394
Kurtosis	1.5949	1.9760	2.0629	4.0223	2.0432	2.5040
Jarque-Bera	3.4677	4.3802	2.7874	3.6449	1.2971	3.4469
Probability	0.1766	0.1119	0.2482	0.1616	0.5228	0.1784
Sum	377.2994	881.2365	223.4943	105.9301	718.9599	132.5062
Sum Sq. Dev.	4.7482	7.3585	0.0797	1.6894	40.7491	4.0211
Observations	34	34	34	34	34	34

Panel B **Correlation coefficient estimates**

	LNC02	LNGDP	LNEU	LNAVA	LNFDI	LNTO
LNC02	1					
T-Stat.	-----					
P.value	-----					
LNGDP	0.6743***	1				
T-Stat.	5.1651	-----				
P.value	0.0000	-----				
LNEU	0.6896***	0.9124***	1			
T-Stat.	5.3880	12.6140	-----			
P.value	0.0000	0.0000	-----			
LNAVA	0.0686	0.27463	0.3098	1		
T-Stat.	0.3892	1.6157	1.8434*	-----		
P.value	0.6998	0.1160	0.0746	-----		
LNFDI	0.4613**	0.8899***	0.8291***	0.4746**	1	
T-Stat.	2.9406	11.0404	8.3875	3.0498	-----	
P.value	0.006	0.0000	0.0000	0.0046	-----	
LNTO	-0.1439	0.0922	0.18475	0.5849***	0.4015**	1
T-Stat.	-0.8228	0.5238	1.0634	4.0797	2.4798	-----
P.value	0.4167	0.6040	0.2956	0.0003	0.0186	-----

Source: Authors computation

*Note: Superscripts ***. **,* represent statistical significance level of 0.01, 0.05, and 10 statistical rejection levels, respectively*

Table3 : Unit root results (Non-stationarity test without break)

Variables	ADF	PP
Level		
*ln*GDP	-1.874(1)	-1.875(1)
*ln*GDP2	-1.828(1)	-1.828(1)
*ln*AVA	-2.065(1)	-1.633(1)
*ln*TO	-1.788(1)	-1.834(1)
*ln*FDI	-2.389(1)	-4.427(1)***
*ln*EU	-2.670(1)	-2.394(1)
lnCO_2	-1.795(1)	-1.795(1)
Δ	ADF	PP
*ln*GDP	-4.967(1)***	-4. 920(1)***
*ln*GDP2	-4.967(1)***	-4.920(1)***
*ln*AVA	-6.915(1)***	-7.634(1)***
*ln*TO	-7.559(1)***	-7.642(1)***
*ln*FDI	-10.866(1)***	-10.735(1)***
*ln*EU	-5.159(1)***	-5.135(1)***
lnCO_2	-5.541(1)***	-5.541(1)***

Source: Authors computation

*Note: Superscripts ***. **,* denote 1%, 5%, and 10% statistical significance rejection level, respectively. The level and difference are also reported with Δ representing first difference. Models with intercept and trend were reported for all test statistics. The lag length of the variables are in brackets.*

Table 4: Zivot and Andrews non-stationarity test (With a single structural break break)

Variable Names	At level		At first difference	
	T-Stat.	Time break	T-Stat.	Time break
*ln*GDP	-3.739(1)	2004	-6.003(1) ***	2004
*ln*GDP2	-3.755(1)	2004	-7.499(1)***	2004
*ln*AVA	-4.291(1) ***	2002	-7.357(1) ***	2001
*ln*TO	-4.153(1)	2000	-5.208(1) **	1990
*ln*FDI	-2.727(1)	2009	-12.297(2)**	1990
*ln*EU	-4.517(1)	1994	-5.307(1)**	1993
lnCO_2	-5.585(1) ***	2000	-6.550(1) ***	2000

Source: Authors computation

*Note: Superscripts ***. **,* denote 0.01, 0.05, and 0.10 percent statistical rejection level, respectively. The numbers in bracket are the optimal lag length of the variables investigated.*

Stationarity tests are conducted among the interest variables under review to avoid a spurious regression trap and ascertain the maximum integration order among the interest variables. In addition to the aforementioned merit of the stationarity test, we must avoid the I(2) variables in estimations. Thus, we adopted conventional non-stationarity tests, such as the ADF and PP tests, to achieve that, and both tests' results are reported in Table 3. The tests confirm that all the interest variables are non-stationary at level except FDI at level form, as observed by using the PP test. However, the first difference version form of all the variables shows they are stationary. That is, the variables are I(1). However, the ADF and PP unit root test have been criticised in the econometric literature for the problems of low power and size. Thus, to ameliorate these problems, we apply the Zivot and Andrews unit root test under a single structural break (Table 4). The test results corroborate the outcomes of the ADF and PP tests. In conclusion, regarding the stationary status of all series, this study affirms that all the selected variables are I(1).

Further analysis from the ZA unit root test reports break dates that resonate with significant happenings and events in Nigeria. For example, from 1995–2000 there was a political regime change from the military rule (the third republic to the fourth republic) to democratic rule. In 2002, there was a political transition to the candidates who won the 2003 election, which resulted in crises in Nigeria's capital Abuja. And in 2004, an internal communal crisis was experienced in the middle belt region, namely, in the Plateau, which led then president Olusegun Obasanjo to declare a state of emergency in the state. In addition, we capture the global crises' year after the crash of Lehman Brothers that resulted in the world financial crisis of 2009.

Table 5: Lag order selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	57.609	NA	0.000	-3.226	-2.951	-3.134
1	194.881	214.486*	2.98e-12*	-9.555*	-7.631*	-8.917*
2	218.235	27.733	0.000	-8.765	-5.192	-7.580

Note: were FPE, LR, AIC, SIC, and HQ are all information criterion. See list of abbreviations for details.

The optimal and most parsimonious lag selections employed for the estimated model are rendered in Table 5. Subsequent analysis is performed in this study and is necessary to avoid model miss specification and achieve the most parsimonious model that is free of all violations of any axioms of classical linear regression analysis. This study relies on the AIC criterion with lag one as given suggested. The criterion is considered as most parsimonious over another criterion, namely, AIC, HQ, and FPE. AIC is also informed by our study sample size.

Table 6: Result of the Bayer-Hanck test for cointegration

Estimated model	EG-JOH	EG-JOH-BO-BDM	cointegration
*ln*C=f(*ln*Y,lnY2,lnE,lnF, lnT)	56.1313***	73.8678***	✓
*ln*C=f(lnE,lnA,lnF,lnT)	18.6043***	33.1369***	✓
*ln*C=f(*ln*Y, lnY, lnA, lnE, lnF lnT)	55.8109***	67.2430***	✓
1% critical value	15.348	29.544	
5% critical value	10.352	19.761	
10% critical value	8.200	15.746	

ARDL Bounds testing to cointegration

lnC=f(lnY,lnY2,lnE,lnA,lnF,lnT)
Significance level F-Stat
3.8679** Lower Bound Upper Bound

Significance level	Lower Bound	Upper Bound
1%	3.27	4.39
5%	2.63	3.62
10%	2.33	3.25

Source: Authors computation

*Note: Superscripts ***. **,* indicate 0.01, 0.05, and 0.10 percent statistical level of rejection, respectively. For the brevity of space, CO_2,Y,Y2,E,A,F,* and *T represent carbon dioxide emission, gross domestic product, quadratic form of GDP, energy consumption, agriculture, foreign direct investment, and trade openness, respectively.*

This study continues with the estimation of the equilibrium relationship, given that all variables are first difference stationary. A cointegration methodology developed by Bayer and Hank(2013) was applied. Table 6 reports the results of the Bayer and Hank(2013) to cointegration with each variable as dependent variables over the considered period. The results confirm the cointegration relationship between carbon dioxide emission, real income, its quadratic form, agriculture, energy consumption, FDI, and trade openness. According to the cointegration test developed by Bayer and Hack (2013), a long-run equilibrium relationship exists between the selected variables. This position is also validated by the bounds test results of the Pesaran test (Table 6). This confirmation was possible with the rejection of the null hypothesis of nocointegration for all the fitted models. For a robustness check, the Pesaran's bounds test at bottom of Table 6 also corroborates the cointegration among the variables considered over the sampled period.

Table:7 ARDL Model CO_2=f(GDP, GDP2, EU,FDI,TO)

Short run analysis			
Variable	**Coefficients**	**Standard Error**	**T-Stat.**
ΔGDP	22.0719*	12.0867	1.8261
ΔGDP2	-0.4129*	0.2319	-1.7807
ΔEU	2.9077**	1.4599	1.9916
ΔFDI	-0.2147***	0.0705	-3.0443
ΔTO	0.0205	0.1443	0.1422
ECM_{t-1}	-0.2262**	0.096	-2.3563
Long-run analysis			
GDP	97.5705	61.6125	1.5836
GDP2	-1.8254	1.1718	-1.5577
EU	2.5641	6.5364	0.3923
FDI	-0.9491*	0.5447	-1.7424
TO	0.0907	0.6527	0.1389

Source: Authors computation

*Note: Superscripts ***. **,* denote 1%, 5%, and 10% statistical significance rejection level, respectively.*

Table 8: ARDL Model CO_2=f(AVA,EU,FDI,TO)

Short run analysis			
Variable	Coefficients	Standard Error	T-Stat.
ΔAVA	0.1683	0.1908	0.8819
ΔEU	4.0488***	1.1247	3.5998
ΔFDI	-0.1431***	0.051	-2.8036
ΔTO	0.0067	0.1179	0.0568
ECMt-1	-0.2157**	0.1084	-1.9899
Long-run analysis			
AVA	0.7802	0.9198	0.8483
EU	18.7731***	8.8573	2.1194
FDI	-0.6636	0.4414	-1.5031
TO	0.0311	0.5542	0.0561

Source: Authors computation

*Note: Superscripts ***. **,* denote 1%, 5%, and 10% statistical significance rejection level, respectively.*

Tables 7 and 8 reports the short and long run analysis for equations 3 and 4 respectively as earlier mentioned in section 3. The need to estimate the separate model is to circumvent for the issue of multicollinearity in the study model. In Table 7 the error correction term (ECM) -0.2262 is statistically easily passing the 5% benchmark. This suggest that environmental degradation converges to its long-run equilibrium path by approximately 23.0% convergence (adjustment pace) through the channel of economic growth, square form of economic growth, energy consumption, foreign direct investment and trade openness. The short run coefficient of GDP and GDP^2 are 22.07 and -0.41 respectively which satisfy the condition for EKC in Nigeria in both short and long run. Thus, this study joins the strands of study that affirms the trade-off between country income level and her environmental quality. This is not surprising for Nigeria being a developing country were emphasis is on high income levels before much later emphasis on quality of the environment (see section 2 for more details). In same fashion consumption of energy also exerts an elastic positive impact on environmental pollution. That is, a 1% increase in consumption of energy further deplete the quality of the environment by 2.9% in the short run and 2.5% in the long run. The same scenario hold for trade openness as trade with rest of the world also degrades the environment. This is revealing and instructive for government personnel's in Nigeria to caution of trade flows that impede the quality of the environment. Interestingly, we observe an inverse relationship between FDI inflows and quality of the environment. This is contrary to *apriori* expectation, were developing countries are perceived as dumping ground for developed economies. Thus, this country fails to find support for the pollution haven hypothesis.

In Table 8, the focus of the fitted model is to evaluate the contribution of agriculture on environment degradation. The model has an ECM of -0.212 which is statistically significant at 5%. The ECM reveals that by 22% adjustment speed a convergence is achieve by the contribution of agriculture, energy consumption, foreign direct investment, trade openness. The coefficient of agriculture(AVA) depicts a positive and inelastic effect on environmental quality in the short run with a magnitude of 0.7802 and 0.1683 in both long and short run respectively. This further corroborates the agriculture induced EKC hypothesis. That is intense agricultural activities increase environmental quality negatively. This is indicative for energy and environmentalist that formulate energy treaties. That there is need to check this phenomenon, given that there is need to intensify agricultural operation for increased food availability and food security. A positive elastic statistical coefficient is seen between energy consumption and environmental pollution. A 1% increase in energy consumption triggers

18.77% and 4.05% corresponding decrease in the quality of the environment in both the long and short run term respectively. The same trajectory is observed for the case of openness to trade as Nigeria embrace trade deplete the quality of the environment. For the case foreign direct investment (FDI) an inverse relationship between FDI and environmental pollution. A 1% increase in FDI decreases by a magnitude of 0.0311% and 0.0067% in environmental pollution in both long and short runs, respectively. This implies that the inflow of FDI helps improve the quality of the environment[3].

Table 9: ARDL short-run and long-run results
Endogenous Variable:
$LnCO_2$=f(GDP,GDP2,EU,AVA,FDI,TO)
(1,0,0,0,1,0,0)

Short-run coefficients

Independent Variables	Coefficients	Standard Error	t-Statistic
Δ LnGDP	19.1878*	10.1467	1.8910
Δ LnGDP2	-0.390*	0.227	-1.718
Δ LnEU	2.355	1.490	1.580
Δ LnAVA	0.339	0.222	1.525
Δ LnFDI	-0.233***	0.069	-3.355
Δ LnTO	0.010	0.154	0.066
ECM_{t-1}	-0.2167***	0.110	-2.975
R-square	0.599		
F-statistic	14.488***		

Long-Run Coefficients

Independent Variables	Coefficient	Std. Error	t-Statistic
LnGDP	83.615*	42.889	1.945
LnGDP2	-1.5582*	0.822	-1.896
LnEU	0.270	4.591	0.059
LnAVA	1.033	0.065	1.585
LnFDI	-0.976**	0.387	-2.522
LnTO	0.031	0.467	0.067
R-square	0.915		
F-statistic	27.537***		

Diagnostic tests

Test	Statistics	P value
Serial correlation	2.191	0.137
ARCH	0.654	0.425

[3]For want of space tables 7 and 8 diagnostic test results can be made available upon request. Both estimations passed all diagnostic tests

White	1.005	0.464
Ramsey	1.476	0.154

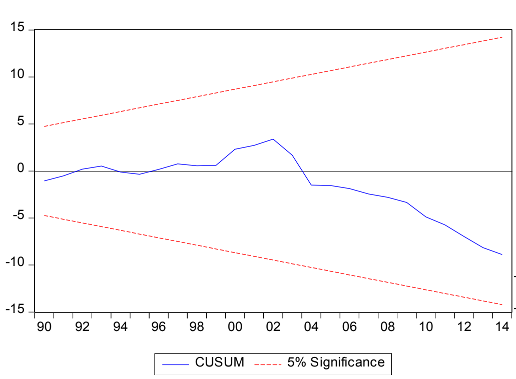
Source: Authors computation

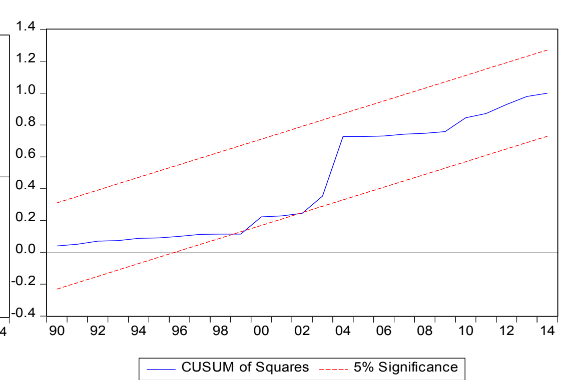
*Note: Superscripts ***. **,* denote 1%, 5%, and 10% statistical significance rejection level, respectively.*

Furthermore equation 5 is estimated. Equation 5 encapsulates all explanatory variables in one model. The long-run and short-run analyses are rendered in Table 9. The estimated model is robust, with an ECT of approximately 22.0% speed of adjustment to its long-run equilibrium path annually by the contribution of real income, quadratic form of real income, trade openness, agriculture, energy consumption, and FDI. In the short run, we observe the significant positive relationship between real income and CO_2 emissions, and a negative relationship is observed between CO_2 and the quadratic form of real income. This pattern is the inverted U-shape relationship. The inverted U-shaped pattern observed is an indication that Nigeria remains at the scale-effect stage in its growth trajectory, where there is less concern for environmental quality. This implies that in Nigeria, the focus on economic growth rather than the quality of the environment (Shahbaz & Sinha, 2018), implying that at a higher threshold level of economic activities (turning point), environmental quality improves. Obviously, from our empirical findings, the income level of Nigeria has not increased to a level that translates into a consciousness for environmental quality. The stage referred to as the technology effect stage, as mostly observed in developed economics, is not the case of Nigeria, which is the focus of this study. Countries that have passed the turning point growth trajectory mainly focus on cleaner and renewable energy sources (Bekun *et al.*, 2019a;Bekun *et al.*2019b;Alola *et al.*, 2019; Akadiri *et al.*,2019c; Sarkodie & Strezov, 2018). This focus implies that for developed economies, after a certain mentioned threshold of income, environmental quality improves. This case is observed in most developing economics in the scale-effect stage. These outcomes have been proven severally in the literature for the case of Turkey (Gökmenoğlu &Taspina, 2016), for the case of China (Doğan, 2018). Additionally, the same pattern was affirmed for the case of Pakistan in the studies of (Gökmenoğlu &Taspina, 2018). This pattern is affirmed in this current study in both periods. This result implies that a 1% increase in economic activities translates into a 19.19% increase in environmental degradation and a0.39% decrease in CO_2 emissions in the short run. A similar trend is observed in the long run with a 1% increase in real income birth corresponding to a 83.615% increase in environmental degradation, and for the case of real income, square leads to a 1.558% decrease in CO_2 emissions in the long run in terms of Nigeria. This outcome provides strong credence to the EKC hypothesis for Nigeria.

Regarding energy consumption, a positive relationship with $CO_2$is observed in the long run and short run, although it is not as significant as Nigeria still relying heavily on non-renewable energy sources such as fossil fuel. This result explains the reason behind the high CO_2 emission. This phenomenon is also true for the case of Turkey (Itodo *et al.*, 2017). A similar positive relationship is observed between agriculture and CO_2emissions in the short run and long run, although not significant for this study. However, agriculture exerts a positive impact on carbon dioxide emissions.

For the case of FDI, our study shows a significant negative relationship. This result is revealing and implies that attraction of FDI helps mitigate carbon emissions in Nigeria. The reason for this attraction might be that investment options attracted to Nigeria are cleaner and environmental friendly, which is desirable. Thus, policymakers and government administrators that design and formulate policies and strategies are encouraged to make the nation a destination for foreign investors. This empirical study also shows that the more open the Nigerian economy is to rest of the world, the less the emissions of CO_2 in the long run and short run, and this result implies that most of the trade is importation less export. A 1% increase in trade-openness births results in a corresponding decrease of 0.01% and 0.030% in the short run and long run, respectively. This result is notable and informative to energy economist and stakeholders. Figures 3 and 4 report the cumulative sum control chart (CUSUM) and CUSUM square, as advanced by Brown *et al.*(1975), and demonstrate that the estimated models are parsimonious and stable and helpful for policy implication decision(s) in Nigeria, given that the blue line falls within (95% confidence interval) the red bandwidth. The fitted model residual diagnostic test (at the bottom of Table 9) shows that the model is stable, as reported by the Ramsey RESET test. Our model is also free from serial correlation and is homoscedastic.





Figures 3 and 4 represent the CUSUM and CUSUM square graphs.

Table 10: Chow forecast test

Chow forecast test from 1999–2014			
	Value	Df	Probability
F-statistic	5.433	(16, 12)	0.0013
Likelihood ratio	54.724	16	0.0000
Chow forecast test from 2000–2014			
	Value	Df	Probability
F-statistic	6.133	(15, 13)	0.0011
Likelihood ratio	48.023	15	0.0000
Chow forecast test from 2009–2014			
	Value	Df	Probability
F-statistic	5.309	(4, 5)	0.0015
Likelihood ratio	15.385	6	0.047

Source: Authors' computation

Table 10 renders the Chow forecast test that depicts the join significant of break dates. This study area's dates reflect significant episodes in Nigeria over the investigated period. For instance, in 1999, our study area experienced a major political regime change that marked the end of military reign and a change to democratic rule, which our study captured and determined, was significant. Similarly, the global financial crisis in late 2008 to early 2009 was reflected by our study.

Table 11: Causality analysis

Null Hypothesis	Causality	F-Stat.	Prob.
$LNCO_2 \neq> LNEU$		0.61632	0.4386
$LNAVA \neq> LNCO_2$	$AVA \neq CO_2$	0.4567	0.5044
LNAVA ≠>LNGDP	AVA→GDP	12.2775^{***}	0.0015
LNGDP ≠>LNAVA		1.0365	0.3168
LNAVA ≠>LNGDP2	AVA→GDP2	12.2776^{***}	0.0015
LNGDP2 ≠>LNAVA		1.0489	0.3140
LNAVA ≠>LNEU	AVA→EU	9.98817^{***}	0.0036
LNEU ≠>LNAVA		0.00110	0.9738
LNFDI ≠>LNAVA	AVA→FDI	0.11452	0.7374
LNAVA ≠>LNFDI		12.1591^{***}	0.0001

Source: Authors computation
*Note: The superscript***. **,* represents 0.01,0.05, and 0.10 percent statistical level of significance, respectively. Here, ≠,→ and ↔ represents No Granger causality, one-way causality, and bi-directional causality, respectively. Additionally, ≠> means 'does not Granger cause'.*

Granger causality analysis is crucial for its inherent directional flow for policy construction. Thus, we conducted the Granger causality among the variables under review in Table 11. We observed one-way Granger causality from energy consumption to economic growth, and this result validates the energy induced growth hypothesis for Nigeria over the investigated period. This implies that Nigeria is energy dependent. Similarly, unidirectional causality is observed from agriculture to economic growth, and this result affirms that Nigeria is an agrarian country because agriculture remains a major contributor to economic growth. This outcome strengthens the studies of (Bekun & Akadiri, 2019; Alola & Alola, 2018; Sertoglu *et al.,* 2017), who indicated that agriculture is the panacea for economic growth in Nigeria. This study also validated the agricultural-induced FDI attraction given the inherent arable land and the substantial potential the agricultural landscape offers in Nigeria. Notably, our study found feedback causality between GDP and FDI. This feedback causality has been recently observed, especially in the energy sector (the oil sector and agricultural sector), with the influx of multinationals such as Shell international and Chevron, among others, to explore, mine, and engage in commerce in the aforementioned sector. Thus, the outcome of this causality is economic growth and vice versa.

5. Concluding Remarks and Policy Implications

Climate change mitigation over the last decades has become a topical discourse for policymakers, environmental scientist, and the academics. Most if not all nations are working diligently to achieve emissions targets. As such, the present study revisits the Environmental Kuznets Curve (EKC) hypothesis with a new perspective. It is on the above premise of climate change mitigation that the current study explores the conventional EKC setting within the framework of agriculture. This is in order to ascertain the impact of agriculture on the environment. The present study also controls for the role of trade liberalization, energy consumption, and FDI inflow as determinant of CO_2 emissions for the case of Nigeria.

Empirical results affirm the inverted U-shape pattern relationship between environmental degradation and the income level over the investigated period for Nigeria. This study is distinct from the study of (Gökmenoğlu & Taspinar, 2016), that affirms the pollution haven hypothesis (PHH). The present study fails to find support for the validation of the PHH in Nigeria. This implies that FDI inflows help to decrease environmental pollution.

The detrimental impact of agriculture on the environment as reported by the current study calls for government administrators and policymakers to be conscious of the importance of agricultural activities to economic growth in Nigeria and the environmental implication(s). The explanation for the agricultural-induced EKC hypothesis is that agricultural activities are primary driven and the sector is characterized by the burning of fossil fuel in the production stage. This increased fossil fuel emissions is triggered by the incessant bush burning practice by farmers in Nigeria and other pollutants such as fume from generators, vehicles emission of CO, and CO_2 emissions. This trend has resulted in Nigeria and ten other countries being ranked as having the worst ambient air in the world, which has increased maternal mortality according to the a report by the Health Effect Institute (HEI,2018). To ameliorate this menace, farmers' awareness must be increased regarding efficient energy sources, especially when there is global awareness for cleaner and sustainable energy (Emir & Bekun, 2018). Thus, the need to invest in research and development to discover alternative cleaner energy sources such renewable energy(e.g. photovoltaic energy, biofuel, and wind energy), and this investment is crucial and would be timely for the Nigerian economy. This position to increase and improve renewable energy sources has been advocated by policymakers. For instance the following empirical studies shed more insight on the need for paradigm shift to renewable energy sources and technologies (Bekun & Agboola, 2019; Samu *et al*., 2019; Balcilar *et al*., 2019; Emir & Bekun, 2018; Ajayi &Ajayi,2013).

Based on the outcome of this study, the need to keep the skies of Nigeria blue is pertinent without trade-off in food security and availability. In doing so, the following pragmatic policy directions were rendered:

(a) The study revealed that agricultural activities contribute to carbon emissions. Therefore, policies should be aimed at reducing agricultural activities that contributes to carbon emissions such as bush burning. Bush burning should be discouraged; instead replaced with improved agricultural practices that require less farm land use such as greenhouse farming. Furthermore, de-composing of brush and weeds which can serve as nutrients to the soil should also be supported.

(b) The quest to meet the sustainable development goals (SDG's) target of efficient, reliable energy as well as food security for all is attainable. As such, there is need for officials to intensify energy mix blend with cleaner technologies in order to attain the climate goal target.

(c) The need for the Nigerian government to strengthen her institutions on environmental treaties and regulations is key. The enforcement of 2016 national energy bill is imperative; this is one of the government's initiatives towards economic growth and poverty alleviation by providing diverse energy sources at affordable and adequate quantity. This bill will help mitigate environmental pollution issues and reduction of GHG emissions

Finally, this study serves as a blueprint for other countries on the African continent to tackle environmental degradation in the quest to increase income levels and achieve sustainable development.

Regarding directions for further research, other scholars can query the theme under consideration for other agrarian-based economies or blocs of agrarian states; most importantly -countries within Africa. In addition, further studies can investigate the aspect of asymmetry to ascertain if asymmetry (non-linearity) holds in the agriculture-induced EKC literature.

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Appendix

List of Abbreviations

Environmental kuznets curve (EKC) hypothesis

Augmented Dickey–Fuller (ADF) unit root test

Phillips–Perron (PP) unit root test

Zivot and Andrews (ZA) unit root test

Autoregressive distributive lag (ADRL)

Greenhouse gas (GHG)

Carbon mono oxide (CO)

Carbon dioxide (CO_2)

Structural adjustment program (SAP)

Bayer and Hanck (BH) cointegration methodology

North American Free Trade Agreement (NAFTA)

Gross Domestic Product (GDP)

Unrestricted error correction model (UECM)

Akaike information criterion (AIC)

Schwarz information criterion (SIC)

Hannan Quinn information criterion (HQ)

Final prediction error (FPE)