



## Interrogating the effects of Carbon-Dioxide (CO<sub>2</sub>) emissions on life expectancy in Nigeria: An ARDL approach

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### Abstract

This study examines the relationship between CO<sub>2</sub> emissions and life expectancy in Nigeria, employing an Autoregressive Distributed Lag (ARDL) model to analyse both short-run and long-run effects. The study utilises data spanning from 1986 to 2020, focusing on CO<sub>2</sub> emissions from different sources—solid, liquid, and gaseous fuels—alongside economic growth indicators and government health expenditures. The findings reveal that CO<sub>2</sub> emissions from all sources negatively affect life expectancy in both the short-run and long-run analyses, with emissions from solid and liquid fuels showing particularly strong adverse effects. Conversely, the study finds that higher GDP per capita and increased government health expenditure significantly enhance life expectancy, acknowledging the critical role of economic development and health funding in improving public health outcomes. The study confirms the necessity for comprehensive environmental policies aimed at reducing pollution and promoting cleaner energy alternatives. Additionally, it highlights the importance of economic policies that foster growth and health sector investments, suggesting these as dual avenues for enhancing the well-being and longevity of the Nigerian population. This paper contributes to the existing literature by providing empirical evidence of the direct and indirect effects of environmental and economic factors on public health. It offers valuable insights for policymakers on the importance of integrated strategies that address both environmental sustainability and economic development toward improving life expectancy in developing countries like Nigeria.

**Keywords:** CO<sub>2</sub> Emissions, Life Expectancy, Nigeria, ARDL Model, Environmental Policy, Economic Growth, Health Expenditure, Sustainable Development.

### Introduction

The relationship between environmental factors, specifically carbon dioxide (CO<sub>2</sub>) emissions, and public health outcomes such as life expectancy is a critical area of research within developmental economics, particularly concerning developing nations like Nigeria. Globally, the decline in life expectancy due to environmental and socio-economic factors is alarming, a trend from which Africa is not exempted (Matthew *et al.*, 2020) [18]. Life expectancy, defined as the average years a person is expected to live based on prevailing mortality patterns at birth (Issaoui *et al.*, 2015) [11], is influenced heavily by environmental quality, among other factors. In Africa, the relationship between life expectancy and environmental conditions presents a paradox. On one hand, certain studies suggest that life expectancy in Africa might be relatively high due to less industrialisation, leading to less pollution, better quality of natural foods, and favourable geographical and climatic conditions (Balani, 2016) [6]. On the other hand, there is a significant body of research indicating that life expectancy is compromised by environmental hazards such as high CO<sub>2</sub> emissions, poor hygiene standards, inadequate healthcare facilities, and low-income levels (Matthew *et al.*, 2020) [18]. Environmental factors, particularly the emission of CO<sub>2</sub>, a major byproduct of fossil fuel combustion, are significant contributors to climate change and have profound implications for human health and productivity (Agbanike *et al.*, 2019) [3]. The quality of air, pivotal for human and animal health, is increasingly jeopardised by the rising levels of atmospheric CO<sub>2</sub>, which not only diminishes life expectancy but also complicates sustainable economic growth (Sharma, 2017) [27]. The case of Nigeria offers a unique perspective due to its status as a major consumer and

producer of fossil fuels, with significant portions of its CO<sub>2</sub> emissions stemming from the transport and energy sectors (Alege *et al.*, 2017) [4]. This scenario presents a direct conflict between the drive for economic growth and the need for environmental sustainability, making the study of CO<sub>2</sub> emissions and their effects on life expectancy particularly pertinent. Hence, this study aims to investigate the complex interrelations between CO<sub>2</sub> emissions and life expectancy in Nigeria.

The increasing global concern over environmental degradation, prompted by CO<sub>2</sub> emissions and its implications for global warming, makes this study timely and relevant. Understanding the dynamics of CO<sub>2</sub> emissions and life expectancy is crucial for policymakers, especially in light of the severe health impacts linked to pollution and climate change. Moreover, with the United Nations Sustainable Development Goal 3 (SDG3) aiming for good health and well-being by 2030, it is imperative to address the environmental challenges that impede these goals, particularly in developing contexts like Nigeria. This study employs the autoregressive distributed lag (ARDL) approach, developed by Pesaran *et al.* (2001) [23], which is particularly suited for examining the dynamics between CO<sub>2</sub> emissions and life expectancy. This methodology allows for effective estimation of both short-run and long-run dynamics and is ideal for handling data properties typical in economic research, such as small sample sizes and integration properties of the series involved.

The rest of this paper is divided into six sections following this introduction. The second section synthesises relevant literature that explores the effect of environmental factors, particularly CO<sub>2</sub> emissions, on life expectancy. The theoretical framework of the study is detailed in the third

section. The fourth section outlines the methodological approach used in the study, including the econometric model employed and the procedures for data analysis. The analysis of the empirical investigations is presented in the fifth section. The sixth section discusses the implications of the empirical results. The seventh section draws on the entire findings of the study to suggest practical policy measures that could be implemented to mitigate the adverse effects of CO<sub>2</sub> emissions on life expectancy.

**Literature Review**

Mahalik *et al.* (2022) [17] provided a comprehensive examination of how CO<sub>2</sub> emissions from different sources influence life expectancy in developing and emerging countries over the period 1990-2017. The study revealed a pervasive negative relationship between life expectancy and CO<sub>2</sub> emissions, regardless of whether the emissions are consumption-based or production-based. This suggests that both the consumption and production of goods contributing to CO<sub>2</sub> emissions detrimentally affect life expectancy through the generation of harmful pollutants. In Asia, Bilgili *et al.* (2021) [17] investigated the relationship between health expenditures and CO<sub>2</sub> emissions from 1991 to 2017. The study found that both public and private health expenditures could mitigate the adverse effects of CO<sub>2</sub> emissions on public health, highlighting the role of financial resources in combating environmental health impacts. Sabra (2022) [25] explored the dynamics between health expenditure, economic growth, fertility rate, life expectancy, and CO<sub>2</sub> emissions in selected middle-income countries in the MENA (Middle East and North Africa) region from 1995 to 2017. The results indicated complex interactions, with health expenditure positively associated with economic growth but negatively associated with fertility rates and CO<sub>2</sub> emissions, suggesting that economic prosperity might reduce fertility rates and improve life expectancy, albeit amidst rising CO<sub>2</sub> emissions.

In Bangladesh, Hassan *et al.* (2019) focused on water pollution and its severe public health implications, revealing the widespread contamination of both surface and groundwater with hazardous pollutants like arsenic, leading to significant health risks and mortality, especially among children. Munawer (2018) [20] addressed broader environmental concerns, examining the health impacts of major air pollutants including COx (Carbon Oxides), NOx (Nitrogen Oxides), SOx (Sulphur Oxides), and PM (Particulate Matter). The study highlighted that emissions from coal combustion significantly contribute to various health issues, including chronic respiratory and cardiovascular diseases. Studies like those by Narayan & Narayan (2008) [21] and Kim & Lane (2013) [14] in OECD (The Organization for Economic Cooperation and Development) and other developed countries have similarly emphasised the relationship between environmental quality and health outcomes, confirming the long-run impacts of environmental pollutants on health expenditures and public health metrics such as infant mortality and life expectancy. For Nigeria, Joseph (2020) [13] and Aderemi *et al.* (2020) [1] both reported a significant negative impact of environmental pollution on life expectancy in Nigeria, with CO<sub>2</sub> emissions from various sources, including fossil fuel consumption, prominently contributing to reduced life expectancy. Igbinedion (2019) [10] further explored these dynamics, linking CO<sub>2</sub> emissions with significant reductions in life

expectancy and pointing out the beneficial effects of improved sanitation and health expenditure on enhancing life expectancy. Afolayan & Aderemi (2019) [2] and Amuka *et al.* (2018) [5] investigated the causal relationships and long-term effects of environmental quality on health, suggesting that while CO<sub>2</sub> emissions have a deleterious impact, factors like government health expenditure and energy consumption patterns also play critical roles. (Amuka *et al.*, 2018) [5]

**Theoretical Framework**

The theoretical foundation of this study is built on the concept of externalities, particularly as it pertains to environmental economics. An externality occurs when the actions of an individual or firm directly affect the well-being of others without these effects being reflected in market prices (Jerumeh *et al.*, 2015) [12]. Concerning environmental impact, CO<sub>2</sub> emissions represent a negative externality because they impose costs on the general public and the environment that are not borne by the producers or consumers of the emissions-generating products. This is represented in equation 2.1 below where life expectancy is considered as a function of carbon dioxide emissions:

$$LE = f(CO_2) \dots \dots \dots (3.1)$$

However, CO<sub>2</sub> emissions will be split into CO<sub>2</sub> emissions from solid fuel (CO<sub>2</sub>SF), liquid fuel (CO<sub>2</sub>LQF) and gaseous fuel (CO<sub>2</sub>GF). Therefore, equation 3.1 in explicit form is presented as equation 3.2 below:

$$LE = f(CO_2SF, CO_2LQF, CO_2GF) \dots \dots \dots (3.2)$$

**Methodology**

**1. Model Specification**

The analysis of the effect of CO<sub>2</sub> emissions on life expectancy in Nigeria employs a regression framework grounded in the externality theory. This approach enables the exploration of how environmental externalities such as CO<sub>2</sub> emissions from various sources affect life expectancy. To enhance the robustness of the model, additional economic variables are included as control variables. The linear regression of the model is given in equation (1) below

$$LE = \beta_0 + \beta_1 CO_2SF + \beta_2 CO_2LQF + \beta_3 CO_2GF + \beta_4 GHE + \beta_5 PO + \beta_6 GDPPC + \beta_7 EXPH + \epsilon \dots \dots \dots (4.1)$$

Where

- **LE:** Life Expectancy at Birth, Total Years
- **CO<sub>2</sub>SF:** CO<sub>2</sub> Emissions from Solid Fuel (kt)
- **CO<sub>2</sub>LQF:** CO<sub>2</sub> Emissions from Liquid Fuel (kt)
- **CO<sub>2</sub>GF:** CO<sub>2</sub> Emissions from Gaseous Fuel (kt)
- **GHE:** Greenhouse Gas Emissions (kt)
- **PO:** Population Total
- **GDPPC:** Gross Domestic Product Per Capita
- **EXPH:** Government Expenditure on Health
- **β<sub>0</sub>:** Intercept Coefficient
- **β<sub>1</sub>-β<sub>7</sub>:** Slope Coefficients
- **ε:** Error Term

The logarithmic form of the equation is also considered to estimate the elasticity of life expectancy for each explanatory variable, given by:

$$\ln LE = \beta_0 + \beta_1 \ln CO_2SF + \beta_2 \ln CO_2LQF + \beta_3 \ln CO_2GF + \beta_4 \ln GHE + \beta_5 \ln P + \beta_6 \ln GDPPC + \beta_7 \ln EXPH + \epsilon \dots \dots \dots (4.2)$$

The a priori expectation posits a negative relationship between life expectancy and all forms of CO<sub>2</sub> emissions, reflecting the detrimental health effect of air pollution. Conversely, a positive relationship is anticipated between life expectancy and economic indicators such as GDP per capita and government health expenditures, indicating that better economic conditions and higher health spending potentially enhance public health outcomes.

**2. Estimation Techniques**

The ARDL approach, developed by Pesaran *et al.* (2001)<sup>[23]</sup>, is selected for this study due to its flexibility in handling variables of different integration orders (I(0) and I(1)) within the same regression framework. This is particularly useful in small sample size and avoids the pitfalls of traditional methods like Ordinary Least Squares (OLS) which require variables to be of the same integration order. The ARDL approach incorporates bounds testing to ascertain the existence of long-run relationships among the variables. This is crucial for understanding the persistent effects of CO<sub>2</sub> emissions on life expectancy over time. Pesaran *et al.* (2001)<sup>[23]</sup> revealed that the ARDL approach begins with an examination of the Vector Auto-Regressive (VAR) of order p, denoted as VAR (p) and often represented as:

$$Z_t = \mu + \sum_{i=1}^p \beta_i z_{t-i} + \varepsilon_t \tag{3}$$

Where,  $z_t$  is a vector of both  $x_t$  and  $y_t$ ;  $y_t$  representing the dependent variables of the different models,  $x_t$  is the vector of the matrix representing a set of explanatory variables. The principle is that  $y_t$  must be an I(1) variable, but the regressor  $x_t$  can either be I(0) or I(1).

ARDL was developed to accommodate current and previous lags of the dependent variable (AR) while various distributive lags of the explanatory variables (DL). In its basic form, an ARDL regression model has the structural form presented in equation 4:

$$y_t = \beta_0 + \beta_1 y_{t-1} + \dots + \beta_p y_{t-p} + \alpha_0 x_t + \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + \dots + \alpha_q x_{t-q} + \varepsilon_t \tag{4}$$

Where  $y_t$  is the dependent variable,  $x_t$  is an explanatory variable, and  $\varepsilon_t$  is an error term.

The model is autoregressive because  $y_t$  is explained (in part) by lagged values of itself. Also, it has a distributed lag component in the form of successive lags of the ‘x’ explanatory variable. Sometimes, the current value of  $x_t$  itself is excluded from the distributed lag part of the structure of the model.

**Analysis**

**1. Descriptive Statistics**

Detailed characterization of all the variables involved in this study is presented statistically in Table 5.1. Starting with the dependent variable, life expectancy (LE), the mean stood at 48 years 8 months with a maximum value of 55 years and a minimum of 45 years 8 months. On the side of the explanatory variables, carbon dioxide emissions from solid fuel (CO<sub>2</sub>SF) has the mean value is 4.249, with a maximum value of 5.693 and a minimum of 1.992. For carbon dioxide emissions from liquid fuel (CO<sub>2</sub>LQF), average value is found to be 10.547; minimum value at 10.01; and maximum value of 11.157. Carbon dioxide emissions from gaseous fuel (CO<sub>2</sub>GF) has an average value of 2.9079 with a maximum value of 3.402 and a minimum of 2.154. The last source of carbon dioxide emissions related, that is, greenhouse gas emissions (GHE) has a mean value of 8.764 with a maximum value of 10.783 and a minimum value of 4.635. Other non-emissions related variables captured in the study are total population (POP) with an average value of 18.702 and a maximum value of 19.144 and a minimum of 18.287. Measure of income level, that is, gross domestic product per capita (GPPPC) has an average value of 11.254 and a maximum value of 13.525 with a minimum of 7.7450. Finally, government expenditure on health (EXPH) has a mean value of 23.542, with a maximum and minimum value of 26.771 and 17.536 respectively.

**Table 1:** Descriptive Statistics

	LE	CO <sub>2</sub> SF	CO <sub>2</sub> LQF	CO <sub>2</sub> GF	POP	GHE	GDPPC	EXPH
Mean	48.802	4.249	10.547	2.908	18.703	8.765	11.254	23.542
Median	47.242	4.632	10.420	3.043	18.698	8.994	11.540	24.255
Maximum	55.018	5.694	11.158	3.402	19.144	10.784	13.526	26.771
Minimum	45.843	1.993	10.010	2.154	18.267	4.636	7.745	17.537
Std. Dev.	3.237	0.920	0.350	0.392	0.264	1.636	1.844	2.635
Skewness	0.635	-0.897	0.416	-0.231	0.030	-0.817	-0.485	-0.648
Kurtosis	1.854	3.017	1.747	1.549	1.804	3.160	1.933	2.248
Jarque-Bera	4.265	4.690	3.302	3.379	2.092	3.932	3.038	3.273
Probability	0.119	0.096	0.192	0.185	0.351	0.140	0.219	0.195
Sum	1708.066	148.723	369.159	101.780	654.594	306.771	393.901	823.980
Sum Sq. Dev.	356.337	28.786	4.168	5.215	2.367	91.043	115.602	236.108
Observations	35	35	35	35	35	35	35	35

Source: Author’s Computation, 2024.

In Table 1 also, the skewness test which measures the asymmetry of the distribution of the series for all the variables are negatively skewed and the skewness is lesser than zero except for LE, CO<sub>2</sub>LQF and POP which are positively skewed as their mean values are greater than zero. The results of kurtosis statistics which is a measure of the peakedness or flatness of the distribution of the series

suggest that all the variables in the model are platykurtic as kurtosis statistics of each of them is less than 3 except for CO<sub>2</sub>SF and GHE which are leptokurtic with their value greater than 3 as reported in Table 5.1. Finally, the Jarque-Bera test indicates that all the variables have a normal distribution curve and are normally distributed.

**2. Correlation Analysis**

Findings from correlation analysis are presented in Table 2. CO<sub>2</sub> emissions from solid fuels (LNCO<sub>2</sub>SF) show a moderate positive correlation with life expectancy (0.323). This suggests a phenomenon of direct association such that areas with higher emissions might also be areas with better access to essential services that can improve life expectancy. Liquid fuel emissions (CO<sub>2</sub>LQF) also have a strong positive correlation with life expectancy (0.845). This unusual finding might indicate that regions with higher economic activities, which result in more emissions, might also have better healthcare infrastructure, thus improving life expectancy. Similarly, gaseous fuel emissions (CO<sub>2</sub>GF) show the strongest positive correlation (0.875) and this replicates the case of emissions from liquid fuels. Additionally, the correlation between population growth (POP) and life expectancy is robustly positive (0.740),

indicating that a growing population might be tied to enhanced infrastructure, including healthcare, which in turn will boost life expectancy. Furthermore, greenhouse gas emissions (GHE) recorded also a strong positive correlation with life expectancy (0.776), reinforcing the notion that economic activities linked to these emissions might also foster better living conditions.

Economic indicators equally came out with significant correlations. GDP per capita (GDPPC) is very strongly correlated with life expectancy (0.856), underscoring the fact that higher economic output per capita typically affords better healthcare, nutrition, and overall living standards. Also, government health expenditure (EXPH) exhibits a strong positive correlation (0.824) with life expectancy, highlighting the direct association of increased healthcare funding on improving public health outcomes.

**Table 2:** Correlation Matrix

	LE	CO <sub>2</sub> SF	CO <sub>2</sub> LQF	CO <sub>2</sub> GF	POP	GHE	GDPPC	EXPH
LE	1.000							
CO <sub>2</sub> SF	0.323	1.000						
CO <sub>2</sub> LQF	0.845	0.352	1.000					
CO <sub>2</sub> GF	0.875	0.067	0.686	1.000				
POP	0.740	0.054	0.756	0.726	1.000			
GHE	0.776	-0.163	0.615	0.813	0.867	1.000		
GDPPC	0.857	-0.089	0.661	0.913	0.777	0.874	1.000	
EXPH	0.825	-0.127	0.653	0.903	0.755	0.861	0.779	1.000

Source: Author’s Computation, 2024

**3. Unit Root Test**

The Augmented Dickey-Fuller test results indicate that most variables are non-stationary at levels but become stationary after differencing, except for LnCO<sub>2</sub>SF, LnGDPPC, and LnEXPH, which are stationary at their levels (See Table 3). This mixed integration order (I(0) and I(1)) necessitates the use of an ARDL bounds testing approach to cointegration,

given its appropriateness when variables integrated at different orders as long as none are integrated at an order higher than I(1). Additionally, the stationarity of variables at I(0) or I(1) confirms the suitability of the ARDL model for investigating both short-run dynamics and long-run relationships among the variables affecting life expectancy in Nigeria.

**Table 3:** The unit root test results

Augmented Dickey Fuller (Constant)			
Variables	Level (t stat)	Difference (t stat)	Decision
LnLE	-1.528	-3.209**	I(1)
LnCO <sub>2</sub> SF	-2.869*		I(0)
LnCO <sub>2</sub> LQF	-1.491	-7.112***	I(1)
LnCO <sub>2</sub> GF	-1.159	-5.481***	I(1)
LnGDPPC	-3.872***		I(0)
LnEXPH	-5.902***		I(0)
LnGHE	-2.510	-6.192***	I(1)
LnPOP	2.707	-2.727*	I(1)

Source: Author’s Computation, 2024.

Note: \*\*\*, \*\* and \* imply 1%, 5% and 10% level of significance

**4. Bounds Test for Co-Integration**

Table 4 shows that the F-statistic significantly exceeds the upper bound across all significance levels. Hence, the null hypothesis of no cointegration among the variables is rejected. This result strongly indicates the presence of a long-term equilibrium relationship between life expectancy and all the explanatory variables captured in this study, that is, CO<sub>2</sub> emissions from various sources, GDP per capita, population growth, and government health expenditure. This finding of cointegration implies that while the variables may deviate from equilibrium in the short run, they tend to move together in the long run, adjusting towards an equilibrium state.

**Table 4:** Bounds Testing for Co-integration Analysis.

Computed Wald F-statistic: 6.8198; K = 7		
Bounds Level	Lower Bound	Upper Bound
1% critical bounds value	2.96	4.26
5% critical bounds value	2.32	3.5
10% critical bounds value	2.03	3.13

Source: Author’s Computation, 2024.

**5. Short-Run Effect of CO<sub>2</sub> Emissions on Life Expectancy in Nigeria**

Table 5 shows that D(LnCO<sub>2</sub>SF), D(LnCO<sub>2</sub>LQF), D(LnCO<sub>2</sub>GF), D(LnGHE), D(LnGDPPC) and D(LnEXPH) among all other variables are statistically significant. The

significant variables are negatively signed except for D(LnGDPPC) and D(LnEXPH) which are positively signed. From the estimated result, D(LnCO<sub>2</sub>SF), is found to be negative and statistically significant with a coefficient of -0.5565. This implies that a 1% increase in the current value of CO<sub>2</sub> emission from solid fuel reduces life expectancy by 55%. Similarly, D(LnCO<sub>2</sub>LQF) is negative and significant, indicating that a 1% increase in the current value of CO<sub>2</sub> emission from liquid fuel reduces life expectancy by 26.3%. Also, the negative coefficient of a change in the current value of CO<sub>2</sub> emission on gaseous fuel is significant with a coefficient of 0.196 implying that a 1% increase in D(LnCO<sub>2</sub>GF) decreases life expectancy by about 19.6%. This finding is in agreement with the result of Afolayan & Aderemi (2019) [2] that confirmed that CO<sub>2</sub> emissions reduced life expectancy in the short run. The results were compiled with the expectation priori of an inverse relationship between emissions of CO<sub>2</sub> and life expectancy. In the same vein, the current value of greenhouse emissions

is negatively signed with a coefficient of 0.033. This indicates that a 1% increase in D(LnGHE) decreases life expectancy by 3.3%.

Conversely, the significant coefficient of GDP per Capita is positive, implying that a 1% increase in the current value of GDP per Capita leads to a 22.4% increase in life expectancy. Also, D(LnEXPH) is found to be positive and significant indicating that a 1% increase in the government expenditure on health in Nigeria leads to a 3.33% increase in life expectancy. This finding is in line with the work of Ranabhat *et al.* (2018) [24] who found that government expenditure on health has a positive and significant relationship with life expectancy. Additionally, the coefficient of the error correction term ECM (-1) is negative and significant. The value of the coefficient is -0.133, indicating that about 13.3% of the disequilibrium in the value of life expectancy of the previous year fluctuations adjusts back to the long-run equilibrium in the current year.

**Table 5:** ARDL Short-Run and ECM Result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LnCO <sub>2</sub> SF)	-0.556594	0.158473	-3.512221	0.0038***
D(LnCO <sub>2</sub> LQF)	-0.263083	0.099386	-2.647072	0.0183**
D(LnCO <sub>2</sub> GF)	-0.196231	0.091673	-2.140557	0.0448**
D(LnPOP)	-19.855426	25.000873	-0.794189	0.4369
D(LnGHE)	-0.033971	0.014208	-2.390989	0.0268**
D(LnGDPPC)	0.224504	0.097025	2.313894	0.0314**
D(LnEXPH)	0.033385	0.018829	1.773099	0.0914*
CointEq(-1)	-0.133073	0.035276	-3.772349	0.0012***
R-square	0.999884			
Dublin Watson	1.665133			
F-Statistics (prob)	132.38 (0.000)			

**Source:** Author's Estimation from E-view 9.

Note: \*\*\*, \*\* and \* denote 1%, 5% and 10% levels of significance respectively, the optimal lag structure is determined by the Schwarz Info Criterion.

**6. Long-Run Effect of CO<sub>2</sub> Emissions on Life Expectancy in Nigeria**

Table 6 revealed that LnCO<sub>2</sub>SF, LnCO<sub>2</sub>LF, LnGDPPC and LnPEXPH are the variables that are significant in the long run. The significant variables are negatively signed except for GDP Per Capita and government expenditure on health which are positively signed. The result further indicates that CO<sub>2</sub> emission from solid fuel negatively affects life expectancy, indicating that a 1% increase in CO<sub>2</sub>SF reduces life expectancy by 24.9%. Similarly, the significant coefficient of LnCO<sub>2</sub>LQF is significant and negatively signified implying that a 1% increase in CO<sub>2</sub> emission from liquid fuel reduces life expectancy by 9.6%. The results conformed to the priori expectation of an inverse relationship between emissions of CO<sub>2</sub> and life expectancy. Furthermore, this finding is in line with (Agbanike, 2019 [3]; and Urhie *et al.*, 2020) [28] which found CO<sub>2</sub> emission impacting negatively on life expectancy in the long run.

Conversely, GDP per capita has a positive significant value on life expectancy. A 1% increase in GDPPC leads to a 60% increase in life expectancy. This result conforms to Joseph (2020) [13], which found a long-run positive relationship between GDP per capita and life expectancy. In the same vein, the coefficient of government expenditure on health is positive and significant. This indicates that a 1% increase in LnEXPH raises life expectancy by 58.5%. This result goes in line with a prior expectation of a positive relationship between expenditure on health and life expectancy. Furthermore, the R-square of 0.9998 indicates that about 99.98% total variation in life expectancy in Nigeria can be explained by all the explanatory variables. The F-statistic of 132.38 with a probability value of 0.000 (See Table 5.5) implies that the overall model is statistically significant at all levels of significance. Furthermore, the Durbin-Watson statistic of 1.6653 means that there is no autocorrelation in the model since the value is still within the acceptance region of no autocorrelation.

**Table 6:** ARDL Long-Run Result

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNCO <sub>2</sub> SF	-0.249637	0.112135	-2.226211	0.0398**
LNCO <sub>2</sub> LQF	-0.682491	0.391782	-1.742018	0.0969*
LNCO <sub>2</sub> GF	-2.425304	1.410136	-1.719908	0.1009
LNPOP	-0.076958	1.161807	-0.066240	0.9479
LNGHE	-0.255278	0.153221	-1.666080	0.1113

LNGDPPC	0.601228	0.300615	1.999996	0.0617*
LNEXPH	0.565938	0.244249	2.317053	0.0312**
C	395.558700	49.126189	-8.051891	0.0000***

Source: Author's Estimation from E-view 9

Note: \*\*\*, \*\* and \* denote 1%, 5% and 10% levels of significance respectively, the optimal lag structure is determined by the Schwarz Info Criterion.

### Discussion of Findings

The analysis in this study has revealed that CO<sub>2</sub> emissions from different sources have a significant detrimental effect on life expectancy in Nigeria across both short-run and long-run. The emissions from solid and liquid fuels are particularly harmful, showing a pronounced negative relationship with life expectancy. This aligns with the externality theory as discussed by Jerumeh *et al.* (2015) [12], which postulates that negative externalities such as pollution adversely affect the well-being of individuals who are not directly involved in the economic transactions that produce these externalities. The robustness of the negative effect of solid fuel emissions, as highlighted in this study is a pointer to the fact that emissions from solid fuels contribute significantly to the deterioration of public health over time in Nigeria. Solid fuel emissions, which often include a high proportion of particulates and other pollutants, have been consistently linked to severe health issues, including respiratory and cardiovascular diseases (Yun *et al.*, 2020 [29]; Chen *et al.*, 2024) [8]. These health conditions are well-documented for their potential to drastically reduce life expectancy, particularly in regions with high exposure levels.

Similarly, emissions from liquid fuels also exhibit a strong negative effect on life expectancy, reinforcing concerns about the wide-ranging impacts of various types of pollution. The particulate matter, sulfur oxides, and volatile organic compounds typically emitted from burning liquid fuels are major contributors to air quality degradation and pose substantial health risks (Liu *et al.*, 2022) [16]. Conversely, the effect of gaseous fuel emissions, while still notably negative, is less severe compared to solid and liquid fuels. This difference can be attributed to the relatively cleaner combustion properties of gaseous fuels, such as natural gas, compared to coal and oil (Oyelade *et al.*, 2022) [22]. Nevertheless, despite their cleaner nature, gaseous fuels still pose significant health risks, particularly in urban areas where their concentration is likely to be higher due to dense energy use. The health implications of these emissions, though less severe, remain a significant concern, emphasizing the need for careful monitoring and regulation. The pool of findings from this study indicate that CO<sub>2</sub> emissions vary significantly in their effect on health, suggesting that policy measures should be specifically tailored to address the distinct characteristics of each type of emission. For instance, implementing stricter emission controls and modernizing fuel usage within both industrial and residential settings could effectively mitigate the identified adverse health impacts. This might involve upgrading to more efficient combustion technologies, enforcing stricter emissions testing, and revising standards for emissions across various sectors. Furthermore, the adoption of cleaner technologies and the active promotion of renewable energy sources are crucial for substantial reductions in the overall health burden related to CO<sub>2</sub> emissions (Shan *et al.*, 2021) [26]. Encouraging the use of solar, wind, and hydroelectric power generation can

significantly decrease reliance on fossil fuels, thus reducing emissions. Additionally, government incentives for energy-efficient appliances could accelerate the transition to a low-carbon economy. Collectively, these initiatives address the immediate health impacts of pollution while also contributing to long-term sustainability and public health improvement.

The analysis in this study has indicated that there exists a strong positive relationship between GDP per capita and government health expenditure on life expectancy. This elaborates on the mechanisms by which economic growth, evidenced by increased GDP per capita, enhances general living conditions. Specifically, as economies grow and per capita income rises, there is typically a corresponding improvement in public infrastructure, including healthcare facilities, which substantially enhances access to essential medical services (Kiross *et al.*, 2020) [15]. This improved access is a key driver of the observed increases in life expectancy, as communities benefit from early and more effective treatment of health issues, comprehensive and preventive care, and generally higher standards of medical services. Furthermore, the analysis underscores the pivotal role of government health expenditures in boosting life expectancy. Additionally, the finding of this study is particularly relevant for developing nations like Nigeria, where public health systems are frequently underfunded and overburdened. The results of this study provide additional empirical evidence supporting the crucial need for proactive investments in the health sector. Increased governmental spending on health can lead to better-equipped health facilities, more medical personnel, and broader accessibility to quality healthcare services, which collectively contribute to improving population health outcomes.

Moreover, government investments are expected and likely to foster a more equitable distribution of health resources, reducing disparities in health access and outcomes between different socio-economic groups. Government expenditure on health plays a critical role in enhancing the overall well-being and longevity of the populace by ensuring that health services are not only available but also accessible to all segments of the population, particularly the underserved and vulnerable (Miranda-Lescano *et al.*, 2023) [19]. The importance of sustainable health financing cannot be overstated, especially in countries where emerging public health challenges require swift and effective responses. For countries like Nigeria, where emerging diseases and other health crises pose a significant threat, robust health sector financing will be vital in securing the resilience of health systems. Thus, investing in health is not only a moral imperative but also a practical strategy that will and can yield high returns in terms of health outcomes and, by extension, economic stability and growth.

### Policy Implications

The implications of these findings carry significant weight for policymakers concerned with public health and

environmental management in Nigeria. The demonstration of the detrimental effect of CO<sub>2</sub> emissions on life expectancy in this study underscores the urgent need for comprehensive environmental regulations. Policymakers must prioritise the development and enforcement of policies that will reduce CO<sub>2</sub> emissions as well as encourage the adoption of cleaner and more sustainable energy sources and technologies. These initiatives could include incentives for renewable energy adoption, stricter emissions standards for industries, and greater investment in green technology. Additionally, the observed positive effects of economic growth and health expenditure on life expectancy highlight an important dual benefit. Governments can enhance economic welfare and improve health outcomes across the population by formulating policies that stimulate economic development while simultaneously increasing funding for health services. Such policies might involve improving healthcare infrastructure, increasing accessibility to medical services, and investing in health education and preventative care programmes. These initiatives can create a virtuous circle, where improved health outcomes contribute to economic stability and growth, which in turn provide more resources for health and environmental sustainability.

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