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# DOES TRADE OPENNESS EXACERBATE CARBON DIOXIDE EMISSION? : EVIDENCE FROM NIGERIA

Oyeranti, Olugboyega Alabi

Department of Economics, University of Ibadan, Ibadan, Nigeria

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## ABSTRACT

High emissions of greenhouse gases components have today become a world phenomenon. In Africa, Nigeria is the second-highest emitter of greenhouse gases (GHGs), after South Africa. Carbon dioxide ($CO_2$) emissions constitute the largest source of GHGs; hence it has become a widely discussed and researched subject. This, however, is a negative unintended consequence that has emanated from the growing interdependence of the world economies. One of the major instruments of achieving a global world which also stood as a major determinant of economic growth is trade openness. This paper, therefore, examines the impact and the relationship between trade openness on $CO_2$ emissions in Nigeria. The method employed to achieve the stated objectives is the Autoregressive Distributed Lag (ARDL) cointegration technique, using the annual time series data sourced from the World Bank Development Indicator, 2020, for periods 1980 to 2019. The major findings from the study show that there is an insignificant positive relationship between trade openness on $CO_2$ emissions. Also, there exists an increasing trend of $CO_2$ emissions in Nigeria, while that of trade openness shows fluctuation for the periodic review and this depicts a high vulnerability to external shocks. With these findings, the study recommends that the Nigerian government should be more proactive and tenacious in implementing environmental and trade policies in favour of a cleaner economy. Also, the Nigerian government must become keener toward attracting only investors that will produce clean goods and not compromise on the necessity to improve environmental quality.

**Keywords:** Carbon dioxide ($CO_2$) emissions, trade openness, greenhouse gases (GHGs), Autoregressive Distributed Lag (ARDL), environmental degradation.

## 1. Introduction

Nigeria is an emerging open market economy, with crude oil as its major export. According to World Bank (2020), the nation recorded a Gross Domestic Product (GDP) of $448.12 billion and

  

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$2,229.859 as GDP per capita in 2019. Also, in the same year, her exports accounted for 14.22% of the GDP, while 19.8% of it was the share of imports. The oil sector accounts for approximately 55% of the nation's export and 40% of oil revenue used to finance its budget due to high dependence on crude oil revenue (Central Bank of Nigeria, 2021). According to United States Energy Information Administration (2016), Nigeria is the world's fourth-largest exporter of liquefied natural gas (LNG), but the natural gas sector has been hampered by a lack of infrastructure that would allow natural gas to be safely commercialized. As a result, experiencing natural gas flaring has made Nigeria the world's seventh-largest gas flaring country with 7.3 billion cubic meters flared, contributing to environmental degradation (The World Bank Press, 2018). In the same vein, one of the main components of greenhouse gas (GHG) which is Carbon dioxide ($CO_2$) emissions have increased in the last few decades (Dong *et al.*, 2018).

Individuals are emitting so much $CO_2$ into the air that the report of emissions over the past fifty million years will be set in the middle of this century. Globally, the $CO_2$ emissions rose from 21,571.7 million metric tons in 1990 to 33,472.0 million metric tons in 2014, indicating an average growth rate of about 1.8% annually (International Energy Agency, 2019). In 2015, Nigeria is the world's 17th biggest emitter of greenhouse gases and the second highest in Africa after South Africa. Thus, the notion that environmental degradation is mostly dominant in industrialized countries and not of unindustrialized countries is fast becoming a myth and no more practically valid. High emissions of GHGs are affecting the industrialized and unindustrialized countries across the world through globalisation. One of the main channels of globalisation and technological transfers is trade openness (Tachie *et al*, 2020). According to Zamil *et al* (2019), trade openness is one of the most influential determinants of the economic growth of a country, and due to its widespread effects, countries tend to focus on improving it to achieve better financial results. With many countries being a part of the World Trade Organization (WTO), a dominant sentiment across the global economy is to focus on more relaxed and even free trade policies.

Trade openness appears to provide many benefits to both the host and home countries. It also appears to have some negative consequences that must be considered (Rahman, 2013). Governments are pushed to cut industrial costs by neglecting or sacrificing the environment as trade liberalization increases (Antweiler *et al.*, 2001). Now, global warming has become a major global concern and has reignited debates over the trade's environmental effects. These developments align with the Environmental Kuznets Curve (EKC) hypothesis (Shahbaz *et al.*, 2021). The world needs nature for survival and sustainability. On the contrary, nature does not need us. This acknowledgement brought about the Climate Change Advocacy by the United Nations Convention together with the 2015 Paris Agreement. The Agreement requires countries to reduce the temperature rise to below 1.5C to attain minimum greenhouse gas emission in

  

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2020. Also, one of the goals of the United Nations Sustainable Development Goals (SDGs) by the year 2030 is to have access to clean and modern energy. Recently, most West African countries are promoting the consumption of clean energy like wind, solar, biomass, geothermal, and hydro-power (Owusu *et al.*, 2016).

This study investigates the impact of trade openness on $CO_2$ emissions in Nigeria. This study is important as environmental challenges linked with climate change have become issues of great concern to policymakers and environmental experts. Stakeholders are interested in the factors that degrade the environment. This concern has earned the interest and attention of scholars and policymakers all over the world. The argument used to be centred on the economic growth effect on the environment in isolation, but more recently, studies have looked inward to interrogate how trade openness affects the environment. Empirically, results are mixed and inconclusive to offer policy recommendations that can be applied mainly due to methodologies and indicators of environmental degradation employed. Some studies (Moyo & Khobai, 2018; Tachie *et al*, 2020; Chen *et al*, 2021) found a significant positive impact of trade openness on $CO_2$ emissions, giving support to the pollution haven hypothesis. Whereas other studies recorded evidence supporting the optimistic view that trade openness is good for the environment (Antweiler *et al.*, 2001; Shahzada *et al*. 2017; Wang & Zhang, 2021). While another stream of empirical studies failed to identify any significant relationship between trade and pollution (Rahman, 2013; Kander & Lindmark, 2006).

Based on these controversial findings, one cannot draw any type of generalizations of the impact of trade on the environment. Hence, this study contributes to the growing literature on the impact of trade openness on $CO_2$ emissions using empirical evidence from Nigeria. The choice of Nigeria was necessitated as the country is an import-dependent nation. This study could aid in policy direction for emission reduction in the country and Africa at large being the second-largest emitter in the continent. Given that the data are an annual time series, this study uses the Auto Regressive Distributed Lag (ARDL) model developed by Pesaran & Yongcheol (1999). Data were sourced from the World Bank Development Indicator 2020 and were restricted to the period 1980–2019 basically due to data availability. Following the introductory segment, this study is organized into five parts; Part two provides the review of related studies on trade openness and $CO_2$ emissions. Part three presents the theoretical framework of the study. Part four is devoted to methodology utilised for the study while the results and the discussion are presented in Part five. The conclusion and policy implications of the study are presented in Part six.

## 2. Literature Review

Zamil *et al*, (2019) investigated the effect of trade openness on $CO_2$ emissions in Oman, the study suggested that both Gross Domestic Product (GDP) per capita and trade openness had a

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positive impact on $CO_2$ emissions. Thus, consequently, a higher GDP per capita and trade openness destructed the environment. In their study, Tachie *et al*, (2020) found out that trade openness positively impacts $CO_2$ emissions in EU-18, also, energy consumption and urbanization have a positive relationship with emissions. Hence, pollution halo and pollution haven hypothesis were confirmed for the countries. Ansari *et al*, (2020) found out that an increase in trade does granger cause $CO_2$ emissions in the long run. Also, there existed a long-run relationship between $CO_2$ emissions and its determinants in the USA, Canada, Iran, Saudi Arabia, UK, Australia, Italy, France, and Spain, while energy consumption was the main determinant of carbon dioxide ($CO_2$) emissions in the long run.

Furthermore, Chen *et al*, (2021) argued that the improvement in trade openness has a significantly positive effect on $CO_2$ emissions, and it also showed that the impact varied with different levels of $CO_2$ emissions. The study concluded that the indirect effect of trade openness on $CO_2$ emissions via the economic effect was positive, while the indirect effect via the energy substitution and the technical effect was negative. Balin *et al*. (2018) found that the inverted U-shape relationship between economic growth and $CO_2$ emissions existed, trade openness has a positive impact on $CO_2$ emissions, foreign direct investment and energy consumption are positively related to $CO_2$ emissions. Exploring developing countries, Van Tran (2020) concluded that trade openness might be harmful to the environment while confirming the existence of an environmental Kuznets curve hypothesis. The study confirmed a positive relationship between trade openness and carbon dioxide emissions, nitrous oxide emissions. In addition, Ayobamiji & Kalmaz (2020), showed that there was a unidirectional causal relationship between trade liberalization and environmental degradation where causality was running from trade liberalization to environmental degradation. The study concluded that trade liberalization has a positive effect on environmental degradation.

On the contrary, Kohler (2013) found that trade openness improved environmental quality as it negatively affected carbon emissions in South Africa. Similarly, Yu & Chen (2017) found that trade volume had a negative effect on emissions for both China and South Korea. The study further revealed that trade diversion between both countries significantly reduced China's $CO_2$ emissions between 2000 and 2010. Further, Murshed (2020) found that ICT-trade had a negative impact on carbon dioxide emissions because it increased renewable energy consumption, enhanced renewable energy shares, reduced the intensity of energy use and facilitated the adoption of cleaner cooking fuels. Moreover, ICT trade also indirectly mitigated carbon dioxide emissions through boosting renewable energy consumption levels, improving energy efficiencies, and enhancing cleaner cooking fuel access. Zhang (2015) suggested that trade in intermediate products mitigated the negative effect of energy consumption on the environment in East Asia. Moreover, when compared with trade in final goods, it was confirmed that final goods

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trade intensity further reduced the adverse effect of energy use on environmental quality among the East Asian economies.

Using 11 ECOWAS countries as a case study, Keho (2016) found out that trade positively affected CO2 emissions, thereby, causing degradation of air quality in some ECOWAS countries while it had an inverse relationship with the environment in other countries. Whereas for 55 middle-income countries, Lv & Xu (2019) concluded that trade openness harmed the environment in the short run but had a positive effect in the long run. Moyo & Khobai (2018) revealed that financial development negatively affects environmental degradation in both the short and long run, and real income per capita had a positive and significant effect on environmental degradation in both the short and long run. Mutascu (2018) found that no co-movement at high frequency between trade openness and gas emissions, confirming the neutral hypothesis in short term. The $CO_2$ emissions positively drove the trade openness at medium frequency. Hence, in the medium term, the inexistence of strong environmental rules stimulated international trade, especially the exports obtained based on pollutant capacities. Curiously, the trade openness positively ran the gas emissions at a low frequency. With evidence from 182 countries, the study of Wang & Zhang (2021) found that trade openness had a negative impact on carbon emissions in high-income and upper-middle-income countries while having no significant impact on carbon emissions of lower-middle-income countries; meanwhile, for low-income countries, trade openness positively impacted carbon emissions. Table 1 below presents summary of the review of the literature on the relationship between trade openness and carbon emissions.

**Table 1: Summary of Literature Reviewed**

| Author/Year | Theory/Method | Findings |
|---|---|---|
| **Positive Relationship** | | |
| Zamil *et al.* (2019) | ARDL | Both GDP per capita and trade openness seem to have a positive impact on $CO_2$ emissions |
| Tachie *et al*. (2020) | EKC/Panel Cointegration | Trade openness increased $CO_2$ emissions in EU-18. |
| Ansari *et al.* (2020) | VECM | An increase in trade does Granger cause $CO_2$ emissions in the long run. |
| Chen *et al.* (2021) | Panel quantile regression | The improvement in trade openness had a significantly positive effect on $CO_2$ emissions. Also, the impact varies with different levels of $CO_2$ emissions. |

  

| | | |
|---|---|---|
| Van Tran (2020) | Two-step generalized method of moment | Trade openness may be harmful to the environment while confirming the existence of an environmental Kuznets curve hypothesis. |
| Balin *et al*. (2018) | ARDL, ECM | Trade openness had a positive impact on $CO_2$ emissions. Also, foreign direct investment and energy consumption were positively related to $CO_2$ emissions. |
| Ayobamiji & Kalmaz (2020) | ARDL, FMOLS and DOLS | Both in the long and short run, economic growth tends to affect $CO_2$ emissions positively. |
| **Negative Relationship** | | |
| Murshed (2020) | Heckscher (1919) and Ohlin (1933) Theory | ICT trade had an indirect relation with $CO_2$ emission. |
| Kohler (2013) | Environmental Kuznets curve/Granger causality tests | Higher levels of trade reduced $CO_2$ emissions |
| Yu & Chen (2017) | Input–output model | Trade had a negative effect on $CO_2$ emissions for both China and South Korea |
| Zang (2015) | Panel fixed-effect regression | Trade in final goods intensity further reduced the adverse effect of energy use on environmental quality among the East Asian economies. |
| **Mixed Relationship** | | |
| Lv & Xu (2018) | STIRPAT model (Dietz and Rosa 1997)/ Pooled Mean Group | Trade openness had a positive effect on the environment in the short run, but a harmful effect in the long run. |
| Mutascu (2018) | Wavelet tools | No co-movement at high frequency between trade openness and gas emissions. The $CO_2$ emissions positively drove trade openness at medium frequency. the trade openness positively ran the gas emissions at low frequency. |
| Wang & Zhang (2021) | OLS and FMOLS | Trade openness decreased carbon emissions in high-income and upper-middle-income countries while having no significant impact on carbon emissions of lower-middle-income countries; even worse, for low-income countries, trade |

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| | | |
|---|---|---|
| | | openness increased carbon emissions. |
| Moyo & Khobai (2018) | ARDL-bounds test approach & the Pooled Mean Group (PMG) model | Real income per capita had a positive and significant effect on environmental degradation in both the short and long run |
| Keho (2016) | Co-integration; Bounds Test, Granger Causality test | Trade cause's degradation of air quality in some countries while it is compatible with environmental improvements in other countries. |

Source: Author's compilation

## 3. Theoretical Framework

Studies have illustrated that the theoretical linkage between trade openness and environment is ambiguous. However, there are two widely accepted theories (Environmental Kuznets Curve Hypothesis & Pollution Haven Hypothesis of which Pollution Haven Hypothesis is the more recognized. The Pollution Haven Hypothesis developed by Copeland & Taylor (2004) explains the influence of trade on the environment. The theory established that free trade cooperation moves manufacturing of pollution-intensive commodities to counties with low standard environmental policies. This would result in the countries with less stringent environmental policies becoming a haven for the most polluting firms and industries in the world (Mutascu, 2018). Consequently, countries with strict environmental policies are expected to gain as regards environmental conditions from trade while less advanced nations which are mostly with less stringent environmental policies suffer severe environmental degradation (Shahzada *et al.*, 2017). Using the Pollution Haven Hypothesis, Millimet & Roy (2016) found a strong negative relationship between environmental policies and foreign direct investment, especially in industries that are tagged "pollution-intensive".

Developed countries have an edge in the production of pollution-intensive commodities, thus, the supply may be shifted to developing nations due to trade liberalization. However, through trade liberalization, the transfer of environmentally friendly technologies and energy-efficient production techniques between countries could lead to lower greenhouse gas (GHG) emissions, specifically CO2 emissions. Therefore, classifying a country as a pollution haven depends on the above-mentioned features, thus, the total effect of international trade on pollution is therefore obscure. As such, following previous studies in the literature (Shahzad et al., 2017; Tachie et al., 2020; Dauda et al., 2021), this study ratifies the Pollution Haven Hypothesis as an appropriate theory to investigate the impact of trade openness on CO2 emissions in Nigeria.

  

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## 4. Methodology

### Model Specification

Theoretically and empirically, studies have established the linkages between trade and the environment (Keho, 2016; Balin *et al*, 2017; Zamil *et al*, 2019). This study evaluated the model specified below:

$$LCO_{2_t} = \beta_0 + \beta_1 OPENNESS_t + \beta_2 LEC_t + \beta_3 LFDI_t + \beta_4 LGDPPC_t + \varepsilon_t \ldots\ldots\ldots (1)$$

Where,

$LCO_2$ = Log of $CO_2$ emissions measured in metric tons per capita

OPENNESS = Trade openness

LEC = Log of Energy consumption measured in kg of oil equivalent per capita

LFDI = Log of Foreign direct investments net inflows in US$

LGDPPC = Log of Gross Domestic Product per capita measured in current US$

ε= error term

### Data Description

From the model specified above, $LCO_{2_t}$ is the log of $CO_2$ emissions measured in metric tons per capita; it is the proxy for the environmental quality. $LEC_t$ is the log of energy consumption in Nigeria for the period of 1980-2019 in Nigeria; it is measured as the kg of oil equivalent per capita. $LGDPPC_t$ is the log of gross domestic product per capita as the proxy for economic growth in Nigeria. $LFDI_t$ is the log of foreign direct investment into Nigeria for the period being studied. It is measured as the sum of equity capital, reinvestment of earnings, and other capital in US dollars. $OPENNESS_t$ is the proxy for trade openness; it is calculated as the sum of exports and imports as a share of GDP. It is derived using the following approach:

$$OPENNESS_t = \frac{X_t + M_t}{GDP_t} \times 100$$

Where; $X_t + M_t$ is the total trade of Nigeria including the export ($X_t$) and import ($M_t$) and $GDP_t$ is the gross domestic product of Nigeria for the time being investigated.

### The ARDL Modelling Technique

  

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This study employed the ARDL method, a time-series approach proposed by Pesaran & Yongcheol (1999) to investigate the impact of trade openness on $CO_2$ emissions in Nigeria. ARDL co-integration model has different advantages as compared to other co-integration techniques. The method was based on the ordinary least squares (OLS) estimation of a conditional unrestricted error correction model (UECM) for cointegration analysis. It was used to test for the existence of a long-run relationship and estimate both the long-run and short-run coefficients of the study. According to Pesaran *et al.* (2001), the ARDL model can be specified as:

$$y_{it} = \alpha_0 + \lambda_i y_{it-1} + \sum_{p=1}^{k} \beta_i(L, p_i) x_{it} + \gamma' k_t + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$t = 1 \ldots \ldots, n$$

where $y_{it}$ is the dependent variables, $\propto_0$ is the constant, $x_{it}$ are the independent variables, L is the lag operator and is the $k \times 1$vector of deterministic variables that captures constant, time trends and other explanatory variables with fixed lags.

The unrestricted Error Correction Model form of the selected ARDL model can be derived by rearrangement of Eq. 2 with respect to the lagged levels and first difference of $x_{1t}$,$x_{2t}$,…,$x_{rt}$ as follows:

$$Dy_t = \alpha_0 + \varpi_{yx} z_{t-1} + \sum_{i=1}^{q-1} \delta_i Dy_{t-i} + \sum_{i=1}^{q-1} \delta_i Dx_{t-i} + \gamma_t w_t + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where D is the first difference operator, the coefficient of $\delta_i$ is expressing the short run dynamics of the model's convergence to equilibrium and $z_t = (y_t', x_t')$.

According to Pesaran *et al.* (2001), equation (1) can be expressed in the unrestricted form of the ARDL model as presented below:

$$D(LCO2)_t = \alpha_0 + \sum_{i=1}^{m1} \alpha_{1i} D(LCO2)_{t-1} + \sum_{i=0}^{m2} \alpha_2 D(OPENNESS)_{t-i} + \sum_{i=0}^{m3} \alpha_3 D(LEC)_{t-i} + \sum_{i=0}^{m4} \alpha_4 D(LGDPPC)_{t-i} + \lambda_1 (LCO2)_{t-1} + \lambda_2 (OPENNESS)_{t-1} + \lambda_3 (LEC)_{t-1} + \lambda_4 (LGDPPC)_{t-1} + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$\alpha_1$,$\alpha_2$, $\alpha_3$,…,$\alpha_4$ are short run parameters while $\lambda_1$, $\lambda_2$, $\lambda_3$,..,$\lambda_4$ are long run parameters. The ARDL framework allows the Bounds test to swiftly determine the cointegrating relation in small sample cases (Tang, 2003).

This technique was appropriate and flexible to any explanatory order of integration, either I(0) or I(1) or mutually cointegrated while the endogenous variable was expected to be I(1). It also allowed for many choices such as decisions with respect to the number of endogenous and explanatory variables. The technique allowed several optimal lags with different combinations

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for different variables as well as capturing short run and long run coefficients independently. This modelling technique has been adopted due to several advantages: the model showed that after appropriate augmentation of the order of the ADRL model, the OLS estimators of the short run parameters were $\sqrt{T}$-consistent with the asymptotically singular covariance matrix; the estimators of the long run coefficients of the ARDL are very reliable; valid inferences on the long run parameters can be determined by employing the standard normal asymptotic theory; the technique yielded consistent estimates of the long run coefficients that are asymptotically normal regardless of the order of integration of the regressors. For this study, 40 annual observations (i.e., 1980-2019) was explored, thus, the utilisation of this approach is very appropriate.

## 5. Result and Discussion

### Descriptive Statistics

Table 2 revealed that the average value of $CO_2$ emissions, OPENNESS, GDPPC, FDI, and EC were 0.637, 32.707, 1297.765, 2434062491, and 19.622, respectively. In addition, the Table indicted that all variables were found not to deviate their actual mean. Furthermore, the Table also revealed the minimum and maximum value of the variables employed for the study; the minimum values are 0.312, 9.136, 270.224, -738870004, and 15.854 for $CO_2$ emissions, OPENNESS, GDPPC, FDI, and EC, respectively; while the maximum value for $CO_2$ emissions, OPENNESS, GDPPC, FDI, and EC are 0.928, 53.278, 3098.986, 8841062051, and 22.845, respectively.

**Table 2: Descriptive Analysis of the Variables Employed**

| Variables | Mean | Std. Deviation | Min | Max |
|---|---|---|---|---|
| $CO_2$ Emissions | 0.637 | 0.179 | 0.312 | 0.928 |
| OPENNESS | 32.707 | 12.511 | 9.136 | 53.278 |
| GDPPC | 1297.765 | 869.191 | 270.224 | 3098.986 |
| FDI | 2434062491 | 236262491 | -738870004 | 8841062051 |
| EC | 19.622 | 1.637 | 15.854 | 22.845 |

Source: Author's Computation using Stata 14

### Unit root test

One important preliminary test that informed whether ARDL bounds test could be performed or not is the unit root test (Tiwari *et al.*, 2013). For this study, two forms of unit root test were carried out, Augment Dickey Fuller (ADF) and Phillips-Perron due to their wide acceptability in the literature (Joshi, 2021). The unit root test was done basically to ensure that the variables were not I(2) stationary or of a higher order than I(1). To avoid spurious results, the times series must

  

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be tested to determine their data generation process. The null hypothesis is a non-stationarity that is performed at 1%, 5% and 10% levels. Table 3 revealed that the results of the ADF test statistic showed that only the foreign direct investment (FDI) and energy consumption (EC) were stationary at levels I(0) at a 10% significance level, while all other variables were found to be stationary at the first difference I(1).

In the same vein, Philip Perron's stationary test statistic was consistent with the ADF results as all variables except FDI and EC are stationary at first-differences I(1) at a 5% significance level as seen in Table 3. Since the result of the conventional unit root tests showed that the series was a mixed order of integration, the consideration of the ARDL Bounds test for cointegration is possible.

**Table 3: Unit Root Tests**

| **Variables** | **Level PP** | **∆ PP** | **Level ADF** | **∆ ADF** |
|---|---|---|---|---|
| $LCO_2$ | -2.068 | -6.334*** | -2.022 | -6.328*** |
| OPENNESS | -2.933** | -8.448*** | -2.713* | -7.938*** |
| LGDPPC | -0.890 | -6.372*** | -0.739 | -6.609*** |
| LFDI | -1.734 | -9.682*** | -1.951 | -9.859*** |
| LEC | -2.844* | -6.042*** | -2.729* | -5.946*** |

*Where Level PP and ∆* PP *denote the level and first-difference of Phillips-Perron unit root test; Level ADF and ∆* ADF *denote the level and first-difference of Augmented-Dickey Fuller unit root test; ***, **, *, denotes rejection of the null hypothesis of no unit root at 1%, 5%, and 10% significance level.*

**Optimal Lag Selection**

ARDL bounds testing approach requires the determination of the optimal lag for the cointegrating equation based on the assumption of serially uncorrelated residual (Nkoro & Uko, 2016). This study employed the popularly used model selection criteria – Akaike Information Criterion (AIC) and Schwarz Bayesian Criterion (SBC). Table 4 below showed that the criterion minimises its value at lag 2. Thus, the study chose lag 2 as the optimal lag.

**Table 4: Optimal Lag Selection**

| Lags | LR | AIC | HQIC | SBIC |
|---|---|---|---|---|
| 0 | | 43.3186 | 43.4559 | 43.7267 |
| 1 | 425.08 | 35.3464 | 36.7196 | 39.4277 |
| 2 | 387.23* | 28.5212* | 31.1304* | 36.2758* |

*Endogenous: $C0_2$Emissions OPENNESS GDPPC EC FDI REER POP UR IQ. Exogenous: _cons*

  

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**Co-integration test**

Using AIC as a guide, a maximum lag order of 2 was chosen for the conditional ARDL. The F-statistic tests for the joint null hypothesis showed that the coefficients of the lagged level variables are zero (i.e., no long-run relationship exists between them). Table 5 indicated that the results of ARDL bound tests and F statistics in detail. The ARDL bound test was utilized to investigate the long-run relations among the variables. All the variables used in this study were not cointegrated as the value of F statistics and t statistics were closer to zero than the lower bound value at the level of 10%, 5%, and 1% level of significance. The calculated F-statistic 1.976 was lower than the lower bound critical value 4.038, 2.669, and 2.128 at the 1%, 5%, and 10% significant levels, respectively. Thus, the null hypothesis of no cointegration is not rejected, which implied that there existed no long-run cointegration relationships amongst the variables.

**Table 5: ARDL Bounds Test**

| Test, statistics | Value | K n=32 |
|---|---|---|
| F Statistics | 1.976 | 4 |
| Critical bound values | | |
| Significance | I(0) Bound | I(1) Bound |
| 10% | 2.128 | 3.467 |
| 5% | 2.669 | 4.230 |
| 1% | 4.038 | 6.134 |

*Note: n is the number of observations while K is the number of regressors. I (0) and I (1) represent the lower and upper boundary respectively. If the value of F-statistic falls above the upper boundary, the long-run relationship exists, however, it does not exist if it falls below the lower boundary. If the F-statistic is in between the lower and the upper boundaries, the long-run relationship is inconclusive.*

**Autoregressive Distributed Lag (ARDL) Estimation Results**

Table 6 below showed that the error of the previous period of $CO_2$ emissions would be corrected in the current period; the result revealed that there was a negative relationship between the previous period of $CO_2$ emissions and the current period, and it was statistically significant at 5% significant level. The co-efficient implied that a percentage change of $CO_2$ emissions in the previous period; t-1, was linked with a 0.38% decline of $CO_2$ emissions in the current period. Also, there was a positive relationship between OPENNESS and $CO_2$ emissions, however, at lag 1; OPENNESS was shown to have a negative relationship with $CO_2$ emissions. Nonetheless, the

  

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result showed that the relationship was found to be statistically insignificant. More so, the result revealed a positive and statistically significant relationship between GDDPC and $CO_2$ emissions. The co-efficient indicated that a percentage point change of GDPPC was associated with a 0.31% point increase of $CO_2$ emissions on average ceteris paribus at a 5% significant level. However, for the period t-1, t-2, and t-3; GDPPC was found to negatively impact $CO_2$ emissions, although the relationship in those periods were not statistically significant.

**Table 6: ARDL Estimation Result**

| **Dep: $CO_2$ Emissions** | | | |
|---|---|---|---|
| **Variables** | **Coefficient** | **Standard error** | **P>\|t\|** |
| D.$CO_2$ Emissions (-1) | -0.3764 | 0.1385 | 0.013 |
| D.OPENNESS | 0.0038 | 0.0058 | 0.523 |
| D.OPENNESS (-1) | -0.004 | 0.0043 | 0.372 |
| D.LGDPPC | 0.3083 | 0.1193 | 0.018 |
| D.LGDPPC (-1) | -0.0472 | 0.189 | 0.805 |
| D.LGDPPC (-2) | -0.0443 | 0.2176 | 0.841 |
| D.LGDPPC (-3) | -0.1783 | 0.1465 | 0.238 |
| D.EC | 0.1485 | 0.2393 | 0.542 |
| D.EC (-1) | 1.0604 | 0.5958 | 0.09 |
| D.FDI | -0.1362 | 0.0685 | 0.061 |
| D.FDI (-1) | -0.1126 | 0.0822 | 0.186 |
| D.FDI (-2) | 0.1463 | 0.0621 | 0.029 |
| R-squared | 0.541 | | |

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

*Source: Author's Computation using Stata 14*

The result in Table 6 showed that EC had a positive relationship with $CO_2$ emissions, but it was not significant. Likewise, there was a positive relationship between EC at period t-1 and $CO_2$ emissions. The result revealed that a percentage change in energy consumption was associated with a 0.15% increase in $CO_2$ emissions at a 1% significant level. Further, the analysis revealed that FDI had a negative relationship with $CO_2$ emissions. The co-efficient of FDI indicated that a percentage point change of FDI was linked with a 0.14% point decline of $CO_2$ emissions at a 1% significant level. While at lag 2, a percentage point change of FDI was associated with a 0.15% point increase of $CO_2$ emissions at a 5% significant level. Also, the R-squared showed how much variation in the dependent variable, $CO_2$ emissions was explained by the independent variables employed for this study. The result showed that 54.1% of the dependent variable was explained by the independent variables.

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**ARDL Model Diagnostics Test**

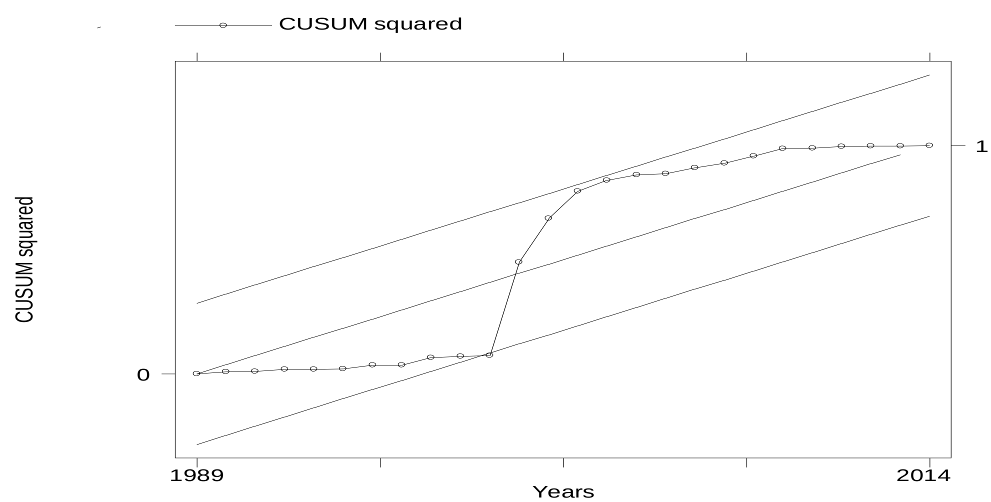
Reported in Table 7 below were the results of the post-estimation tests to ensure the ARDL estimation satisfied the Classical Linear Regression Model (CLRM) assumptions. The null hypotheses for tests employed serial correlation test, autocorrelation test, heteroskedasticity test, Ramsey reset test and skewness test. The results showed that there was no serial correlation problem, there existed a homoscedastic relationship, the model was correctly specified, and the error term was normally distributed, respectively. Since the probability values were all greater than 0.05, that is a 5% significance level, the study accepts the null hypothesis and concluded that the model adopted does not suffer from serial correlation, linearity, heteroskedasticity, and non-normality. Also, Figure 1 showed the CUSUM test to check for the stability of the model; the graph revealed that the model is stable.

**Table 7: ARDL Diagnostic Results**

| **Diagnostic statistics tests** | **Values** | **Results** |
|---|---|---|
| Dubin Watson Test | 1.823 | No serial correlation problem |
| Breusch Godfrey LM | 0.784 | No autocorrelation problem |
| Breusch-Pagan-Godfrey | 0.417 | No heteroscedasticity problem |
| Ramsey RESET test | 0.4518 | Model is specified correctly |
| Skewness Test | 0.4652 | Model is normally distributed |
| CUSUM Test | | No instability problem |

Source: Author's Computation using Stata 14.

**Figure 1: CUSUM Test of Model Stability**



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**Discussion of Findings**

The ARDL estimation results showed that there was a negative and statistically significant relationship between $CO_2$ emissions in the previous period and the current period; this implied that ceteris paribus the higher the $CO_2$ emissions of the previous period; t-1, the lower the emissions generated in the current period. The result revealed that a 1% change in the $CO_2$ emissions for the previous period had a decelerating effect of 0.38% on $CO_2$ emissions in the current period. The study also showed a positive relationship between trade openness and $CO_2$ emissions in Nigeria, which suggested that, as trade openness increases, the rate of $CO_2$ emissions in Nigeria increases too. Hence, a 1% increase in trade openness resulted in a 0.0038% increase in $CO_2$ emissions per capita in Nigeria. This result collaborated with the accelerating effect found by Zamil *et al* (2019) for Oman. Their findings indicated that trade openness had a positive impact on $CO_2$ emissions. Also, Cosmas *et al* (2019) found a positive effect of trade openness on $CO_2$ emissions in Nigeria. Whereas the study contradicted the conclusion by Keho (2016) for ECOWAS countries that found that trade openness was compatible with environmental improvements in some countries.

In addition, this study revealed that increasing trade in Nigeria had an accelerating effect on $CO_2$ emissions; thus, trade was responsible for higher $CO_2$ emissions in the atmosphere. However, the result showed that the relationship was statistically insignificant. This result aligned with the studies of Moyo & Khobai (2018); Rahman, (2013); Kander & Lindmark (2006) that found no significant relationship between trade and pollution. Furthermore, the result showed that there was a positive impact of GDP per capita on $CO_2$ emissions in Nigeria. Therefore, when GDP per capita increases by 1%, it had an accelerating effect of 0.31% on $CO_2$ emissions in Nigeria. The result implied that increasing GDP per capita was responsible for environmental degradation and decreasing GDP per capita is helping in the protecting environment from $CO_2$ emissions. This result supported the accelerating effect found by Cosmas *et al* (2019) for Nigeria where the study stated that changes in GDP per capita showed strong magnitude of impacts on $CO_2$ emission in Nigeria. In the same view, Ayobamiji & Kalmaz (2020) found that economic growth tends to affect $CO_2$ emissions positively.

Likewise, the results showed that there was a positive and statistically significant relationship between energy consumption and $CO_2$ emissions (at lag 1). The result implied that for every 1% change in energy consumption, there was a 1.06% increase in $CO_2$ emissions. Hence, energy consumption was found to increase $CO_2$ emissions. Therefore, increasing energy consumption is responsible for $CO_2$ emissions and the declining energy consumption is helping in protecting the environment from $CO_2$ emissions in Nigeria. This result supported the findings of Mesagan *et al* (2018) that reported that energy consumption Granger caused the increasing $CO_2$ emissions in Nigeria and South Africa. Similarly, Van Tran (2020) concluded that energy consumption had a

  

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positive and significant contribution to the deteriorating environment. The findings of this study showed that foreign direct investment had a negative significant relationship with $CO_2$ emissions, which implied that a 1% change in foreign direct investment would have a decreasing effect of 0.14% on $CO_2$ emissions in Nigeria. Thus, a decrease in foreign direct investment is associated with an increase in $CO_2$ emissions and an increased foreign direct investment resulted in a decrease in $CO_2$ emissions in Nigeria. This result aligned with the decelerating effect of Ayobamiji & Kalmaz (2020), which revealed that $CO_2$ emissions tend to be negatively affected by foreign direct investment in Nigeria. However, the result for lag 1 showed that foreign direct investment had a positive relationship with $CO_2$ emissions in Nigeria.

## 6. Conclusion and Policy implications

The empirical findings of this study indicated that increasing trade in Nigeria has an accelerating effect on $CO_2$ emissions. Thus, trade openness was responsible for higher $CO_2$ emissions in the atmosphere in Nigeria. The results collaborated the accelerating effect found by Cosmas *et al*, (2019) where their study concluded that there existed a positive effect of trade openness on $CO_2$ emissions in Nigeria. Furthermore, the increasing trend of GDP per capita and energy consumption were symmetrically found to have caused a rise in $CO_2$ emissions in Nigeria. Therefore, coordinating the macroeconomic drivers of $CO_2$ emissions in Nigeria's energy policy and creating a responsible climate policy institution would help greatly in attaining high trade growth and yet maintaining environmental sustainability in Nigeria.

Based on the findings of the study, there is vast knowledge that increases in greenhouse gases pose threat to an economy. As such, the government of Nigeria must work out formidable energy and environmental policies that will help in addressing the challenge of greenhouse gas emission. Nigeria should be tenacious in meeting the requirement in the signed pacts of the Paris Agreement on greenhouse gas emission, thus, the policies designed to improve trade must put into consideration the environment. The imposition of pollution taxes such as carbon taxes and tariffs, to regulate the operations of trade that has a negative effect on the environment, as well as encouraging the importation of clean goods can help in controlling the level of $CO_2$ emissions in the country. Furthermore, the Nigerian government should adopt policies that will make the business environment friendly to attract more investments into the country. However, it should attract investments that will produce only clean goods such that the composition effect can reduce emissions and improve environmental quality.

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