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AIR POLLUTION, INCOME AND HEALTH CARE EXPENDITURE INTERACTION: NON-LINEAR ARDL APPROACH

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ABSTRACT

The paper employs a nonlinear autoregressive distributed lag (NARDL) approach to cointegration in order to examine the interactions among air pollution, economic growth and healthcare expenditure in Nigeria by using a time series data from 1990 to 2022. The results show the long run impact of air pollution (Carbon dioxide emission) on health expenditure to be positive and statistically significant at 1%. Also, it reveals the existence of significant nonlinear effect of economic growth on healthcare expenditure. Specifically, 1 percent point increase in gross national income leads to -0.383919 percent point decrease in total health expenditure as a share of Gross Domestic Product.1 percent point decrease in gross national income leads to 571.143839 percent point decrease in total health expenditure as a share of GDP. As such, Nigerian government should increase public health expenditure so that the health of the individuals in the society will be adequately taken care of and mortality rate reduced. Similarly, Nigerian government alongside development actors should institute low-carbon mechanisms like green infrastructure and renewable energy systems that reduce energy consumption and carbon dioxide emissions.

Keywords: Non-Linear ARDL, Asymmetry, CO_2 emission, Gross National Income, Population

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INTRODUCTION

In 1948, the World Health Organization (WHO) defined health with a phrase that is still used today: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". It further clarified in 1986 that health is: "A resource for everyday life, not the objective of living. Health is a positive concept emphasizing social and personal resources, as well as physical capacities" (Nordqvist, 2017). This means that health is a resource to support an individual's function in wider society. A healthful lifestyle provides the means to lead a full life.

However, the upturn in the economic activities in most developing countries goes along with an increase in energy consumption which eventually leads to increase in air pollutions that pose danger to human health (Yazdi and Khanalizadeh, 2017). The air pollution that adversely affects human health has a negative impact on labour productivity. This affects the industrial production and domestic output, thus affecting the growth of businesses and the economy. The financial implication of outdoor air pollution in developing countries has been marked to the tune of 5 % of their GDP (United Nations Environment Program, 2016).

Several theoretical and empirical studies have been done on the health-growth, health-energy and energy-growth relationship over the years; and some of them are have been country-specific and cross-county studies on the issues (Strauss and Thomas, 1995; Knowles and Owen, 1997; Bloom and Canning, 2000; Torras, 2005; Acemoglu and Johnson, 2007; Wang, 2009; Strittmatter and Sunde, 2011; Smith et al., 2013; Gbesemete and Gerdtham, 1992; Murthy and Ukpolo, 1995; Hansen and King, 1996; Matteo and Matteo,1998; Gerdtham and Lothgren, 2000; Murthy and Okunade, 2000; Herwartz and Theilen, 2003; and Yousef et al., 2016).

The novelty of this paper is the investigation particularly on the dynamic interactions among air pollution, economic growth and healthcare expenditure in developing countries especially Nigeria. Also, to capture the asymmetric impact of national income on healthcare expenditure in Nigeria base on the assumption that the more a country's income grows the more they spend on their health. However, developing countries bear more consequences of the air impurity (USEPA 2010) and undertaking such study in the context of Nigeria is highly imperative as little or no study has been carried out concerning this relationship given the peculiarity of the country.

According to Ogundipe (2018) the air people breathe in Nigeria is more likely to cause harm than the air in any other country in Africa because Nigeria currently has the highest burden of fatalities from air pollution in Africa and 4th highest in the world with 150 deaths per 100,000 people attributable to pollution. In the released annual State of the Global Air Report published by the Health Effects Institute (HEI), air quality in Nigeria and at least 10 other countries is among the deadliest anywhere on earth with higher than ambient air pollution death rates as a result of the environmental hazards combined with extreme pollution sources like generator fumes, vehicle emissions and crop burning among others(Ogundipe, 2018) which lead to CO_2 emission. Though Nigeria's CO_2 emissions fluctuated substantially in recent years, it tended to decrease through 1997 - 2016 period ending at 82,634.2 kt in 2016 (Knoema, 2019a).

However, gross national income (GNI) based on purchasing power parity (PPP) of Nigeria increased from 271,279 million international dollars in 1999 to 1,117,357 million international dollars in 2018 growing at an average annual rate of 7.83 % (Knoema, 2019b).

On the contrary, health indicators in Nigeria are some of the worst in Africa. The country has one of the fastest growing populations globally. With 5.5 live births per woman and a population growth rate of 3.2 percent annually, it is estimated to reach 440 million people by 2050 (USAID, 2019). With its rapidly growing population and development challenges, the country drags down the socioeconomic indicators for the entire African continent. Health expenditure, total (% of GDP) in Nigeria was 3.67 as of 2014 (Indexmundi, 2019). Its highest value over the period 1995-2014 (19 years) was 4.47 in 2007, while its lowest value was 2.43 in 2002 (Indexmundi, 2019).

Following this introduction that covers review of empirical studies, the remaining parts of the paper is organized as follows: Section two presents the methodology of the study. The main thrust of section three is data analysis and discussion of result while section four gives conclusion and recommendations.

1. METHODOLOGY

1.1. Model Specification

Given the bivariate model of New-house (1977):

$$HEX = f(INC) \tag{1}$$

Where H is health expenditure ; INC is income

The bivariate model in (1) is thus expressed for this purpose of this paper in a multivariate framework :

$$\log(HEX)_t = \tilde{\omega}_0 + \tilde{\omega}_1 \log(INC)_t + \tilde{\omega}_2 \log(CO2)_t + \phi_t \tag{2}$$

Where HEX is health expenditure (total health expenditure as a share of GDP- Total health expenditure is the sum of public and private health expenditure. It covers the provision of health services (preventive and curative), family planning activities, nutrition activities, and emergency aid designated for health but does not include provision of water and sanitation); INC is income (proxy by gross national income based on purchasing-power-parity in current prices); CO_2 is carbon dioxide emissions (kt) (proxy for air pollution) and ϕ_t stands forthe error term that is assumed to be identically and independently distributed. All variables were converted into log form to be interpreted as elasticity. The apriori expectation are: $\tilde{\omega}_1 \uparrow$; $\tilde{\omega}_2 \uparrow$

1.2 Data Source and Technique of Analysis

This study is based on secondary date. The data used were sourced from Knoema.com, Index Mundi data portal and relevant literatures. The variables employed are total health expenditure as a share of GDP; carbon dioxide emissions (kt); and gross national income based on purchasing-power-parity in current prices. The data span the period 1990 to 2022. The logical basis for choosing these periods is owing to data availability and accessibility. Augmented Dickey Fuller (ADF) was employed to check the stationarity of the time series, which is important to consider while estimating cointegration equations. The 'bounds testing' approach of Pesaran et al. (2001) also known as the Autoregressive Distributed Lag (ARDL) approach was applied to detect the presence of any long run equilibrium relationships among the variables.

The econometric advantages of the ARDL bounds testing method compared to other cointegration methods is that it can test cointegration of variables with I(0) or I(1). Thereafter, the nonlinear autoregressive distributed lag (NARDL) technique was employed to investigate the asymmetrical effects of air pollution and national income on health care expenditure. The NARDL model is the extension of the conventional ARDL model introduced by Pesaran and Shin (1999) which was applied to time series data. Such linear ARDL model was then extended by Shin, Yu, and Greenwood-Nimmo (2011) to include nonlinearity elements. This technique distinguishes the short and long-term asymmetrical effects of the explanatory variables on the dependent variable within an error correction framework.

As such using NARDL and accounting asymmetric impact of national income on healthcare expenditure in Nigeria, equation (2), can now be specified as follows:

$$\log(HEX)_t = \phi_0 + \phi_1 \log(INC)_t^+ + \phi_2 \log(INC)_t^- + \phi_3 \log(CO2)_t + \varepsilon_T \quad (3)$$

Where ϕ_I is a vector of long-run coefficients. The asymmetric impact of national income is accounted for by including the positive changes $\log INC_t^+$ and negative changes $\log INC_t^-$.

2. DATA ANALYSIS AND INTERPRETATION OF RESULTS

Table 1 depicts the ADF test result. The results are based on the model specification with intercept following the Schwarz criterion with a maximum of 6 lags. The findings show the variables to be integrated of order I(0) or I(1).

Table 1: ADF Test Results

	Variable	ADF test		
		Level	K	First difference
Intercept	LOGHEX	-2.671038***	6	-8.377442*
	LOGCCO$_2$	-1.307247	6	-4.398819*
	LOGGNIC2	-0.231536	6	-2.982096**

Notes: ADF denotes the Augmented Dickey-Fuller. Maximum lag order (k) is set to 6 and it is based on Schwarz criterion in the ADF test. Also, *, ** and ***indicate rejection of the null hypotheses at the 1 %, 5 % and 10 % significance levels respectively. The critical values are taken from MacKinnon (1996) one-sided p-values.

Source: Author's computation using Eviews 9 software

Table 2 shows the simple ARDL model result with maximum dependent lags of 4 was automatically selected and Akaike info criterion(AIC) model selection method. Table 3 shows the simple ARDL model converted into Non-linear ARDL model. Table 4 is the Breusch-Pagan-Godfrey heteroskedasticity test result for Non-linear ARDL model in Table 3. This output contains the set of test statistics on which Breusch-Pagan-Godfrey heteroskedasticity test are based. The F test values of all three statistics are above 5% level, invariably, all three statistics cannot reject the null hypothesis of homoskedasticity. Similarly, Breusch-Godfrey serial correlation LM Test in result shows that the residuals are not serially correlated, as such, the null hypothesis cannot be rejected at 5% level.

Table 2: Simple ARDL Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LOGHEX(-1)	0.689777	0.237695	2.901937	0.0124
LOGHEX(-2)	-0.211043	0.166669	-1.266236	0.2276
LOGHEX(-3)	0.263275	0.171538	1.534791	0.1488
LOGGNIC2	-1.704548	0.771372	-2.209762	0.0457
LOGGNIC2(-1)	3.033859	1.100929	2.755725	0.0164
LOGGNIC2(-2)	-1.391696	0.619583	-2.246182	0.0427
LOGCCO2	-0.459088	0.151585	-3.028577	0.0097
LOGCCO2(-1)	0.968203	0.236553	4.092971	0.0013
LOGCCO2(-2)	-0.867397	0.236643	-3.665422	0.0029
LOGCCO2(-3)	0.919092	0.211080	4.354233	0.0008
LOGCCO2(-4)	-0.486537	0.200267	-2.429435	0.0304
C	1.198779	1.252673	0.956976	0.3560

R-squared	0.842580	Mean dependent var	1.241092
Adjusted R-squared	0.709378	S.D. dependent var	0.155298
S.E. of regression	0.083720	Akaike info criterion	-1.816593
Sum squared resid	0.091119	Schwarz criterion	-1.231533
Log likelihood	34.70741	Hannan-Quinn criter.	-1.654322
F-statistic	6.325585	Durbin-Watson stat	2.422413
Prob(F-statistic)	0.001276		

*Note: p-values and any subsequent tests do not account for model selection.

Source: Author's computation using Eviews 9 software

Table 3: Dynamic NARDLModel (Short Run)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LOGHEX(-1)	-0.484679	0.162357	-2.985270	0.0204
LOGHEX(-2)	-0.418343	0.146925	-2.847314	0.0248
LOGHEX(-3)	0.237278	0.111475	2.128526	0.0708
LOGGNIC2_POS	-3.452578	0.847130	-4.075618	0.0047
LOGGNIC2_POS(-1)	-0.691144	0.880464	-0.784977	0.4582
LOGGNIC2_POS(-2)	0.799751	0.837389	0.955054	0.3714
LOGGNIC2_POS(-3)	2.704460	0.977704	2.766133	0.0278
LOGGNIC2_NEG	617.8589	187.5515	3.294342	0.0132
LOGGNIC2_NEG(-1)	404.1070	204.7232	1.973919	0.0890
LOGGNIC2_NEG(-2)	-35.60339	147.8719	-0.240772	0.8166
LOGGNIC2_NEG(-3)	-17.49865	5.261334	-3.325895	0.0127
LOGGNIC2_NEG(-4)	-17.48488	4.604614	-3.797251	0.0067
LOGCCO2	-0.304867	0.085791	-3.553599	0.0093
LOGCCO2(-1)	0.702907	0.165705	4.241930	0.0038
LOGCCO2(-2)	0.159247	0.195388	0.815032	0.4419
LOGCCO2(-3)	1.039715	0.188145	5.526136	0.0009
C	6.422177	3.812729	1.684404	0.1360

R-squared	0.969026	Mean dependent var	1.250502
Adjusted R-squared	0.898229	S.D. dependent var	0.151181
S.E. of regression	0.048229	Akaike info criterion	-3.041181
Sum squared resid	0.016282	Schwarz criterion	-2.206726
Log likelihood	53.49417	Hannan-Quinn criter.	-2.819800
F-statistic	13.68737	Durbin-Watson stat	3.240469
Prob(F-statistic)	0.000896		

*Note: p-values and any subsequent tests do not account for model selection.

Source: Author's computation using Eviews 9 software

Table 4: Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	0.935352	Prob. F(16,7)	0.5742
Obs*R-squared	16.35169	Prob. Chi-Square(16)	0.4287
Scaled explained SS	0.985492	Prob. Chi-Square(16)	1.0000

Source: Author's computation using Eviews 9 software

Table 5: Serial Correlation LM Test: Breusch-Godfrey

F-statistic	3.219256	Prob. F(2,5)	0.1263
Obs*R-squared	13.50913	Prob. Chi-Square(2)	0.0012

Source: Author's computation using Eviews 9 software

In applying the NARDL bounds test, trend specification was constant and model selection criteria was the Akaike info Criterion (AIC) with maximum dependent lags of 4 which was automatically selected. The result is presented in Table 6. Obviously, the F test value of 21.59088 is bigger than any of the I1 Bound value hence there is cointegration among the variables. Nonetheless, the F test value of 13.60432 from the Wald Test result on Table 7 rejects the equality of LOGGNIC2_POS and LOGGNIC2_NEG in Table 7. That means, in the NARLD long run coefficients shown in Table 7, asymmetry is detected between LOGGNIC2_POS and LOGGNIC2_NEG variables.

Table 6: NARDL Bounds Test Result

Test Statistic	Value	K
F-statistic	21.59088	3

Critical Value Bounds

Significance	I0 Bound	I1 Bound
10%	2.72	3.77
5%	3.23	4.35
2.5%	3.69	4.89
1%	4.29	5.61

Source: Author's computation using Eviews 9 software

Table 7: Wald Test

Test Statistic	Value	df	Probability
t-statistic	-3.688404	8	0.0061
F-statistic	13.60432	(1, 8)	0.0061
Chi-square	13.60432	1	0.0002

Source: Author's computation using Eviews 9 software

Table 7 presents the long run coefficients computed from the dynamic model shown in Table 3. The results reveal the long run impact of air pollution (CO_2 emission) on health expenditure to be positive and statistically significant at 1%. In particular, it suggests that 1% increase in CO_2 emission leads to about 0.96% increase in total health expenditure. Noted that de-carbonization is often not a priority for developing country like Nigeria, compared to key issues such as economic growth and poverty alleviation. When the human body is exposed to too much CO_2, acid imbalance is created in the lungs as there is more carbon dioxide absorbed in proportion to oxygen (De et al., 2018). This affects the internal respiration and the victim may experience symptoms such as asphyxiation, frostbite, kidney damage, coma (Thind, 2013), headaches, dizziness, nausea, increased heart rate, cardiac arrhythmia, memory disturbance, lack of concentration, restlessness, sweating, vomiting, eye and extremity twitching, visual and hearing disturbances (including hearing loss and ringing in the ears, photophobia, blurred vision, transient blindness), convulsion and death (De et al., 2018). These increase the demand for health services at an alarming rate. Since 2000, expenditure on health of Nigeria increased from 2,014 million US dollars to 14,756 million US dollars in 2016 growing at an average annual rate of 18.75 % (Knoema, 2019c).

Another revelation from the long run coefficient of NARDL result in Table 8 is that 1 percent point increase in gross national income leads to -0.383919 percent point decrease in total health expenditure as a share of GDP. Evidence from a Public Expenditure Review of the health sector and National Health Accounts (NHA) suggests that on average, most states government in Nigeria spend less than 5% of their total expenditure on health care (ASFH, 2019). Expenditure from all tiers of government amounts to less than 6% of total government expenditure and less than 25% of total health spending in the country (ASFH, 2019).

On the other hand, as depicted in Table 8, 1 percent point decrease in gross national income leads to 571.143839 percent point decrease in total health expenditure as a share of GDP. This huge magnitude (571.143839 percent) decrease in total health expenditure as shown in the result is not surprising because the country has ignored the commitment it made alongside other African countries 16 years ago on funding of health care services for its citizens. Since the "Abuja Declaration" under which the African Union (AU) leaders in 2001 pledged to commit at least 15 percent of their annual budgets to improving their health sector, Nigeria has not attained the pledged funding benchmark as the federal government has never voted more than six percent of its annual budget to the health sector. The highest percentage since the declaration was in 2012 when 5.95% of the budget was allotted to health (Onyeji, 2017). According to Bhardwaj (2016), Nigeria has one of the lowest health budget in Africa. The country has suffered from chronic underfunding for many years now.

Various statistics also show that Nigeria has one of the worst health care delivery records in the world. According to the World Health Organization, Nigeria is rated 187th out of 191 countries in terms of health care delivery. WHO said one-third of more than 700 health facilities have been destroyed in the country and about 3.7 million people are in need of health assistance (Onyeji, 2017). In the 2018 Budget proposal, health sector was allocated N340.45 billion, representing 3.9 percent of the N8.6 trillion expenditure plan to the health sector. According to Onyeji (2017), the allocation is less than the 4.16 percent and 4.23 percent made to the health sector in the 2017 and 2016 budgets.

Table 8: NARLD Long Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LOGGNIC2_POS	-0.383919	0.061893	-6.202932	0.0004
LOGGNIC2_NEG	571.143839	139.646685	4.089920	0.0046
$LOGCCO_2$	0.958733	0.138375	6.928500	0.0002
C	3.855442	2.061064	1.870607	0.1036

Source: Author's computation using Eviews 9 software

Regarding the short run result in Table 3, it can be seen that gross national income has asymmetric and significant impact on health expenditure after three lag periods. In the third lag period, the health expenditure effect of positive changes in national income appears to be positive and statistically significant at 5%, whereas the negative changes in national income is found to be significant at 5% specifically, it suggests that 1% negative change in national income leads to approximately -17.50% increase in health expenditure in the third lag period. This same result is experienced in the fourth lag period at 1% level. This result is not surprising because according to ASFH (2019) the private sector accounts for 75% of health spending in Nigeria, with 90% of this coming from household out-of-pocket expenditures. It should be noted that in Northern Nigeria, the public sector provides over 90% of all health services, in contrast to states in Southern Nigeria, where the private sector provides over 70% of health services, mostly on a fee-for-service basis (ASFH, 2019).

Furthermore, LOGHEX one lag period affects health expenditure negatively and significantly at 5% while the three lag period of LOGHEX affects health expenditure positively and significantly at 10%. Similarly, $LOGCCO_2(-1)$ and $LOGCCO_2(-3)$ both affect health expenditure positively and significantly at 1% level.

3. CONCLUSION AND POLICY IMPLICATIONS

The first wealth of a nation is its health. This is because it significantly enhances its economic development, and vice versa. Nonetheless, it has been enunciated that the pursuit of better health should not await an improved economy; rather measures to improve health will themselves contribute to economic growth and environmental quality. Also, the way a country finances its health care system is a key determinant of the health of its citizenry. As such, Nigerian government should increase public health expenditure so that the health of the individuals in the society will be adequately taken care of and mortality rate reduced. To achieve this, it should increase tax-base health financing and also allocate a more reasonable percentage of its income to the health sector. Such re-constitution of revenue collection can represent a great leap forward for the health sector. In a similar manner, Nigerian government alongside development actors should institute low-carbon mechanisms like green infrastructure and renewable energy systems that reduce energy consumption and carbon dioxide emissions. For example, investments in low-carbon infrastructure like hydropower and soil carbon capture technology. This will help reduce air pollution.

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