Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Asymmetric effect of crude oil price on the quality of environment in Nigeria: An application of non-linear ARDL

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ABSTRACT
The study aimed at examining the asymmetric effect of crude oil price on the quality of environment in Nigeria. The study utilizes the time series form of annual data from 1970 to 2019 and applies the model of NARDL (Non-Linear ARDL) to determine the short-run and long-run asymmetries. The results revealed that positive shocks in crude oil price reduces the amount of carbon emissions thereby enhancing the quality of the environment in the long run, while negative shock increases the amount of carbon emission and hence deteriorate the quality of the environment. In the short the positive shock increases the amount of carbon emissions while the negative shocks reduces the carbon emissions and also improve the quality of the environment. Nonetheless, the magnitude and sign of positive as well as negative shocks of crude oil price are essential in environmental management policies. Henceforth, on the basis of the sign as well as magnitude, the study recommends for more subsidy on clean energy as well as formulation of a favorable form of policies for the implementation of renewable form of energy such as solar by residential consumers and industries particularly during the period of low crude oil price.

Keywords: Oil price, Environmental Quality, Non-Linear ARDL.
Article type: Research Article.

INTRODUCTION
Energy plays an essential role in many countries' development all over the world. However, the use of energy in the process of production is related directly to carbon (CO_2) emissions as well as resulting to climate change (Ahmed *et al.* 2020). The resulting challenges of the environment that is the spread of diseases, droughts, floods, and rising sea level instigated by climate change made the whole world to seek measures of environmental sustainability (Sulaiman *et al.* 2020). Given the emissions of greenhouse gases (GHGs), the global environment, especially since the last decade, has been undergoing a transition that is threatening human survival. Attempting to address this global condition, the Intergovernmental Panel on Climate Change (IPCC) informs the world's economies that during the twenty-first century, the global average temperature ratio ought not to surpass 2 °C. Thus, each economy should pay careful attention to restricting the space available for carbon dioxide emissions (Hassan *et al.* 2016; Li *et al.* 2018; Saidu *et al.* 2018; Dabachi *et al.* 2020; Jakada *et al.* 2020b; Jakada *et al.* 2020c; Adam *et al.* 2021). Nowadays, every country, particularly those in the developing stage, uses enormous quantities of fossil fuels to achieve robust growth; accordingly, the carbon dioxide emissions ratio is rapidly growing (Wang *et al.* 2016; Yang *et al.* 2016; Zhu *et al.* 2017). An important issue that has recently emerged is how to effectively restrict and reduce the ratio of CO_2 emissions without affecting stable economic growth (Khan & Majeed 2019; Jakada *et al.* 2022). International organizations' attempts to minimize the detrimental effects of

Caspian Journal of Environmental Sciences, Vol. 21 No. 3 pp. 493-507 Received: Feb. 17, 2023 Revised: May 06, 2023 Accepted: June 26, 2023
DOI: 10.22124/CJES.2023.6925

Publisher: University of Guilan,

global warming have also been focused on measures to curb CO_2 emissions (Tamazian *et al.* 2009; Acheampong & Boateng 2019; Alkhawaldeh *et al.* 2020; Danmaraya *et al.* 2021). Despite global attempts to minimize CO_2 emission, it has been rising. Globally energy-related CO_2 emissions amplified by 1.4% percent in 2017 as reported by the International Energy Agency (IEA 2018). This marks an incredible rise of 460 million tonnes (Mt) to a record peak of 32.5 gigatons (Gt), whilst staying stagnant for the past three years. The Paris Agreement on Climate Change conflicts with this astronomical increase in CO_2 emissions. The IEA (2018) study indicates that strong global economic growth, greater energy conservation efforts, and lower prices of fossil-fuel are the result of the increase in global CO_2 emissions. Recently climate change is no longer be considered only as an issue of environment anymore. It turns to be an issue of development when considering its prospective effect on economic activities. It is a significant threat to many developing countries' sustainable development with Nigeria, not an exception. For example, climate change is expected to result in some kind of a loss of 6% to 30% of GDP in Nigeria by 2050 that transforms into US$ 100 billion to US$ 460 billion if no mitigation and adaptation steps are taken (Cosmas *et al.* 2019). For this reason, International agencies such as United Nation Development Program (UNDP) together with Global Environment Facility (GEF) are currently at work in Nigeria via their programs for the purpose of supporting CO_2 emissions mitigation policies. For example, the master plan of renewable energy is financed in Nigeria by UNDP, while the World Bank is currently undergoing a project via its sustainable project fund (Eleri *et al.* 2013). Despite all the efforts of CO_2 emissions mitigation, the country was ranked 44th in the world in the list of the most emitted countries in over 200 countries (Danmaraya & Hassan 2016; Sulaiman & Abdul-Rahim 2018; Nailevich *et al.* 2020, Melnik *et al.* 2021; Vlasenko & Sudarikov 2021; Jakada *et al.* 2022). Similarly, the amount of CO_2 emissions escalated from 68.04 mt in 1980 to 107.30 mt in 2017 (IEA 2019). Henceforth, Nigeria is likely to devise a sustainable process of CO_2 emissions mitigation. Henceforth, the fall in the global price of oil by more than half its price from mid-2014 to early 2016 has contributed to significant fiscal disruptions for most of the world's oil-exporting economies. The eventual gradual decline in the context of Brent oil, the worldwide proxy for the price of crude oil, was from $110 per barrel in mid-2014 towards $80 in November of the same year. The Brent price of oil subsequently dropped dramatically to far less than $50 per barrel in January 2015 following the meeting of the Organization of Petroleum Exporting Countries (OPEC) during November 2014. The decrease in prices was primarily due to higher supplies from the non-OPEC countries, especially from shale oil in the United States, and higher supplies from member economies of OPEC, such as Libya, Kuwait, Iraq, and Saudi Arabia (IMF 2015). Increment in economic activities has a direct influence on the efficiency of the environment, as per the Environmental Kuznets Curve (EKC) literature (Mahmood *et al.* 2021; Bader & Ganguli 2019). Although the overriding effect of the price of oil on economic activities in oil-exporting economies has been recognized by researches (Hamdi & Sbia 2013; Nwani 2017), in evaluating the effect of the oil price on CO_2 emissions, there has been little empirical consideration (Dong *et al.* 2017; Jakada *et al.* 2022). By reducing fossil fuel energy consumption, higher energy prices may indirectly affect CO_2 emissions. Relatively low energy prices, on the other hand, will influence CO_2 emissions by increasing the intake of fossil fuel energy. The premise behind evaluating the impact of the drop in oil prices on environmental sustainability is that consumption of fossil fuel energy contributes 40% out of 80% CO_2 emissions to GHGs (WDI 2015), can be evaluated by the price of energy. Higher oil prices will indirectly affect the CO_2 emissions via lower energy consumption of fossil fuels. Lower oil prices, on the other hand, will influence CO_2 emissions by elevating the intake of fossil fuel energy. Oil prices thus serve as an indicator of differences in the use of fuel energy that leads to CO_2 emissions. As a result, the further replacement of fossil fuel energy with oil prices enables both to confiscate the effect of fossil fuel form of energy on CO_2 emissions as well to avoid the possible endogeneity issues resulting from the direct incorporation of fossil fuel form of energy utilization in the econometric model (Balaguer & Cantavella, 2016; Maji *et al.* 2017). Most studies including Hammoudeh *et al*. (2014) and Dodder *et al*. (2015) in the case of USA; Maji *et al.* (2017) for Malaysia, Agbanike *et al*. (2019) looking at the case of Venezuela, while Li *et al*. (2020) in the case of China and Jakada *et al.* (2020a) in the case of Nigeria who investigated the symmetric influence of the price of energy on the emissions of carbon dioxide. The asymmetric form of effects of the oil prices on CO_2 emissions was noticed by a few of the previous studies such as Boufateh (2019) for two economies that happened to be the major CO_2 emissions contributors and Malik *et al*. (2020) in the case of Pakistan, none to the best knowledge of the investigators have been considered in the case of Nigeria. In addition, linear modeling approaches have been used in previous literature for empirical research, producing contradictory results. Therefore, in the case of Nigeria, it is essential to evaluate the asymmetrical effects of the prices of oil on the quality of the environment. Recently Apergis & Gangopadhyay (2020) and Jakada *et al.* (2020d) indicated that models of non-linear ARDL are quite well-suited to explain heterogeneity as well as asymmetries between changes in oil prices and environmental degradation. Whereas, more detailed and authoritative findings are given by the asymmetric form of modeling. It is therefore essential to evaluate the asymmetrical impacts of oil prices on the quality of the environment. This technique of asymmetric time series is implemented based on the claim of Bahmani-Oskooee & Hasanzade (2020), and Chishti *et al.* (2020), who indicated that the approach of panel data suffers from an aggregation form of bias that is not appropriate for the disaggregated single country data. Our research uses a time series asymmetric ARDL approach to minimize the aggregation bias, which takes the analysis into account for a single country level. The current study, therefore, follows Boufateh (2019) estimation technique, which uses the time series technique to determine the short as well as the long-term impact of shifts in the oil price on carbon emissions for the USA and China. By arguing that the effects of oil price fluctuations on CO_2 emissions may be asymmetric, we, therefore, deviate from the existing empirical literature. We have used a non-linear model because asymmetry in the impact of oil prices is seldom observed in real-world scenarios. Previous empirical research typically assumes symmetric relationships, which may be misleading. The use of non-linear models becomes more acceptable, realistic, and practical over linear models while faced with a fluctuating factor like oil prices. In order to examine the asymmetric effect, NARDL is considered a modern dependable technique where the positive or negative oil price effect is dominant, efficient, and of great importance in environmental policy. Using the time-series form of annual data for Nigeria from 1970 to 2019, this study offers a detailed empirical analysis of oil price fluctuations' effect on the quality of the environment. Unlike prior studies, this analysis uses the non-linear model of ARDL to analyze the asymmetries between long and short runs. The results of this research are expected to provide effective policy choices for managing environmental quality and sustainable economic development in Nigeria as well as other oil-rich counties.

LITERATURE REVIEW

Previous researches have investigated the effect of oil prices on economic growth and government expenditure in consideration of oil-exporting countries. For example, Nusair (2016) investigated the asymmetric influence of shocks on the price of oil for the countries of GCC, and the findings reveal that the economic growth of GCC countries gains the paybacks on account of the positive trend in the price of oil, nonetheless, the descending trend in the prices revealed no effects that are significant. In the same vein, El Anshasy & Bradley (2012) inferred that the foremost oil-exporting countries enlarge their fiscal spending largely in the long run as related to the short run when the price of oil upsurge. Meanwhile, the leading determination of this study is to explore the price of oil variation and carbon emissions nexus as few kinds of research are available in this respect. A study by Malik *et al.* (2020) examined the long run as well as the short effect of economic growth, FDI as well as the price of oil on the number of carbon emissions via the ARDL as well as non-linear ARDL techniques of co-integration together with Granger causality within the perspective of Pakistan over the period of 1971-2014. The symmetric results reveal that economic growth and FDI escalates carbon emissions while the price of oil upsurge emissions in the short run as well as minimize emissions over the long run, albeit, the asymmetric outcomes reveal that positive oil price minimizes emissions and negative oil price upsurge emissions. Similarly, another by Ullah *et al*. (2020) examined the asymmetric influence of the changes in oil price on environmental degradation considering ten leading carbon emitters in the world. The study utilizes annual time series data over the period of 1981-2018 as well as using a model of non-linear ARDL. The outcomes reveal positive shocks in the price of diesel in Canada, Iran, South Korea, Germany, Japan, India, and the USA, whereas negative shocks in India and China minimize carbon emissions in the state in the long run. On the other hand, an escalation of the price of gasoline in Iran and Russia while the decline in the price of gasoline in Canada, Japan, Russia, and the USA minimize the amount of carbon emissions in the state of the long run. The asymmetric outcome also reveals that positive as well as negative changes in the price of oil affect the amount of carbon emissions differently in Canada, Saudi Arabia, Iran, South Korea, Germany, Japan, Russia, India, and the USA both in the short and long runs. Similarly, Agbanike *et al.* (2019) also investigated the link between economic growth, oil price, and carbon emissions concerning Venezuela over the period of 1971 - 2013. By employing the techniques of ARDL, the study reveals that the ratio of energy consumption and government usage enlarges on the account of oil price escalation. However, higher use of energy deteriorates the quality of the environment through the carbon emissions generation that affects the economic growth of Venezuela adversely. In addition, Zaghdoudi (2017) scrutinized the causal form of relationship between economic growth, oil price, renewable energy, and carbon emissions considering the case of OECD countries over the period of 1990 to 2015. By using the panel co-integration model, the study showed a negative and significant association between renewable energy, oil price, and carbon dioxide emissions. The results of the study revealed the presence of a quadratic relationship in the long run between economic growth and carbon emissions, justifying the existence of the EKC hypothesis for the OECD countries. The study supported the fact that oil price fall declines the amount of carbon emissions in the OECD countries. Additionally, Maji *et al.* (2017) investigated the influence of energy prices on environmental quality in Malaysia. The study utilized an annual form of time series data covering the period of 1983 - 2014 through the use of three co-integration method of estimation for the purpose of confirming the consistency of the result. The findings of the study revealed that lower oil prices can increase the amount of CO_2 emissions as well as deteriorates the quality of the environment. In the case of Ecuador, Nwani (2017) examined the relationship between energy use, oil price, and carbon emissions over the period of 1971 - 2013 through the use of ARDL techniques. The outcome of the results revealed that the escalation of oil prices leads to an increasing impact on the amount of CO_2 emissions. Another study was undertaken by Saboori *et al*. (2016) in consideration of ten OPEC member countries over the period of 1977-2008 via the use of ARDL techniques of the short- as well as long-run estimation. The outcomes of the study revealed that the quality of the environment for the selected countries withstands degradation on the account of carbon emissions emanating from the level of high oil consumption. However, escalation on oil prices ameliorates the deterioration of the environment through the reduction of the detrimental consequence of carbon emissions. Likewise, in most of the circumstances, the causal relationships among the concern variables are not made available, including the causality between carbon emissions and oil price. Similarly, Alshehry & Belloumi (2015) evaluated the impacts of the price of oil on carbon emissions and economic growth for Saudi Arabia, and inferred that an elevating trend in the price of oil, upraises utilizing oil as a result, hence, deteriorates the quality of the environment by increasing the amount of CO_2 emissions. However, the economy of Saudi Arabia not yet get the benefits as the growth of GDP exhibits an insignificant reaction. In general, even though many studies intended to investigate the major determinants of energy use and carbon emissions as well as their dynamic form of association, yet little attention is geared to discover the link between the price of energy, particularly the crude oil price and the quality of the environment. Furthermore, most of the earlier studies use an asymmetric form of modeling with little studies such as Ullah *et al.* (2020) for the top ten leading emitting countries in the world as well as Malik *et al.* (2020) for Indonesia. Henceforth, an asymmetric form of modeling can give out accurate and reliable findings (Rasheed *et al.* 2019). As such it is worth investigating the asymmetric influence of the changes in the price of oil on environmental quality.

MATERIALS AND METHODS

Data

The study used the time series annual form data that covered the specific period of 1970 to 2019 looking at the case of Nigeria. The data used for CO_2 emissions that measure the quality of environment is the CO_2 emissions in metric tons per capita, the price of oil is measured by the WTI (West Texas Intermediate) crude oil price, economic growth to be measured by GDP of 2005 US$, foreign direct investment measured by the inflow of FDI percentage of GDP, and renewable energy output measured by the renewable electricity output. The data used in the study were sourced from the WDI (World Development Indicator) except the price of crude oil that were generated from the Organization of Petroleum Countries (OPEN) data stream.

Model Specification

The study used the price of oil as a measure of energy use variation to eliminate problems of endogeneity related with direct insertion of energy use variable in the environmental quality model. This due to the fact that carbon emissions are measured by multiplying numerous energy sources by their rates of emissions. As a result, the functional form of relationship between oil price and the quality of environment following the work of Maji *et al.* (2017) and Ullah *et al.* (2020) is given as follows:

$$CO_t = f(OP_t, Z_t) \qquad (\mathbf{1})$$

where CO_t represents the quality of environment variable, OP_t signifies the price of oil, Z_t denotes additional control variables within the model that comprise GDP_t as economic growth, FDI_t for inflow of foreign direct investment and RE_t for renewable energy output. After the transformation of the variables, the extended form of model that expressed the quality of environment as a function of the price of oil as well as other determinants is expressed as follows:

$$lnCO_{2t} = \beta_0 + \beta_1 lnOP_t + \beta_4 lnRE_t + \beta_2 lnGDP_t + \beta_3 lnFDI_t + \mu_t \qquad (\mathbf{2})$$

where β_0 is the parameter of the drift; μ_t is the error term, β_1, β_2, β_3 and β_4 are the elasticities of oil price, economic growth, FDI, and renewable energy, respectively.

Econometric methodology

The segment begins with the introduction of the conventional test of unit root that are linear in nature, specifically the ADF (Augmented Dickey-Fuller), and the ADFGLS (Augmented Dickey-Fuller Generalized Least Square) test of unit root that were employed to examine the linear stochastic trend within the series. The non-linear test of unit root that is KPSS (Kwiatkowski Phillips-Schmidt-Shin) nonlinear tests of unit root were used also to test whether the variables follow the form of nonlinear trend. In addition, the BDS (Brock-Dechert-Scheinkman) (1996) test of nonlinear would be employed to see if the series are linear or nonlinear and the nonlinear ARDL techniques of estimation were applied to examine the nonlinear effect of oil price on the quality of environment as well as the asymmetric nature of their relationship.

Non-Linear ARDL Model

The present study used the NARDL techniques since the method uses the negative as well as positive restricted sum disintegrations of the predetermined independent variables as well differentiating between long run and short run effect of the explanatory variables on the explained variable as it incorporates a dynamic form of error correction. Moreover, this technique does not require the order integration among the variables to be the same, the technique can accommodate the order of integration to be either at level or at first difference that is I(1) or I(0) respectively (Ahmad *et al.* 2015a; Ahmad *et al.* 2015b; Alkhawaldeh *et al.* 2020; Sehrawat, 2020; Vasichenko *et al.* 2020;). Henceforth, the study piloted a technique of non-linear ARDL ensuing the approach of Shin *et al.* (2014). Similar to ARDL, non-linear ARDL also does not require all variables to be integrated at the same order. Thus, the model stated as Eq. 2 of this study will extend in form as follows:

$$lnCO_{2t} = \beta_0 + \beta_1 lnOP_t^+ + \beta_2 lnOP_t^- + \beta_1 lnRE_t^+ + \beta_2 lnRE_t^- + \beta_1 lnGDP_t^+ + \beta_2 lnGDP_t^- + \beta_1 lnFDI_t^+ + \beta_2 lnFDI_t^- + \mu_t \qquad (\mathbf{3})$$

where in Eq. 3, $lnOP_t^+ and\ lnOP_t^-$ symbolizes the positive as well as negative partial sum process form of variation in OP derived from Eq. 4, $lnGDP_t^+\ and\ lnGDP_t^-$ characterizes positive as well as negative partial sum process form of variation in GDP derived from Eq. 5, $lnFDI_t^+\ and\ lnFDI_t^-$ signifies positive as well as negative partial sum process form of variation in FDI derived from Eq. 6, while $lnRE_t^+ and\ lnRE_t^-$ embodies positive as well as negative partial sum process form of variation in RE derived from Eq. 7.

$$lnOP_t^+ = \sum_{k=1}^{t} \Delta lnOP_t^+ = \sum_{k=1}^{t} max(\Delta lnOP_k, 0), lnOP_t^- = \sum_{k=1}^{t} \Delta lnOP_k^- = \sum_{k=1}^{t} min(\Delta lnOP_k, 0) \quad (\mathbf{4})$$

$$lnRE_t^+ = \sum_{k=1}^{t} \Delta lnRE_t^+ = \sum_{k=1}^{t} max(\Delta lnRE_k, 0), lnRE_t^- = \sum_{k=1}^{t} \Delta lnRE_k^- = \sum_{k=1}^{t} min(\Delta lnRE_k, 0) \quad (\mathbf{5})$$

$$lnGDP_t^+ = \sum_{k=1}^{t} \Delta lnGDP_t^+ = \sum_{k=1}^{t} max(\Delta lnGDP_k, 0), lnGDP_t^- = \sum_{k=1}^{t} \Delta lnGDP_k^- = \sum_{k=1}^{t} min(\Delta lnGDP_k, 0) \quad (\mathbf{6})$$

$$lnFDI_t^+ = \sum_{k=1}^{t} \Delta lnFDI_t^+ = \sum_{k=1}^{t} max(\Delta lnFDI_k, 0), lnFDI_t^- = \sum_{k=1}^{t} \Delta lnFDI_k^- = \sum_{k=1}^{t} min(\Delta lnFDI_k, 0) \quad (\mathbf{7})$$

Following the same procedure undertaken under the techniques of ARDL, the study uses the nonlinear ARDL method to study the asymmetric form of relationship between the variable of the study. The equation is stated as follows:

$$\Delta lnCO2_t = \alpha_0 + \sum_{j=1}^{b} \alpha_j \Delta lnCO2_{t-j} + \sum_{J}^{b} \left(\alpha_i^+ \Delta lnOP_{t-j}^+ + \alpha_i^- \Delta lnOP_{t-j}^-\right) + \sum_{j}^{b} \left(\alpha_i^+ \Delta lnRE_{t-j}^+ + \alpha_i^- \Delta lnRE_{t-j}^-\right)$$
$$+ \sum_{j}^{b} \left(\alpha_i^+ \Delta lnGDP_{t-j}^+ + \alpha_i^- \Delta lnGDP_{t-j}^-\right) + \sum_{j}^{b} \left(\alpha_i^+ \Delta lnFDI_{t-j}^+ + \alpha_i^- \Delta lnFDI_{t-j}^-\right)$$
$$+ \ +\gamma_1 \Delta lnCO2_{t-1} + \gamma_2^+ lnOP_{t-1}^+ + \gamma_3^- lnOP_{t-1}^- + \gamma_2^+ lnRE_{t-1}^+ + \gamma_3^- lnRE_{t-1}^- + \gamma_2^+ lnGDP_{t-1}^+$$
$$+ \gamma_3^- lnGDP_{t-1}^- + \gamma_2^+ lnFDI_{t-1}^+ + \gamma_3^- lnFDI_{t-1}^- + \mu_t \qquad \mathbf{(8)}$$

where $\sum_{j=1}^{b} \alpha_j^+ \ and \ \sum_{j=1}^{b} \alpha_j^-$ captures the short-run positive as well as negative effect of oil price, renewable energy, economic growth and FDI on carbon emission, while γ_i^+ and γ_i^- captures the long-run effect of oil price, renewable energy, economic growth and FDI on carbon emission. The error correction model of Eq. 8 is represented as follow:

$$\Delta lnCO2_t = \alpha_0 + \sum_{j=1}^{b} \alpha_j \Delta lnCO2_{t-j} + \sum_{j}^{b} \left(\alpha_i^+ \Delta lnOP_{t-j}^+ + \alpha_i^- \Delta lnOP_{t-j}^-\right) + \sum_{j}^{b} \left(\alpha_i^+ \Delta lnRE_{t-j}^+ + \alpha_i^- \Delta lnRE_{t-j}^-\right)$$
$$+ \sum_{j}^{b} \left(\alpha_i^+ \Delta lnGDP_{t-j}^+ + \alpha_i^- \Delta lnGDP_{t-j}^-\right) + \sum_{j}^{b} \left(\alpha_i^+ \Delta lnFDI_{t-j}^+ + \alpha_i^- \Delta lnFDI_{t-j}^-\right) + \varphi_i ECT_{t-1}$$
$$+ \mu_t \quad \mathbf{(9)}$$

In the Eq. 9, φ_i represents error correction term, which also shows the long-run equilibrium speed of adjustment after the shock in the short-run. α_i represents the short-run coefficients, while α_i^+ and α_i^- represents short-run adjustment asymmetries. Similar to ARDL, the bound test is conducted using the F statistic for a joint significance test to determine if there is a co-integration relationship (Pesaran *et al.* 2001) and standard Wald test is conducted to examine short-run symmetry $\alpha = \alpha^+ + \alpha^-$ and long-run symmetry $\gamma = \gamma^+ + \gamma^-$ for OP, GDP, FDI and RE respectively. After confirmation of long-run relationship, the dynamic multiplier effect is assessed, where 1% change in $lnOP_{t-1}^+$, $lnOP_{t-1}^-$, $lnGDP_{t-1}^+$, $lnGDP_{t-1}^-$, $lnFDI_{t-1}^+$ $lnFDI_{t-1}^+$, $lnRE_{t-1}^+$, $lnRE_{t-1}^-$ can be derived from Eq. 10, Eq. 11, Eq. 12 and Eq. 13.

$$L_b^+ = \sum_{i=0}^{b} \frac{\theta CO2_{t+i}}{\theta lnOP_t^+}, L_b^- = \sum_{i=0}^{b} \frac{\theta CO2_{t+i}}{\theta lnOP_t^-} = 1,2,3, \ldots.. Noting\ that\ b \rightarrow \infty, L_b^+ \rightarrow \rho_2^+, L_b^- \rightarrow \rho_3^- \quad \mathbf{(10)}$$
$$L_b^+ = \sum_{i=0}^{b} \frac{\theta CO2_{t+i}}{\theta lnRE_t^+}, L_b^- = \sum_{i=0}^{b} \frac{\theta CO2_{t+i}}{\theta lnRE_t^-} = 1,2,3, \ldots.. Noting\ that\ b \rightarrow \infty, L_b^+ \rightarrow \rho_8^+, L_b^- \rightarrow \rho_9^- \quad \mathbf{(11)}$$
$$L_b^+ = \sum_{i=0}^{b} \frac{\theta CO2_{t+i}}{\theta lnGDP_t^+}, L_b^- = \sum_{i=0}^{b} \frac{\theta CO2_{t+i}}{\theta lnGDP_t^-} = 1,2,3, \ldots.. Noting\ that\ b \rightarrow \infty, L_b^+ \rightarrow \rho_4^+, L_b^- \rightarrow \rho_5^- \quad \mathbf{(12)}$$
$$L_b^+ = \sum_{i=0}^{b} \frac{\theta CO2_{t+i}}{\theta lnFDI_t^+}, L_b^- = \sum_{i=0}^{b} \frac{\theta CO2_{t+i}}{\theta lnFDI_t^-} = 1,2,3, \ldots.. Noting\ that\ b \rightarrow \infty, L_b^+ \rightarrow \rho_6^+, L_b^- \rightarrow \rho_7^- \quad \mathbf{(13)}$$

Based on the estimated dynamic multipliers, shocks affecting the system can be observed, with dynamic adjustment from and to the new equilibrium. The study further tests for short- and long- run symmetric effects through the use of a WALD test statistic. The null form of hypothesis of the test emphatically states that $T_{lnX}^+ = T_{lnX}^-$. In a similar vein, the standard form of Wald test is applied to test for the short run. The null hypothesis emanating from this test is that $\sum_{i=0}^{q-1} \vartheta_{t-i}^{+\prime} = \sum_{i=0}^{q-1} \vartheta_{t-i}^{-\prime}$.

BDS (Brock- Dechert-Scheinkman) test

A number of nonlinearity statistical test were invented to explore the relationships among economic and financial form of time series. These tests comprise the test of Brook (1986), as well as that of Brock-Dechert Scheinkman (1996) respectively. The current study centers on the test of Brock-Dechert-Scheinkman known popularly as the BDS test. It can applied as a recommended test for model misspecification in relation to its high power of statistics in given out information as if a model is linear or correctly specified as associated to an immense variety of other categories of tests. It is used as a test of misspecification that is used to the residuals of a fitted form of linear model such as GARCH (p and q), ARCH (q), or ARMA (p and q) models. The test of BDS can be applied to identify the dependence as well as the presence of omitted form of nonlinear configuration via a null hypothesis test that the data for the series are independently as well as identically distributed (IID) respectively. Henceforth, in a situation where the null hypothesis failed to be rejected, at that juncture the initial linear model would not be rejected. Likewise, in a situation where the null hypothesis happened to be rejected, the fitted form of linear model is said to be mis-specified. The test is characterized by the following statistics with a minimal normal distribution standard.

$$BDS_{\varepsilon,n} = \frac{\sqrt{M\left[C_{\varepsilon,n} - \left(C_{\varepsilon,I}\right)^{n}\right]}}{\sqrt{U_{\varepsilon,n}}} \quad (\mathbf{14})$$

The term $\left[C_{\varepsilon,n} - \left(C_{\varepsilon,I}\right)^{n}\right]$ has an asymptotic form of normal distribution that have mean with zero value as well as variance $U_{\varepsilon,n}$ defined as:

$$U_{\varepsilon,n} = 4\left[K^{n} + 2\sum_{j=1}^{n-1} K^{n-j} C_{\varepsilon}^{2j} + (n-1)^{2} C_{\varepsilon}^{2n} - C_{\varepsilon}^{2n} - n^{2} K C_{\varepsilon}^{2n-2}\right] \quad (\mathbf{15})$$

where, K=$K_{\varepsilon} = \frac{6}{N_n(N_n-1)(N_n-2)} \sum_{i<j<n} h_{i,j,n,\varepsilon}$; $h_{i,j,n,\varepsilon} = \frac{\left[I_{i,j,\varepsilon} I_{j,n,\varepsilon} + I_{i,j,\varepsilon} I_{j,n,\varepsilon} + I_{i,j,\varepsilon} I_{j,n,\varepsilon}\right]}{3}$

The test of BDS is a two tailed form of test and, the null form of hypothesis of the linearity is bound to be rejected when the calculated test statistics is greater than the critical value under the conventional form of significance level. The null hypothesis rejection discloses the existence of nonlinear form of dependence within the data. The formulation of the hypothesis is stated as:

$$H_0: \mathit{The\ series\ are\ dependent\ linearly}$$
$$H_1: \mathit{the\ series\ are\ not\ dependent\ linearly}$$

Henceforth, in a small form of samples that have a distribution which is unusual, the test statistics distribution of the BDS can be different quite from the asymptotic form of normal distribution as well this lead to the erroneous rejection of the independently and identically hypothesis by the test. To reimburse this, the test recommends for bootstrapping addition to the test of BDS statistics. This will give out an accurate form of estimation through the generation of the critical values for the analyzed series in order to get rid of critical values that are asymptotically biased.

Unit Root Tests

The reliability of the time series statistical model hinge on the stationary nature of the data. Time-series are vulnerable to shocks that can cause permanent fluctuation, which leads to inaccurate estimates. So, keeping in mind the significance of stationarity, the variables form of time series are tested using unit root tests for stationarity. Literature made available numerous form of stationarity tests. The current study execute a number of conventional tests of unit root that include the tests of (ADF) Augmented Dickey-Fuller, and the test of ADFGLS (Augmented Dickey-Fuller Generalized Least Square of Elliot, Rothenberg and Stock (1996) as used by Ahmad *et al*. (2015c) and Ahmad *et al*. (2020) respectively. In the same vein, the study examined the stationarity properties of the data via the nonlinear KSS test of unit root proposed by Kapetanios *et al.* (2003) that could be applied to determine if the time series data follow the trend of nonlinear. The behavior of the test can be apprehended via the model that accommodate the autoregressive parameter to smoothly vary in a two form of regime model under which the change of the regime is smooth fairly than abrupt. In addition, the nonlinearity of the data generation method in such a model indicates symmetric changes for variations above as well as below the level of equilibrium. The model is termed as ESTAR (exponential star model), Kapetanios *et al.* (2003) postulated the model of ESTAR as follows:

$$\Delta Y_t = \emptyset Y_{t=1} + \delta Y_{t=1}[(1 - \exp(-\theta Y_{t=d}^{2})] + \mu_t \quad \mathbf{(16)}$$

where, θ termed as a determinant parameter of the degree of mean relapse. The term of the stochastic μ_t is assumed to be distributed normally, with constant form of variance as well as zero mean. In equation 16 the hypothesis states that $H_0: unit\ root\ (\theta = 0) as\ well\ H_1: Non-linear\ stationary\ (\theta > 0)$. As the test based on equation 16 is not feasibly given mathematically that δ is not recognized beneath the null form of hypothesis. KSS test suggests the use of Taylor first order approximation for the estimate of ESTAR model under null through the re-estimating the regression model below while controlling the occurrence of serial correlation while adding lagged expressions:

$$\Delta Y_t = \gamma Y_{t-1}^3 + \sum_{t-1}^{j} \sigma_1 \Delta Y_{t-1} + error_t \qquad \textbf{(17)}$$

In equation 17, the form of the null hypothesis states that $\gamma = 0$ and the alternate form of the hypothesis is that $\gamma < 0$. In order to estimate the nonlinear model of KSS of equation 17, it is put forward that the study apply the OLS (Ordinary Least Square) techniques, while conducting the test of unit root, the test statistic $t_{NL} = \frac{\hat{\gamma}}{s} S.e.(\hat{\gamma})$. The KSS test offer the critical values at 1%, 5% as well as 10% level of significance to be applied in undertaking the test.

RESULTS AND DISCUSSION

This part of the study presents the empirical findings from the aforementioned empirical techniques. The study begins with the descriptive statistics and the correlation analysis of the variables of study and Table1 presents the statistical features of the variables employed. It is detected that on average lnFDI is 20.771 which is large fairly with the value of standard deviation that is 1.203 compared to lnRE (M=4.457, SD= 0.014), lnOP (M=3.390, SD = 0.650), lnGDP (M = 1.473, SD = 0.650) and $lnCO_2$ (M = -0.462, SD = 0.320). In general, for the concern series to be distributed normally or symmetric, the actual value of the kurtosis and skewness should be three and zero respectively. The outcome from Table 1 per the kurtosis and skewness gives out the inference that none among the series observed followed a distribution that is normal. Precisely, the values of the skewness reveals that, the series (lnCO, lnRE and lnGDP) are skewed negatively. This justify the fact that the series are flattering towards the left compared to a distribution that is normal whereas lnOP and lnFDI are positively skewed, meaning flattering towards the right. Therefore, this signifies the fact that, majority of the series are spreading to the negative edge for the first three distribution. In addition, from the result of kurtosis, the distribution of lnRE is mesokurtic approximately (kurtosis value approximately 3), whereas the distribution of lnGDP is leptokurtic (kurosis value that is above 3). Hence, lnCO, lnOP and lnFDI have a kurosis value that is less than the normal value signifying that the curve of the kurtosis this distribution is said to be platykurtic.

Table 1. Descriptive statistic and correlation matrix

	$lnCO_2$	**lnOP**	**lnRE**	**LnGDP**	**lnFDI**
Mean	-0.462557	3.390232	4.457415	1.473042	20.77150
Median	-0.363036	3.259428	4.459868	1.677129	20.49914
Maximum	0.009908	4.595726	4.486745	3.219165	22.90268
Minimum	-1.164707	2.503892	4.418311	-2.797779	19.05813
Std. Dev.	0.320999	0.650352	0.014141	0.989443	1.203992
Skewness	-0.874344	0.462291	-0.492019	-2.043465	0.337815
Kurtosis	2.616579	1.964361	3.094019	9.042360	1.757286
Jarque-Bera	6.676918	4.015418	2.035770	110.8606	4.168366
Sum	-23.12783	169.5116	222.8708	73.65210	1038.575
Sum Sq. Dev.	5.048979	20.72495	0.009798	47.97088	71.03029
Observations	50	50	50	50	50
$lnCO_2$	1.000000				
	-----				
lnOP		1.000000			
	0.238037	-----			
lnRE			1.000000		
	-0.313427	0.184590	-----		
lnGDP				1.000000	
	0.138097	0.041655	-0.332621	-----	
lnFDI					1.000000
	0.020138	0.846234	0.144843	0.027403	-----

After confirming that none of the skewness and kurtosis values for the aforementioned variables meet up the normality conditions, the study conclude that the series are not symmetric. The effect of this outcome is that the asymmetric approach may be more fitting to describe the relationships among the variables. Similarly, in the lower part of Table 1, the correlation findings show the degree of interaction between the variables. We now aimed to define the order of integration of both variables under analysis, considering the descriptions (Table 2). We performed a variety of traditional root unit tests for this purpose including ADF (Augmented Dickey-Fuller), as well as ADFGLS (Augmented Dickey-Fuller Generalized Least Squares). We also tested, in addition, whether such a variables are integrated through KSS non-linear test of unit root. The results in Table 2 reveals that all the concern variables are bound to be stationary at I (0) as well as I(1), while no any other variables that a found to be integrated of order two I(2), meaning that all the applied variables are integrated.

Table 2. Unit Root Test results.

VARIABLES	DF-GLS	ADF	KPSS
lnCO_2	-2.105	-2.529	-1.823
lnOP	-2.164	-2.142	-2.525
lnRE	-3.046	-3.152	-1.281
lnGDP	-5.395***	-5.960***	-4.415***
lnFDI	-1.957	-1.785	-1.724
ΔlnCO_2	-6.122***	-7.216***	-3.963**
ΔlnOP	-6.549***	-6.436***	-3.803**
ΔlnRE	-7.363***	-7.207***	-5.004***
ΔlnGDP	-11.456***	-7.753***	-3.749**
ΔlnFDI	-11.562***	-11.493***	-5.939***

Note: ***, ** and * represent levels of significance at 1%, 5% and 10% level, respectively.

After confirming the stationarity properties of the variables, then the study proceeds and determines if the variables have a long run relationship and have a co-integration relationship. The study inspects the joint-F statistics as in contrast to the critical values made available by Pesaran *et al.* (2001). As shown by the results in Table 3, the F-statistics calculated values were greater than upper and lower bound critical values of Narayan (2005) table and the outcomes were found to be significant statistically at 1% significance level. The study concludes that there exist an asymmetric co-integration association among the concern variables of the study. In addition, the results of the BDS test were revealed in Table 3 which propose the null hypothesis rejection that the series are dependent linearly. The test endorse that all the included variables are not linear as the BDS test statistics happened to be statistically significance for all the embedded dimensions. It made available indication of strong form of nonlinearity for all available large dimensions.

Table 3. BDS Test Statistics results.

Series	D2	D3	D4	D5	D6
lnCO_2	0.135736*	0.225088*	0.275831*	0.298145*	0.296256*
lnOP	0.151880*	0.248282*	0.318372*	0.368444*	0.395103*
lnRE	0.088296*	0.139820*	0.151548*	0.160059*	0.154195*
lnGDP	0.043686*	0.059687*	0.047096*	0.025371*	0.034871*
lnFDI	0.144572*	0.253321*	0.310382*	0.338942*	0.361964*

Note: ***, ** and * represent levels of significance at 1%, 5% and 10%, respectively.

Similarly, the symmetry results on the basis of Wald test (Table 4), specify that in the long run, ln OP and ln RE are significant statistically at 1% and 5% respectively, indicating that the symmetry assumptions are not hold. Henceforth there is indication of asymmetry in the connection between ln OP and ln CO as well as ln RE and ln CO respectively. Likewise, in the short run, the symmetry assumption cannot be hold in the case of ln OP, ln GDP and ln RE revealing an asymmetric form of relationship between these variables and the quality of environment. In general the results made an indication that applying a symmetric form of model to examine the nature of relationship between the variables apprehended in the model might be possible to give out misspecification.

Table 4. Non-Linear ARDL Wald test.

Explanatory Variables	Long run results		Short run Results	
	F-Stat.	Prob.	F-Stat	Prob.
Ln OP	12.508	0.000	4.303	0.021
Ln RE	10.826	0.000	25.016	0.000
Ln GDP	1.302	0.284	8.607	0.013
Ln FDI	0.176	0.839	1.510	0.220

The major concern of this study is about the effect of crude oil price changes on the quality of environment in Nigeria. Therefore, Table 5 reveals the results regarding the asymmetries between the crude oil price changes and the amount of carbon dioxide emissions, in both the short- and long- run. The long run coefficients reveal that partial sum of positive changes in crude oil price (ln OP-pos.) has a negative and significant effect on the amount of carbon emissions in Nigeria. This infers that a 1% increment in ln OP-pos. would lead to a 0.122% decline in the amount of carbon dioxide emissions in the long run. The outcome of the result is in line with Ullah *et al.* (2020) who noted that positive form of changes in crude oil price lead to a decline in the amount of carbon emissions and hence improve the quality of environment. This result is also in line with Boufateh (2019) that recognized that shocks in oil price affect the amount of carbon emissions in China and USA differently. The findings advocates that positive form of crude oil price change are transformed to higher quality of environment. This finding may be accredited to the clean and green form of environmental-friendly sources of energy. One of several basic justifications is that as oil prices rise in the economy, households as well as industries use a smaller amount of energy resources. The findings suggest also that higher prices of oil replicates a higher degree of the scarcity of energy that stimulates the substitution of cheaper and cleaner form of alternative sources of energy, then subsequently the quality of environment enhances. In a similar vein, the findings also revealed that the negative partial sum of crude oil price change has a positive and significant effect on the amount of carbon emissions in Nigeria. It means that a 1% of ln OP-neg. would lead to an escalation on the amount of carbon emissions by 0.240% respectively. Henceforth, in just the last few years, the steadfastly lower prices of the crude oil have not only pull down the burden inflicting on the balance of payments, but also correspondingly help out to fuel economic growth at the cost of deteriorating the quality of the environment. The result concludes that negative oil price shocks enhance economic activities but keep the environments unclean. This result is in support of the finding of Maji *et al.* (2017) who put forward that environmental deterioration enlarges by the fall in the price of oil. The use of cleaner energy sources to mitigate carbon emissions during lower oil price can be a useful policy measure to reduce environmental pollution during lower oil prices. Since the issue of environment have become a global problem, and lower price of energy can lead to deterioration of the environment, the use of cleaner energy sources to mitigate carbon emissions during lower oil price can be a useful policy measure to reduce environmental pollution during lower oil prices. Similarly in the short run, the coefficient of the positive component of crude oil price change revealed a positive and statistically significant effect on the amount of carbon emissions at 1% level of significance. It means that in the short run a 1% elevation in Dln OP-pos. leads to an upraised amount of CO_2 emissions (ln CO), meaning that positive asymmetric effect deteriorate the quality of environment through the escalation of carbon emissions in the short run. On the contrary, the negative component of the crude oil price changes that is related negatively with the amount of carbon emissions and the relationship is significant statistically at 1% level of significance. It means that 1% elevation in Dln OP-neg. leads to a decline in the amount of CO_2 emissions (ln CO). This result implies that negative component of oil price changes improve the quality of environment through the carbon emission decline. The ECT (Error Corrections Term) coefficient necessitates that the speed of adjustment towards the state of long run equilibrium is 53%. The study performed further sensitivity or diagnostic tests on the data of time series for policy inferences as well as robust empirical estimations (Table 4) respectively. As stated by the estimated form of the model, all the results of the diagnostic tests reveal that the null hypothesis failed to be rejected for statement of no serial correlation, heteroscedasticity and the normality functional form of the model. The value of the NARDL model R-square (0.6443) reveals that ln OP, ln GDP, ln RE and ln FDI2 explain fully the environmental quality model for both the long and short run in a single form of equation. In addition, Figs. 1-2 reveal that the CUSUMSQ (cumulative sum of square) and CUSUM (cumulative sum) of the recursive residual test statistics are within the 5% critical value of the significance level. Therefore, signs of the series' graphical plots are stable in the model of error correction. In the estimated model, the Durbin Watson test statistics also verify the exclusion of autocorrelation.

Table 5. NARDL Model Estimation results.

Variables	Long run Estimate Coefficients	t-Statistics	Probability
LN OP_POS	0.277	1.313	0.197
LN OP_NEG	-0.136	-0.512	0.611
LN RE_POS	-13.926	-3.472	0.001
LN RE_NEG	-15.311	-4.203	0.000
LN GDP_POS	-0.071	-0.997	0.325
LN GDP_NEG	0.053	0.833	0.410
LN FDI2_POS	0.028	0.142	0.887
LN FDI2_NEG	0.051	0.522	0.604
C	0.060	2.494	0.017
	Short run Estimate		
D(LN OP_POS)	0.482	2.833	0.007
D(LN OP_NEG)	-0.072	-0.498	0.621
D(LN RE_POS)	-7.384	-3.034	0.004
D(LN RE_NEG)	-8.119	-4.421	0.000
D(LN GDP_POS)	0.008	0.235	0.814
D(LN GDP_NEG)	0.028	0.794	0.432
D(LN FDI_POS)	-0.142	-1.929	0.061
D(LN FDI_NEG)	0.027	0.501	0.619
Coint. Eq. (-1)	-0.530	-4.535	0.000

Table 6. Diagnostic test results.

Test	*T-Statistics*	*Probability*
χ^2Arch	0.847	0.362
χ^2B-G	0.411	0.666
χ^2J-B	2.344	0.309
R-squared	0.644	
Adjusted R-squared	0.611	
Durbin-Watson stat	2.131	

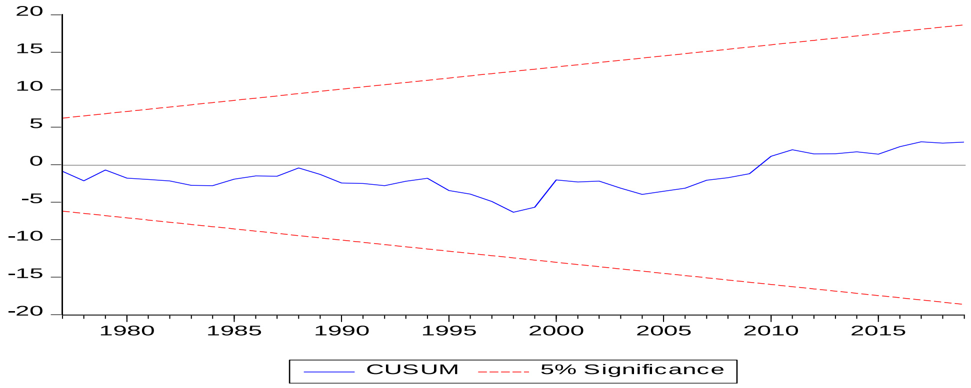

Fig. 1. Cumulative sum of recursive residuals.

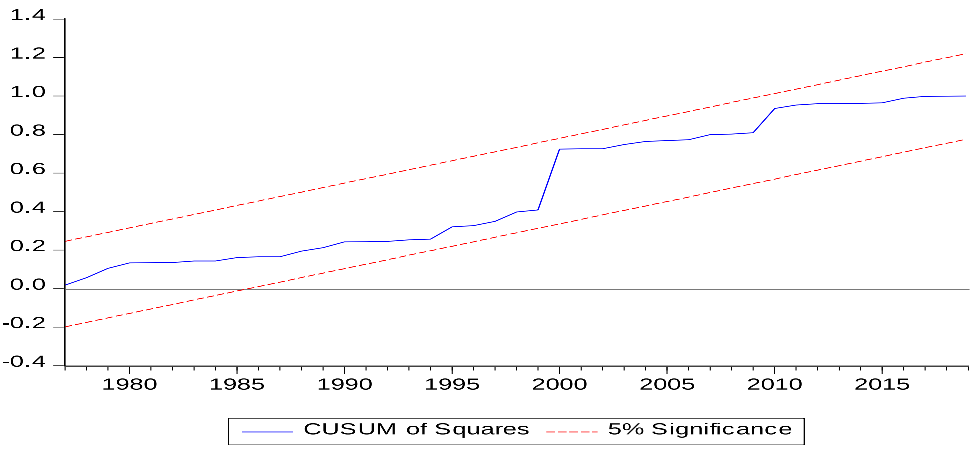

Fig. 2. Cumulative sum of squares of recursive residuals.

CONCLUSION AND POLICY RECOMMENDATION

The acknowledgement that changes in the price of oil have adverse environmental consequences seems to have become a global issue. Therefore, the major objective of conducting this study was to examine the asymmetric effect of oil price on the quality of environment in Nigeria through the use of annual form of time series data ranging from 1981 to 2019. Based on the previous studies, changes in oil price and carbon emissions is applied in the asymmetric techniques and has great influence in environmental and energy policies. The results of non-linear ARDL model showed that in the long run partial sum of positive changes in crude oil price has a negative and significant effect on the amount of carbon emissions in Nigeria, meaning that positive elevation in the price of oil leads to decline in carbon emissions and hence improve the quality of environment. On the other hand, the negative partial sum of crude oil price change has a positive and significant effect on the amount of carbon emissions in Nigeria. It means that negative increase in the price of oil leads to carbon emission escalation and hence deteriorate the quality of environment in the long run. This could be justified on the ground that the prices of other oil-related goods are also dropping during the lower oil prices. The decline in oil-related commodity prices subsequently enhances the purchasing power of energy-related goods by the buyer. Subsequently, the rise in demand of energy-related goods such as crude oil and natural gas raises carbon emissions and thus decreases the quality of the environment. Premised on these results, the study recommend for more subsidy on clean energy as well as formulation of a favorable form of policies for the implementation of renewable form of energy such as solar by residential consumers and industries particularly during the period of low crude oil price. This would promote the use of alternative sources of energy, such as renewable energy sources, in an effective and creative manner that would thus reduce the environmental issues. The income level was also strongly linked to the environmental performance measure. Its consequence is that environmental protection is not taken into account in the process of economic development and growth. However, in order for the economy to achieve its aim of higher economic growth, the inclusion of sustainability in the process of economic growth is essential. In addition, the current study proposes that degradation of the environment should be viewed as a leak from the level of production. So that, its effects can be subtracted in order to achieve the real performance of the economy. This would go a long way toward guaranteeing that, at the cost of environmental sustainability, the achievement of economic growth is not accomplished.

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Bibliographic information of this paper for citing:
Jakada, AH, Ibrahim, BA, Danmaraya, IA, Fagge, AM, Yola, AT 2023, Asymmetric effect of crude oil price on the quality of environment in Nigeria: An application of non-linear ARDL. Caspian Journal of Environmental Sciences, 21: 493-507.