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Research Article

The Asymmetric Effects of Climate Change on Health Expenditures in Nigeria: Evidence from Nonlinear ARDL Model

Nuhu Musa[a]

Abstract

Introduction: This study demonstrates the asymmetric impacts of climate change on Nigeria's health expenditures. Climate change has been acknowledged as one of the greatest environmental challenges facing the globe and posing serious threat to human health. The increasing prevalence of climate-sensitive diseases across the world today is largely as a result of environmental degradation. The climate shocks and the associated extreme weather conditions have imposed greater challenges on human health, leading to increase in government and household health expenditures.

Method: A time series analysis was conducted using non-linear autoregressive distributed lag (NARDL) approach in conjunction with Granger causality test over the period spanning from 1990 to 2023. We measure climate change using carbon emission (CO_2) and temperature anomalies. To ascertain the possible asymmetric effects of the variables, we decompose carbon emission (CO_2) and temperature anomaly into positive and negative partial sums.

Results or Findings: Findings show that positive temperature and CO_2 shocks significantly increase costs in both short and long terms, highlighting the urgency for climate action. Conversely, negative CO_2 shocks yield long-term health expenditure reductions, showcasing mitigation's potential. The established unidirectional causality from CO_2 emissions to per-capita health spending strengthens the case for targeted emission reduction policies.

Discussion or Conclusion: The finding that a positive shock in temperature and CO_2 significantly increases health expenditures underscores the urgent need for climate mitigation strategies.

Keywords: greenhouse gas emission, climate change, temperature, health outcomes, healthcare expenditure, zero-net emission

JEL Codes: Q50, Q54, Q57

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Araştırma Makalesi

Nijerya'da İklim Değişikliğinin Sağlık Harcamaları Üzerindeki Asimetrik Etkileri: Doğrusal Olmayan ARDL Modelinden EldeEdilen Kanıtlar

Nuhu Musa[a]

Öz

Giriş: Bu çalışma, iklim değişikliğinin Nijerya'nın sağlık harcamaları üzerindeki asimetrik etkilerini göstermektedir. İklim değişikliği, dünyanın karşı karşıya olduğu en büyük çevresel zorluklardan biri olarak kabul edilmekte ve insan sağlığı için ciddi bir tehdit oluşturmaktadır. Günümüzde dünya genelinde iklime duyarlı hastalıkların artan yaygınlığı büyük ölçüde çevresel bozulmanın bir sonucudur. İklim şokları ve ilişkili aşırı hava koşulları, insan sağlığı üzerinde büyük zorluklar yaratmış ve hükümet ve hanehalkı sağlık harcamalarında artışa yol açmıştır.

Yöntem: 1990'dan 2023'e kadar olan dönemde Granger nedensellik testiyle birlikte doğrusal olmayan otoregresif dağıtılmış gecikme (NARDL) yaklaşımı kullanılarak bir zaman serisi analizi yürütülmüştür. İklim değişikliği, karbon emisyonu (CO2) ve sıcaklık anomalileri kullanarak ölçülmüştür. Değişkenlerin olası asimetrik etkilerini belirlemek için karbon emisyonu (CO2) ve sıcaklık anomalisi pozitif ve negatif kısmi toplamlara ayrılmıştır.

Sonuçlar ya da Bulgular: Bulgular, pozitif sıcaklık ve CO2 şoklarının hem kısa hem de uzun vadede maliyetleri önemli ölçüde artırdığını ve iklim için eyleme geçmenin aciliyetini vurgulamaktadır. Tersine, negatif CO2 şokları uzun vadeli sağlık harcamalarında azalmaya yol açar, bu da CO2'i azaltmanın potansiyel etkisini göstermektedir. CO2 emisyonlarından kişi başına düşen sağlık harcamalarına doğru kurulan tek yönlü nedensellik, emisyon azaltma hedefli politikaların uygulanmasının gerekliliğini güçlendirmiştir.

Tartışma ya da Yapılan Çıkarımlar: Sıcaklık ve CO2'deki pozitif şokun sağlık harcamalarını önemli ölçüde artırdığı bulgusu, iklim değişikliğiyle mücadele stratejilerine acil ihtiyaç olduğunu ortaya koymuştur.

Anahtar Kelimeler: sera gazı emisyonu, iklim değişikliği, sıcaklık, sağlık sonuçları, sağlık harcamaları, sıfır net emisyon

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Introduction

Climate change has been acknowledged as one of the greatest environmental challenges facing the globe and posing serious threat to human health (Chien, Chau, &Sadiq, 2023, Ali et al., 2024). The increasing prevalence of mortality and morbidity across the world today is largely as a result of environmental degradation (Zeeshan et al., 2021). More than 95 per cent of the population in low income countries use firewood, charcoal and biomass gasses for cooking and other domestic work. In developing countries, burning of fossil fuel has been identified as one of the major causes of climate variation. Fossil fuels- coal, oil and gas flaring – are the largest contributor to global climate change, accounting for 75 per cent of global greenhouse gas emission and 90 per cent of carbon dioxide emission (Pörtner, et al., 2022). This poses significant challenges on human health. Although, climate change is a global trend affecting both advanced and developing world, less developed countries (LDCs) are more vulnerable to the effects than the advanced countries, probably as a result of lack of infrastructure and technologies to adapt to the climate resilience (FAO, IFAD, UNICEF, WFP and WHO,2023). The climate shocks and the associated extreme weather conditions have imposed greater challenges on human health, leading to increase in government and household health expenditures. The need to reduce levels of carbon emission gave rise to the invention of technologies to build resilience to climate change. The most successful examples of such technologies include renewable energy technologies, energy efficiency and climate smart agricultural technologies, ICTs among others. These technologies have been successfully adopted in developed world as important mechanisms for adaption to climate risk. However, due to some structural rigidities, weak adaptive capacity, poor infrastructure, inadequate financial resources, technology transfer, limited research capacity and expertise, developing countries particularly sub- Saharan Africa are yet to benefit from the innovations, making their economies more vulnerable to the effects. (Adenle et al., 2015).

The Intergovernmental Panel on Climate Change (Field, et al., 2014) define climate change as any change in the atmospheric condition over a time period which may be as a result of natural variability or human activities. The emission of carbon dioxide from combustion of fossil fuels in electricity generation and industrial activities leads to concentration of cloro-fluorocarbons and greenhouse gasses (CO_2) in the atmosphere (To *et al.,* .2022; XU et al., 2019; Chaabouni & Saidi, 2017). Climate change variability significantly affect human health (Zhang, et al., 2017; Lee & Romero,2023). The increasing environmental degradation resulting from industrial activities and emission of toxic substances into the atmosphere (e.g. carbon dioxide, carbon monoxide, methane, chlorofluoro carbons, nitrous oxide etc) has increased the prevalence of health related diseases (To & King ,2022). Nigerian economy is among the countries in African sub-region with prevalence of greenhouse gas (GHG) emission, which may be due to burning of fossil fuels and other industrial activities.

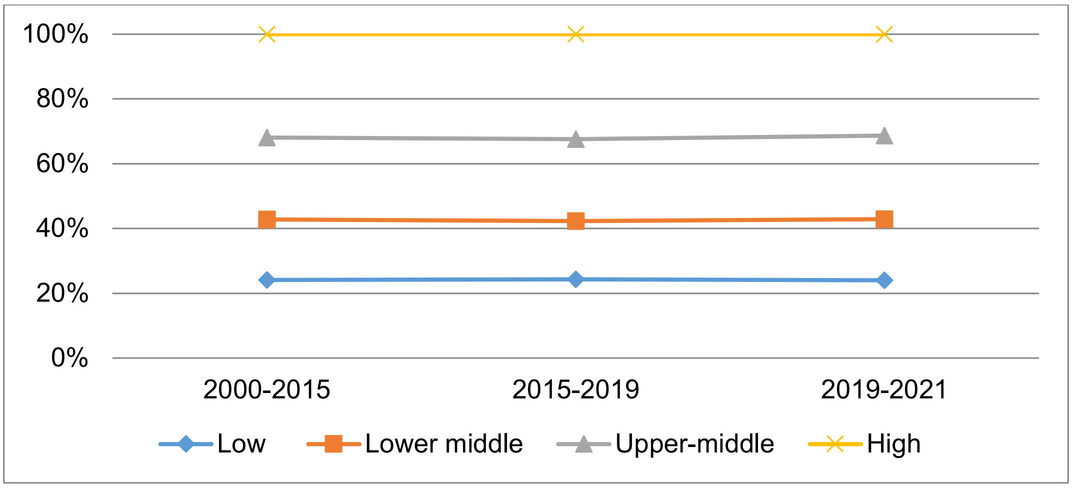
The escalating occurrence of weather and climatic events leads to proliferation of air-borne diseases which affect human health leading to deaths of millions of people across the globe (Wang et al., 2023), making government health care expenditure to increase (Khoshnevis & Khanalizadeh,2017; Erdogan et al., 2020; Chien et al., 2023; Lee & Romero,2023; Wang et al.,2023). Statistics from World Health Organization has shown that millions of people worldwide die as a result of extreme heat (WHO, 2023). Indeed, Mehfoz et al. (2023) argue that rising temperature and CO_2 emission increase health-care cost and this affect health care quality.

Figure 1 shows the global percentage allocation to health expenditure. From the figure we note that high income countries spend an average 9% on health expenditure from 2019-

2021. For Upper-middle income countries (UMIC), health spending as a share of GDP was 6.5% in 2019, 7% in 2020 and remain same in 2021. And for lower-middle income countries, health expenditure as a percentage of GDP was 4.8% in 2019, 5.1% in 2020 and 5.4% in 2021. In low income countries, health expenditure as percentage of GDP rose from 6.2% in 2019 to 6.9% in 2020 and 2021 respectively.

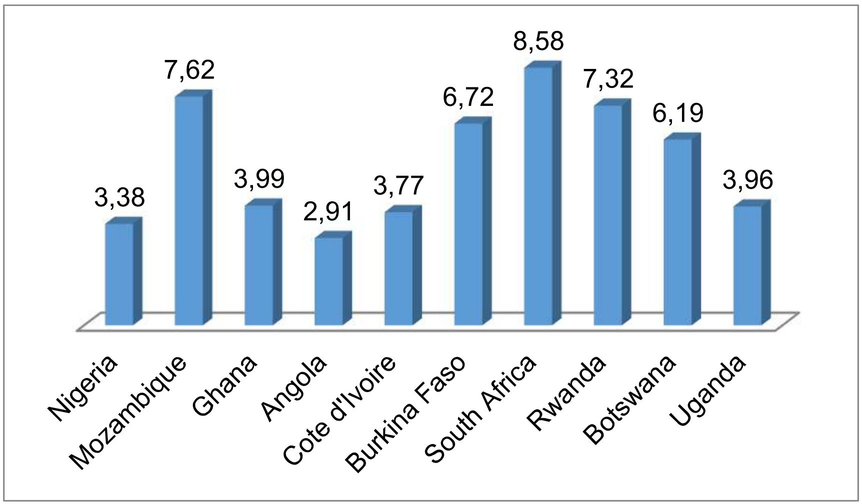
Figure 1

Global Health Expenditure, 2000-2021 (%)



Note. WHO Global Health Expenditure database, 2023

Figure 2
Allocation to Health Sector by Selected African Countries in 2022



Note. Created by the author

Figure 2 shows funding allocation to the health sector of some selected countries in sub-Saharan Africa in 2022. The figure indicates that countries like, Mozambique spent 7.62% of its GDP on health, Ghana 3.99% Angola 2.91%, Cote d'Ivoire 3.77 %, South Africa, 8.58%, Rwanda 7.32%, Botswana 6.19% and Uganda,3.96%. Nigeria spent a miniscule of 3.38% which is far less than 15%benchmark recommended by African Union's budgetary allocation to the health sector.

In recent times, the effect of climate change on health expenditure has attracted the attention of many scholars (see, for example, Frankovic, 2017; Chen et al.,2019; XU et al., 2019; Erdogan *et al.*,2019; Oyelade et al., 2020; Akbar et al., 2021; Melina & Chaido,2023; Socol, et.al., 2023; Mehfoz, et al., 2023). Most of these studies have applied linear specifications such as ARDL and traditional methods like Ordinary Least Squares (OLS) and quantile regression in their analysis which may produce biased results and reliable estimates could not be ascertained (see Chen et al.,2019;XU et al., 2019; Oyelade et al., 2020).Very few studies such as Zeeshan et al., (2021) have specifically explored the asymmetric relationship between climate change and health expenditures, yet their study was restricted to China. To the best of the author's knowledge, this is the first study that is targeted at exploring the asymmetric association between climate change and health expenditures in Nigeria. This current research fills this research lacuna by focusing on the asymmetric effects of climate change on household healthcare expenditures in Nigeria by employing nonlinear autoregressive distributed lag (NARDL) technique over the period 1990-2023.

Our study's contributions to the body of knowledge are as follows; first the asymmetric relationship between climate change and health expenditure in Nigeria has not been previously explored by many scholars. Second, we employ asymmetric or nonlinear autoregressive distributed lag (NARDL) approach developed by Shin et al. (2014) to determine the asymmetric nexus between climate change using both CO_2 emission and temperature anomaly in our model which will help us to ascertain the degree of shocks of these variables. Third, we conduct robustness checks to strengthen the reliability and validity of our model results. Finally, we incorporate some control variables like GDP per capita and inflation rate to make the result robust. The finding is expected to assist policy-makers in adopting appropriate policy measures to mitigate climate change effect on health status.

The primary objective of this paper is to empirically investigate the asymmetric relationship between climate change and health expenditures in Nigeria. In doing so, annual data was utilized spanning the period 1990 to 2023, based on NARDL (non-linear autoregressive distributed lag) technique.

Theoretical and Empirical Literatures

The Environmental Kuznet curve (EKC) hypothesis provides a theoretical basis for this work. According to this hypothesis, there exist an inverted U-shaped correlation between carbon emission and economic growth. The hypothesis posits that the amount of carbon emissions first increases with economic growth, but over time, when the economic growth levels of a country exceed a certain turning point or reaches a certain threshold level, there will be an inverse correlation with economic growth, a situation referred to as the Kuznets inverted U-shaped hypothesis (Zhao et al., 2005; Song et al., 2013). The validity of EKC hypothesis is contentious in developing countries; while some scholars (see, for example, Akpan & Chuku, 2011) did not find strong evidence of EKC hypothesis, others (for example, Apergis, 2016; Zhang, et al., 2017) found strong evidence. However, many scholars, using varied methods, argue that rising CO_2 emissions positively influenced public health costs.

Cheng et al. (2024) present a study that analyzes the relationship between CO_2 emission and health expenditure in OECD.countries. They find CO_2 emission led to increased government health expenditures. Sohail et al. (2023) find that increased government healthcare investment is germane in addressing health issues caused by CO_2 emissions. Wang et al. (2023) find that in the long term, globalization, industrialization and economic growth influence CO_2 emissions.

Mehfoz et al. (2023) examine climate change, economic growth and health expenditure nexus in Pakistan from 1985-2020. Using ARDL model, they found that greenhouse gas emission has significant positive impact on health expenditure.

Anwar, et al. (2022) explored health care expenditure and climate variability using generalized method of moment (GMM). They discover a positive relationship between government health spending and climate change. Azam and Awan (2022) carried out a research on climate change and health care expenditure. Their findings show that increase in greenhouse gas emission has led to a considerable increase in government expenditure. Samah et al. (2020) carried out similar study in Malaysia using Group Method of Moment (GMM). They discovered that temperature and GHG emission had positive association with healthcare spending. A study by Chen et al. (2019) found that climate change factors, including GHG emissions, average temperature, positively and significantly influenced health expenditures. Zeeshan et al., (2021) used NARDL and granger causality and discovered positive shocks in CO_2 emissions positively affect health expenditures. Wang et al. (2019) utilized data from 1995 to2017, and ARDL model to study the dynamic relationship between climate change, health expenditure and economic growth in Pakistan. They found that greenhouse gas emissions, average temperature, positively and significantly influenced health expenditures in Pakistan.

Aboubacar and Xu et al. (2017), in their study found that changing climate conditions have led to increase in public health expenditures. Another study by Shabestari et al. (2020) for Sweden and China confirmed a positive relationship between carbon emission and health expenditure. Erdogan, Kirca, and Gedikli (2020) found similar result. In contrast, Eckelman et al. (2020) did not find any relationship between CO_2 emissions and public expenditures in United States. The same result was discovered by Boachie et al. (2014). In addition, a study by Wang et al. (2019); Oyelade et al. (2020) and Akbar et al. (2021) also confirmed positive relationship between GHG and health expenditure, concluding that when GHG emissions increase, expenditure on health would also increase.

Methodology

Data Sources

The study utilized annual dataset, spanning from 1990 to 2023. The choice of this timeframe was necessitated by data availability. Data on climate change variable (global average temperature anomaly and carbon emissions) are obtained from World Bank Group climate change knowledge portal, whereas data on inflation and GDP per capita are taken from Central Bank of Nigeria's Statistical Bulletin online database. Data on health expenditure is obtained from World Health Organization Global Health Expenditure database.

Econometric Technique and Model Specification

The method of analysis employed in this study was Nonlinear Autoregressive Distributed Lag (NARDL). The choice of this approach is justified for many reasons, first the nonlinear model also called asymmetric autoregressive distributed lag is preferred over other techniques of analysis because of its ability to systematically address nonlinear nature of climate change as suggested by most scholars such as Zeeshan et al., (2021). Second, NARDL has the ability to handle mixed order of integration I(1) or at level; I(0), provided none is integrated at order 2 (Pesaran et al, 2001) Third, the data used also exhibit non-linear characteristics, thereby supporting our preference for opting NARDL. Fourth, it is the most appropriate technique that takes into consideration both the short and long-term dynamic nature of climate change. Finally and most importantly, it is suitable for small sample size.

We specify a model similar to Wang, et al. (2019), Barati and Fariditavana (2020) and Zeeshan et al., (2021) and utilize GHG emission and temperature anomaly as proxy for climate change. We use per capita health expenditure as our dependent variable. As a departure from previous work, we incorporate inflation rate and GDP per capita as control variables in our model to make the result robust. Specifically our model for this study takes the following form;

LnHealthexp=*f* (lnTEMP, lnGHG , lnLEXP, INFL, GDPPC) (3.1)

Econometric specification of the model in Eq. (3.1) is re-specified as follows:

$$Healthexp = \delta_0 + \delta_1 \ln TEMP + \delta_2 \ln CO_2 + \delta_3 \ln LEXP + \delta_4 \ln INFL + \delta_5 \ln GDPPC + \mu \quad (3.2)$$

Following Shin *et al* (2014), we transform Eq (3.2) into NARDL model as follows;

$$\begin{aligned} \Delta Hexp_t &= \gamma_0 + \gamma_1 Hexp_{t-1} + \Delta\gamma_2 Temp^+{}_{t-1} + \Delta\gamma_3 Temp^-{}_{t-1} + \Delta\gamma_4 Ghg^+{}_{t-1} + \Delta\gamma_5 Ghg^-{}_{t-1} \\ &+ \gamma_6 Lexp_{t-l} + \gamma_7 Gdppc_{t-1} + \sum_{i=1}^{p} \delta_1\, Hexp_{t-1} + \sum_{i=0}^{q} \delta_2\, \Delta Temp^+{}_{t-1} + \sum_{i=0}^{r} \delta_3\, \Delta Temp^-{}_{t-k} \\ &+ \sum_{i=0}^{s} \delta_4\, \Delta Ghg^+{}_{t-k} + \sum_{l=0}^{t} \delta_5\, \Delta Ghg^-{}_{t-l} + \sum_{i=1}^{u} \delta_6\, \Delta Lexp_{t-1} + \sum_{i=1}^{p} \delta_6\, \Delta Infl_{t-1} \\ &+ \sum_{l=0}^{p} \delta_7\, \Delta Gdppc_{t-l\,+} \\ &+ \mu_t \end{aligned} \quad (3.3)$$

In Eq. (3.3), *Hexp* represents per capita health spending (measured in million US$), *Temp* denotes global average temperature anomalies (measured in ºC), *Ghg* refers to carbon emission (CO_2) measured in metric tons per capita, *Lexp* stands for life expectancy (measured by LE at births per 1000 people), *Gdppc* represents gross domestic product per capita expressed in constant USD . And $\gamma_0$denotes constant intercept, ($\delta_1 - \delta_5$) are the coefficients, and μ_t represents stochastic error term.

To examine the asymmetric relationship between the variables, following Shin *et al.* (2014), we decompose climate change variables into negative and positive shocks in temperature and carbon emissions and re-specify our model as follows;

$$Temp^+ = \sum_{i=0}^{h} \Delta Temp^+ = \sum_{i=0}^{p} \max(\Delta Temp_i, 0) \quad (3.4)$$

$$Temp^- = \sum_{i=0}^{h} \Delta Temp^- = \sum_{i=0}^{p} \max(\Delta Temp_2, 0) \quad (3.5)$$

$$Ghg^+ = \sum_{i=0}^{h} \Delta Ghg^+ = \sum_{i=0}^{p} \max(\Delta Ghg_i, 0) \quad (3.6)$$

$$Ghg^- = \sum_{i=0}^{h} \Delta Ghg^- = \sum_{i=0}^{p} \max(\Delta Ghgp_2, 0) \quad (3.7)$$

where:$Temp^+$ and $Temp^-$denote the partial sum of positive and negative shocks of temperature anomaly while Ghg^+ and Ghg^- are partial sums of positive and negative changes in carbon emissions respectively.

Results and Discussions

Descriptive statistic Test

Before computing NARDL regression, we first carry out some pre-estimation analysis to avoid spurious regression results. In doing so, we performed descriptive statistic test and unit root tests: the ADF (Augmented Dickey-Fuller) and P-P (Phillips-Perron) tests. The outcome of our descriptive statistics in *Table 1*shows that all the series are positively skewed with the exception of life expectancy rate (LEXP). Meaning there is asymmetry in the distribution. The values of Jarque-Bera are higher than the Kurtosis, indicating that the series are normally distributed. In addition, stationarity test results in *Table 2* show that the series *HEALTHEXP*, GHG,LE, and *INFL,* are stationary at order I (1), whereas TEMP and GDPPC are stationary at level; I(0). This result indicates that the variables' levels of integration are not the same, as demonstrated by ADF and PP unit root tests, suggesting that the series do not exhibit the same order of integration, thereby lending credence to the use of nonlinear ARDL bounds co-integration test as opined by Pesaran, Shin and Smith (2001).

Table 1

Descriptive Statistic Results

TEST STATISTIC	HEX	TEMP	GHG	LE	INFL	GDPPC
Mean	13.86485	53.93939	40.36818	9.701818	72.42576	79.84121
Median	14.00000	53.70000	18.43000	8.600000	61.30000	17.30000
Maximum	26.00000	56.70000	141.1300	22.10000	157.5000	450.0000
Minimum	6.130000	50.30000	6.130000	-2.340000	3.600000	0.200000
Std. Dev.	3.612044	1.666759	43.46582	7.072449	57.85769	124.0301
Skewness	0.733819	0.047569	1.218148	0.565122	0.161480	1.794635
Kurtosist	5.705877	0.885484	2.846099	2.309688	1.339911	5.095330
J-B	13.02913	2.203170	8.193938	2.365713	3.932774	23.75075
Prob. values	0.001482	0.642273	0.016623	0.315107	0.139962	0.000007

Note. Author's computations

Table 2

Results of Unit-Root Test

Regressors	*ADF*	Remark	*PP*	Remark
HEXP	-8.382**	1(1)	-4.59**	1(1)
TEMP	-4.27***	1(0)	-3.94***	1(0)
GHG	-5.31***	1(1)	-6.31***	1(1)
LE	-5.02**	1(1)	-5.01***	1(1)
INFL	-5.01**	1(1)	-4.99**	1(1)
GDPPC	3.23**	1(0)	3.60**	1(0)

Asterisks*** and ** imply 1% and 5% significance levels.

Note. Own computation

Table 3
Bounds Test Results in Non-linear ARDL

Model	F-Statistic	Upper Bound 1(1)	Lower Bound 1(0)
*(F(HEALTHEXP / $TEMP^{-}$ $POGDPPC$))***	4.581594		
Critical Values			
10%		3.00	2.08
5%		3.34	2.39
1%		4.15	3.06

Note. Author's computations

We further check for the short-run and long term asymmetric relationship between climate change and health expenditures by employing Wald test. Findings from Wald test confirm long-run asymmetry. The outcome in Table 3, indicate that ($\mathrm{F-statistic} = 4.581594 > 3.34$).This implies that long-term association exists among the selected variables.

Table 4
Estimated Short-Run Non-linear ARDL Model Results
(Dependent Variable is HEALTHEX)

Regressors	Coefficient	t-Statistic	Prob.
D(HEALTHEXP(-1))	-16.04940	-2.122159	0.0574
D(TEMP_NEG)	-6.151678	-1.720353	0.1133
D(TEMP_NEG(-1))	-12.53371	-2.943808	0.0087
D(TEMP_POS)	0.341660	2.106202	0.0487
D(TEMP_POS(-1))	9.527166	1.211251	0.2512
D(GHG_NEG)	-12.53371	-2.943808	0.0087
D(GHG_NEG(-1))	-12.72189	-1.659610	0.1143
D(GHG_POS)	0.207147	3.092505	0.0066
D(LE)	100.0230	2.412977	0.0267
D (LE(-1))	17.85562	3.914606	0.0006
D(INFL)	0.389609	3.347128	0.0024
D(INFL (-1))	0.445745	2.387737	0.0235
D(GDPPC1)	0.062443	3.277075	0.0047
D(GDPPC(-1))	134.1102	2.444051	0.0326
CointEq(-1)*	-0.070419	-8.364358	0.0000

Note. Author's computations

Table *5*

Estimated Long-Run Non-linear ARDL Model
(Dependent Variable: HEALTHEX)

Regressors	Coefficient	t-Statistic	Prob.
TEMP_POS	0.264204	2.327702	0.0334
TEMP_NEG	-19.75916	-1.195549	0.2570
GHG_POS	0.264204	2.327702	0.0334
GHG_NEG	17.26640	0.375681	0.7143
LE	11.47650	2.697988	0.0147
INFL	0.104800	2.141975	0.0479
GDPPC	1.097311	3.269565	0.0048
R-squared	0.755465		
Adj. counterpart	0.541497		
D-W	2.057411		
F-value	3.530739		

Asterisks ****, ** and * explain 1%, 5% and 10% significance levels of sig.*
Note: Author's calculations

The estimated short-run asymmetric relationships are displayed in Table4. The analysis indicates that in the short-run, positive shocks in temperature positively contribute to household health spending while a negative shock reduces per capita health expenditure, thereby confirming the asymmetries between temperature anomaly and health expenditure. This implies that a rise in average temperature by 1ºC can cause an increase in per capita healthcare expenditure by approximately 0.34%. This result is in line with the submissions of XU et al (2019) and Chen et al (2019) which found that higher temperature and rising carbon dioxide emission have a positive correlation with public healthcare spending. The outcome also indicates a positive shock of carbon emission has a positive and significant effect on household health expenditure while a negative shock dampens health spending. This simply means that as CO_2 increases, per-capita household expenditure increases, this pushes up healthcare costs. Zeeshan et al., (2021) argue that a rise in average annual temperature by 1ºC can cause a significant increase in per capita health expenditure. As temperature gets worse, individuals incur higher healthcare costs. This finding confirms non-linear relationship between carbon emissions and per capita health spending. Also Wang *et al*. (2019) found that climate change was a major factor affecting health conditions. Hence as the result portrays, a 1 % increase in carbon emission, government spending on healthcare facilities will increase by approximately 0.207%. From our analysis, we discover that GDP significantly influences healthcare expenditure. The implication of this result is that a robust per capita GDP often leads to higher household health care expenditures. With enhanced per capita income, individual purchasing power will also increase making healthcare facilities accessible and affordable. This result corroborates with submission by Chaabouni and Saidi (2017); Barati and Farditavana (2020) which found in their studies that higher GDP per capita significantly influenced health expenditures. This finding agrees with studies by XU et al. (2019) and Wang *et al* (2023). Also, inflation (INFL) was found from our estimated result above to be positive and significant, implying that given a 1% increase in inflation, healthcare expenditure would also increase by approximately 0.389 per cent. This finding clearly supports studies by Siami-Namini (2018). This means that when inflation rises, the cost of healthcare facilities, including medical supplies, medications and labour would increase. The finding also indicates that LE rate has positive link with health spending. This means that an increase in healthcare spending improves quality of life and increases life expectancy. This suggests that life expectancy can be improved through improvement in healthcare. As climate changes and shocks in CO_2 emission increases, the health conditions of millions of people are affected and it increases healthcare costs. The estimated coefficient of *ecm* (error correction term) of-0.070 was significant, and appropriately negatively signed, indicating a very high speed of adjustment to equilibrium after a shock.

Table 5 shows the long-run analysis of the model. In the long-term, a positive shocks in temperature positively influences health spending while a negative shocks reduces per capita health expenditure. As shown in the regression results, given a 1% variation in temperature extreme, health expenditure would increase by approximately 0.26%. Similarly, carbon emission positively correlates with per capita health spending, meaning risingCO_2emission is disastrous to human health, thereby leading to increase in government health spending. Our result also indicates that in the long term GDPPC has a positive effect on health expenditure. Life expectancy rate also relates positively with health expenditure. This result was confirmed by the studies of Frankovic (2017) and Wang et al. (2023). Inflation rate (INFL) is found to be positively related to HEX (health spending) meaning that increased inflation rate increases healthcare costs, thereby resulting in increased government healthcare expenditure. Barati and Fariditavana (2020) also found similar results. The coefficient of determination (R^2) as shown in table 5 is 0.755465. This indicates high explanatory power. Also, the F-value is highly significant at 5% level, implying that the explanatory variables have strong forecasting power on the dependent variable (HEX).

Robustness Checks

To confirm the robustness of the models' results we conducted Heteroskedasticity, Serial Correlation and Ramsey RESET test. The results are presented in Table 6.

Table 6

Results of Diagnostic Check

Test	F-calculated	Prob. Value
A. Serial Correlation LM Test	1.308256	0.3014
B. Heteroskedasticity Test	2.448661	0.0443
C. Ramsey RESET Test	1.162244	0.2845
D. Normality Test	1.406130	0.2357

Note. Author's computations

Diagnostic findings in Table 6 show that our model does not have autocorrelation issue. Results also indicate absence of heteroskedasticity problem. We also discover that the model does not suffer misspecification bias. The normality test also indicates that the residuals are normally distributed.

Asymmetry Test

Wald was carried out to confirm the existence of asymmetry in the nonlinear ARDL model. Results in Table 7 indicate the existence of non-linear correlation among the variables.

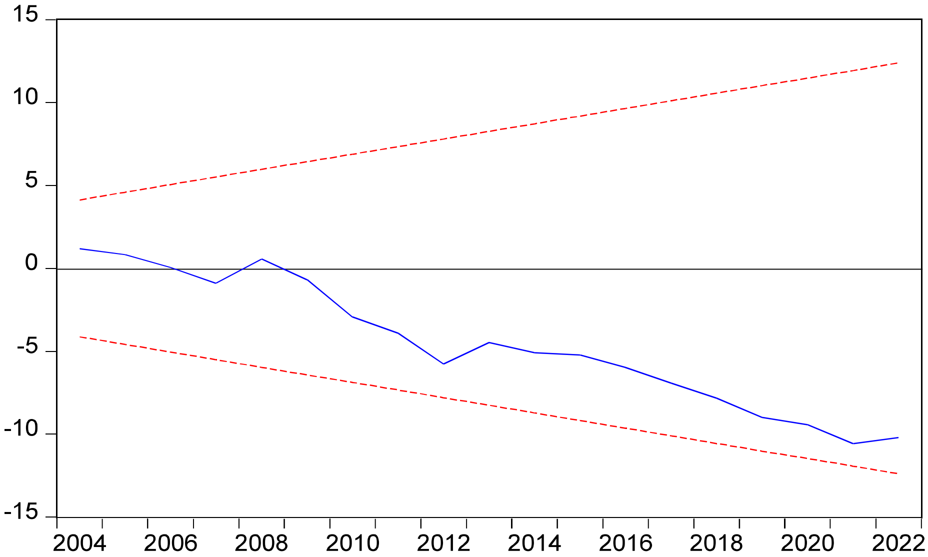
Table 7
Wald Test

Test Statistic	Value	Df	Prob. Values
F-statistic	5.683363	(2, 17)	0.0129
Chi-square	11.36673	2	0.0034

Note. Author’s calculations

Furthermore, we performed the CUSUMsq (Cumulative sum of squares) and CUSUM (Cumulative sum) to ascertain the model's stability. Results are displayed in Figures 3a and b. We found that recursive residuals were within the two critical lines, suggesting our models are stable, reliable and robust for policy analysis.

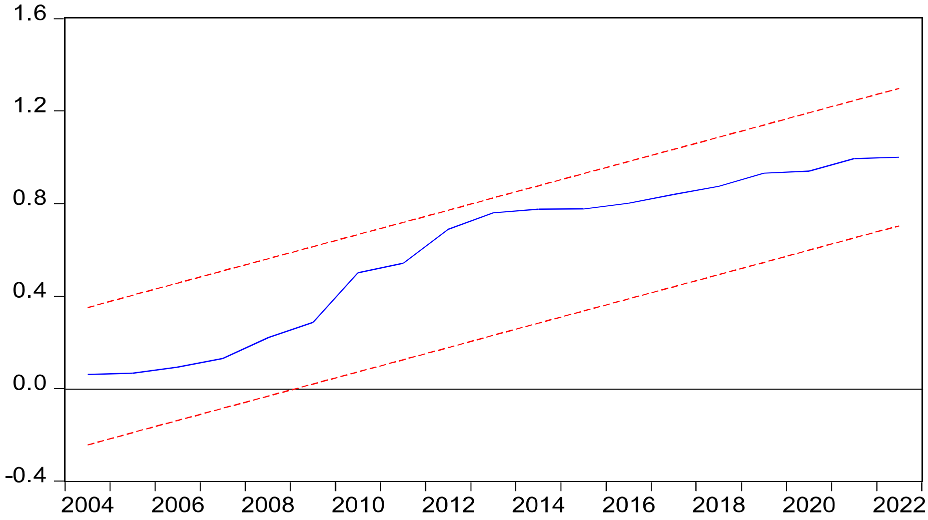
Figure 3 a
Non-linear ARDL CUSUM



Note. Author’s computation

Figure 3 b

Non-linear ARDL CUSUM of Squares



Note. Author's computation

Table *8*

Granger Causality Test

Null Hypothesis:	F-Statistic	Prob.
TEMP does not Granger Cause HEX	9.92432	0.0006
HEX does not Granger Cause TEMP	0.24416	0.7851
CO_2 does not Granger Cause HEX	4.79458	0.0165
HEX does not Granger Cause CO_2	0.56036	0.5775
LE does not Granger Cause TEMP	0.60005	0.5559
TEMP does not Granger Cause LE	2.58342	0.0941
LE does not Granger Cause CO_2	1.67638	0.2059
CO_2 does not Granger Cause LE	9.92432	0.0006

Note. Calculated by the author

The results of granger-causality indicate a unidirectional causality between CO_2 emission and health expenditure as revealed by F-statistics which was found to be significant at 5%. The findings are in support with empirical results by Melina and Chaido (2023) but contradict the findings by (Khoshnevis & Khanalizadeh, 2017; Chen et al., 2019; Xu et al., 2019). The result also indicates evidence of a unidirectional causality running from TEMP to HEX. Similar result was established between temperature and life expectancy, meaning that extreme temperature could have harmful effect on life expectancy. Further evidence of unidirectional causation was also established between CO_2 and LE, confirming that climate change could have detrimental effects on health conditions. This finding is in accordance with submission by Zeeshan et al., (2021).

Conclusion

This study effectively demonstrates the asymmetric impact of climate change on Nigerian health expenditures (1990-2023) using NARDL and Granger causality. Key findings show positive climate shocks increase costs, while negative shocks decrease them. Unidirectional causality from emissions to health spending is confirmed, highlighting the detrimental effects of extreme climate conditions. The study contributes by confirming an asymmetric nexus, emphasizing the need for climate mitigation policies to protect public health. There is need to adopt clean energy to achieve climate goals while enhancing public health expenditure. The findings and the actionable policy recommendation represents a valuable contribution. The study provides solid empirical support for the relationship between climate change and health costs, offering a foundation for future research and policy in Nigeria and similar developing nations.

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