Ambient Air Pollution and Mortality Rate in Nigeria: An ARDL Approach

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ABSTRACT

The study on ambient air pollution and mortality rate in Nigeria is an attempt to evaluate the effect of ambient air pollution proxied by carbon dioxide on non-accidental, cardiovascular and respiratory disease related mortality in Nigeria from 1970-2019. Time series data adopted from World Development Indicators were analyzed using Auto Regressive Distributed Lag Model. Results suggest a positive relationship between CO₂ and crude death rate in Nigeria. Thus, the result of ARDL for lnCruder as the dependent variable showed that carbon dioxide emission was positively related to the crude death rate. Consequently, one unit increase in the quantity of carbon dioxide emission increased the death rate by 19% at lag 1, all things being equal. A similar result was obtained for CO₂ and life expectancy where carbon dioxide emission was found to have a negative effect on life expectancy. The study concludes that carbon dioxide emission has a negative effect on human health and causes death in human beings. Therefore, further study is recommended on ways of abating carbon dioxide emissions through the use of technologies that generate less carbon dioxide and the adoption of domestic practices that reduce the quantity of CO₂ produced in the environment.

Keywords: Ambient air pollution, ARDL, mortality rate, Nigeria.

Published Online: December 3, 2021

ISSN: 2736-660X

DOI: 10.24018/ejdevelop.2021.1.4.49

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I. INTRODUCTION

Air pollution is one of the global challenges of the 21st Century and a major concern for emerging economies, especially developing nations. This is because air pollution has caused many illnesses that have led to mortality in human beings such as respiratory infections, cardiovascular diseases, lung cancer, bronchitis, pneumonia, cancer, and asthma. Discomfort in the nose and eyes, chest pain, dryness of the throat is among other effects of air pollution on the human body. It is thus one of the leading causes of respiratory diseases in human beings which increases human mortality globally especially in areas where it is highly prevalent. World Health Organization (2016) report on global Air Quality showed that air pollution is the 4th leading cause of death worldwide with the majority of the deaths recorded in poorer nations while minor deaths in advanced and industrialized nations of the world. Data from the report showed that household and ambient levels of contaminated air in most developing countries continue to exceed the Air Quality Guideline established by the World Health Organization.

Nigeria as the most populous country in Africa ranks number one (1) and number four (4) worldwide in the list of countries with the high number of deaths recorded due to household and ambient air pollution. According to the annual State of Global Air Report published by the Health Effects Institute, Air Quality in Nigeria is among the poorest anywhere in the world. Nigeria in the HEI report recorded 150 deaths per age-standardized deaths per 100,000 people due to air pollution in 2016. Compared to countries in Europe, Asia, Middle East, United States and Canada deaths per 100,000 people is highest in Nigeria. Countries that have recorded higher deaths than Nigeria attributable to air pollution include Afghanistan, Pakistan, China, and India (HEI, 2016). See Fig. 1 below for age-standard deaths per 100,000 people.

The chart in Fig. 1 compares between countries with the biggest and smallest amounts of polluted air in some selected countries around the world. Countries with low mortality rates are evidently nations that have demonstrated significant commitment in reducing emissions and air pollution levels whereas poor nations with high mortality rates suggest that they have shown little success in curbing air pollution problems in their economies. A total of 2.5 billion people were exposed to household air pollution from the use of solid fuels most of whom live in low- and middle-income countries in Asia and Africa and therefore face a severe exposure to air pollution with its associated threat to human health (HEI report, 2016).

Fig. 1. Age-standard deaths/100,000 population (HEI report, 2016).

In most Nigerian homes and businesses, combustion generators and kerosene stoves are commonly used as alternative power sources which produced toxic smoke making the air in most homes and marketplaces unhealthy to breathe. Crowded housing settlement makes cross-ventilation difficult, trapping such toxic air which household population inhales thereby creating health problems for them. The WHO report on Air Quality for Nigeria showed that the amount of contaminated air in selected states has exceeded the recommended annual level of $20 \mu\text{g}/\text{m}^3$. Consequently, the majority of Nigerians are thus unprotected against household and ambient air pollution. In Anambra State (Southeastern, Nigeria) average annual mean concentration of particulate matter for PM10 was $594 \mu\text{g}/\text{m}^3$ per population of 100,000 people. Abia and Kaduna states were ranked among the top 20 cities with poor Air Quality in Africa measured by PM10 (WHO, 2016).

Countries in Europe, UK, U.S, Canada, and East Asian states have been able to keep at its barest minimum the amount of contaminated air they breathe and the impact of such air on the health of their citizens through environmentally friendly policies and technological innovations that promote quality air and clean environment. This is evident by the moderately high amount of Air Quality and the low number of deaths caused by air pollution in these countries. But not so for Nigeria, it is still among the countries that have a high quantity of household and ambient air pollution (PM10) exceeding the Air Quality Guideline established by WHO and high deaths occurring from it. Nigeria is deficient in tackling environmental clumsiness which produces bad air, poor sanitation habits among citizens, lack of technology for refuse collection and processing, and inefficient laws for protecting the environment all add to the deplorable state of unsafe air within the Nigerian environment. This study, therefore, examined the effect of household and ambient air pollution on human health in Nigeria from 1970-2019. Specifically, the study aims to examine the effect of air pollution on the mortality rate in Nigeria.

II. CONCEPTUAL AND THEORETICAL FRAMEWORK

In economic theory, individual behavior in the everyday economic transaction as a way of life is not isolated from impacting members of the society and the physical environment. This description is known in economic parlance as an externality. Mankiw (2008) defined externality as the impact of one person's actions on the well-being of a bystander. This impact as pointed out by Ngregory Mankiw can be a negative or positive one. As much as outcomes of economic productivity have been enjoyed by masses and have produced positive externality, it also has produced a negative one with its attendant effects on human health and the physical environment. One example of such effects is the increased spread of household and outdoor air pollution caused by human activities. According to HEI report 2016, the world's 95 percent population breaths unhealthy air produced by domestic and industry activities. The report noted that protracted exposure to air pollution has caused more than six (6) million deaths in 2016 with various respiratory diseases such as cancer of the lungs, cardiovascular dysfunction among several other health consequences in human beings.

Air Quality Guideline is an annual mean concentration guideline for Particulate Matter established by WHO. To measure Air Quality, values are reported in terms of daily or annual mean concentrations of PM_{2.5}/PM₁₀ particles per cubic meter of air volume (m³) in the air. The guideline stipulates that PM_{2.5} and PM₁₀ ought not to exceed 10µg/m³ and 20µg/m³ annual mean. The sources of PM_{2.5}/PM₁₀ in Africa include the use of worn-out engines of automobiles, old and worn-out combustion generators, household cooking stove, indiscriminate burning of dirt, bush burning, burning of firewood for domestic use, cigarette smoking are among several man-made activities that have produced a large amount of Carbon dioxide (CO₂) and other toxins that contaminate the air we breathe. Growing poverty and falling income rates have continued to exacerbate the increased effect of air pollution on human health in low-income countries. WHO report on Air Quality in Africa recorded 70 µg/m³ annual mean concentration for Particulate Matter (PM₁₀) in 2016. This, therefore, means that Africa's health indices are reflective of the state of air quality and the standard of environmental cleanliness achieved on the continent. Population growth and increased economic activities have continued to create more sources for the emission of substances that contaminate clean air without any corresponding effort to curb excessive spillage of the contaminants on both human health and the environment.

Particulate Matter (PM) is a common proxy indicator for air pollution. The major components of PM are sulfate, nitrates, ammonia, sodium chloride, carbon dioxide, mineral dust, and water. It consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. Severe exposure to the particles contributes to the risk of developing heart and respiratory diseases, as well as cancer of the lungs more than any other pollutant within the environment which is deadly.

III. LITERATURE REVIEW

Scholarly researchers have found significant effects of household and ambient air pollution on human health to include respiratory diseases, cardiovascular dysfunction, infant and adult mortalities among other several air pollutions induced morbidities'. Although there are many factors responsible for ill-health in human beings, poor quality air intake has been found to be one of the major causes of mortality in human beings.

Curtis *et al.* (2006) did a review of the health effects of major outdoor air pollutants such as carbon monoxide, sulfur, and nitrogen oxides. They have found out that many studies have linked atmospheric pollutants to many types of health problems of body systems including respiratory and cardiovascular diseases. The authors recommended that further research on the health effects of air pollution and air pollutant abatement methods will be very helpful to physicians, public health officials, industrialists, politicians, and the general public.

Kan *et al.* (2010) investigated the acute effects of outdoor air pollution on mortality outcomes in Shanghai, China using time-series data from 2001-2004 obtained from the Shanghai Municipal Center of Disease Control and Prevention, Shanghai Environmental Monitoring Center, and Shanghai Meteorologic Bureau. A result from the study showed significant associations between air pollution and mortality outcomes in Shanghai, China. The results also showed associations between air pollution and daily mortality outcomes to be more pronounced in the cool season than in the warm. The study concluded that short-term exposure to gaseous pollutants might have independent health effects in the city and therefore recommended that further research will be needed to disentangle the effects of various air pollutants on socio-demographic characteristics on the associations between air pollution and daily mortality.

Aliyu & Ismail (2016) studied the effects of air pollution on human mortality and whether gender difference matters in African countries. The study used Particulate Matter (PM₁₀) and Carbon dioxide (CO₂) to examine the effects of poor air quality on human mortality. Panel data from 35 African countries were analyzed and the result showed that elevated levels of PM₁₀ and CO₂ have a significant effect on the increasing mortality rates in infants, under-five children, and adults. The study also found out that the effect of poor air quality on adults differs between genders although such difference is not statistically significant. The study, therefore, concluded that the effects of air pollution between genders are similar in African countries.

Lin *et al.* (2017) studied the mortality effects of short-term and long-term exposures to various air pollutants among Chinese population. The literature reviewed identified sufficient information to support significant short-term mortality effects of various air pollutants such as PM₁₀, PM_{2.5}, SO₂, NO₂, and O₃ on mortality rates. The study found out that there was a positive effect of long-term exposure to air pollution on mortality and lung cancer risk among Chinese population. They recommended further studies especially of cohort type to provide more evidence to support the existing facts found in the literature.

Xia *et al.* (2019) carried out ecological research on the relationship between atmospheric pollutants and risk of death caused by cardiovascular and respiratory diseases and malignant tumors in Shenyang, China from 2013-2016 using data collected in Shenyang, China from April 2013 to March 2016. Results from the

study indicated that an increase in the daily average of air pollution increased the risk of death by cardiovascular diseases.

Sui *et al.* (2021) explored the short-term impacts of PM_{2.5}/O₃ on daily death in Hefei from 2013 to 2018 using time-series data on daily death of Hefei residents, meteorological factors, and air pollutants collected from January 1, 2013, to December 31, 2018. The study found out that an increase in the amount of air pollution increased non-accidental deaths. In cold seasons, air pollution had a stronger effect on the deaths resulting from non-accidental, cardiovascular, and respiratory diseases. The study, therefore, concluded that short-term exposure to PM_{2.5} as a proxy for air pollution was positively correlated with increased deaths due to non-accidental deaths in Hefei.

IV. METHODOLOGY

Time series data from World Development Indicators 1970-2019 were used to evaluate the effect of household and ambient air pollution on human mortalities in Nigeria. The dependent variable in the model's equation is crude death rate while the explanatory variables are carbon dioxide emissions, life expectancy at birth, per capita income, and annual percentage of population growth. The Augmented Dickey Fuller test was conducted to determine the order of integration of the variables. The model's equation for unit root test is specified in (1):

$$\Delta Y_t = \beta_1 + \beta_2 + \delta Y_{t-1} + \alpha \sum_{i=1}^m \Delta Y_{t-i} + \varepsilon_t \quad (1)$$

where

Y_t : is the variable that was investigated;

Δ : is the differential factor;

ε_t : error term.

If the variables are integrated of different orders, that is I(0) and I(1) ARDL models are specified. The model can also be specified with ARDL technique if all the variables are integrated of order one, that is I(1). The generalized ARDL (p, q) model is specified as:

$$Y_t = \gamma_{oi} + \sum_{i=1}^p \delta_i Y_{t-1} + \sum_{i=0}^q \beta'_i X_{t-1} + \sum_{it} \quad (2)$$

where

Y'_t is a vector and the variables in $(X'_t)'$ are allowed to be purely I(0) and I(1) or cointegrated;

β and δ are coefficients;

γ is the constant;

$i = 1, \dots, k$;

p, q are optimal lag orders;

$\sum_{it}$ is a vector of the error terms-unobservable zero mean white noise vector process (serially uncorrelated or independent).

The dependent variable is a function of its lagged values, the current and lagged values of other exogenous variables in the model

The lag lengths for p, q may not necessarily be the same.

p lags: used for the dependent variable.

q lags: used for the exogenous variables.

Hypotheses:

$$H_0: b_{1i} = b_{2i} = b_{3i} = b_{4i} = b_{5i} = 0 \text{ where } i = 1, 2, 3, 4, 5$$

$$H_1: b_{1i} \neq b_{2i} \neq b_{3i} \neq b_{4i} \neq b_{5i} = 0$$

To perform the bounds test for cointegration, the conditional ARDL model (p, q₁, q₂, q₃, q₄) with five (5) variables is specified as;

$$\begin{aligned} \Delta \ln \text{CRUDER}_t = & a_{01} + b_{11} \ln \text{CRUDER}_{t-1} + b_{21} \ln \text{CO}_2 \text{EMS}_{t-1} + b_{31} \ln \text{LEXB}_{t-1} + b_{41} \ln \text{PCI}_{t-1} + b_{51} \ln \text{POPGROWTH}_{t-1} \\ & + \sum_{i=1}^p a_{1i} \Delta \ln \text{CRUDER}_{t-i} + \sum_{i=1}^{q_1} a_{2i} \Delta \ln \text{CO}_2 \text{EMS}_{t-i} + \sum_{i=1}^{q_2} a_{3i} \ln \text{LEXB}_{t-i} + \sum_{i=1}^{q_3} a_{4i} \Delta \ln \text{PCI}_{t-i} + \sum_{i=1}^{q_4} \\ & a_{5i} \Delta \ln \text{POPGROWTH}_{t-i} + \varepsilon_{1t} \end{aligned} \quad (3)$$

$$\Delta \ln \text{CO}_2 \text{EMS}_t = a_{02} + b_{12} \ln \text{CRUDER}_{t-1} + b_{22} \ln \text{CO}_2 \text{EMS}_{t-1} + b_{32} \ln \text{LEXB}_{t-1} + b_{42} \ln \text{PCI}_{t-1} + b_{52} \ln \text{POPGROWTH}_{t-1} + \sum_{i=1}^p a_{1i} \Delta \ln \text{CO}_2 \text{EMS}_{t-i} + \sum_{i=1}^{q_1} a_{2i} \Delta \ln \text{CRUDER}_{t-i} + \sum_{i=1}^{q_2} a_{3i} \Delta \ln \text{LEXB}_{t-i} + \sum_{i=1}^{q_3} a_{4i} \Delta \ln \text{PCI}_{t-i} + \sum_{i=1}^{q_4} a_{5i} \Delta \ln \text{POPGROWTH}_{t-i} + e_{2t} \quad (4)$$

$$\Delta \ln \text{LEXB}_t = a_{03} + b_{13} \ln \text{CRUDER}_{t-1} + b_{23} \ln \text{CO}_2 \text{EMS}_{t-1} + b_{33} \ln \text{LEXB}_{t-1} + b_{43} \ln \text{PCI}_{t-1} + b_{53} \ln \text{POPGROWTH}_{t-1} + \sum_{i=1}^p a_{1i} \Delta \ln \text{LEXB}_{t-i} + \sum_{i=1}^{q_1} a_{2i} \Delta \ln \text{CRUDER}_{t-i} + \sum_{i=1}^{q_2} a_{3i} \Delta \ln \text{CO}_2 \text{EMS}_{t-i} + \sum_{i=1}^{q_3} a_{4i} \Delta \ln \text{PCI}_{t-i} + \sum_{i=1}^{q_4} a_{5i} \Delta \ln \text{POPGROWTH}_{t-i} + e_{3t} \quad (5)$$

$$\Delta \ln \text{PCI}_t = a_{04} + b_{14} \ln \text{CRUDER}_{t-1} + b_{24} \ln \text{CO}_2 \text{EMS}_{t-1} + b_{34} \ln \text{LEXB}_{t-1} + b_{44} \ln \text{PCI}_{t-1} + b_{54} \ln \text{POPGROWTH}_{t-1} + \sum_{i=1}^p a_{1i} \Delta \ln \text{PCI}_{t-i} + \sum_{i=1}^{q_1} a_{2i} \Delta \ln \text{CRUDER}_{t-i} + \sum_{i=1}^{q_2} a_{3i} \Delta \ln \text{CO}_2 \text{EMS}_{t-i} + \sum_{i=1}^{q_3} a_{4i} \Delta \ln \text{LEXB}_{t-i} + \sum_{i=1}^{q_4} a_{5i} \Delta \ln \text{POPGROWTH}_{t-i} + e_{4t} \quad (6)$$

$$\Delta \ln \text{POPGROWTH}_t = a_{05} + b_{15} \ln \text{CRUDER}_{t-1} + b_{25} \ln \text{CO}_2 \text{EMS}_{t-1} + b_{35} \ln \text{LEXB}_{t-1} + b_{45} \ln \text{PCI}_{t-1} + b_{55} \ln \text{POPGROWTH}_{t-1} + \sum_{i=1}^p a_{1i} \Delta \ln \text{POPGROWTH}_{t-i} + \sum_{i=1}^{q_1} a_{2i} \Delta \ln \text{CRUDER}_{t-i} + \sum_{i=1}^{q_2} a_{3i} \Delta \ln \text{CO}_2 \text{EMS}_{t-i} + \sum_{i=1}^{q_3} a_{4i} \Delta \ln \text{LEXB}_{t-i} + \sum_{i=1}^{q_4} a_{5i} \Delta \ln \text{PCI}_{t-i} + e_{5t} \quad (7)$$

If there is **no cointegration**, the ARDL (p, q_1, q_2, q_3, q_4) model is specified as:

$$\Delta \ln \text{CRUDER}_t = a_{01} + \sum_{i=1}^p a_{1i} \Delta \ln \text{CRUDER}_{t-i} + \sum_{i=1}^{q_1} a_{2i} \Delta \ln \text{CO}_2 \text{EMS}_{t-i} + \sum_{i=1}^{q_2} a_{3i} \Delta \ln \text{LEXB}_{t-i} + \sum_{i=1}^{q_3} a_{4i} \Delta \ln \text{PCI}_{t-i} + \sum_{i=1}^{q_4} a_{5i} \Delta \ln \text{POPGROWTH}_{t-i} + e_t \quad (8)$$

$$\Delta \ln \text{CO}_2 \text{EMS}_t = a_{02} + \sum_{i=1}^p a_{1i} \Delta \ln \text{CO}_2 \text{EMS}_{t-i} + \sum_{i=1}^{q_1} a_{2i} \Delta \ln \text{CRUDER}_{t-i} + \sum_{i=1}^{q_2} a_{3i} \Delta \ln \text{LEXB}_{t-i} + \sum_{i=1}^{q_3} a_{4i} \Delta \ln \text{PCI}_{t-i} + \sum_{i=1}^{q_4} a_{5i} \Delta \ln \text{POPGROWTH}_{t-i} + e_t \quad (9)$$

$$\Delta \ln \text{LEXB}_t = a_{03} + \sum_{i=1}^p a_{1i} \Delta \ln \text{LEXB}_{t-i} + \sum_{i=1}^{q_1} a_{2i} \Delta \ln \text{CRUDER}_{t-i} + \sum_{i=1}^{q_2} a_{3i} \Delta \ln \text{CO}_2 \text{EMS}_{t-i} + \sum_{i=1}^{q_3} a_{4i} \Delta \ln \text{PCI}_{t-i} + \sum_{i=1}^{q_4} a_{5i} \Delta \ln \text{POPGROWTH}_{t-i} + e_t \quad (10)$$

$$\Delta \ln \text{PCI}_t = a_{04} + \sum_{i=1}^p a_{1i} \Delta \ln \text{PCI}_{t-i} + \sum_{i=1}^{q_1} a_{2i} \Delta \ln \text{CRUDER}_{t-i} + \sum_{i=1}^{q_2} a_{3i} \Delta \ln \text{CO}_2 \text{EMS}_{t-i} + \sum_{i=1}^{q_3} a_{4i} \Delta \ln \text{LEXB}_{t-i} + \sum_{i=1}^{q_4} a_{5i} \Delta \ln \text{POPGROWTH}_{t-i} + e_t \quad (11)$$

$$\Delta \ln \text{POPGROWTH}_t = a_{05} + \sum_{i=1}^p a_{1i} \Delta \ln \text{POPGROWTH}_{t-i} + \sum_{i=1}^{q_1} a_{2i} \Delta \ln \text{CRUDER}_{t-i} + \sum_{i=1}^{q_2} a_{3i} \Delta \ln \text{CO}_2 \text{EMS}_{t-i} + \sum_{i=1}^{q_3} a_{4i} \Delta \ln \text{LEXB}_{t-i} + \sum_{i=1}^{q_4} a_{5i} \Delta \ln \text{PCI}_{t-i} + e_t \quad (12)$$

However, if there is **cointegration**, the error correction model (ECM) equation is specified as:

$$\Delta \ln \text{CRUDER}_t = a_0 + \sum_{i=1}^p a_{1i} \Delta \ln \text{CRUDER}_{t-i} + \sum_{i=1}^{q_1} a_{2i} \Delta \ln \text{CO}_2 \text{EMS}_{t-i} + \sum_{i=1}^{q_2} a_{3i} \Delta \ln \text{LEXB}_{t-i} + \sum_{i=1}^{q_3} a_{4i} \Delta \ln \text{PCI}_{t-i} + \sum_{i=1}^{q_4} a_{5i} \Delta \ln \text{POPGROWTH}_{t-i} + \lambda \text{ECT}_{t-1} + e_t \quad (13)$$

$$\Delta \ln \text{CO}_2 \text{EMS}_t = a_{02} + \sum_{i=1}^p a_{1i} \Delta \ln \text{CO}_2 \text{EMS}_{t-i} + \sum_{i=1}^{q_1} a_{2i} \Delta \ln \text{CRUDER}_{t-i} + \sum_{i=1}^{q_2} a_{3i} \Delta \ln \text{LEXB}_{t-i} + \sum_{i=1}^{q_3} a_{4i} \Delta \ln \text{PCI}_{t-i} + \sum_{i=1}^{q_4} a_{5i} \Delta \ln \text{POPGROWTH}_{t-i} + \lambda \text{ECT}_{t-1} + e_t \quad (14)$$

$$\Delta \ln \text{LEXB}_t = a_{03} + \sum_{i=1}^p a_{1i} \Delta \ln \text{LEXB}_{t-i} + \sum_{i=1}^{q_1} a_{2i} \Delta \ln \text{CRUDER}_{t-i} + \sum_{i=1}^{q_2} a_{3i} \Delta \ln \text{CO}_2 \text{EMS}_{t-i} + \sum_{i=1}^{q_3} a_{4i} \Delta \ln \text{PCI}_{t-i} + \sum_{i=1}^{q_4} a_{5i} \Delta \ln \text{POPGROWTH}_{t-i} + \lambda \text{ECT}_{t-1} + e_t \quad (15)$$

$$\Delta \ln \text{PCI}_t = a_{04} + \sum_{i=1}^p a_{1i} \Delta \ln \text{PCI}_{t-i} + \sum_{i=1}^{q_1} a_{2i} \Delta \ln \text{CRUDER}_{t-i} + \sum_{i=1}^{q_2} a_{3i} \Delta \ln \text{CO}_2 \text{EMS}_{t-i} + \sum_{i=1}^{q_3} a_{4i} \Delta \ln \text{LEXB}_{t-i} + \sum_{i=1}^{q_4} a_{5i} \Delta \ln \text{POPGROWTH}_{t-i} + \lambda \text{ECT}_{t-1} + e_t \quad (16)$$

$$\Delta \ln \text{POPGROWTH}_t = a_{05} + \sum_{i=1}^p a_{1i} \Delta \ln \text{POPGROWTH}_{t-i} + \sum_{i=1}^{q_1} a_{2i} \Delta \ln \text{CRUDER}_{t-i} + \sum_{i=1}^{q_2} a_{3i} \Delta \ln \text{CO}_2 \text{EMS}_{t-i} + \sum_{i=1}^{q_3} a_{4i} \Delta \ln \text{LEXB}_{t-i} + \sum_{i=1}^{q_4} a_{5i} \Delta \ln \text{PCI}_{t-i} + \lambda \text{ECT}_{t-1} + e_t \quad (17)$$

V. RESULTS AND DISCUSSION

TABLE I: DESCRIPTIVE STATISTICS-COMMON SAMPLE (SOURCE: AUTHOR'S EVIEWS 9.0 OUTPUT)

Variable	Mean	Median	Std. Dev.	Skewness	Kurtosis	Jarque-Bera/Prob.
lnCruder	18.15	18.52	2.43	-0.30	2.75	0.81 _{0.67}

lnCO ₂ EMS	65, 398.74	65, 602.63	24, 077.89	0.19	1.75	3.22 _{0.20}
lnLEXB	46.40	45.99	2.76	0.42	3.06	1.34 _{0.51}
lnPCI	1.57	2.53	6.49	0.01	4.95	7.13 _{0.03}
lnPogrowth	2.60	2.58	0.16	0.89	4.25	8.92 _{0.01}

The subscript on Jarque-Bera values is the corresponding probability for each variable.

The description of the data set used is given in Table I. Not all the data set used are normally distributed. Specifically, data sets on per capita income and population growth are not normally distributed given by the Jarque-Bera statistics and their corresponding probability values as contained in Table I. For crude death rate, carbon dioxide emissions, and life expectancy have their data set normally distributed. This is indicated by their standard deviation which showed that most of the numbers contained in the data sets are closed to the average mean. However, since data set on lnLEXB, lnPCI, and lnPogrowth are leptokurtic in form because of their values that are greater than 3 as indicated by their Kurtosis, it is therefore prone to produce outliers in the series.

TABLE II: AUGMENTED DICKEY FULLER UNIT ROOT TEST RESULTS (SOURCE: AUTHOR'S EVIEWS 9.0 OUTPUT)

Variable	ADF Unit Root Test	t-Statistic	Prob.*	Order of Integration
lnCRUDER	ADF test statistics	-3.666089		
	Test critical value: 5%	2.935001	0.0084	I (1)
lnCO ₂ EMS	ADF test statistics	-6.997467		
	Test critical value: 5%	-2.931404	0.0000	I (1)
lnLEXB	ADF test statistics	-3.152288		
	Test critical value: 5%	-2.935001	0.0304	I (1)
lnPCI	ADF test statistics	-5.563922		
	Test critical value: 5%	-2.923780	0.0000	I (0)
lnPOPGROWTH	ADF test statistics	-4.247551		
	Test critical value: 5%	-2.941145	0.0018	I (0)

Three variables were integrated of order one, crude death rate, carbon dioxide emissions, and life expectancy at birth. Per capita income and population growth were integrated of order zero, that is at levels.

TABLE III: BOUNDS TEST FOR COINTEGRATION USING MODEL 3 (CONSTANT) UNRESTRICTED CONSTANT AND NO TREND (SOURCE: AUTHOR'S EVIEWS 9.0 OUTPUT)

Dependent Variable	F-statistics	Critical value I0 Bound and I1 Bound at 5% significance	Cointegration
lnCRUDER _t	F _{18,53649}	2.86 and 4.01	Cointegrated
lnCO ₂ EMS _t	F _{3,741392}	2.86 and 4.10	Inconclusive
lnLEXB _t	F _{20,50364}	2.86 and 4.10	Cointegrated
lnPCI _t	F _{6,960834}	2.86 and 4.10	Cointegrated
lnPOPGROWTH _t	F _{47,82730}	2.86 and 4.10	Cointegrated

The rule of thumb for interpreting ARDL bounds test is that if F-statistics is higher than the upper bound I1, there is cointegration. If it is less than the lower bounds I0, then there is no cointegration. However, if F-statistics is higher than the lower bound but less than the upper bound, cointegration is inconclusive. Following this rule, the result of the bounds test in Table IV indicated four cointegrating variables, lnCRUDER, lnLEXB, lnPCI, lnPOPGROWTH however, lnCO₂EMS was inconclusive. Cointegrating variables necessitated the use of Error Correction Model (ECM) in equations (13) to (17).

TABLE IV: ARDL FOR LNCRUDER (SOURCE: AUTHOR'S EVIEWS COMPUTATION)

Dependent Variable: LNCRUDER	Method: ARDL	Maximum dependent lags: 2
Dynamic regressors (2 lags, automatic): LNCO2EMS LNLEXB LNPCI LNPOGROWTH		
Model selection method: AIC	Selected Model: ARDL (2, 2, 2, 2, 2)	
Substituted Equation		
$\ln CRUDER = 1.74_{(0.00)} [23.28] * \ln CRUDER(-1) - 0.73_{(0.00)} [-9.25] * \ln CRUDER(-2) - 5.39e-08_{(0.06)} [-1.93] * \ln CO2EMS + 1.90e-08_{(0.54)} [0.62] * \ln CO2EMS(-1) - 5.60e-08_{(0.04)} [-2.13] * \ln CO2EMS(-2) - 0.71_{(0.00)} [-45.12] * \ln LEXB + 1.25_{(0.00)} [17.85] * \ln LEXB(-1) - 0.53_{(0.50)} [0.69] * \ln LEXB(-2) + 3.61e-05_{(0.10)} [1.70] * \ln PCI + 8.58e-05_{(0.06)} [1.90] * \ln PCI(-1) + 9.40e-05_{(0.02)} [-2.46] * \ln PCI(-2) - 0.05_{(0.06)} [1.95] * \ln POPGROWTH + 0.07_{(0.04)} [-2.19] * \ln POPGROWTH(-1) - 0.05_{(0.02)} [-2.58] * \ln POPGROWTH(-2) - 0.72$		
Note: p values () in bracket while t-stat in parenthesis[]		
R ² =1.0 Adjusted R ² = 1.0 S.E. of Regression = 0.001 DW statistics = 1.38 ECM = 0.39		

The result of ARDL for lnCruder as the dependent variable showed that carbondioxide emissions were positively related to the crude death rate. Consequently, a one unit increase in the quantity of carbon dioxide emissions increased the death rate by 19% at lag 1, all things being equal. However, at lag 2 a unit decrease in carbon dioxide emissions was not found to reduce the crude death rate, this is because there are many causes of adult mortalities that are responsible for increasing the number of crude death rates in Nigeria such as accidents and insurgency apart from carbon dioxide emissions being one of the leading causes.

Similarly, an increase in the amount of carbon dioxide emissions was found to reduce life expectancy at birth thus increasing the death rate. A similar result was found between per capita income and crude death rate which were positively correlated. Thus, as income generating activities continue to increase people become more exposed to risk factors that caused mortality in human beings.

The goodness of fit test is a statistical hypothesis test of how well sample data fits a distribution from a population with a normal distribution. In the case of $\ln\text{Cruder}$ as the dependent variable in the ARDL model, the result indicated that the sample data fit well since the data is from a normal distribution with a R^2 and adjusted R^2 of 1.0 respectively. The Durbin Watson statistics of 1.38 is proof of the presence of positive autocorrelation. The ARDL equation indicated a cointegrated relationship which necessitated an error correction model. The ECM indicated a speed of adjustment of 39%.

TABLE V: ARDL FOR $\ln\text{CO}_2\text{EMS}$ (SOURCE: AUTHOR'S EVIEWS COMPUTATION)

Dependent Variable: $\ln\text{CO}_2\text{EMS}$	Method: ARDL	Maximum dependent lags: 1
Dynamic regressors (1 lag, automatic): $\ln\text{CRUDER}$ $\ln\text{LEXB}$ $\ln\text{NPCI}$ $\ln\text{POGROWTH}$		
Model selection method: AIC Selected Model: ARDL (1, 1, 1, 0, 0)		
Substituted Equation		
$\ln\text{CO}_2\text{EMS} = 0.43_{(0.002)[3.44]} * \ln\text{CO}_2\text{EMS}(-1) - 801668.98_{(0.001)[-3.56]} * \ln\text{CRUDER} + 829307.46_{(0.001)[3.56]} * \ln\text{CRUDER}(-1) - 507216.95_{(0.002)[-3.44]} * \ln\text{LEXB} + 535802.58_{(0.002)[3.45]} * \ln\text{LEXB}(-1) + 831.32_{(0.004)[3.06]} * \ln\text{NPCI} - 41885.29_{(0.01)[-2.75]} * \ln\text{POGROWTH} - 1724314.39$		
Note: p values () in bracket while t-stat in parenthesis []		
$R^2=0.89$ Adjusted $R^2 = 0.87$ S.E. of Regression = 8423.798 DW statistics = 1.82		

The result of $\ln\text{CO}_2\text{EMS}$ as the dependent variable indicated that carbon dioxide emissions were found to reduce life expectancy by 507217.0 given increases in morbidities that caused human mortality such as respiratory and cardiovascular diseases. However, an increase in carbon dioxide emissions caused by economic activities both within household and business circles increase per capita income of economic agents. Thus, the result showed a positive relationship between carbon dioxide emissions and per capita income. ARDL outcome also revealed a positive relationship between Population growth and carbon dioxide emissions. Life expectancy boosts population growth that is a significant factor in producing carbon dioxide emissions brought about by a sustained increase in activities of economic agents. These activities produce toxic substances that pollute the environment causing damages to human health and ultimately, death. The model's goodness of fit points to the fact that all the variables used explained the changes caused by the explanatory variables by 89%.

TABLE VI: ARDL FOR $\ln\text{LEXB}$ (SOURCE: AUTHOR'S EVIEWS COMPUTATION)

Dependent Variable: $\ln\text{LEXB}$	Method: ARDL	Maximum dependent lags: 2
Dynamic regressors (2 lags, automatic): $\ln\text{CRUDER}$ $\ln\text{CO}_2\text{EMS}$ $\ln\text{NPCI}$ $\ln\text{POGROWTH}$		
Model selection method: AIC Selected Model: ARDL (2, 2, 2, 2, 2)		
Substituted Equation		
$\ln\text{LEXB} = 1.80_{(0.00)[25.63]} * \ln\text{LEXB}(-1) - 0.78_{(0.00)[-10.29]} * \ln\text{LEXB}(-2) - 6.33e-08_{(0.12)[-5.58]} * \ln\text{CO}_2\text{EMS} + 3.48e-08_{(0.42)[0.82]} * \ln\text{CO}_2\text{EMS}(-1) - 7.67e-08_{(0.05)[-2.08]} * \ln\text{CO}_2\text{EMS}(-2) - 1.39_{(0.00)[-45.12]} * \ln\text{CRUDER} + 2.46_{(0.00)[28.42]} * \ln\text{CRUDER}(-1) - 1.06_{(0.00)[-10.67]} * \ln\text{CRUDER}(-2) + 5.18e-05_{(0.49)[0.70]} * \ln\text{NPCI} + 0.0001_{(0.09)[1.78]} * \ln\text{NPCI}(-1) + 0.0001_{(0.05)[2.09]} * \ln\text{NPCI}(-2) - 0.06_{(0.03)[-2.27]} * \ln\text{POGROWTH} + 0.10_{(0.08)[1.83]} * \ln\text{POGROWTH}(-1) - 0.06_{(0.05)[-2.01]} * \ln\text{POGROWTH}(-2) - 0.81$		
Note: p values () in bracket while t-stat in parenthesis []		
$R^2=1.0$ Adjusted $R^2 = 1.0$ S.E. of Regression = 0.002 DW statistics = 1.39 ECM= 0.36		

ARDL test results showed a positive relationship between life expectancy and per capita income. Income is a significant factor in determining the quality of life of an individual economic agent viz quantity and quality of goods and services that an individual can afford in terms of access to quality health care, quality education, access to nutritional foods, and balanced diet including quality accommodation and the overall standard of living which determines longevity. Similarly, there was found a negative relationship between life expectancy and population growth. This outcome is more glaring in developing economies where there is the surge in population growth rate but little economic progress to take care of the new numbers. Consequently, poor economies are characterized by worsening living standards such as poor housing, health care, and sub-standard education amongst growing insecurity that is a result of sheer negligence by the government. The resultant effect of bad governance is increased anarchy that sees to the death of people on daily basis. Therefore, increase in population without corresponding wherewithal to manage the increase, the death rate would rise.

TABLE VII: ARDL FOR $\ln\text{NPCI}$ (SOURCE: AUTHOR'S EVIEWS COMPUTATION)

Dependent Variable: $\ln\text{NPCI}$	Method: ARDL	Maximum dependent lags: 1
Dynamic regressors (0 lag, automatic): $\ln\text{CRUDER}$ $\ln\text{CO}_2\text{EMS}$ $\ln\text{LEXB}$ $\ln\text{POGROWTH}$		
Model selection method: AIC		
Substituted Equation		

$$\ln\text{PCI} = 0.24_{(0.07)[1.87]} * \ln\text{PCI}(-1) - 6.28_{(0.09)[-1.71]} * \ln\text{LEXB} + 8.94e-05_{(0.08)[1.79]} * \ln\text{CO}_2\text{EMS} - 6.85_{(0.11)[-1.66]} * \ln\text{CRUDER} + 0.95_{(0.89)[0.14]} * \ln\text{POPGROWTH} + 408.06$$

Note: p values () in bracket while t-stat in parenthesis []

$$R^2=0.29 \text{ Adjusted } R^2 = 0.19 \text{ S.E. of Regression} = 5.16 \text{ DW statistics} = 2.24 \text{ ECM} = -0.01$$

According to the ARDL test, per capita income and population growth have a positive relationship. Thus, a one unit increase in per capita income causes a population increase by 94% in Nigeria. Per capita income is a very significant variable in determining the living standard of a people. Developed economies are characterized by high per capita income among other important variables such as high life expectancy and high standard of living, however they are able to control their population growth. Per capita income among other things is influential in helping people afford quality health care, adopt eco-friendly energy to curtail environmental pollution, and improve life expectancy. Sadly, developing countries such as Nigeria has one of the lowest per capita incomes among their working populace. Wages are extremely low consequently resulting in widespread poverty especially among teeming population of unemployed youth. In Nigeria, evidence abound of the negative relationship between population growth and per capita income. This is because growing population shrinks the available resources for improving livelihood and standard of living. In Nigeria therefore, as population size increases without a corresponding increase in economic resources per capita income is bound to fall. Thus, population increase is negatively related to shrinking per capita income without a due increase in resources that improve income.

TABLE VIII: ARDL FOR LNPOPGROWTH (SOURCE: AUTHOR'S EViews COMPUTATION)

Dependent Variable: LnPopgrowth	Method: ARDL	Maximum dependent lags: 2
Dynamic regressors (2 lags, automatic): LNCRUDER LNCO ₂ EMS LNLEXB LNPCI		
Model selection method: AIC	Selected Model: ARDL (2, 2, 0, 2, 2)	

Substituted Equation

$$\text{POPGROWTH} = 1.66_{(0.00)[33.93]} * \text{POPGROWTH}(-1) - 0.97_{(0.00)[22.66]} * \text{POPGROWTH}(-2) - 0.0003_{(0.52)[-0.66]} * \text{PCI} - 0.001_{(0.16)[1.44]} * \text{PCI}(-1) - 0.001_{(0.10)[-1.70]} * \text{PCI}(-2) - 2.31_{(0.02)[-2.43]} * \text{LEXB} + 3.78_{(0.05)[2.07]} * \text{LEXB}(-1) - 1.37_{(0.14)[-1.52]} * \text{LEXB}(-2) - 3.47e-07_{(0.13)[-1.56]} * \text{CO}_2\text{EMS} - 3.44_{(0.01)[-2.64]} * \text{CRUDER} + 5.50_{(0.03)[2.22]} * \text{CRUDER}(-1) - 1.95_{(0.12)[-1.61]} * \text{CRUDER}(-2) - 5.79$$

Note: p values () in bracket while t-stat in parenthesis []

$$R^2=0.99 \text{ Adjusted } R^2 = 0.99 \text{ S.E. of Regression} = 0.01 \text{ DW statistics} = 1.17 \text{ ECM} = 0.39$$

Air pollution has been known from empirical literature to cause diseases such as cardiovascular and respiratory conditions and ultimately mortality in human beings. From the results of ARDL obtained for this study, there is a positive relationship between CO₂ and mortality rate in Nigeria. Similarly, CO₂ as a proxy for ambient air pollution was found to reduce life expectancy within the years covered. This result is in line with the study conducted by Xinmiao *et al.* (2021) where the study explored the short-term effect of PM_{2.5}/O₃ on daily mortality in Hefei China where they found out that short term exposure to PM_{2.5} was positively correlated with increased deaths due to non-accidental, cardiovascular, and respiratory diseases in Hefei. Results of ARDL between per capita income and carbon dioxide suggest a positive correlation, therefore, further study is recommended for carbon dioxide abatement without any decrease in economic activities since per capita income is essential for healthy living and improved wellbeing.

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