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Growth, Trade Openness and Environmental Degradation in Nigeria

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Abstract

This study provides empirical insight into the relationship between growth, trade openness, and environmental degradation in Nigeria. The autoregressive distributed lag bounds testing approach was applied on time series data from 1960-2017. Employing the Pollution Haven and Environmental Kuznets Curve hypotheses, empirical findings validate the EKC hypothesis in Nigeria in the long-run. All estimated parameters were found to have the expected signs in the short- and long-run, except population, with the expected sign only in the long-run. The analysis proves that trade openness and population aid environmental degradation in the short-run. It reveals that financial development counters environmental degradation in both the short- and long-run, and real income per capita has a positive and significant effect on environmental degradation in both the short- and long-run. The coefficient of the error correction term suggests that 62.5% of the divergence between actual and equilibrium CO_2 emissions is corrected annually. Post-estimation tests employed proves the robustness of the result. The RESET test affirmed the specification of the model and the CUSUM and CUSUM of squares tests confirm the stability of the parameters. Consequently, Nigeria should foster policies that encourage the development and utilization of renewable energy to boost economic development.

Keywords: Growth; trade openness; environmental degradation, pollution haven hypothesis, environmental Kuznets curve, sustainable development

1. Introduction

The expedition of trade openness and CO_2 emissions illustrates two of the major topics commonly investigated over the past decades; having obvious reasons. O'Rourke, Kevin and Sinnott (2001) agrees that trade openness represents one of the major links of globalization alongside technological transfers, migration, foreign direct investments, and capital flows, though the effects of trade openness on environmental quality remain controversial (Mutascu, 2018). Shahbaz *et al.* (2016) agrees that sustainable development is difficult to attain beside climate change adversities and rising temperature. The African region, particularly sub-Saharan Africa, is beginning to feel the impacts of climate change in no small measure. Adverse economic effects of climate change associated with swift natural capital depletion remain noteworthy problems for many countries' performance, especially for resource-driven economies and economies severely susceptible to climate change (Kurniawan and Managi, 2018).

On the sustainable development case, particularly in countries with high growth rates, studies associated with the Environmental Kuznets Curve (EKC) is gaining attention in the relevant literature (Faqin, 2017). The EKC postulates that the linkage between economic growth and environmental indicators ensures an inverted U-shaped curve (Le *et al.,* 2016). It posits aptly that after attaining a particular level of Gross Domestic Product (GDP) per capita, the rising pattern of environmental indicator overturns such that increasing GDP per capita stimulates economic recovery (Haug and Ucal, 2019).

On another hand, trade economists and environmentalists maintain that trade liberalization through proficient use of resources could make an indispensable contribution regarding creating the significant conditions for environmental improvements (Kurniawan and Managi, 2018). They also maintain that liberalization of trade and environmental policies will be advantageous through enhancing allocative efficiency, rectifying market failures, and solidifying the capability of the internalization of environmental instruments.

The economic effects of climate change on the tertiary and secondary levels of economic activities are extensive and multifaceted. These effects are greater on agricultural sustainability, human health, and productivity (Kurniawan and Managi, 2018). The major reason for not agreeing to a policy consensus in the trade-climate talks is the multifaceted and contested nature of pulling off an environmental consensus on trade openness (Shahbaz *et al*., 2016). In reality, many of the economies of the world are yet to enact their emission cutback policies.

Whether trade is beneficial or not for the environment has always been hugely debated. Pieces of evidence show that trade seems to be beneficial or at least not detrimental to the environment from some cross-country analysis (for example, Copeland and Taylor, 2001; Copeland and Taylor, 2003, 2004; Frankel and Rose, 2005). However, this observation may not be a true reflection of the case of developing nations like Nigeria. While studies including James (1996) and Topcua and Payne (2018) have pruned the benefits of trade openness to the environment; particularly in the developed world, some others including Managi *et al*., (2009) have posited otherwise.

The key argument behind this is that while trade is beneficial to developed countries, it often results in environmental degradation in less developed countries. The case for less developed countries is majorly an outcome of adopting negligent or careless environmental measures in other to attract multi- and/or transnational corporations which more often than not, export pollution-intensive goods, as broadly defined by the so-called pollution haven hypothesis (Cole and Elliott, 2003; Cole, 2004).

The most recent group of contributions examines various economies and periods, and varying empirical tools and time incidences. The evidence of trade openness on environmental degradation from individual countries varies according to their income levels, and this may be due to differences in policy, economic structure, level of economic openness and country-specific variables (Baek *et al*., 2009; Naranpanawa 2011; Wiebe *et al*., 2012; Forslid and Okubo, 2014; Shahbaz *et al*., 2016).

Nigeria's response to CO_2 emissions threats in the context of policy development framework remains a major challenge. Despite its high dependence on fossil fuel and high vulnerability to climate change, Nigeria is just in the process of putting in place emission control policies or response strategies that could address the issues of financial requirements, mitigation and adaptation measures and mobilization. A wide aperture can, therefore, be deduced, particularly for the Nigerian case, on the dynamics of trade openness and CO_2 emissions. This study explains the dynamics of the relationship between trade openness, real income per capita, and CO_2 emissions and validates the existence of the environmental Kuznets curve for Nigeria. To closely adhere to the Environmental Kuznets curve narratives, CO_2 emissions are considered as a proxy of environmental pressure for Nigeria for which hitherto has not been optimally explored in the EKC debate.

The study is organized into six sections with this section containing the introduction. Review of related literature and theoretical framework and model specification are contained in sections two and three respectively. The fourth section contains the estimation framework while the interpretation of results and discussion is contained in section five. The last section presents the conclusion and policy recommendations.

2. Review of Related Literature

From a global perspective, the earliest focus on the issues of environmental pollution can be traced back to the late 1960s (Zeng *et al*., 2019). Amongst a wealth of economic theories, three of them stand out and are preferred by researchers in the analysis of trade openness and environmental pollution. These theories include pollution haven hypothesis, Heckscher-Ohlin impact (scale, composition and technique) hypothesis and Environmental Kuznets Curve. Whilst some studies including Michael and Manish (2008), Sebri and Ben-Salha (2014), Solarin and Shahbaz (2014), Nasreen and Anwar (2014), Sohag *et al*., (2015), Liddle (2017), Matheus (2018), Topcua and Payne (2018), Akadiria A. *et al*., (2019) and Amri (2019) are not specific regarding the theoretical framework employed, several others including Kasman and Duman (2015), Halicioglu and Ketenci (2016), Le *et al*., (2016), Bhattacharya *et al*., (2017), Mutascu (2018), Chen *et al*., (2018), Haug and Ucal (2019), and Zeng *et al*., (2019) explicitly presented a theoretical analysis of the relationship between environmental pollution/degradation, trade openness, and economic growth.

Kurniawan and Managi (2018), Ertugrula *et al*., (2016), and Huang and Zhao (2018) noted the significance of the Environmental Kuznets Curve and highlighted the possibility of testing the hypothesis in developed and developing countries. Studies considering financial development as an important determinant of environmental performance are rare. For such analysis, we see Shahbaz *et al*., (2013), Omri *et al*., (2015), Kumar *et al*., (2015), Khan *et al*., (2017), Shahzada *et al*., (2017), Huang and Zhao (2018), Matheus (2018), Haug and Ucal (2019).

Boutabba (2014), Sohag *et al*., (2015), Chen *et al*., (2018), and Kurniawan and Managi (2018) employed Autoregressive Distributed Lag (ARDL) in analyzing the linkage between trade openness, economic growth, CO_2 emissions, and other control variables. The environmental Kuznets curve stood as a basis to examine the relationships among the variables in the studies.

Khan, Yaseen and Ali (2017), Ma *et al*., (2019) and Amri (2019) employed the Generalized Method of Moments (GMM) in examining the influence of CO_2 emission (or environmental quality) and/or trade openness on selected variables, while Matheus (2018) employed the Arellano-Bond Dynamic Generalized Method of Moments (GMM) Model on the panel data examining the impact of trade openness on the consumption of energy in Andean community countries.

Interestingly, Mutascu (2018) examined a time-frequency analysis of trade openness and CO_2 emission in France using the wavelet tool. The analysis offers detailed interaction between Trade openness and CO_2 emissions for different sub-periods of time and frequencies. Sohag *et al*., (2015) found that trade openness and economic growth are significant factors in determining energy use in Malaysia, and Sannassee and Boopen (2016) found that a positive relationship exists between trade openness and CO_2 emissions in Mauritius. Managi *et al*., (2009) opined that the relationship between trade openness and environmental quality depends largely on individual countries. The study took samples from OECD and non-OECD countries and showed that while trade is beneficial to the environment in OECD countries, it is detrimental to non-OECD countries.

Major studies have examined the impact of environmental degradation on economic growth, or the relationship between energy consumption and trade. Studies, including Adewuyi and Adeniyi (2015), assessed the inter-relationship between trade (import and export, distinctly) and consumption of energy varieties (particularly electrical and road transport energy) in Nigeria [1]; however, did not examine the impact of trade and energy consumption on environmental degradation. This study hopes to test the validity of the environmental Kuznets curve in the Nigerian case (hence considering CO_2 emissions to closely adhere to the EKC narratives), however, the major objective remains to ascertain the relationship between trade openness and

[1] And five (5) other West African countries.

CO_2 emissions in Nigeria employing control variables including real per capita gross domestic product, financial development (proxied by domestic credit to the private sector (% of GDP)) and population, between 1960 and 2017.

3. Theoretical Framework and Model Specification

The Pollution Haven Hypothesis posits that, at free trade, Transnational and/or Multinational corporations move the manufacturing of pollution-intensive commodities to developing countries, ceasing the benefits of the less stringent environmental regulations in those countries. This results in a case where developing nations grow a comparative advantage in pollution-intensive goods and industries then turn out to be "havens" for the most polluting firms and industries in the world (Mutascua, 2018). Hence, advanced countries are anticipated to gain as regards environmental conditions (and quality) from trade, while less advanced nations deteriorate (Shahzada *et al*., 2017). Millimet (2013) revealed that a strong negative relationship exists between environmental policies and foreign direct investment, especially in industries that are tagged 'pollution-intensive' [2]. The study also reveals that regulations on environmental use in a neighboring country have no significant effect on a country's trade flows.

Before the EKC, it was believed that rich or developed economies degraded the environment at a pace faster than that of poorer or developing economies (Ertugrula *et al*., 2016). The EKC hypothesis posits that as a country passes through the phase of mechanizing its agriculture (industrialization), rural populations will fall as migration to urban centers increases, hence a fall in inequality.

[2] When measured by employment.

The concept is, therefore, that as economic growth occurs, the environment will initially worsen until a point where the economy reaches a particular average income. At this point, it is believed that the country now possesses enough resources and can invest back into the environment; thereby restoring the environment. Some analysts, on a critiquing note, have argued that economic growth does not always result in improved environmental quality, that in fact, the opposite might be the case (Huang and Zhao, 2018). Though limitations to this hypothesis abound, several studies including Omri *et al*., (2015), Kumar R. *et al*., (2015), Khan *et al*., (2017), Shahzada *et al*., (2017), Huang and Zhao (2018), Koengkan (2018), Haug and Ucal (2019) have shown that certain environmental issues including the likes of carbon dioxide, sulfur dioxide, fecal coliform and suspended particulate matter follow the Environmental Kuznets Curve hypothesis. Therefore, agreeing with Faqin (2017), Ertugrula *et al*., (2016), Kim *et al*., (2018), and Mutascua (2018) the theory can be ratified as being appropriate for this study.

Model Specification and Data

Following the work of Shahbaz *et al*., (2014), Solarin and Shahbaz (2015), Le *et al*., (2016) and Kurniawan and Managi (2018), the basic EKC regression model is adopted as follows

$$E = f(X, Y, Y^2) \quad (1)$$

The dependent and independent variables are shown explicitly and is stated as follows

$$E_{it} = \alpha_i + f\,(Y_{it}) + f\,(X_{it}) + \mu_{it} \quad (2)$$

E_{it} represents environmental quality or pressure, α_i represents the intercept parameters, Y_{it} represents per capita income, X_{it} captures all explanatory variables, μ_{it}, the error term, and f represents the function of per capita income and all explanatory variables respectively.

Equation 1 and 2 is rewritten in equation 3 below

$$CO_2 = f(TO, RY, RY^2) \quad (3)$$

$$CO_{2t} = \alpha + \beta_1 RY_t + \beta_2 RY_t^2 + \beta_3 TO_t + \mu \quad (4)$$

Where α and μ are as defined, RY is Real Per Capita GDP, RY^2 is Squared Term of Real Per Capita GDP, TO is Trade Openness (Trade % of GDP), β_t is the coefficient to be estimated.

It is worthy of note, as stated by Shahbaz *et al*., (2013), that the squared term of Real Per Capita GDP is included in our model to test the existence of the Environmental Kuznets Curve for Nigeria. The validation of the EKC verifies whether the Nigerian economy is attaining growth at the cost of the environment or not, which is the third objective of this study.

Existing literature on the EKC employs trade openness and energy consumption [3] to omit any specification bias. However, studies that employed financial development as a significant determinant of environmental performance are very rare (Shahbaz *et al*., 2013). The financial sector entices foreign investors, which resultantly boost economic growth, thereby improving environmental quality (Shahzada *et al*., 2017). Also, Claessens and Feijen (2007) considered that a developed financial sector is important in trading in carbons as environmental regulators may enact programs that are linked with the financial market and constantly provide information on the environmental performance of firms.

Equation 4 can, therefore, be restated to include a proxy for financial development as follows

[3] Energy consumption is excluded from this study because according to Haug and Ucal (2019), energy consumption is one of the viable determinants of CO_2 emissions, thus, can lead to a bias regression result.

$$CO_{2t} = \alpha + \beta_1 RY_t + \beta_2 RY_t^2 + \beta_3 TO_t + \beta_4 FD_t + \mu \quad (5)$$

FD is Domestic credit to the private sector (% of GDP), a proxy for financial development.

According to Bhattacharya *et al*., (2015) the EKC indicates that in the beginning stages of development, the economy grows in a broad manner owing to population growth. Also, environmental pollution increases persistently to the point of exceeding the carrying capacity of the environment, thus, it would be significant to include total population in the model (Sannassee and Boopen, 2016).

Equation 5 can therefore be rewritten as

$$CO_{2t} = \alpha + \beta_1 RY_t + \beta_2 RY_t^2 + \beta_3 TO_t + \beta_4 FD_t + \beta_5 P_t + \mu \quad (6)$$

P is Total population

The equation above is given as a multiple linear regression [4] and is non-linear.

The EKC hypothesis suggests that $\beta_1 > 0$ and $\beta_2 < 0$. Positive β_1 shows a phenomenon such that as income rises, CO_2 emissions increases and a negative β_2 shows that as income passes through the threshold, CO_2 emissions fall, reflecting an inverted U-shaped pattern (Shahbaz *et al*., 2014; Topcua and Payne, 2018; Chen *et al*., 2018).

$\beta_5 > 0$ implies that changes in population are expected to affect CO_2 emissions positively. This means that as population increase, CO_2 emissions are expected to rise (Shahbaz *et al*., 2015; Tiba and Frikha, 2018). $\beta_3, \beta_4 > 0$ or < 0. This implies that for financial development and trade openness, the expectation is either a positive or negative estimated parameter. This is because while financial development can be detrimental to environmental quality, it can also be

[4] In Linear-Linear form

advantageous. A scenario is when the financial sector improves environmental quality by enabling firms to adopt cleaner and environmentally friendly techniques, and vice versa (Boutabba, 2014; Shahzada *et al*., 2017). Trade openness expected sign is dependent on the development stage of the country (Shahbaz *et al*., 2013).

The scope of this study is restricted to Nigeria for which annual data on variables employed are collected for 1960-2017. CO_2 emissions account for the largest share in greenhouse gas emissions and are often used to proxy environmental degradation. The variables used in this study thus include CO_2 emissions (Kt) denoted by CO2, Real per capita Gross Domestic Product denoted by RY, the squared term of Real per capita Gross Domestic Product denoted by RY_SQ, Trade 'as a percentage of Gross Domestic Product' (a proxy for trade openness) denoted by TO, Domestic credits to private sector 'as a percentage of Gross Domestic Product' (a proxy for financial development) denoted by FD, and Total population denoted by P. All variables employed were sourced and compiled from the World Development Indicator [5] (WDI, 2019) of the World Bank.

4. Estimation Framework

The Autoregressive Distributed Lag (ARDL), the framework employed, is a least squares regression consisting of the lags of the dependent variables 'the *autoregressive terms*' and the lags of the explanatory variables the '*distributed lag terms*'.

Employing a working sample of ARDL (p, $q_1 .... q_K$), the model is stated algebraically as

$$Y_t = \alpha + \sum_{i=1}^{p} \gamma_i Y_{t-i} + \sum_{j=1}^{k} \sum_{i=0}^{qj} X_{j,t-i}{}' \beta_{j,i} + \epsilon_t \quad (7)$$

Considering ARDL (1, 1), where p = 1, K = 1 and qj = 0, 1, it is represented as

[5] World Development Indicators, 2019 can be accessed at https://databank.worldbank.org/home.aspx

$$Y_t = \alpha + \gamma Y_{t-1} + \beta_0 X_t + \beta_1 X_{t-1} + \epsilon_t \qquad (8)$$

Consequently, the ARDL model specification of equation 8 is given in equation 9 below

$$\Delta CO2_t = \gamma_0 + \gamma_1 RY_{t-1} + \gamma_2 RY^2_{t-1} + \gamma_3 TO_{t-1} + \gamma_4 FD_{t-1} + \gamma_5 P_{t-1} + \sum_{g=0}^{u} \beta_g \Delta RY_{t-g} + \sum_{h=0}^{p} \beta_h \Delta RY^2_{t-h} + \sum_{v=0}^{l} \beta_v \Delta TO_{t-v} + \sum_{w=0}^{r} \beta_w \Delta FD_{t-w} + \sum_{k=0}^{s} \beta_k \Delta P_{t-k} + \mu_t \qquad (9)$$

Accordingly, the unrestricted error correction model (ECM) which follows the order of ARDL specification in the above equation is presented in equation 10 below

$$\Delta CO2_t = \delta_1 + \sum_{g=0}^{u} \delta_2 \Delta RY_{t-g} + \sum_{g=0}^{u} \delta_3 \Delta RY^2_{t-h} + \sum_{v=0}^{l} \beta_4 \Delta TO_{t-v} + \sum_{g=0}^{u} \delta_5 \Delta FD_{t-w} + \sum_{g=0}^{u} \delta_6 \Delta P_{t-k} + \eta ECM_{t-1} + \varepsilon_t \qquad (10)$$

5. Discussion of Results

The ADF unit root tests results at constants show that CO_2 emissions, real per capita GDP, the square term of real per capita GDP, trade openness, financial development, and population are stationary at the first difference, in other words, integrated of order one, I(1). Since the result of the conventional unit root tests showed that the series are integrated of order one, I(1), the consideration of ARDL Bounds test for cointegration is plausible. The unit root test results are shown in the table below.

Table 1. Summary of the Augmented Dickey-Fuller Test for Unit Root

Variables	ADF Test Statistics	**Mackinnon critical values for the rejection of the hypothesis of a unit root**			P-value	Remark
		1%	**5%**	**10%**		
CO2	-7.798758	-3.552666	-2.914517	-2.595033	0.0000*	**I(1)**
RY	-4.906693	-3.552666	-2.914517	-2.595033	0.0002*	**I(1)**
RY_SQ	-2.739861	-3.557472	-2.916566	-2.596116	0.0740**	**I(1)**

TO	-8.685273	-3.552666	-2.914517	-2.595033	0.0000*	**I(1)**
FD	-6.456031	-3.557472	-2.916566	-2.596116	0.0000*	**I(1)**
P	-9.235224	-3.581152	-2.926622	-2.601424	0.0000*	**I(1)**

SOURCE: Authors Computation *(*)-1% level of significance (**)-10% level of significance*

There are various criteria required for choosing the optimal number of lags. Table 2 below reports the optimal lag length as recommended by the Sequential Modified Likelihood Ratio test statistic (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SC) and Hannan-Quinn Information Criterion (HQ) at 5% level of significance. The study, therefore, adopts four lags, as selected by all the criteria.

Table 2. Lag Length Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-3859.417	NA	6.03e+54	143.1636	143.3846	143.2488
1	-3356.933	874.6949	1.91e+47	125.8864	127.4334	126.4830
2	-3264.920	139.7241	2.52e+46	123.8118	126.6848	124.9198
3	-3178.012	112.6583	4.35e+45	121.9264	126.1253	123.5457
4	-3074.711	110.9525*	4.71e+44*	119.4337*	124.9587*	121.5645*

SOURCE: Authors Computation

The series in the model are cointegrated thus have a long-run relationship. This is because the associated F-statistic falls above the I(1) critical value bounds at a 10% level of significance. Having found a long-run relationship among the variables, we proceed by estimating the ARDL estimate of the long-run and short-run parameters.

Table 3. Summary of ARDL Bounds Test for Cointegration

	Computed Wald (F-statistic): 3.200174					
	0.10		0.05		0.01	
K = 5	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
F* =	2.08	3	2.39	3.38	3.06	4.15

k represents the number of regressors in the ARDL model, while F-statistic with unrestricted intercept with no trend.
SOURCE: Authors Computation

Estimated Long-Run and Short-Run Relationship

Table 4. Long-Run and Short-Run Estimates

PANEL A: LONG-RUN ESTIMATES			
DEPENDENT VARIABLE: CO2			
Regressor	**Coefficient**	**Standard Error**	**T-Statistic (Probability)**
Constant	**-60338.29**	40282.19	-1.497890 (0.1429)
RY_t	**0.556931**	0.321779	1.730786 (0.0921) ***
RY_SQ_t	**-1.102380**	6.036979	-1.826045 (0.0761) ***
TO_t	**-7.066964**	226.5322	-0.031196 (0.9753)
FD_t	**-5.777292**	545.0801	-0.010599 (0.9916)
P_t	**-0.001813**	0.000725	-2.502175 (0.0170) **
PANEL B: SHORT-RUN ESTIMATES			
DEPENDENT VARIABLE: CO2			
Regressor	**Coefficient**	**Standard Error**	**T-Statistic (Probability)**
D(RY)	**0.534568**	0.285673	1.084172 (0.0529) ***
D(RY_SQ)	**-6.424698**	2.444804	-2.627898 (0.0125) **
D(TO)	**159.8540**	157.5191	1.014823 (0.3170)
D(TO(-1))	**-94.79625**	167.6797	-0.565341 (0.5753)
D(TO(-2))	**-425.5304**	152.2650	-2.794669 (0.0083) *
D(FD)	**-4.427834**	238.6493	-0.000532 (0.6529)
D(P)	**0.182964**	0.076128	2.403376 (0.0215) **
D(P(-1))	**-0.273168**	0.137072	-1.992880 (0.0539) ***
D(P(-2))	**0.173041**	0.074023	2.337655 (0.0251) **
ECT (-1)	**-0.624734**	0.122204	-5.112216 (0.0000) *
DIAGNOSTICS (POST ESTIMATION TESTS) *Adj R^2 = 0.40, RESET = 1.90 (0.1763), JB [X^2 (2)] = 2.39 (0.302135), BG X^2 = 0.59 (0.5604), BPG = 1.44 (0.1756), CUSUM = Stable, CUSUMSQ = Stable.*			

Probability values are in Brackets ( ) *- *,**,*** 1%,5%,10% Level of Significance*
R2: Goodness of fit for the model
RESET: Ramseys regression equation specification error test.
JB: Jaque Bera test for normality of residuals
BG: Breusch Godfrey Lm test for Serial Correlation
BPG: Breusch-Pagan-Godfrey test for heteroscedasticity
CUSUM: Cumulative Sum of Recursive Residuals
CUSUMSQ: Cumulative Sum of Squares of Recursive Residuals
Source: Author's computation

Long-Run Estimates

A positive and statistically significant relationship is found between real income per capita and CO_2 emissions while a negative and statistically significant relationship exists between the squared term of real income per capita and CO_2 emissions. The coefficients show that an increase in real income per capita by one (1) unit[6] leads to a 0.56 unit rise in CO_2 emissions; likewise, CO_2 emissions fall by 1.1 units as the squared term of real income per capita increases by 1 unit. This follows a priori being found to be consistent with the Environmental Kuznets Curve narrative.

Intuitively, the result suggests that as real income per capita increases, CO_2 emissions also increase but not as much as the increase in real income per capita. In other words, over the years, more than half of the increase in real income per capita has been expended on CO_2 emissions prone activities. This suggests the importance of the role of real income per capita on environmental quality in Nigeria.

The estimates show that TO_t has a negative relationship with CO_2 emissions consistent with the a priori expectation of either a negative or positive coefficient (Boutabba, 2014). The coefficient shows that CO_2 emissions decrease by 7.1 unit as trade openness increase by 1 unit inferring that trade openness is beneficial to the Nigerian climate in the long-run. While the

[6] Recall linear-linear model specification.

coefficient shows that CO_2 emissions were on the increase, the analysis does not show whether the increase is caused by import and/or export activities.

The results show a negative relationship between FD_t and CO_2 emissions. The coefficient implies that for every 1-unit increase in financial development in Nigeria, there will be a 5.8 unit fall in CO_2 emissions. This result implies that over the years, financial development has been beneficial to the environment through environmentally friendly practices. The sign satisfies the a priori expectation of a positive or negative relationship (Boutabba, 2014).

A negative and statistically significant relationship exists between P_t and CO_2 emissions. This indicates that in the long-run, a rise in population by 1 unit leads to a fall in CO_2 emissions by 0.002 units. The result suggests that an increase in population aids environmental quality. The a priori expectation is negated and a likely reason might be the subsistence livelihood of a good number of the Nigerian population.

The constant term C shows the collaborative effect of the independent variables on CO_2 emissions in Nigeria. The results suggest that equating all independent variables to zero, CO_2 - emissions will fall, thereby attesting to the role of the independent variables on CO_2 emissions in Nigeria.

Short-Run Estimates

Similarly, the results of the estimated short-run parameters are presented in table 4. For the error correction specification, the co-efficient of RY_f and RY_SQ_f maintain a positive and negative relationship respectively, and are statistically significant. The positive co-efficient of RY_f suggests that as real income per capita increases, CO_2 emissions also increase, and the negative co-efficient of RY_SQ_f shows that an inverse relationship exists between the square term of RY and CO_2 emissions depicting an inverted U-shaped curve, hence validating the EKC.

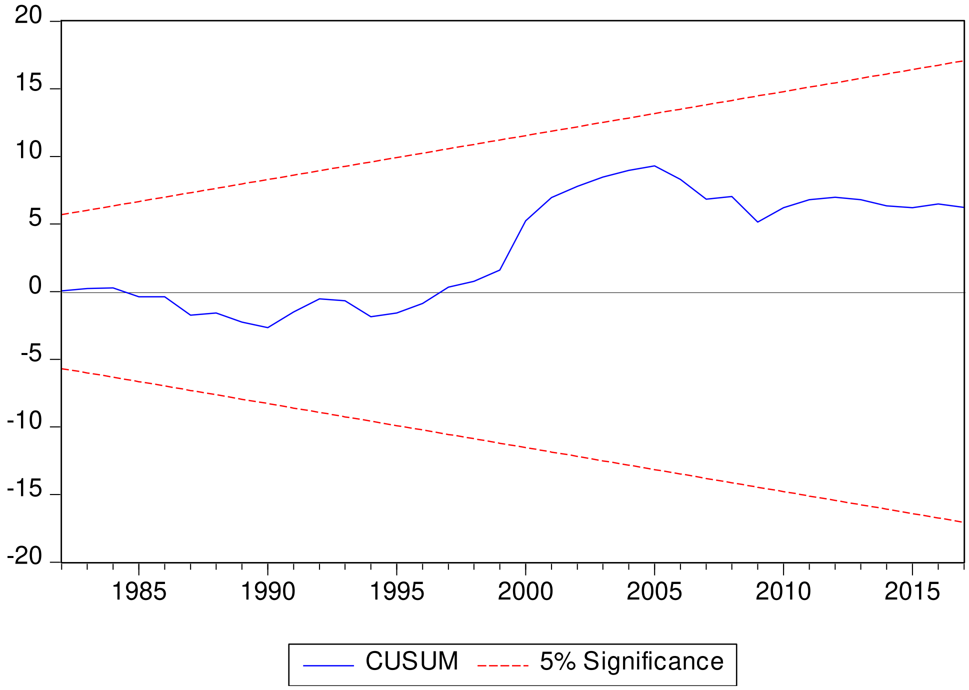
Conversely, there is a positive and significant relationship between TO_f (at lag 2) and CO_2 emissions in the short-run. In other words, an increase in trade openness increases CO_2 emissions by a significant amount and is consistent with the a priori expectation. FD_f has a negative relationship with CO_2 emissions being consistent with the apriori expectation. A similar result obtains in the long-run.

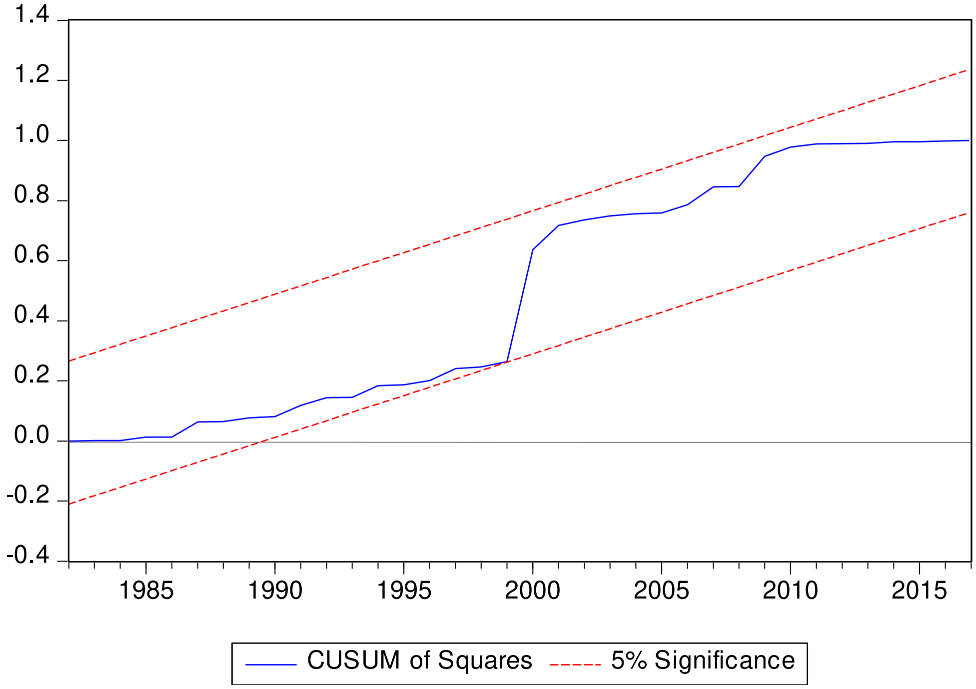
P_f is found to be consistent with the a priori expectation and statistically significant at 5% level. The result suggests that an increase in population, in the short-run, has a direct or positive relationship with CO_2 emissions. This implies that an increase in population leads to an increase in CO_2 emissions.

A negative (-0.62) and statistically significant (0.00 P-value) ECT further lends credence to the cointegration among variables under investigation. The coefficient of the error correction term suggests that in the absence of variation in the specified macroeconomic variables in the short run, 62.4 percent of the divergence between actual and equilibrium CO_2 emissions is corrected annually in the economy. Overall, the results indicate that in the short run, changes in real income per capita, trade openness, and population have a significant impact on environmental quality in Nigeria.

Post-Estimation Tests

Reported in the last column in table four are results of the post estimation tests. The null hypotheses for tests employed, such as, serial correlation test, heteroskedasticity test, and Ramsey reset test are that there is no serial correlation, homoscedastic relationship, and correct functional form representation respectively. Since the probability values are all greater than 0.05, that is a 5% significance level, we accept the null hypothesis and conclude that the model for this study does not suffer from serial correlation, linearity, and heteroskedasticity. The Jarque-Bera test confirms that the error term is normally distributed, and the Cumulative Sum of Recursive Residuals (CUSUM) and Cumulative Sum of Squares of Recursive Residuals (CUSUMSQ) tests showed that the long-run and short-run parameters are stable. The graphs for both tests are presented below. The blue lines in the graph represent significance at 5% levels indicating the stability of parameters.





6. Conclusion and Policy Recommendations

The findings reflect that trade openness and population aid environmental degradation in the short-run with a rather quickly-cushioned effect. Financial development, on the other hand, is important to boost environmental quality; thus, underlying the pertinence to channel resources towards environmentally friendly practices across the board. The result confirms that environmental quality fosters sustainable development. Therefore, the Nigerian government should adopt policies that promote responsible production patterns and boost public-private partnerships that encourage the development and utilization of renewable energy thereby fostering clean and sustainable communities.

Also, global climate change has been on the rise; perhaps, a major topic of discourse for a while. Hence, a major defense remains an increase in national income. Policies therefore should be directed at boosting economic growth, and improving the lives and welfare of citizens.

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Appendices

Appendix 1

Correlation Matrix

	RY	RY_SQ	TO	FD	P
RY	1.000000	0.995808	0.296684	0.675555	0.585563
RY_SQ	0.995808	1.000000	0.272991	0.688162	0.611200
TO	0.296684	0.272991	1.000000	0.309460	0.304840
FD	0.675555	0.688162	0.309460	1.000000	0.720879
P	0.585563	0.611200	0.304840	0.720879	1.000000

Lag Length Criteria

VAR Lag Order Selection Criteria
Endogenous variables: CO2 RY RY_SQ TO FD P
Exogenous variables: C
Date: 08/06/19 Time: 13:45
Sample: 1960 2017
Included observations: 54

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-3859.417	NA	6.03e+54	143.1636	143.3846	143.2488
1	-3356.933	874.6949	1.91e+47	125.8864	127.4334	126.4830
2	-3264.920	139.7241	2.52e+46	123.8118	126.6848	124.9198
3	-3178.012	112.6583	4.35e+45	121.9264	126.1253	123.5457
4	-3074.711	110.9525*	4.71e+44*	119.4337*	124.9587*	121.5645*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Unit Root Tests

Null Hypothesis: D(CO2) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.798758	0.0000
Test critical values:	1% level	-3.552666	
	5% level	-2.914517	
	10% level	-2.595033	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(RY) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.906693	0.0002
Test critical values:	1% level	-3.552666	
	5% level	-2.914517	
	10% level	-2.595033	

Null Hypothesis: D(RY_SQ) has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.739861	0.0740
Test critical values:	1% level	-3.557472	
	5% level	-2.916566	
	10% level	-2.596116	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(TO) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-8.685273	0.0000
Test critical values:	1% level	-3.552666	
	5% level	-2.914517	
	10% level	-2.595033	

Null Hypothesis: D(FD) has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.456031	0.0000
Test critical values:	1% level	-3.557472	
	5% level	-2.916566	
	10% level	-2.596116	

Null Hypothesis: D(P) has a unit root
Exogenous: Constant
Lag Length: 10 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*

Augmented Dickey-Fuller test statistic		-9.235224	0.0000
Test critical values:	1% level	-3.581152	
	5% level	-2.926622	
	10% level	-2.601424	

Appendix 2

Long Run Estimates and Bounds Test

ARDL Long Run Form and Bounds Test
Dependent Variable: D(CO2)
Selected Model: ARDL(4, 1, 3, 1, 1, 4)
Case 2: Restricted Constant and No Trend
Date: 08/06/19 Time: 15:05
Sample: 1960 2017
Included observations: 54

Conditional Error Correction Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-60338.29	40282.19	-1.497890	0.1429
CO2(-1)*	-0.624734	0.185925	-3.360141	0.0019
FD**	-5.777292	545.0801	-0.010599	0.9916
P(-1)	-0.001813	0.000725	-2.502175	0.0170
RY**	0.556931	0.321779	1.730786	0.0921
RY_SQ(-1)	-1.10E-06	6.04E-07	-1.826045	0.0761
TO(-1)	-7.066964	226.5322	-0.031196	0.9753
D(CO2(-1))	0.262910	0.193331	1.359897	0.1823
D(CO2(-2))	0.532135	0.193011	2.757019	0.0091
D(CO2(-3))	0.326933	0.188460	1.734762	0.0913
D(FD)	-4.427834	321.2861	-0.000653	0.7863
D(P)	0.182964	0.104902	1.744140	0.0897
D(P(-1))	-0.273168	0.186421	-1.465329	0.1515
D(P(-2))	0.173041	0.106840	1.619634	0.1140
D(RY)	0.534568	0.303529	1.356241	0.0836
D(RY_SQ)	-6.42E-07	6.41E-07	-1.002979	0.3226
D(TO)	159.8540	197.6690	0.808695	0.4240
D(TO(-1))	-94.79625	223.8451	-0.423490	0.6745
D(TO(-2))	-425.5304	177.1377	-2.402257	0.0216
D(TO(-3))	-414.1690	165.7883	-2.498180	0.0172

* p-value incompatible with t-Bounds distribution.
** Variable interpreted as Z = Z(-1) + D(Z).

F-Bounds Test — Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	3.200174	10%	2.08	3
k	5	5%	2.39	3.38
		2.5%	2.7	3.73
		1%	3.06	4.15

			Finite Sample:	
Actual Sample Size	54		n=55	
		10%	2.226	3.241
		5%	2.617	3.743
		1%	3.543	4.839
			Finite Sample:	
			n=50	
		10%	2.259	3.264
		5%	2.67	3.781
		1%	3.593	4.981

Appendix 3

Short Run Estimates

ARDL Error Correction Regression
Dependent Variable: D(CO2)
Selected Model: ARDL(4, 1, 3, 1, 1, 4)
Case 2: Restricted Constant and No Trend
Date: 08/07/19 Time: 17:31
Sample: 1960 2017
Included observations: 54

ECM Regression
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CO2(-1))	0.262910	0.131272	2.002790	0.0528
D(CO2(-2))	0.532135	0.141538	3.759665	0.0006
D(CO2(-3))	0.326933	0.145634	2.244900	0.0310
D(FD)	-4.427834	238.6493	-0.000532	0.6529
D(P)	0.182964	0.076128	2.403376	0.0215
D(P(-1))	-0.273168	0.137072	-1.992880	0.0539
D(P(-2))	0.173041	0.074023	2.337655	0.0251
D(RY)	0.534568	0.285673	1.084172	0.0529
D(RY_SQ)	-6.42E-07	2.44E-07	-2.627898	0.0125
D(TO)	159.8540	157.5191	1.014823	0.3170
D(TO(-1))	-94.79625	167.6797	-0.565341	0.5753
D(TO(-2))	-425.5304	152.2650	-2.794669	0.0083
D(TO(-3))	-414.1690	146.1862	-2.833160	0.0075
CointEq(-1)*	-0.624734	0.122204	-5.112216	0.0000

R-squared	0.486000	Mean dependent var	1702.260
Adjusted R-squared	0.351380	S.D. dependent var	9633.010
S.E. of regression	7758.130	Akaike info criterion	20.94400
Sum squared resid	2.53E+09	Schwarz criterion	21.38600
Log likelihood	-553.4880	Hannan-Quinn criter.	21.11446
Durbin-Watson stat	2.109866		

* p-value incompatible with t-Bounds distribution.

Appendix 4

Post-Estimation Tests

Ramsey RESET Test
Equation: EQ01
Specification: CO2 CO2(-1) CO2(-2) CO2(-3) CO2(-4) FD P P(-1) P(-2) P(-3) RY RY_SQ RY_SQ(-1) TO TO(-1) TO(-2) TO(-3) TO(-4) C
Omitted Variables: Squares of fitted values

	Value	df	Probability
t-statistic	1.380035	35	0.1763
F-statistic	1.904496	(1, 35)	0.1763

F-test summary:

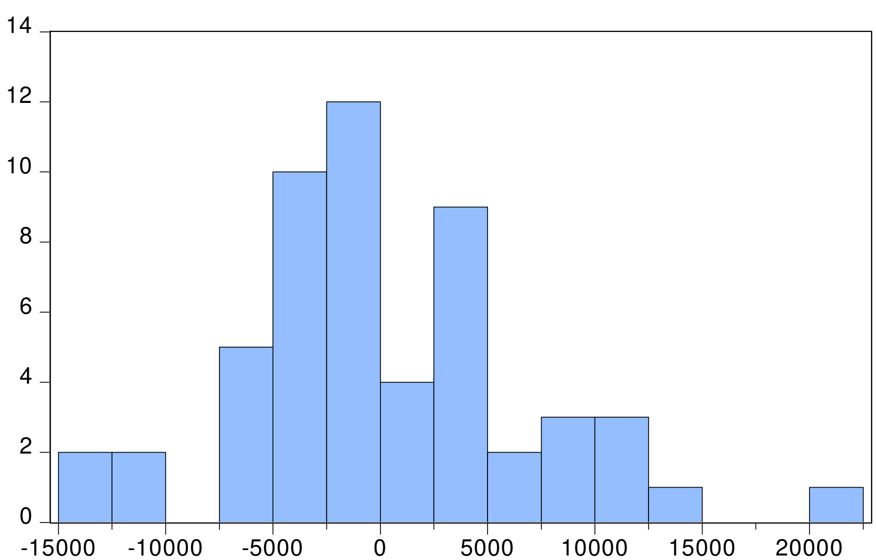
	Sum of Sq.	df	Mean Squares
Test SSR	1.30E+08	1	1.30E+08
Restricted SSR	2.53E+09	36	70220011
Unrestricted SSR	2.40E+09	35	68498982

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.589076	Prob. F(2,34)	0.5604
Obs*R-squared	1.808514	Prob. Chi-Square(2)	0.4048

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.438772	Prob. F(17,36)	0.1756
Obs*R-squared	21.84604	Prob. Chi-Square(17)	0.1907
Scaled explained SS	12.97043	Prob. Chi-Square(17)	0.7382



Series: Residuals
Sample 1964 2017
Observations 54

Mean	1.66e-09
Median	-1221.065
Maximum	20992.25
Minimum	-14828.85
Std. Dev.	6906.273
Skewness	0.391363
Kurtosis	3.671740
Jarque-Bera	2.393762
Probability	0.302135