

Research Article

Modelling the Dynamic Effects of Climate-related Risks on Long and Healthy Living: Evidence from Nigeria

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Abstract

The prevalence and severity of climate risks in oil-rich nations, including Nigeria, have generated considerable interest in understanding their implications for longevity and public health. Accordingly, this study investigates the influence of climate risks, particularly carbon dioxide (CO₂) emissions from gas, methane, and oil sources, on healthy and long life, with a specific focus on life expectancy in Nigeria. Annual time series data obtained from the World Bank and the United Nations Development Programme Human Development Report were analysed employing descriptive statistics, pre-estimation tests such as unit root and cointegration tests, and the least-squares estimation method. The results indicate that while the short-term impact of CO₂ emissions from gas on life expectancy is negative but statistically insignificant, the long-term impact is positive and statistically significant at the 5% level. This underscores the long-term benefits of transitioning to cleaner, modern gas resources to enhance life expectancy at birth. Furthermore, CO₂ emissions from methane were found to negatively affect life expectancy in both the short- and long-term. This suggests that methane-related emissions diminish the lifespan of the Nigerian population. Similarly, CO₂ emissions from oil production were observed to significantly reduce life expectancy, highlighting the adverse effects of oil production on public well-being. In light of these findings, this study recommends that the government promote the transition to clean, modern gas for electricity generation, cooking, and transportation, thereby improving the life expectancy of the Nigerian population. Additionally, policymakers should ensure the enforcement of methane-specific regulations through stricter penalties, consistent monitoring, and transparent reporting to mitigate the increasing CO₂ emissions from methane and their associated impact on life expectancy.

Keywords

Climate Risks, Life Expectancy, Longevity, CO₂ Emissions, Methane Emissions and Nigeria

1. Introduction

Climate risks pose a substantial challenge to human health and well-being globally, with their effects disproportionately affecting developing nations, such as Nigeria, due to limited adaptive capacity and reliance on climate-sensitive sectors, including agriculture and fossil-fuel-based energy. According

to a 2019 report by the International Energy Agency (IEA), 81% of the world's primary energy supply came from fossil fuels. While these non-renewable resources have played a pivotal role in stimulating economic growth, accelerating technological advancements, and supporting urbanisation, their

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widespread use has also led to significant environmental challenges. [5] posit that fossil fuels are primarily responsible for the recent rise in global temperatures. They elaborated that the combustion of coal, oil, and gas used in factories emits carbon dioxide, which traps heat from the sun and contributes to the planet's warming. As Africa's dominant oil and gas producer, Nigeria significantly contributes to greenhouse gas (GHG) emissions, notably carbon dioxide (CO₂) and methane (CH₄), through its fossil fuel industry. These emissions, when measured per capita, reflect the extent of industrial activity and demographic factors. In 2021, Nigeria's annual GHG emissions were estimated at 380.73 million tonnes of CO₂ equivalent (MtCO₂e), with per capita emissions approximating 1.7 tonnes of CO₂e, substantially below the global average of 7 tonnes but significant given developmental challenges [4].

Additionally, in 2018, emissions from the energy sector totalled 209 million tonnes of CO₂ equivalent, with oil and gas operations accounting for 33% of these emissions [3]. The interrelation among climate risks —specifically per capita CO₂ emissions, methane emissions from gas operations, and emissions from oil production and life expectancy—constitutes a critical yet underexplored domain in Nigeria. The life expectancy at birth was estimated at 53.1 years in 2021, ranking among the lowest globally, reflecting a confluence of factors including poverty, inadequate healthcare infrastructure, and environmental degradation [28]. Economists and environmental scientists assert that GHG emissions exacerbate these challenges by intensifying climate-related stressors, such as air pollution, heatwaves, and food insecurity, which undermine public health [19]. For example, gas flaring in Nigeria, which emitted 5.3 billion cubic meters of gas in 2022 across 174 flare sites, exemplifies such environmental impacts [27]. Similarly, oil spills in the Niger Delta tend to contaminate water and soil, reducing agricultural productivity and increasing morbidity.

Despite Nigeria's notable contribution to global GHG emissions through its oil and gas sector, there is limited research examining the relationships among per capita CO₂ emissions, methane emissions from gas operations, and oil production emissions, and their effects on health outcomes, especially life expectancy. In essence, Nigeria's distinctive socio-economic and geographic attributes increase its vulnerability to the effects of global warming, thereby jeopardising the feasibility of its development objectives. The country's energy portfolio, primarily reliant on fossil fuels and supplemented by the prospective use of renewable resources, is crucial to its environmental footprint. As climate risks progress, these factors present substantial risks to Nigeria's economy, agriculture, and overall public health. Most existing studies primarily focus on aggregate national emissions or sectoral impacts without disaggregating per capita contributions or exploring specific health implications. This research gap is problematic because Nigeria's low life expectancy stands in contrast to global trends, raising critical questions

about the influence of climate-related risks on health disparities [26]. Consequently, this study aims to deepen the understanding of how climate-related risks, especially per capita CO₂, methane, and oil production emissions, influence long and healthy living among the Nigerian populace. Our choice of these variables primarily followed their a priori link to life expectancy at birth and their relevance to SDG 3, SDG 7, SDG 5, and SDG 13, among others. After this introduction, the rest of the research is organised as follows: Section II reviews the relevant literature, while Section III details the methodology and data sources. Then, Section IV presents and discusses the findings. Finally, Section V concludes the paper with a summary and policy insights.

2. Related Literature

Climate change is increasingly acknowledged as a vital factor influencing human health, exerting both direct and indirect effects on long-term well-being through various mechanisms. [18] theory of environmental determinism, which was popularised by [20], provides the foundational framework for investigating the causal relationship between climatic conditions and public health. The theory asserts that environmental and climatic conditions predominantly shape human health, behaviour, and societal progress. This underscores that climate change is not merely an environmental concern but also a determinant of health disparities, particularly in vulnerable regions with limited adaptation capacity. Consequently, the theory elucidates why the health impacts of climate change differ across geographical locations. [9] posit that temperature extremes affect human physiological capacity, leading to heat exhaustion, cardiovascular illnesses, and increased mortality during heatwaves, according to deterministic principles [9]. This demonstrates the direct influence of the environment on human survival and productivity.

Additionally, the Environmental Kuznets Curve (EKC) hypothesis, pioneered by [11], also provides a theoretical insight into how climate-induced health outcomes vary across levels of economic development. This is based on the hypothesised inverted U-shaped relationship between income per capita and environmental pollution. Essentially, at low-income levels, nations prioritise economic growth over environmental protection, resulting in high emissions, poor waste management, and the degradation of air, water, and soil quality, thereby directly exacerbating public health outcomes. As economies develop, institutional capacity and environmental regulations improve; consequently, governments begin investing in cleaner technologies and climate adaptation strategies, thereby reducing exposure to environmental risks. However, at a more advanced stage, high-income nations adopt sustainable practices, renewable energy, and green policies, thereby reducing carbon emissions and climate-related risks. Overall, the EKC hypothesis elucidates differences among countries in their vulnerability to climate change. While developing countries tend to experience

greater health burdens from climate change due to weak infrastructure and regulatory capacity, high-income countries generally face lower health risks from environmental degradation owing to greater adaptive capacity and cleaner technologies.

More importantly, a substantial body of research has examined the health implications of climate risks across the disciplines of economics, environmental sciences, and health sciences. The majority of these studies focus on the impacts of climate change on human health, particularly on life expectancy, utilising various methodologies, data sources, and geographic scales. The findings of these studies have also varied across time, methodologies, and study areas. For instance, studies such as [24, 12-14, 10, 7, 25, 1] found evidence to justify the adverse implications of climate risks, especially

CO₂ and methane emissions, on human health, including life expectancy at birth and maternal mortality. These findings suggest that reducing greenhouse gas emissions will improve human health and longevity. Conversely, [23] found that the use of fossil fuels enhances life expectancy. However, other studies have indicated that emissions from CO₂, oil, and methane sources do not affect life expectancy at birth [2]. Given the conflicting findings in previous studies, we contributed to the literature by exploring how climate-related risks, including emissions from various sources, affect life expectancy at birth in Nigeria.

Stylized Facts on the Dynamics of Climate-related Risks

The dynamics of climate change risks, comprising trends of per capita CO₂ emissions from gas and oil production as well as methane emissions are presented in Figure 1.

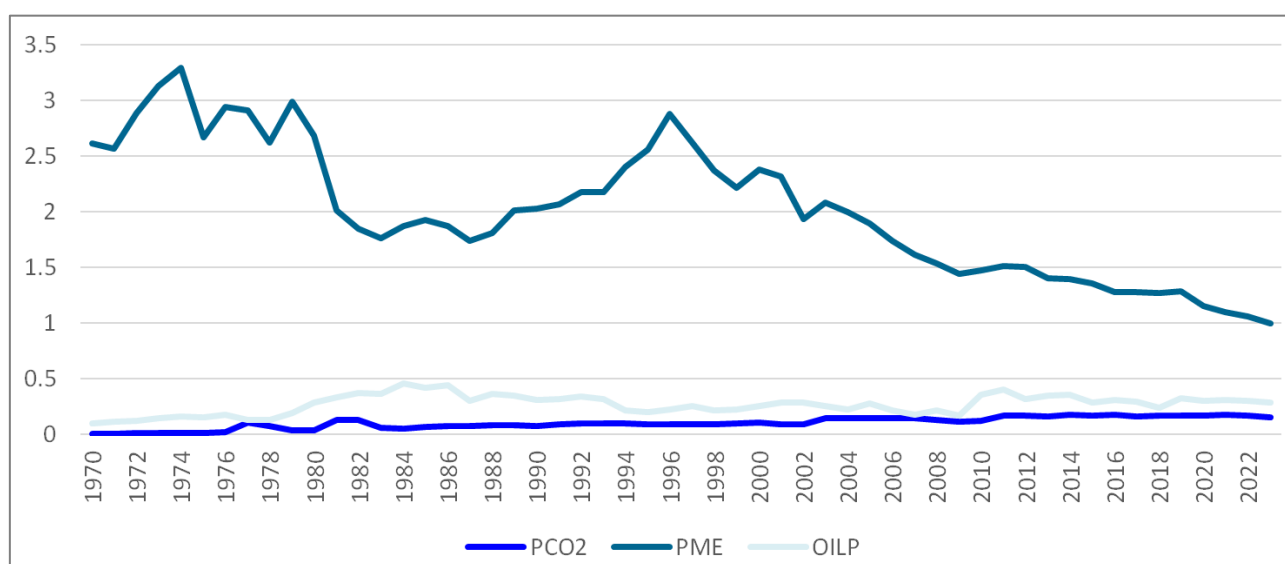


Figure 1. Time series trends of per capita CO₂ emissions from gas (PCO₂), per capita CO₂ emissions from oil production (OILP) and methane emissions (PME) in Nigeria, 1970-2023.

The analysis of variable trends revealed that per capita methane emissions exceeded per capita CO₂ emissions from gas and oil sources. This indicates systemic inefficiencies in energy production, inadequate emission regulations, and significant environmental costs. Additionally, the findings highlight growing environmental challenges, including energy-sector inefficiencies, agricultural practices, waste mismanagement, and land-use changes. Notably, methane emissions ranged from a maximum of 3.28 tonnes per person to a minimum of 0.99 tonnes per person, demonstrating a decreasing trend from 1996 to 2023, which is likely attributable to improvements in agricultural practices, land use, and the transition to clean energy. Additionally, the trends suggest that CO₂ emissions from oil production have surpassed those from gas, reflecting the dominant role of the oil sector in Nigeria's energy economy, which is more carbon-intensive and less efficiently managed than the gas sector.

3. Methodology

3.1. Data and Variables Description

To estimate the health implications of climate-related risks, we used time-series data spanning 1970-2023. Life expectancy at birth was used as the dependent variable to capture long and healthy living among the population. As a continuous and time-varying variable, life expectancy at birth reflects the average number of years a newborn is expected to live under prevailing mortality conditions at the time of birth. We further utilised per capita CO₂ emissions from gas and oil sources, as well as methane emissions, to measure the climate-related risks. In particular, per capita CO₂ emissions measure the annual CO₂ divided by total population to obtain per capita values, capturing the health implications of gas

flaring and combustion, which are prevalent in Nigeria's oil-producing regions. Data on life expectancy at birth were obtained from the World Bank's World Development Indicators 2023, while time-series data on climate-related variables, including CO₂ emissions from gas and oil sources and methane emissions, were obtained from the Global Carbon Budget.

3.2. Model Specification

Following [18] theory of environmental determinism and the EKC hypothesis, and extending [8] health capital model, and recent studies by [7] and [1], we explored the public

health implications of climate-related risks, with a focus on life expectancy at birth. The function specification of the model is provided as follows:

$$LEXP = f(PCO_2, PME, OILP) \quad (1)$$

Where: LEXP = Life Expectancy at Birth, PCO₂ = Per capita CO₂ emissions from gas, PME = Per capita methane emissions and OILP = Per capita emissions from oil production

The Autoregressive Distributed Lag (ARDL) version of the above model is expressed in the equation below:

$$\Delta LEXP_t = \alpha_0 + \sum_{i=1}^p \alpha_1 \Delta LEXP_{t-1} + \sum_{i=1}^q \alpha_2 \Delta PCO_{2,t-1} + \sum_{i=1}^q \alpha_3 \Delta PME_{t-1} + \sum_{i=1}^q \alpha_4 \Delta OILP_{t-1} + \beta_1 LEXP_{t-1} + \beta_2 PCO_{2,t-1} + \beta_3 PME_{t-1} + \beta_4 OILP_{t-1} + \varepsilon_t \quad (2)$$

Where: α_0 = constant parameter to be estimated, $\alpha_1 - \alpha_5$ = short-run parameters to be estimated, $\beta_1 - \beta_5$ = long-run multipliers, p = optimal lag operator for each of the dependent variables, q = optimal lag operator of the independent variables, Δ = first difference operator and ε_t = error terms.

3.3. Estimation Method

In this study, we used the least squares method to estimate the ARDL model. Compared with other estimation methods, the ARDL approach has several advantages. First, the ARDL model is well-suited for models that deal with mixed-integrated series (I(0) and I(1)). Second, it is considered superior to the traditional Ordinary Least Squares (OLS) method, given that it can handle smaller datasets effectively. We also employed the augmented [6] unit root test, commonly known as the ADF test, to determine the order of integration for each series. The ADF unit root test is a statistical test that determines whether a time series is stationary. A

stationary time series has a constant mean, variance, and autocorrelation over time, while a non-stationary time series has a time-varying mean and variance. The specification of the unit root test model is expressed as follows:

$$\Delta y_t = \mu + \beta t + (\theta - 1)y_{t-1} + \sum_{i=1}^p \delta_i \Delta y_{t-i} + \varepsilon_t \quad (3)$$

Where: Δy_t = the first difference of the series, μ = a constant, β = the coefficient of a time trend, θ = the coefficient of the lagged level of the series, δ_i = the coefficients of the lagged differences of the series and ε_t = an error term.

We further tested the series for cointegration using the [17] bounds test. This was motivated by the mixed integration evidence from the ADF unit root test results. To validate the reliability of the estimated model, we conducted post-estimation tests, especially residual diagnostics tests comprising serial correlation, heteroskedasticity and normality tests at the 5% significance level.

4. Results and Discussion

Table 1. Summary of descriptive statistics.

	LEXP	PCO ₂	PME	OILP
Mean	47.72132	0.101814	2.009487	0.267280
Median	46.38770	0.094738	1.960710	0.284773
Maximum	54.46230	0.176185	3.287814	0.457210
Minimum	40.00840	0.003802	0.994614	0.098264
Std. Dev.	3.641484	0.052483	0.597373	0.087085
Jarque-Bera	1.341069	2.857990	2.308356	0.963846
Probability	0.511435	0.239550	0.315317	0.617595

	LEXP	PCO ₂	PME	OILP
Observations	54	54	54	54

Source: E-views software output

The descriptive statistics revealed that the average life expectancy at birth was 47.72 years from 1970 to 2023, suggesting that human development in Nigeria remains low. Additionally, the results indicated that per capita CO₂ emissions from gas averaged 0.101 tonnes per person, while per capita methane emissions and per capita CO₂ emissions from oil averaged 2.009 and 0.267 tonnes per person, respectively. This shows that methane emissions exceeded CO₂ emissions

from gas and oil activities. The standard deviation indicated that the data for life expectancy clustered around the mean of 47.72 years, highlighting that Nigerians generally experience low life expectancy at birth. Likewise, the standard deviation indicated that the observations for each per capita emissions indicator clustered around their respective means. The Jarque-Bera statistics confirmed that the data for each variable is normally distributed at the 5% significance level.

Table 2. ADF unit root test results.

Variable	Test at levels	Test at first difference	5% Critical value	Order of Integration
LOG(LEXP)	-0.741	-3.198***	-2.919	I(1)
LOG(PCO ₂)	-4.099***	-	-2.919	I(0)
LOG(PME)	-0.210	-6.491***	-2.919	I(1)
LOG(OILP)	-2.979**	-	-2.919	I(0)

Source: E-views software output

Note: ***, ** and * denote significant at 1%, 5% and 10% levels

The unit root test results showed that per capita CO₂ emissions from gas and oil are stationary. The evidence of the levels stationarity in these variables implies that they are integrated of order zero, I(0). On the other hand, the observations for life expectancy at birth and per capita methane

emissions are nonstationary at levels. However, the variables became stationary after first differencing; hence, they are considered to be integrated of order one (I(1)). Overall, the unit test results indicated that the variables are mixed-integrated, which necessitated the bounds cointegration test.

Table 3. Summary of bounds cointegration test results.

Null Hypothesis: No levels relationship				
Test Statistic	Value	Significance level	I(0)	I(1)
F-statistic	32.817	10%	2.37	3.2
K	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66

Source: E-views software output

Note: k denotes the number of explanatory variables

The results showed that the computed F-statistic (32.817) exceeds the corresponding critical value (3.67) at the 5% level.

This implies that the null hypothesis of no cointegration is rejected. Thus, life expectancy has a long-run relationship

with the independent variables, which provides the basis for estimating the long-run and short-run regression models.

Table 4. Summary of ARDL results.

Dependent Variable: LOG(LEXP)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Short run coefficients				
DLOG(LEXP(-1))	0.361509	0.118914	3.040078	0.0040
DLOG(PCO ₂)	-0.000407	0.001443	-0.281935	0.7793
DLOG(PME)	0.005481	0.006298	0.870233	0.3890
DLOG(PME(-1))	-0.021670	0.005668	-3.822923	0.0004
DLOG(OILP)	-0.005868	0.002113	-2.776607	0.0081
CointEq(-1)	-0.065278	0.026765	2.438954	0.0189
Long Run Coefficients				
LOG(PCO ₂)	0.063468	0.016172	3.924608	0.0003
LOG(PME)	-0.124290	0.037411	-3.322320	0.0018
LOG(OILP)	0.089893	0.049293	1.823640	0.0752
C	4.174761	0.062003	67.331660	0.0000

Source: E-views software output

The results showed that CO₂ emissions from gas have mixed effects on life expectancy. While the results showed that per capita CO₂ emissions from gas have a negative and significant effect on life expectancy at birth in the short run, the long-term results showed that CO₂ emissions have a positive impact on life expectancy. This suggests that although pollution from gas poses a threat to life expectancy in the short run, it tends to decrease over the long run, partly due to the growing transition to cleaner, modern gas for cooking and transportation. The negative effect of CO₂ emissions from gas on life expectancy is consistent with the findings of [14] and [21], while the positive effect aligns with the findings of [15]. The results further showed that CO₂ emissions from methane negatively affected life expectancy in both the short and long run. This implies that methane-related emissions reduce the

life expectancy of the Nigerian population. This finding corroborates the results of [22] and [16], who established that methane emissions are detrimental to human health. Additionally, evidence of a negative and significant effect of CO₂ emissions from oil production was established in the short run. The finding highlights the adverse implications of oil production on the well-being of the population. Although CO₂ emissions from oil production positively affected life expectancy in the long run, this effect was not significant at the 5% level, possibly due to the poor energy transition in the oil sector. The error coefficient (-0.065) is negative and significant at the 5% level, indicating that the model adjusts to the long-run equilibrium at a rate of 6.5%. This corroborates the evidence of a long-term relationship among the variables in the model.

Table 5. Post-estimation test results.

Test type	Test Statistic	Prob. Value	Inference
Breusch-Godfrey Serial Correlation LM Test	5.121	0.077	No serial correlation
White Heteroskedasticity Test	11.311	0.1847	Homoscedastic
Normality	2.318	0.3137	Normally distributed

Source: E-views software output

The Breusch-Godfrey serial correlation LM test result showed that the probability value (0.077) of the test statistic (5.121) is greater than 0.05. This implies that there is no serial correlation in the residuals at the 5% level. Similarly, the residual is homoscedastic at the 5% level, given that the probability value (0.1847) of the test statistic (11.311) for the White heteroskedasticity test is greater than 0.05. This finding validates the reliability of the estimated model. Additionally, the residuals are normally distributed at the 5% level. This is based on the fact that the probability value (0.3137) of the Jarque-Bera statistic is greater than 0.05.

5. Concluding Remarks

The central focus of this study is to examine the impact of climate risks on life expectancy in Nigeria. This investigation is prompted by increasing concerns about rising CO₂ emissions from various sources, including gas, methane, and oil production. The findings indicate that CO₂ emissions from gas have a short-term negative effect on life expectancy. Furthermore, it was observed that the long-term impact of CO₂ emissions from gas is also negative and statistically significant. This underscores the long-term benefits of transitioning to clean, modern gas resources for human health. The results further provide evidence of the adverse effects of CO₂ emissions from methane on life expectancy, emphasising that increased methane emissions jeopardise population health. Additionally, CO₂ emissions from oil production are shown to significantly reduce life expectancy, highlighting the implications of oil exploration on human development in Nigeria. Based on these findings, the study concludes that climate risks, particularly CO₂ emissions from methane and oil production, impede human development by substantially decreasing life expectancy. Consequently, it is recommended that the government support the transition to clean and modern gas sources for electricity generation, cooking, and transportation to improve the life expectancy of the Nigerian population. Moreover, policymakers should enforce methane-specific regulations through stricter penalties, regular monitoring, and transparent reporting to mitigate the rising CO₂ emissions from methane and their associated impacts on life expectancy.

Abbreviations

CO ₂	Carbon Dioxide Emissions
WHO	World Health Organisation
GHG	Greenhouse Gases
EKC	Environmental Kuznet Curve

Conflicts of Interest

The authors declare no conflicts of interest.

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