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RENEWABLE ENERGY AND THE STATE OF ENVIRONMENTAL QUALITY IN NIGERIA

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Abstract
The study aimed at examining the effect of renewable energy on quality of the environment in Nigeria from 1980 to 2019. The ARDL bound test of cointegration shows the presence of a cointegration relationship among the analyzed variables. In the long run renewable energy is related negatively with to CO2 emissions, meaning that an increase in renewable energy enhances the quality of the environment by reducing the number of CO2 emissions in the long run while in the short-run renewable energy is positively related to carbon emissions, meaning that increases in the number of renewable energy deteriorate the quality of environment in the short run. The Granger causality test proposed by Toda and Yamamota (1995) reveals that a bidirectional causal relationship exists between renewable energy and the number of CO2 emissions, meaning that changes in renewable energy affect the quality of environment and at the same time changes in the quality of environment affect the renewable energy in Nigeria. Policymakers should implement a multilateral mechanism to ensure energy efficiency and to promote the use of renewable energy.

Keywords: Renewable Energy, Environmental Quality, Nigeria
JEL Classifications: Q52, Q56, Q58

1. Introduction

Global warming associated with greenhouse gases (GHGs) and energy constraints are two key threats to the global economy. The most significant of the GHGs is CO2 emissions, which account for about 72% of emitted GHGs (Sanglimsuwan, 2011; IPCC, 2007). The Climate Resilience Handbook (2018) reports that 2017 was a record year for natural disasters including hurricanes, wildfires, heat waves, and droughts which led to the loss of 31 billion-dollar globally. The situation is more serious for the Sub-Sahara African (SSA) region because of poverty, low technological know-how and more importantly over half of the population depends on climate-driven businesses such as smallholder farming, peasant mining, agriculture and hawking (Ngwenya et al, 2018; Frimpong et al., 2017; Fawcett et al., 2015). Though sub-Sahara Africa (SSA) pollutes the environment the least, it is the worst affected by climate change (Toulmin, 2009; IPCC, 2007; Conway & Schinner, 2011; Bouimetarhan et al., 2018).

The World Health Organization [WHO], 2014) estimates that about 4.3 million people die every year from indoor air pollution, with the majority of these deaths occurring in less developed countries (LDCs) (Collier, 2008). Also, the Africa Progress Panel (APP) (2015) reports that global warming associated with climate change vulnerability and food insecurity are amplifying the risks of conflict and unrest in many developing countries. In recent times, renewable energy has been argued to be critical in dealing with Africa's energy poverty and climate change problems because renewable energy technologies (RETs) provide attractive environmentally

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sound technology options for electricity (Karekezi, 2003). Fundamentally, renewable energy sources, for example, solar and hydro have low carbon content and are therefore expected to pollute the environment less compared to non-renewable energy sources. Analysts and international agencies are therefore promoting the use of renewable energy as a strategy not only to increase access to electricity but also to reduce environmental degradation because of its lower level of carbon dioxide emissions (Africa Progress Report, 2016; Shahbaz et al., 2017).

Nigeria is one of the highest emitters of greenhouse gases in Africa. The practice of flaring gas by the oil companies operating in Nigeria has been a major means through which greenhouse gases are released into the atmosphere. Carbon dioxide emissions in this area are among the highest in the world. Some 45.8 billion joules of heat are discharged into the atmosphere of the Niger Delta from flaring 1.8 billion ft3 of gas every day. Gas flaring has raised temperatures and rendered large areas uninhabitable. Between 1970 and 1986, a total of about 125.5 million m3 of gas was produced in the Niger Delta region, about 102.3 million m3 (81.7 %) were flared, while only 2.6 million m3 were used as fuel by oil-producing companies and about 14.6 million m3 were sold to other consumers (Africa Progress Report, 2016). The use of renewable energy sources will reduce the over dependence on the burning of fossil. Moreover, instead of flaring gas in Nigeria, the gases can be converted to methanol and used as fuels for both domestic and industrial use. With good energy efficiency practices and products, the burning of fossil fuels for energy will be greatly minimized.

With the impetus for renewables, the big question is how has this impacted on the environment? This is the question the study seeks to answer. It is important to mention that to date; many studies have examined the effect of renewable and nuclear energy on economic growth but not much on how they impact carbon emissions. Thus, the study fills this gap, because the few available literature have yielded mixed results (Apergis et al., 2010; Saidi and Mbarek, 2016). This suggests that country-specific studies could help shed more light on the scope of the study.

To achieve the research objective and provide consistent estimates, the study further considers other variables as control variables to reduce the problem of omitted variable bias, we control for the urbanization process. In achieving the research objective, we contribute to the literature by using the latest and update data while analyzing the effect of renewable energy on carbon emissions. Finally, we employ a more robust technique; the ARDL bounds testing procedure by using critical values and approximate p-values based on response surface regression and the CUSUM test for detecting structural breaks over the period 1980–2019. The rest of the paper is organized as follows: Literature review, Methodology, Results and discussion, and Conclusion.

2. Literature Review

The development of environmental problems resulting from technological progress and human activities has continued to deteriorate biodiversity. However, the utilization of renewable energy has been acknowledged to improve biodiversity and the environment. Studies across various countries and regions have supported this claim. One of such studies is that of López-Menéndez et al. (2014) on a panel data of 27 European Union countries running from 1996 to 2010, with empirical results revealing that renewable energy reduces the volume of CO2

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emissions. Bölük and Mert (2014) also observed using a panel fixed effects model that renewable energy contributes about 0.5 less per unit of GHG emissions in European Union countries as compared with non-renewable energy. The result of their study suggests that a change in energy consumption in combination with renewable energy technologies reduces GHG emissions.

Apergis and Payne (2015) examined the correlation among renewable energy, output, CO2 emissions, and oil prices using a panel of 11 South American countries from 1980 to 2010. The result from the panel error correction model indicates a feedback relationship among the variables employed in the study. Further results show that renewable energy is significant for both the growth of output and the control of CO2 emissions in the countries, thereby improving environmental quality. Sulaiman et al. (2013) in their study also show that renewable energy can guarantee sustainability of electricity supply and likewise reduce CO2 emissions in Malaysia. Shafiei and Salim (2014) surveyed the link between non-renewable and renewable energy and CO2 emissions for the Organisation of Economic Co-operation and Development (OECD) countries employing the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model on data from 1980 to 2011. The outcome from the empirical analysis shows that renewable energy decreases CO2 emissions. Bilgili et al. (2016) assessed 17 OECD countries from 1977 to 2010 employing the panel fully modified ordinary least squares and showed that renewable energy reduces CO2 emissions.

Karasoy and Akçay (2019) examined the impacts of renewable energy and trade on environmental pollution in Turkey from 1965 to 2016 using ARDL and VECM techniques for estimation. The aftermath of the empirical study showed that an increase in the consumption of renewable energy reduces environmental pollution from CO2 emissions. Employing a panel error correction model on a group of nineteen developed and developing countries, Apergis et al. (2010) examined the underlying changes between emissions, nuclear energy, renewable energy, and economic growth during the period 1984–2007. The finding from the long-run assessments displays a significant positive relationship between emissions and renewable energy. However, the panel Granger causality test outcome suggests that in the short run renewable energy does not contribute to emission reduction which could be linked to adequate storage technology.

Farhani and Shahbaz (2014) examined the underlying link between conventional and non-conventional energy, output, and CO2 emissions for 10 MENA countries between 1980 and 2009. Employing the Pedroni cointegration test as well as the FMOLS and DOLS techniques, the findings show that conventional and non-conventional energy enhances CO2 emissions. Also, the long-run Granger causality test appears to have a bidirectional causality between conventional and non-conventional energy and CO2 emissions. Bölük and Mert (2014) studied the connection between renewable energy, growth, and environmental Kuznets curve in Turkey from 1961 to 2010 employing ARDL techniques. Results revealed that renewable energies (hydropower sources excluded) have a negative and substantial long-run influence on CO2 emission. However, the reverse exists in the short run.

This study avails the extant literature with a novelty. Empirical investigations on the

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mitigating and enhancing factors of CO2 emissions are at the premature stage for Nigeria. This implies little is on records regarding the factors influencing variations in the country's carbon emissions. More empirical-based studies are inevitable to enhance an all-inclusive understanding, of which the present study constitutes a novel scope of research.

3. Methods and Data

The study employs the annual time series data covering the period of 1980 to 2019 for the case of Nigeria. The data for carbon dioxide emissions (CO_2 emissions, in metric tons per capita), renewable energy output (RE, % of total electricity output), price of oil (OP, the West Texas Intermediate (WTI) price of crude oil), economic growth (GDP, GDP in constant 2005 US$), and the foreign direct investment (FDI, the total inflow of FDI percentage of GDP), are sourced from the database of World Development Indicator (WDI) except for crude oil price that was sourced from the OPEC database.

Model Specification

Following the work of Maji et al. (2017), the study adopts the following linear model to empirically investigate the relationship between the oil price and carbon dioxide emissions in Nigeria.

$$CO_{2t} = f(RE_t, Z_t) \text{ ---------- (1)}$$

Where CO_2 is representing the quality of environment variable, RE_t is the renewable energy, Z_t stands in the model as other control variables that comprise OP_t as oil price, FDI_t as foreign direct investment, and GDP_t as economic growth. After the transformation of the variables, then the expanded model that expressed the quality of environment as a function of renewable energy as well as other control variables is specified as follows:

$$\ln CO_{2t} = \alpha_0 + \alpha_1 \ln RE_t + \alpha_2 \ln OP_t + \alpha_3 \ln FDI_t + \alpha_4 \ln GDP_t + \mu_t \text{ ---------- (2)}$$

Where t symbolizes the time, α_0 is the parameter of drift, μ_t is the residual error term, α_1, α_2, α_3 and α_4 represent the elasticities of renewable energy, oil price, foreign direct investment, and economic growth respectively. It is projected that $\alpha_1 < 0$ meaning that RE is expected to be negatively related to carbon emissions, $\alpha_2 < 0$ meaning that oil price is expected to be negatively related to the quality of environment and then $\alpha_3 < 0 < \alpha_3$ meaning that FDI could be expected to either be positively or negatively related with carbon emissions. The coefficient $\alpha_4 > 0$ indicates that an increase in GDP is expected to deteriorate the quality of environment.

Unit Root Tests

The study utilizes the following tests of unit root: the Dickey & Fuller (1981) as well as the Phillips & Perron (1988) approaches. A known feebleness of Augmented Dickey Fuller (ADF) as well as the Phillip Perron (PP) tests of unit roots is the prospective structural breaks confusion in the series as an indication of no stationarity. Meaning that, the hypothesis of unit root failed to be rejected if the series possess a structural break. A series that happened to be I(1), may possibly be stationary I(0) even with the structural breaks but classified erroneously as I(1). To override this, the current study employed a more robust and efficient approach proposed by (Zivot & Andrews, 2002). The Zivot-Andrews (ZA) tests of unit root give room for one structural break. In this type of test, the null hypothesis states that the series possess a unit root along with a structural break as against the alternate

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hypothesis that the series is stationary along with a break.

ARDL Cointegration Analysis

Ever since Pesaran and Shin (1999) as well as Pesaran, Shin, & Smith (2001) developed their works, the approach of ARDL bound test to cointegration become one of the most commonly used methods of analysis. This is because the techniques possess some advantages when compared with other related techniques of cointegration such as Johansen & Juselius (1990), as well as (Engle & Granger, 1987). Under this technique, no need to have many variables that have the same order of integration or to have the variables that possess similar optimal lags in the system, no need to have a sample that is large or nonexistence of endogeneity among the regressors to get an estimator that is efficient and the techniques do not require to have an equation that is multiple because a reduced-form of an equation that is single may give the same findings (Farhani & Ozturk, 2015). Contrarily, the technique is associated with some number of disadvantages that the critical bound delivered by Narayan (2005) and Pesaran et al. (2001) will not come out to be valid when the integration order of the variables is higher than 1 and it is obligatory to compute base on the fact that the order of integration of the variables is either 1 or 0. To fulfill this requirement, the study starts with the test of unit root to certify that the variables of concern meet the essential assumptions of bound test techniques of ARDL cointegration before continuing to the stage of estimation.

Essentially, the ARDL approach of bound test to cointegration requires two estimating steps of long run relationship. The step of the first is mean to explore the presence of long run association between the variables in equation (2). Therefore, the model of ARDL would be given as follows:

$$\begin{aligned}\Delta lnCO_{2t} = {} & \emptyset_0 + \sum_{i=1}^{n-1} \emptyset_{1i}\, \Delta lnCO_{2t-i} \\ & + \sum_{i=1}^{n-1} \emptyset_{2i}\, \Delta lnRE_{t-i} \\ & + \sum_{i=1}^{n-1} \emptyset_{3i}\, \Delta lnOP_{t-i} \\ & + \sum_{i=1}^{n-1} \emptyset_{4i}\, \Delta lnFDI_{t-i} \\ & + \sum_{i=1}^{n-1} \emptyset_{5i}\, \Delta lnGDP_{t-i} \\ & + \beta_1 lnCO_{2t-1} + \beta_2 RE_{t-1} \\ & + \beta_3 lnOP_{t-1} + \beta_4 lnFDI_{t-1} \\ & + \beta_5 lnGDP_{t-1} \\ & + \mu_t \qquad (3)\end{aligned}$$

Where Δ represents the term of the first difference and μ_t is the error term that is presumed to have a zero mean value as well as variance that is constant. To the test of joint significance that takes into account the null hypothesis of the absence of cointegration $H_0: \beta_1 = \beta_2 = \beta_4 = \beta_5 = 0$ contrary to the alternative hypothesis $H_1: \beta_1 \neq \beta_2 \neq \beta_4 \neq \beta_5 \neq 0$, it would be perform for equation (3).

For the F-statistics, Pesaran et al. (2001) offered two sets of critical values: the lower bound corresponds to the case where all variables are I(0) and the upper bound corresponds to the case where all variables are I(1). If the F-statistic resides below the lower limit, no co-integration can occur. If the F-statistic is over the upper limit, then there will be a cointegration. If the F-statistics comes between the upper limits and the lower limits, therefore the test is inconclusive.

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The second of the steps consist of performing the representation of the general error correction of the selected model of ARDL of Eq. (4) below:

$$\Delta lnCO_{2t} = \emptyset_0 + \sum_{i=1}^{n-1} \emptyset_{1i} \Delta lnCO_{2t-i} + \sum_{i=1}^{n-1} \emptyset_{2i} \Delta lnRE_{t-i} + \sum_{i=1}^{n-1} \emptyset_{3i} \Delta lnOP_{t-i} + \sum_{i=1}^{n-1} \emptyset_{4i} \Delta lnFDI_{t-i} + \sum_{i=1}^{n-1} \emptyset_{5i} \Delta lnGDP_{t-i} + \varphi ECT_{t-1} + \mu_t \quad (4)$$

Where φ is the parameter of the error correction and ECT_{t-1} stand as the lagged residuals that are gotten from the long run cointegrating equation estimate that is eq. (2). The lagged residual would separate from eq. (4) at this level and be defined in eq. (5) below:

$$ECT_{t-1} = lnCO_{2t-1} + \hat{\alpha}_4 RE_{t-1} + \hat{\alpha}_1 lnOP_{t-1} + \hat{\alpha}_2 lnFDI_{t-1} + \hat{\alpha}_3 lnGDP_{t-1} \quad (5)$$

Granger Causality Test

Given the conditions associated with performing the standard Granger causality test to decide whether the variables are co-integrated, Toda & Yamamoto (1995) test bypasses the deficiencies connected with specifying the unit root as well as the co-integration relationship status of the variables before estimating the specific model needed for the Granger causality test. The approach of Toda and Yamamoto (TY) fits the VAR model to series levels, thus minimizing the risk connected with the tendency to misidentify the series ' order of integration (Mavrotas & Kelly, 2001). Concerning the TY test, there is no need for the order of integration of variables before the causality analysis can be carried out. In other words, the test of long-run causality naturally increases the correct order of the VAR (optimal lag, k) by the maximum integration order (maximum difference, dmax), assuring the standard asymptotic distribution of test statistics for Granger causality (Wolde-Rufael, 2010). Thus if the series are I (0), I (1), or I (2), the TY procedure can be applied. Zapata & Rambaldi (1997) argued that TY prevents the Granger causality test-related power and size distortions problem. The TY uses a Modified Wald (MWALD) test for the test of causality and thus guarantees that the test statistics have asymptotic chi-square distribution, with k degrees of freedom within the limit when the increased VAR (k+dmax) is estimated at the highest level of integration. The lagged dmax function is omitted when using a MWALD test of long-run causality. Toda and Yamamoto causality analysis can be symbolized as follows due to a bivariate association:

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$$\Delta lnCO_{2t} = \emptyset_0 + \sum_{\substack{i=1 \\ k+dmx}}^{n} \beta_1 \Delta lnCO_{2_{t-i}} + \sum_{\substack{i=k+1 \\ n}} \beta_2 \Delta lnCO_{2_{t-i}} + \sum_{\substack{i=o \\ k+dmx}} \delta_1 \Delta lnRE_{t-i} + \sum_{\substack{i=k+1 \\ n}} \delta_2 \Delta lnRE_{t-i} + \sum_{\substack{i=0 \\ k+dmx}} \gamma_1 \Delta lnOP_{t-i} + \sum_{\substack{i=k+1 \\ n}} \gamma_2 \Delta lnOP_{t-i} + \sum_{\substack{i=0 \\ k+dmx}} \theta_1 \Delta lnFDI_{t-i} + \sum_{\substack{i=k+1 \\ n}} \theta_2 \Delta lnFDI_{t-i} + \sum_{\substack{=o \\ k+dmx}} \vartheta_1 \Delta lnGDP_{t-i} + \sum_{i=k+1} \vartheta_2 \Delta lnGDP_{t-i} + \mu_{1t} \quad (6)$$

$$\Delta lnRE_{t-i} = \emptyset_0 + \sum_{\substack{i=o \\ k+dmx}}^{n} \delta_1 \Delta lnRE_{t-i} + \sum_{i=k+1} \delta_2 \Delta lnRE_{t-i} + \sum_{\substack{=o \\ k+dmx}}^{n} \vartheta_1 \Delta lnGDP_{t-i} + \sum_{i=k+1} \vartheta_2 \Delta lnGDP_{t-i} + \sum_{\substack{i=0 \\ k+dmx}}^{n} \theta_1 \Delta lnFDI_{t-i} + \sum_{\substack{i=k+1 \\ k+dmx}} \theta_2 \Delta lnFDI_{t-i} + \sum_{\substack{i=k+1 \\ k+dmx}} \gamma_1 \Delta lnOP_{t-i} + \sum_{i=k+1} \gamma_2 \Delta lnOP_{t-i} + \sum_{\substack{i=1 \\ k+dmx}}^{n} \beta_1 \Delta lnCO_{2_{t-i}} + \sum_{i=k+1} \beta_2 \Delta lnCO_{2_{t-i}} + \mu_{1t} \quad (7)$$

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$$\Delta lnOP_t = \emptyset_0 + \sum_{i=k+1}^{k+dmx} \gamma_1 \Delta lnOP_{t-i} + \sum_{i=k+1}^{k+dmx} \gamma_2 \Delta lnOP_{t-i} + \sum_{i=1}^{n} \beta_1 \Delta lnCO_{2_{t-i}} + \sum_{i=k+1}^{k+dmx} \beta_2 \Delta lnCO_{2_{t-i}} + \sum_{i=0}^{n} \theta_1 \Delta lnFDI_{t-i} + \sum_{i=k+1}^{k+dmx} \theta_2 \Delta lnFDI_{t-i} + \sum_{=o}^{n} \vartheta_1 \Delta lnGDP_{t-i} + \sum_{i=k+1}^{k+dmx} \vartheta_2 \Delta lnGDP_{t-i} + \sum_{i=o}^{n} \delta_1 \Delta lnRE_{t-i} + \sum_{i=k+1}^{k+dmx} \delta_2 \Delta lnRE_{t-i} + \mu_{1t} \quad (8)$$

$$\Delta lnFDI_t = \emptyset_0 + \sum_{i=0}^{n} \theta_1 \Delta lnFDI_{t-i} + \sum_{i=k+1}^{k+dmx} \theta_2 \Delta lnFDI_{t-i} + \sum_{i=k+1}^{k+dmx} \gamma_1 \Delta lnOP_{t-i} + \sum_{i=k+1}^{k+dmx} \gamma_2 \Delta lnOP_{t-i} + \sum_{i=1}^{n} \beta_1 \Delta lnCO_{2_{t-i}} + \sum_{i=k+1}^{k+dmx} \beta_2 \Delta lnCO_{2_{t-i}} + \sum_{=o}^{n} \vartheta_1 \Delta lnGDP_{t-i} + \sum_{i=k+1}^{k+dmx} \vartheta_2 \Delta lnGDP_{t-i} + \sum_{i=o}^{n} \delta_1 \Delta lnRE_{t-i} + \sum_{i=k+1}^{k+dmx} \delta_2 \Delta lnRE_{t-i} + \mu_{1t} \quad (9)$$

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$$\Delta lnGDP_{t-i} = \emptyset_0 + \sum_{=o}^{n} \vartheta_1 \Delta lnGDP_{t-i} + \sum_{i=k+1}^{k+dmx} \vartheta_2 \Delta lnGDP_{t-i} + \sum_{i=0}^{n} \theta_1 \Delta lnFDI_{t-i} + \sum_{i=k+1}^{k+dmx} \theta_2 \Delta lnFDI_{t-i} + \sum_{i=k+1}^{k+dmx} \gamma_1 \Delta lnOP_{t-i} + \sum_{i=k+1}^{k+dmx} \gamma_2 \Delta lnOP_{t-i} + \sum_{i=1}^{n} \beta_1 \Delta lnCO_{2_{t-i}} + \sum_{i=k+1}^{k+dmx} \beta_2 \Delta lnCO_{2_{t-i}} + \sum_{i=o}^{n} \delta_1 \Delta lnRE_{t-i} + \sum_{i=k+1}^{k+dmx} \delta_2 \Delta lnRE_{t-i} + \mu_{1t} \quad (10)$$

Where the series remain as defined in Eq. (2) and μ_t is an error term that is assumed to have zero mean and constant variance. $\emptyset_0, \beta_1, \beta_2, \gamma_1, \gamma_2, \theta_1, \theta_2, \vartheta_1, \vartheta_2, \delta_1 \; and \delta_2,$ represents the parameters of the model, k denotes the Lag length, dmx stands as the maximum order of integration, $\mu_{1t}\mu_{2t}\mu_{3t}\mu_{4t},, \sim N(0, \; \mu_{1t}\mu_{2t}\mu_{3t}\mu_{4t})$ are the models' residual. The null hypothesis (H_0) of non-Causality among the variables is expressed as:

$H_0: \beta_1 \; and \; \beta_2 \; = \; 0 \forall_i =$ 1,2,3 $k, \gamma_1 \; and \; \gamma_2 \; = \; 0 \forall_i =$ 1,2,3 $k, \theta_1 \; and \; \theta_2 \; = \; 0 \forall_i =$ 1,2,3 $k, \vartheta_1 and \; \vartheta_2 \; = \; 0 \forall_i =$ 1,2,3 $k, \delta_1 and \; \delta_2 \; = \; 0 \forall_i =$ 1,2,3 $k, \sigma_1, and \; \sigma_2 \; = \; 0 \forall_i =$ 1,2,3 k are tested using MWALD (modified Wald) test.

4. Findings and Discussions

In this section, the empirical results of the study are presented and discussed. The study first presents the descriptive statistics of the identified variables in Table 1 below. The results of the probability values and the Jarque-Bera reveal that the variables are distributed normally. The Kurtosis and Skewness in the distribution do not incorporate extreme values. Equally, the correlation matrix results in Table 1 disclose the degree of association among the variables.

Table 1: Descriptive Statistics

	LCO_2	LRE	LFDI	LGDP	LOP
Mean	-0.452047	1.490415	92.05495	12.65941	1.543887
Median	-0.482964	1.534975	92.02341	12.73897	1.481443
Maximum	-0.190103	1.621850	99.46507	14.11097	1.995898
Minimum	-0.671872	1.245298	82.76840	10.70131	1.158061
Std. Dev.	0.145742	0.108632	4.668428	1.057741	0.262399
Skewness	0.240541	-0.962717	-0.106828	-0.215213	0.365731
Kurtosis	1.719220	2.628547	2.080886	1.650916	1.854232

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Jarque-Bera	3.041735	6.248566	1.446933	3.258602	3.002713
Probability	0.218522	0.043968	0.485068	0.196067	0.222828

Correlation Matrix

	LCO_2	LRE	LFDI	LGDP	LOP
LCO_2	1.000000				

LOP	-0.258420	1.000000			
	0.1122	-----			
LFDI	-0.638262	0.551933	1.000000		
	0.0000	0.0000	-----		
LGDP	-0.529549	0.686849	0.581109	1.000000	
	0.0005	0.0000	0.0000	-----	
LRE	0.465961	-0.684763	-0.521043	-0.736995	1.000000
	0.0028	0.0000	0.0000	0.0000	-----

Source: Extracted by the Researcher (2023)

It is important to note that the "lag-order" is fairly sensitive to the statistical performance in statistical analysis of the time-series data and therefore the identification of the lag-length in an appropriate criterion is relevant. "Schwarz Information Criterion" (SIC) is superior to any other criterion used in a small sample size below 60 observations, according to Ahmad, Abdullah, Abdullahi, & Muhammad (2015). The result of the lag selection criterion of the study is presented in Table 2 below:

Table 2: Lag Selection Criterion

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-19.89033	NA	1.70e-07	1.438352	1.702271	1.530467
1	194.8033	345.8952	8.54e-12	-8.489070	-6.641632*	-7.844265
2	236.7788	53.63541	7.30e-12	-8.821045	-5.390087	-7.623549
3	316.9985	75.76307*	1.04e-12*	-11.27770*	-6.263219	-9.527509*

Source: Extracted by the Researcher (2023)

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. * denotes Lag order selected by the criterion.

In addition, the discussions of the results will continue with the test of the order of integration of the series to ensure that the variables are stationary. To fulfill this, the study first applied the Dickey & Fuller (1981) as well as the Phillips & Perron, (1988) techniques of unit root test. The results from these two techniques are consistent as shown in Table 3 with $LNCO_2$, LNRE, LNFDI and LNOP being stationary at first difference meaning that integrated of order one while LNGDP is stationary at level meaning integrated of order zero. On the other hand, since the ADF and PP test of unit root techniques undergoes problems of finite sample size, the study used additional techniques of unit root test that is considered more efficient proposed by (Zivot & Andrews, 2002). The result from Table 3 reveals that all the identified variables are in the same order of integration. Not any of the mentioned variables reach the second difference, meaning that none of them that is integrated of order two I(2), in this condition

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therefore, an ARDL Bound testing approach is considered the most suitable and correct model to estimate these variables.

Table 3: Unit Root Test

Variables	ZA Test				ADF Test		PP Test		Decision
	Level		Δ		Level	Δ	Level	Δ	
	P.value	Time break	P.value	Time break	P.value	P.value	P .Value	P.Value	
$LNCO_2$	0.1517	1993	<0.01*	2000	0.4544	0.0002*	0.3557	0.0002*	I(1)
LNRE	0.3463	2008	<0.01*	2015	0.7046	0.0006*	0.6109	0.0004*	I(1)
LNOP	0.2588	2003	<0.01*	2000	0.7274	0.0000*	0.7274	0.0000*	I(1)
LNFDI	0.4656	2002	<0.01*	2013	0.7126	0.0000*	0.5424	0.0000*	I(1)
LGDP	0.6664	1992	<0.01*	1995	0.0247	-	0.0485	-	I(0)

*, **, *** indicate Significance levels at 1, 5, and 10%, respectively

Source: Extracted by the Researcher (2023)

After the validation of the level of integration among the variables, the study calculates the F-statistics with the aid of bound test approach. The result reveals that the F-statistics is higher than the applicable critical value of the upper and lower bound at 1%, 5%, and 10% level of significance. Therefore, the null hypothesis of no cointegration among the concerned variables is rejected. Specifically, from these outcomes, it is evidently shown that long run relationship among the $LNCO_2$, LNOP, LNFDI, LNGDP and LNRE exists

Table 4: Bound Test Result

Level of Sig.	1% sig. level		5% sig. level		10% sig. level	
Critical Bound	Lower (0)	Upper (1)	Lower (0)	Upper (1)	Lower (0)	Upper(1)
Critical Value	3.41	4.68	2.62	3.79	2.26	3.35
F-Statistics = 9.471968	K= 5					

Critical values are obtained from Narayan (2005; Table Case III: Unrestricted intercept and no trend; p. 1988) *, **, *e** indicate Significance levels at 1, 5, and 10%, respectively

Source: Extracted by the Researcher (2023)

The next level of the ARDL techniques would be to estimate the long run and the short run relationship coefficients of the variables as well as the associated Error Correction Term (ECT). The estimated coefficients of the long run relationship among the variables are presented in Table4.

LNRE is having a negative coefficient and is statistically significant even at 1% level of significant, this indicates that a 1% increase in renewable energy would result into a 0.58% decrease in the number of carbon emissions in Nigeria, this result confirms the a priori expectation, meaning that enhancing the renewable energy source in Nigeria will enhance the quality of the environment. As such the coefficient of the LNOP is negative and statistically significant and the result confirms a priori expectation, meaning that as the price of oil increase by 1% carbon dioxide emissions would decrease by 0.7% in Nigeria, this result support s the findings of (Layachi, 2019; Maji et al., 2017). For the coefficient representing LNFDI reveals a positive sign and is statistically significant, meaning that a 1% increase in FDI would lead to 0.07% increase in the amount of carbon emissions, this result confirms a priori expectation and support the pollution halo

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hypothesis. In the same vein, the coefficient representing LNGDP exhibits a positive sign and is statistically significant at 1% level, meaning an increase in the level of economic growth by 1% in Nigeria would lead to 0.32% increase in the level of carbon emissions, this result is in line with a priori expectation. The TB_{1993} represents an unknown structural break revealed by Zivot and Andrew techniques of unit root. This phenomenon represents the period when a MOSOP (Movement for Survival of the Ogoni People) organizes a protest that involved around 300, 000 Ogoni people against the shell exploration activities that endangered the habit because of the emissions that pollute the environment. As a result of this in 1993 shell ceased production activities in Ogoniland (Yakubu, 2017). The coefficient of TB_{1993} is negative and statistically significant at 5% level. This revealed the fact that the occurrence of the phenomenon leads to a decrease in carbon emissions level in Nigeria.

Table 5: Estimated Long run Coefficients for ARDL Model

Regressors	Coefficient	Std. Error	t-Statistics	Prob.
LRE	-0.582742	0.296260	5.342402	0.0000*
LOP	-0.704570	0.114447	6.156291	0.0000*
LFDI	0.073783	0.010051	-7.340777	0.0000*
LGDP	0.324949	0.054992	5.909036	0.0000*
TB_{1993}	-0.209033	0.085611	-2.441659	0.0236**
C	-0.105482	1.262592	-0.875565	0.3912

*, **, *** indicate Significance levels at 1, 5, and 10%, respectively

Source: Extracted by the Researcher (2023)

In a similar vein, table 5 reveals the result of the short run form of dynamic model. The value of the F-statistic specifies that the variables are highly and jointly significant. The R^2 value of 0.65 shows that on average 65% change in the dependent variable is accounted for by the independent variables, which further confirms the presence of strong relationship between the environmental quality (CO_2 emissions) that is the dependent variable and the various explanatory variables. Further, the $LNCO_2$ is positively and significantly related LNOP, this justifies the fact that in the short run increase in the price of oil has an effect of deteriorating the quality of environment. Similarly, LNGDP is having a positive coefficient and is significant statistically, meaning that increase in economic growth reduces the quality of environment even in the short run in Nigeria, this result supports the EKC hypothesis because the long run elasticity coefficient of LNGDP is less than the short run elasticity coefficient of the LNGDP. Contrarily, LNFDI is having negative association with $LNCO_2$ in the short run and the relationship is statistically significant, this entails that in the short run increase in the inflow of FDI would improve the quality of environment in Nigeria. Additionally, the sign as well as the value of ECT(-1) coefficient as revealed in Table 5 are negative and statistically significant at 1% level. This indicates that the model can adjust for the dynamics of the short run variables with their values in of long run, because of the presence of self-adjustment device in the model. Additionally, this proves the presence of long run relationship between the explanatory variables and the quality of environment (CO_2 emissions). The -0.68 value of the ECT(-1) coefficient shows the speed of adjustment to the state of equilibrium. The fairly high speed shows that the deviation in

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the growth CO_2 emissions from the state of equilibrium is adjusted by about 68% next year.

However, the study conducted different diagnostic test that include the Lagrange Multiplier for autocorrelation, the ARCH (Auto Regressive Conditional Heteroskedasticity) test for heteroscedasticity as well as the test of normality for the residual terms are presented in Table 5, suggesting that the mode of the ARDL passes all these diagnostic tests. This is because we found no evidence of heteroscedasticity and serial correlation. Normally, the residual terms are distributed and the model's functional term appears to be well specified.

Table 6: Error Correction Representation

Regressors	Coefficient	Std. Error	t-Statistics	Prob.
LRE	-0.963513	0.237784	4.052061	0.0006*
LOP	0.165957	0.079242	2.094291	0.0485***
LFDI	-0.015561	0.003604	-4.318121	0.0003*
LGDP	0.423712	0.043153	5.184216	0.0000*
TB_{1993}	-0.143909	0.065137	-2.209331	0.0384***
ECT(-1)	-0.688452	0.090104	-7.640682	0.0000*

Statistical Tests	
R^2	0.657069
Adj R^2	0.761782
AIC	-3.379727
SC	-2.719927
F-Statistic	8.994573

Diagnostic Test	F-statistic	Prob.
Autocorrelation Test	1.246374	0.3100
Hetroskedasticity Test	0.972287	0.5095
Normality Test		0.366401

*, **, *** indicate Significance levels at 1, 5, and 10%, respectively

Source: Extracted by the Researcher (2023)

However, to ensure the robustness as well as the stability of the model parameters, CUSUM (cumulative sum of recursive residuals) and the CUSUMQ (cumulative sum of square of recursive residuals) were applied to test for stability. The two graphs of the test were shown in the following Figure 1a and 1b, with regard to the stability of the parameters, the decision rule was based on the position of the graphs of CUSUM and CUSUMQ. As presented both CUSUM and CUSUMQ tests of stability are considered stable and consistent because the models fall within the critical bounds at the 5% level of significance.

for ARDL model

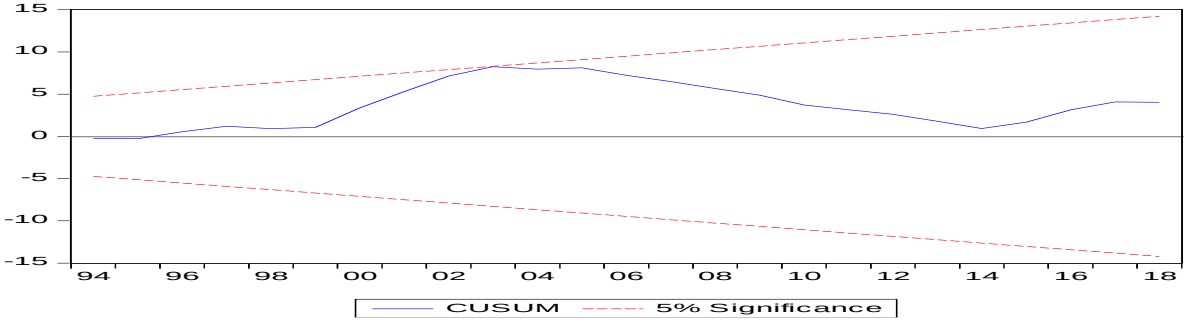


Figure 1a: Cumulative sum of recursive residuals.

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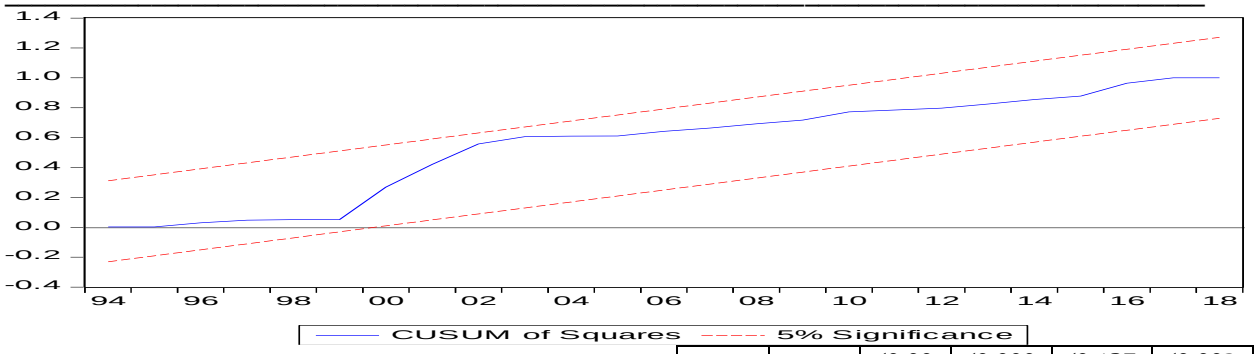


Figure 1b: Cumulative sum of squares of recursive residuals.

The study uses the Wald test to investigate the dynamic form of causal relationship between the crude oil price as well as the quality of environment in Nigeria. The summary of the results are presented in Table 7 and the results show that there is bidirectional relationship between CO_2 emissions and crude oil price this result is in line with the findings of (Layachi, 2019; Zaghdoudi, 2017). At the same time, a feedback effect exists between CO_2 emissions and FDI and also between CO_2 emissions and renewable energy output. In the same vein, feedback effects exist between crude oil price and FDI, economic growth and FDI as well as the FDI and renewable energy output. On the other hand, a unidirectional causal relationship is bound to exist running from economic growth to carbon emissions, economic growth to crude oil price, from crude oil price to renewable energy output and also from economic growth to renewable energy output.

Table 7: MWALD/Non-Granger Causality Test

Dependent Variable (χ^2)					
Variable	*LNCO2*	*LNRE*	*LFDI*	*LNGDP*	*LNOP*
$LNCO_2$	-	10.062	8.508	2.124	5.998
			(0.000)*	(0.000)*	(0.137)	(0.002)*
LNRE	15.636 (0.000)*	-	3.215 (0.034)**	0.180 (0.836)	9.764 (0.000)*
LNFDI	25.822 (0.000)*	7.667 (0.000)*	-	2.206 (0.035)**	5.771 (0.005)*
LNGDP	22.059 (0.000)*	-2.519 (0.018)*	10.912 (0.000)*	-	5.476 (0.012)**
LNOP	11.902 (0.000)*	-1.582 (0.126)	3.334 (0.040)**	0.421 (0.660)	-

*, **, *** indicate Significance levels at 1, 5, and 10%, respectively

Source: Extracted by the Researcher (2023)

5. Conclusion and Policy Implications

The paper examines the effect of renewable energy on the quality of environment in Nigeria. The study used time series data covering the period of 1980-2019 and applied the bound test of ARDL techniques of analysis as well as the Wald test of granger causality. The findings from the estimation techniques show that renewable energy consistently decreases carbon dioxide (CO2) emissions. In what follows, attendant policy implications are discussed.

The significant renewable energy use makes a path towards sustainable economic growth

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and ensures a transformation towards a low carbon economy. Our empirical outcome also reveals that the use of renewable energy decreases the CO_2 emissions in Nigeria. Therefore, for higher economic growth with low CO_2 emissions, it is worth promoting the use of renewable energy. In addition, the significant exploration of RE sector may initiate an opportunity for energy sector modernization as suggested by the policymakers to acknowledge the purpose of sustainability (Kaygusuz et al. 2007).

i. As pointed out by Hirschl (2009), at the international level, policymakers should implement a multilateral mechanism to ensure energy efficiency and to promote the use of renewable energy.
ii. Appropriate incentive measures for the market accessibility and the development of renewable energy should be implemented and executed across the globe.
iii. Cooperation on the development of renewable energy markets between the private and public sectors stakeholder in terms of financing the project investments, technological advancements, and the ways of on-going projects would again initiate vital contributions to the significant exploration of the renewable energy sector.

References

Africa Progress Panel (2015). Power people planet: seizing Africa's energy and climate opportunities: Africa Progress Report

Ahmad, A. U., Abdullah, A., Abdullahi, A. T., & Muhammad, U. A. U. (2015). Stock Market Returns and Macroeconomic Variables in Nigeria : Testing for Dynamic Linkages with a Structural Break. *Scholars Journal of Economics, Business and Management*, *2*(8A), 816–828.

Apergis N, Payne JE (2015) Renewable energy, output, carbon dioxide emissions, and oil prices: evidence from South America. Ener Sces Part B Econ Plan Pol 10(3):281–287

Apergis N, Payne JE, Menyah K, Wolde-Rufael Y (2010) On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. Ecol Econ 69(11):2255–2260

Bilgili F, Koçak E, Bulut U (2016) The dynamic impact of renewable energy consumption on CO2 emissions: a revisited Environmental Kuznets Curve approach. Renew Sust Energ Rev 54:838–845

Bölük G, Mert M (2014) Fossil & renewable energy consumption, GHGs (greenhouse gases) and economic growth: evidence from a panel of EU (European Union) countries. Energy 74:439–446

Bouimetarhan, I., M. Carré, and R. Cheddadi (2018), Assessing and understanding climate change in Africa, Eos, 99, https://doi.org/10.1029/2018EO099627. Published on 25 May 2018.

Collier, P. (2008). The bottom billion: Why the poorest countries are failing and what can be done about it. Oxford University Press, USA.

Conway , D., & Schipper, E. L. F. (2011). Adaptation to climate change in Africa: Challenges and opportunities identified from Ethiopia. Global Environmental Change, 21(1), 227-237.

Dickey, D. A., & Fuller, W. A. (1981). Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root. *Econometrica*, *49*(4), 1057. https://doi.org/10.2307/1912517

Engle, R. F., & Granger, C. W. J. (1987). Co-Integration and Error Correction : Representation , Estimation ,. *Econometrica*, *55*(2), 251–276.

Farhani S, Shahbaz M (2014) What role of renewable and non-renewable electricity consumption and output is needed to initially mitigate CO2 emissions in MENA region? Renew Sust Energ Rev 40:80–90

Farhani, S., & Ozturk, I. (2015). Causal relationship

ISSN: 2786-9695
DOI: https://10.57233/gujeds.v3i1.15 Vol. 3(1) July 2023

between CO2 emissions, real GDP, energy consumption, financial development, trade openness, and urbanization in Tunisia. *Environmental Science and Pollution Research*, *22*(20), 15663–15676. https://doi.org/10.1007/s11356-015-4767-1

Fawcett, J. W. (2015). The extracellular matrix in plasticity and regeneration after CNS injury and neurodegenerative disease. Progress in brain research, 218, 213-226.

Frimpong, K., Van Etten EJ, E., Oosthuzien, J., Fannam Nunfam, V., & MPHIL Development Studies. (2017). Heat exposure on farmers in northeast Ghana. International journal of biometeorology, 61, 397-406.

Hirschl, R. (2009). Towards juristocracy: the origins and consequences of the new constitutionalism. Harvard University Press.

IPCC (2007) Climate Change 2007: The physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, UK

Johansen, S., & Juselius, K. (1990). Maximum Likelihood Estimation and Inference on Cointegration - With. *OXFORD BULLETIN OF ECONOMICS AND STATISTICS*, *2*(52), 169–210.

Karasoy A, Akçay S (2019) Effects of renewable energy consumption and trade on environmental pollution: the Turkish case. Manag Environ Qual 30(2):437–455

Karekezi, E. (2003). Kubamenyesha gahunda.

Kaygusuz, K. (2007). Energy for sustainable development: key issues and challenges. Energy Sources, Part B: Economics, Planning, and Policy, 2(1), 73-83.

Layachi, O. B. (2019). Effects of Energy Prices on Environmental Pollution : Testing Environmental Kuznets Curve for Algeria. *International Journal of Energy Economics and Policy*, *9*(5), 401–408.

López-Menéndez AJ, Pérez R, Moreno B (2014) Environmental costs and renewable energy: re-visiting the environmental Kuznets curve. J Environ Manag 145(1):368–373

Maji, I. K., Habibullah, M. S., Saari, M. Y., & Abdul-Rahim, A. S. (2017). The nexus between energy price changes and environmental quality in Malaysia. *Energy Sources, Part B: Economics, Planning and Policy*, *12*(10), 903–909. https://doi.org/10.1080/15567249.2017.1323052

Mavrotas, G., & Kelly, R. (2001). Old wine in new bottles: Testing causality between savings and growth. The Manchester School, 69, 97-105.

Narayan, P. K. (2005). The saving and investment nexus for China: evidence from cointegration tests. Applied economics, 37(17), 1979-1990.

Ngwenya, L. B., Gardner, R. C., Yue, J. K., Burke, J. F., Ferguson, A. R., Huang, M. C., ... & Manley, G. T. (2018). Concordance of common data elements for assessment of subjective cognitive complaints after mild-traumatic brain injury: a TRACK-TBI Pilot Study. Brain Injury, 32(9), 1071-1078.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, *16*(3), 289–326. https://doi.org/10.1002/jae.616

Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled mean group estimation of dynamic heterogeneous panels. Journal of the American Statistical Association, 94(466), 621-634.

Phillips, P. C. B., & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika*, *75*(2), 335–346. https://doi.org/10.1093/biomet/75.2.335

Sanglimsuwan, K. (2011). Carbon dioxide emissions and economic growth: an econometric analysis. International Research Journal of Finance and Economics, 67(1), 97-102.

Shafiei S, Salim RA (2014) Non-renewable and renewable energy consumption and CO2 emissions in OECD countries: a comparative analysis. Energy Policy 66:547–556

Shahbaz, M., Nasreen, S., Ahmed, K., & Hammoudeh, S. (2017). Trade

ISSN: 2786-9695
DOI: https://10.57233/gujeds.v3i1.15 **Vol. 3(1) July 2023**

openness– carbon emissions nexus: The importance of turning points of trade openness for country panels. Energy Economics, 61, 221-232.

Sulaiman J, Azman A, Saboori B (2013) The potential of renewable energy: using the environmental Kuznets curve model. Am J Environ Sci 9(2):103–112

Toda, H. Y., & Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. *Journal of Econometrics*, *66*(1–2), 225–250. https://doi.org/10.1016/0304-4076(94)01616-8

Toulmin, C. (2009). Climate change in Africa. Zed Books Ltd.

WHO Expert Committee on the Selection, Use of Essential Medicines, & World Health Organization. (2014). The Selection and Use of Essential Medicines: Report of the WHO Expert Committee, 2013 (including the 18th WHO Model List of Essential Medicines and the 4th WHO Model List of Essential Medicines for Children) (Vol. 985). World Health Organization.

Wolde-Rufael, Y. (2010). Bounds test approach to cointegration and causality between nuclear energy consumption and economic growth in India. *Energy Policy*, *38*(1), 52–58. https://doi.org/10.1016/j.enpol.2009.08.053

Yakubu, O. H. (2017). Particle (soot) pollution in Port Harcourt Rivers State, Nigeria—double air pollution burden? Understanding and tackling potential environmental public health impacts. Environments, 5(1), 2.

Zaghdoudi, T. (2017). Oil prices, renewable energy, CO2 emissions and economic growth in OECD countries. Economics Bulletin, 37(3), 1844-1850.

Zaghdoudi, T. (2017). Volume 37 , Issue 3 Oil prices , renewable energy , CO2 emissions and economic growth in OECD countries. *Economics Bulletin*, *37*(3), 1844–1850.

Zapata, H. O., & Rambaldi, A. N. (1997). Agricultural economics. *Agricultural Economics*, *59*(2), 285–298. https://doi.org/10.12737/766

Zivot, E., & Andrews, D. W. K. (2002). Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. *Journal of Business and Economic Statistics*, *10*(3), 251–270.https://doi.org/10.1080/07350015.1992.10509904