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Public Health Expenditure and Infant Mortality Rate in Nigeria: New Empirical Insight from the ARDL Model

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ABSTRACT

This study investigates the impact of public health expenditure on infant mortality in Nigeria within 42 years (1980–2021). Secondary data were sourced from the World Development Indicators (WDI). The study employed several econometric techniques, including the Phillips-Perron (PP) unit root test, the Autoregressive Distributed Lag (ARDL) bounds testing approach, the ARDL estimation technique, and the Granger causality test. Post-estimation diagnostic tests were conducted to ensure the robustness and validity of the empirical results. The findings indicate that public health expenditure exerts a strong, negative, and statistically significant effect on infant mortality in Nigeria. Furthermore, household disposable income (HHDI) and physician density (PHDE) exhibit a bi-directional causal relationship with infant mortality. The study recommends that the Nigerian government prioritize increased investment in public health, particularly in socioeconomically disadvantaged regions, as a means of improving population health outcomes, reducing infant mortality, and enhancing overall living standards.

Keywords: *Public Health expenditure, Infant mortality, Granger Causality, ARDL Bound Testing, Nigeria*

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INTRODUCTION

Despite the remarkable improvements in health conditions worldwide, infant mortality remains a significant public health problem globally (Morankinyo & Fagbamigbe, 2017). While recent reports have indicated a general annual global decline of 2.2% in infant mortality (Rajaratnam *et al.*, 2010); the observed rate of decline still falls short of the projected 4.4% needed to achieve the third United Nations Sustainable Development Goal on Child Survival by 2030. However, these trends in infant mortality rates vary from one region to another. For instance, Sub-Saharan African countries, and indeed, Nigeria still suffer from some of the worst health problems (Akinlo & Sulola, 2019). Globally, Nigeria is ranked second only to India in neonatal deaths, recording 42.9 deaths per 1000 live births. The country also has the highest under-five mortality rate in Africa, at 113.8 deaths per 1000 live births (United Nations International Children Emergency Fund [UNICEF], 2020). The main objectives of the study is to appraise Public Health Expenditure and Infant Mortality Rate in Nigeria using new empirical insight from the ARDL Model.

Table 1: Trends of Infant Mortality Rate in Nigeria and the World

Infant Mortality: Nigeria and the Rest of the World (2000-2020)		
YEAR	**NIGERIA (Rate per 1000, live births)**	**WORLD (Rate per 1000, live births)**
2000	109.8	52.8
2002	103.8	49.3
2004	97.8	45.9
2006	92.3	42.6
2008	87.7	39.6
2010	84.3	36.9
2012	81.9	34.4
2014	80.1	32.3
2016	78.3	30.6
2018	75.7	28.9
2020	72.2	27.4

Source: World Bank

Figure 1: Trends of Infant Mortality Rates between Nigeria and the World

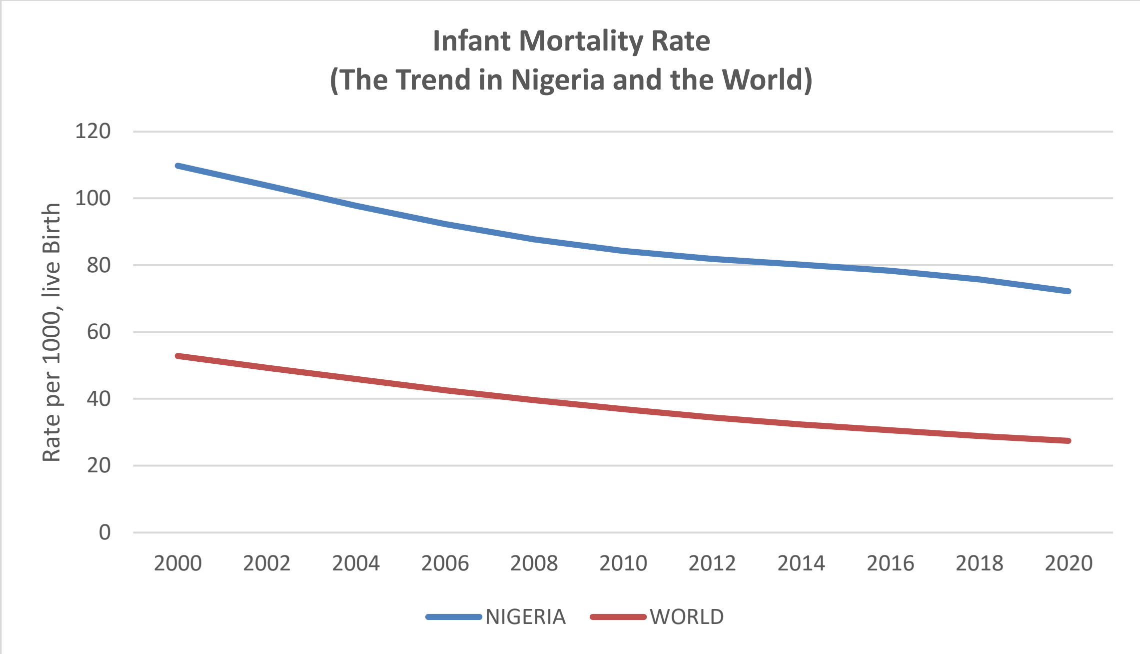

Table 1 and Figure 1 illustrate the trend in child mortality in Nigeria from 2000 to 2020. While Nigeria's population represents 2.4% of the world's population, available statistics show that Nigeria currently accounts for 10% of global infant deaths annually, implying that each year approximately 262,000 babies die at birth, a figure that makes it the world's second-highest. At present, the mortality rate of infants is 69 deaths per 1,000 live births, while for under-fives, the mortality rate has risen to 128 per 1,000 live births. In general, over 64% of under-five mortalities in Nigeria emanate from preventable or treatable causes such as malaria, pneumonia, or diarrhoea (UNICEF, 2017a; WHO, 2006). It has been generally observed that infant and child mortality rate in Nigeria show wide geographical variation; the highest rates are seen in the North-East and North-West Zones of the country, and the lowest rates are noticed in the South-West and South-East (Ogunjimi *et al.*, 2012).

These startling infant mortality statistics imply that 1 in every 8 Nigerian children dies before attaining the fifth natal day – a statistic approximately 21 times the average rate in developed countries (World Health Organization [WHO], 2013). If Nigeria and other countries continue falling below the target of the United Nations Sustainable Development Goal (SDG) on child survival, over 60 million children will not avert death between 2017 and 2030, and half of them will be newborn (UNICEF, 2017b).

Health expenditure is among the fundamental factors affecting the improvement of the population's status. This is true in all dimensions of healthcare, including child mortality rates. Nigeria is the most populous country on the continent, with a population estimate of 214 million people and a population growth rate of 2.53% per annum and projected to be 550 million by the year 2070. The population is predominantly young, with about 42% aged under 15 years and 50% under 54 years, while women of childbearing age (15-49 years) account for about 22% of the total population (CIA World Fact Book, 2020).

The World Health Organization (WHO) report on global health expenditure indicates that global spending on health has increased in low- and middle-income countries by 6 per cent and in high-income countries by 4 per cent (WHO, 2019). In Nigeria, data available indicates that while the total public health expenditure has increased tremendously from N43 billion to over N250 billion between 2000 and 2020, the percentage share of public health expenditure to Gross Domestic Product (GDP) has decreased considerably from 5% to 2% (World Bank, 2019; Central Bank of Nigeria [CBN], 2019; Olayiwola et al, 2021). Evidence from literature has shown that absence or lack of significant impact from health expenditures on health outcomes in less developed countries like Nigeria can be attributed to the incremental costs of medical technology, innovation, inadequate and inefficient expenditure on health care (Dhrifi, 2018).

This present situation notwithstanding, it may not mean that there has not been improvement in the infant mortality rates in the country, but the pace remains too slow to achieve the SDG target on child survival by the year 2030, as the current infant mortality rates remain unacceptably high in the country. It is particularly worrisome that despite the huge increase in government health expenditure, the contribution to health care delivery is still marginally low; and the magnitude of its impact on infant mortality rate cannot be categorically ascertained, thereby raising thereby raising the question of what the long-run relationship between the pattern of public health expenditure and the infant mortality rate in Nigeria is. The objective of this paper is to analyze the long run relationship between public health expenditure and infant mortality rate in Nigeria. We therefore hypothesize in the null form.

H_0: There is no long run relationship between government health expenditure and infant mortality rate in Nigeria.

1. EMPIRICAL LITERATURE REVIEWS

There is a large empirical literature on the determinants of infant mortality on health outcomes and their consequent implications on health expenditure, in both developing and developed countries, but empirical consensus on its impact remains lacking. While some studies have found the existence of a strong correlation, others have revealed a weak correlation, and a few other have shown no impact of government health spending on the child mortality rate. From a theoretical perspective, there are three separate schools of thought with divergent arguments on the relationship between public health expenditure and infant mortality rates. While the first argument holds that government spending has no significant positive impact on infant mortality rates, the second argument views that government health expenditure has a significant impact on health outcomes directly and indirectly. The third argument emphasizes that the effectiveness of government and the quality of bureaucratic institutions will determine whether government health expenditure will significantly affect health outcomes (Rajkumar & Swaroop, 2008; Yaqub et al., 2012).

1.1 No Public Health – Expenditure Effect on infant Mortality

Filmer and Pritchett (1997) provided empirical evidence that government expenditure on health care does not serve as a factor in reducing or influencing child mortality. Their findings further revealed that variables such as women's education, level of income, and inequality in income explain nearly all the variation in child mortality rates. They, therefore, concluded that, instead of increasing government health spending allocation, policies should be tailored towards poverty reduction, female education and equity promotion to reduce infant and child mortality rate. Their findings coincide with Bogg and Roberts (2004), who alluded that children born into lower-income households naturally stand a risk of experiencing growth and health problems as they advance in age. Similarly, to study the links between public spending, governance, and outcomes, Rajkumar & Swaroop (2008) adduce that government health expense decreases child mortality rates more in countries with good governance. They consequently concluded that government healthcare expenditure does not have any impact on health and education outcomes among countries that lack good governance. Also, while justifying the impact of quality institutions on health outcomes, rather than public health expenditure, Wagstaff *et al* (2001) revealed that the development of good policy frameworks and the quality of existing institutions and their framework of operation are the basic variables of the impact of public health expenditure in the production sector.

1.2 Health Expenditure and Child Mortality: Negative versus Positive Relationships

Khaleghian and Gupta (2005) shows that government health expenditure plays a less indispensable role in high income countries and a more indispensable role for the poor and low-income countries. The research further revealed health care spending returns are much more in low income countries than other counterparts. This finding coincides with Berger and Messer (2002) who discovered that mortality rates depend simultaneously on the type of health insurance and the health expense. They alluded that, a 1 unit increase in the amount of government health expenditure that is allocated to healthcare has a very strong impact on reduction in mortality rates. In the same vein, Wang Y. and Wang J. (2002) discovered that public health expenditure at the national level thus significantly reduce child mortality. Similarly, Bokhari, *et al* (2007) argued that although both government expenditure and economic growth have significant influence on the health outcomes in developing countries, public expenditure is more veritable and indispensable. Their findings corroborate with Harttgen and Misselhorn (2006), who examined child mortality and the consequential effect of under nutrition both in the Sub-Saharan Africa sub region and the South Asia region employing the dynamics of multi-level approach. Their findings show that while the soundness of health care infrastructure and having access to it is crucial in significantly reducing child mortality, socio-economic factors are the fundamental determinants of child health status.

Issa and Ouattara (2005) revealed a strong negative relationship between health expenditure and infant mortality rates. This view agrees with Edeme et al (2017), who discovered that government health expense and the expected health outcome both have a long run relationship. Similarly, Matthew et al (2015) showed a significant relationship between public spending on health with health outcomes in Nigeria. Eboh et al. (2018) revealed that both health care capital and recurrent expenditure negatively influence mortality rate of infants significantly. Their findings agree with Anyanwu and Erhijakpor (2009), who discovered an econometric linkage of African countries' Per Capita Income (PCI) and health outcomes. They alluded from their empirical findings that health expense has a statistically significant inverse impact on infant and under five mortalities in African continent. Their finding agrees with Yaqub et al (2012) who using OLS in a two stage least square examined the effectiveness of public health and how it is affected by governance in Nigeria. Findings revealed a consequential negative effect of public health expense on infant mortality. Also, Rima and Akpan (2012) examined 'Healthcare Financing and Health outcomes in Nigeria. Findings revealed that a high degree of mortality and morbidity of infant was linked to high out of pocket expense and high disparity in income levels in the country. The study further noted disparity in the spatial distribution health facilities to also being a probable factor determining child mortality rate, in a similar way, Md Juel and Srinivas (2017) who alluded that there a significantly negative relationship between total health care spending and child mortality.

1.3 Determinants of Infant Mortality: Empirical Evidence from Nigeria

Empirical evidence from literature suggests that infant mortality in Nigeria is linked to several factors. While some studies have linked the prevalence of childhood diseases in the country to infant mortalities, others have identified mothers' education and family income as key determinants of infant mortalities. For instance, a study by UNICEF revealed that many children die in Nigeria because of malaria infection, diarrhea, neonatal tetanus, tuberculosis, whooping cough and bronchopneumonia (UNICEF, 2017b). Similarly a study by Jinadu *et al* (1991) revealed that several diseases that are associated with infant mortality have linkages with sanitary – hygiene conditions and unclean environment; this include among others such as the complete lack good water storage mechanisms and practices, reusage of unclean and dirty utensils, unclean kid-feeding bottles, and lack of timely disposal of household refuse bin or bags. Other studies have shown that mother's education is a crucial determining factor influencing child survival (Osonwa, Iyam & Osonwa, 2012; Antai, 2011). The Nigeria Demographic and Health Survey (NDHS), shows that children born to mothers with no education have the highest under-five mortality rates (209 deaths per 1,000 live births), while mothers with secondary education have 68 per 1,000 live births (National Population Commission [NPC], 2013). Similarly, Yaya *et al* (2017) revealed the age at first birth, the index of wealth in the family, the religion of the parents, the level of parental education, the location and region and the residential environment are key determinant factors associated with childhood mortality. While linking family income status to infant mortality, the Nigerian Country Policy Brief report that there is an interrelationship between poverty level, ignorance, poor health, malnutrition, and reduced child survival, which is further worsened by social exclusion and political marginalization (Nigeria Policy Project [NPP], 2002). Going by the divulge empirical views and findings from the various studies, it would therefore be worthwhile to analyze the nature of this relationship in Nigeria using time series data from 1980-2021

2. THEORETICAL FRAMEWORK

This study adopts Grossman (1972) model of health demand as theoretical framework. The theory is hinged on the postulation that the demand for healthcare is based on the interplay of the demand function and supply function for health. The model hypothesize that people inherit an initial stock of health at infancy that gradually depreciates with time but can be increased by investing in health. By this theory, government expenditure in health translate to societal investment in health which invariably affect the measures of societal health outputs i.e. infant mortality, still births, perinatal deaths, and total death (Wibowo & Tisdell, 1992). The theoretical health production function as developed by Grossman is specified in its functional form as:

$$H = \boldsymbol{f}(\boldsymbol{Q}) \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \qquad (\boldsymbol{i})$$

Where H is a measure of output of an individual's health and Q is a vector matrix of the individual's input in the production function of health F. The elements of the input vector Q include: literacy rate, public health expenditure, physician densities, and per capita income. To measure the twin aspect of both the consumption and investment of health inputs, the individual demand function for health is analysed in the framework utility optimization function specified as:

$H_t = \beta Q_t + \varepsilon t, t = 1 \ldots T$ … … … … … … (ii)

Where H_t is the dependable variable, Q_t is a vector matrix of independent which can influence health outcomes, t is the time series, β represent the coefficient of the independent variables and εt is the stochastic term with zero mean and constant variance. This study therefore found a linear relationship between the health output measure (infant mortality) and the inputs element.

3. METHODOLOGY

3.1 Data Sources and Measurement variables

The data for this study are annual time series data sourced from World Bank Development Indicators (WDI) and other cognate publications of the Central Bank of Nigeria (CBN). The variables for this study are measured in percentage growth rates so that the effect of irregular movements and trends are eliminated.

3.2 Data Description

The model we specified is in consistency with the literature and the theoretical framework of our study. The model makes it possible to identify the various determining factors affecting infant mortality over time. The identified variables are defined below:

- **Infant Mortality (IFMO)**: This is proxied by under-five mortality rate (U5R-deaths per 1,000 live births). It measures the proportion of death that occur among children below the age of five years. This infant mortality index is a fundamental measurement and indicator of a country's level of socio-economic wellbeing and development.
- **Public Health Expenditure (PHEX)**: This is the level of current health expenditure expressed as a percentage of GDP. Estimates of current health expenditures include healthcare goods and services consumed during each year. As argued, "countries with huge budgetary allocations and expenditure on health care have high tendencies of experiencing huge decline in mortality rate and longer life expectancy ratio" (Mosley & Chen, 1984). Thus, *a priori* is expected to be negative.
- **Household Disposable Income (HHDI):** This is proxied by the income per capita (at constant 2005 USD). This used to measure average income per head of the total population. This index provide an overview of the overall socio-economic wellbeing of the nation. As observed in the Nigerian Policy brief, a child born to a hitherto financially incapacitated and deprived home faces a huge risk of experiencing

perinatal death most especially within the first month of life (Nigeria Policy Project, 2002). This therefore implies that the *a priori* expectation is negative.

- **Household Education Status (HHES)**: This is proxied by the prevailing female literacy rate, which is considered a very key determinant of child health status as there exist an infallible nexus between household and maternal educational attainment and lower mortality rates (Antai, 2011). This implies that the *a priori* for this variable is expected to be negative.
- **Physician Density (PHDE):** This measures the ratio of the number of available physicians to total number of inhabitants usually expressed in terms of the number of practicing doctors per 1,000 inhabitants and is a very essential index often used to evaluate for the supply of total available health care in the country. The index is vital in that, where a country has large number of practicing doctors as compared to the total population, it is an indicator of the existence of easier access to health care and should consequently have a negative correlation with mortality rate (Dhrifi, 2018). The implication of this is that *a priori* is expected to be negative.

3.3 Model Specification and Estimation Technique

Unit root test

To avoid inappropriate model specification and to increase the confidence of the results, time series properties of the data are investigated. Although there are a number of methods used to test for stationarity and the presence of unit roots, the method used here is the Phillip-Peron (PP) test. By definition a series is stationary if it has a constant mean and a constant finite variance. On the contrary, a non-stationary series contains a clear time trend and has a variance that is not constant overtime. If a series is non-stationary, it will display a high degree of persistence.

The Phillip-Peron (PP) unit root test is expressed algebraically

$$\Delta y_t = \gamma y_{t-1} + x_t'\delta + \epsilon_t \qquad \dots \quad \dots \quad \dots \quad \dots \qquad (iii)$$

The t-ratio of the γ coefficient is tested so that the asymptotic distribution of the test statistics is not affected by serial correlation. The statistics for the PP test is

$$\bar{t}_\gamma = t_\gamma \left(\frac{\gamma_0}{f_0}\right)^{1/2} - \frac{T(f_0 - \gamma_0)\big(s\epsilon(\hat{\gamma})\big)}{2f_0^{\frac{1}{2}}s} \qquad \dots \quad \dots \quad \dots \qquad (iv)$$

Where $\hat{\gamma}$ is the estimate, t_γ is the t-ratio of γ, $s\epsilon(\hat{\gamma})$ is the standard error of the coefficient. γ_0 is a consistent estimate of error variance and the f_0 is residual spectrum estimator at zero frequency.

Cointegration test

The presence of either long-run or short-run relationship is tested using the ARDL bounds test for cointegration proposed by Pesaran, Shin and Smith (2001). This test could produce robust result in the event of the mixture in order of integration among the series. The suitable equation for testing cointegration relations among the variables is stated thus:

$$
\begin{aligned}
IFMO = \alpha_0 &+ \sum_{i=1}^{p} \beta_1 \Delta IFMO_{t-1} + \sum_{j=0}^{q} \gamma_j \Delta HHES_{t-j} \\
&+ \sum_{k=0}^{r} \varphi_k \Delta HHDI_{t-k} + \sum_{l=0}^{s} \vartheta_l \Delta PHDE_{t-l} \\
&+ \sum_{m=0}^{t} \omega_m \Delta PHEX_{t-m} + \mu_1 IFMO_{t-1} + \mu_2 HHES_{t-1} + \mu_3 HHDI_{t-1} \\
&+ \mu_4 PHDE_{t-1} + \mu_5 PHEX_{t-1} \\
&+ v_t \quad .. .. \qquad (\mathbf{v})
\end{aligned}
$$

Where, *p, q, r, s* and *t* denote the respective optimal lagged differences of *IFMO, HHES, HHDI, PHDE, and PHEX*.

Estimated Model

Guided by the Grossman (1972) theoretical framework and existing literatures, the set of explanatory variables includes Public Health Expenditure (PHEX) which has been identified to have potential implication on child mortality. We however control for Household Disposable Income (HHDI), Household Education Status (HHES), and Physician Density (PHDE) in our quest to examine the relationship between public health expenditure and infant mortality rate in pursuit of the objective of this study. Following (Bello & Joseph, 2014), with modification, the determinant of infant mortality rate can be expressed as a functional relationship between infant mortality rate and public health expenditure.

The Auto Regressive Distributive Lag (ARDL) model was employed to define the long-run effect while the ADRL Error Correction Model (ECM) was employed to define the short-run effect for this empirical investigation. The ARDL model is hereby specified thus, putting into consideration the various theoretical underpinnings and assumptions of the model:

$$\mathrm{IFMO} = \mathrm{F}\,(\mathrm{HHES}, \mathrm{HHDI}, \mathrm{PHDE}, \mathrm{PHEX}) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (\mathrm{vi})$$

The model can be further transformed into an econometric model in the form of a long-run model, and a short-run model (ECM) thus:

The Long-run Model

$$\mathrm{IFMO_t} = \emptyset_1 + \partial_{1i}\mathrm{IFMO_{t-1}} + \partial_{2i}\mathrm{HHES_{t-1}} + \partial_{3i}\mathrm{HHDI_{t-1}} + \partial_{4i}PHDE_{\mathrm{t-1}} + \partial_{5i}\mathrm{PHEX_{t-1}} + \varepsilon_{1t} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \text{(vii)}$$

The Short-Run Model (ECM)

$$\Delta\mathrm{IFMO_t} = \emptyset_1 + \sum_{t=1}^{p}\partial_{1i}\Delta\mathrm{IFMO_{t-1}} + \sum_{t=1}^{q}\partial_{2i}\Delta\mathrm{HHES_{t-1}} + \sum_{t=1}^{q}\partial_{3i}\Delta\mathrm{HHDI_{t-1}} + \sum_{t=1}^{q}\partial_{4i}\Delta\mathrm{PHDE_{t-1}} + \sum_{t=1}^{q}\partial_{5i}\Delta\mathrm{PHEX_{t-1}} + \varphi\mathrm{ECM_{t-1}} + \varepsilon_{1t} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \text{(viii)}$$

Granger Causality Test

Granger causality is a statistical concept that aids in the verification of directional causation between variables via prediction. Its mathematical formulation is based on stochastic process linear regression modeling (Granger 1969). It establishes the causal relationship between variables. This experiment would be conducted to determine the direction of causation between Infant Mortality Rate and Household Education Status, Infant Mortality Rate and Household Disposable Income, Infant Mortality Rate and Physician Density, and Infant Mortality Rate and Public Health Expenditure in Nigeria

However, to establish a causal link between Infant Mortality Rate and Household Education Status, Infant Mortality Rate and Household Disposable Income, Infant Mortality Rate and Physician Density, and Infant Mortality Rate and Public Health Expenditure in Nigeria, the granger causality general form is defined as follows:

$$\mathrm{IFMO} = \alpha_0 + \sum_{i=1}^{p}\beta i\mathrm{IFMO_{t-i}} + \sum_{i=1}^{p}\theta i HHES_{\mathrm{t-i}} + \mathrm{E_t} \quad \ldots \ldots \ldots \ldots \ldots \quad \text{(ix)}$$

$$\mathrm{HHES} = \mathrm{a_0} + \sum_{i=1}^{p}\beta i\mathrm{IFMO_{t-i}} + \sum_{i=1}^{p}\theta i\mathrm{HHES_{t-i}} + \mathrm{E_t} \quad \ldots \ldots \ldots \ldots \ldots \quad \text{(x)}$$

$$\mathrm{IFMO} = \mathrm{a_1} + \sum_{i=1}^{p}\beta i\mathrm{IFMO_{t-i}} + \sum_{i=1}^{p}\theta i\mathrm{HHDI_{t-i}} + \mathrm{E_t} \quad \ldots \ldots \ldots \ldots \quad \text{(xi)}$$

$$HHDI = a_1 + \sum_{i=1}^{p} \beta iIFMO_{t-i} + \sum_{i=1}^{p} \theta iHHDI_{t-i} + E_t \quad \dots \quad (xii)$$

$$IFMO = a_2 + \sum_{i=1}^{p} \beta iIFMO_{t-i} + \sum_{i=1}^{p} \theta iPHDE_{t-i} + E_t \quad \dots \quad (xiii)$$

$$PHDE = a_2 + \sum_{i=1}^{p} \beta iIFMO_{t-i} + \sum_{i=1}^{p} \theta iPHDE_{t-i} + E_t \quad \dots \quad (xiv)$$

$$IFMO = a_3 + \sum_{i=1}^{p} \beta iIFMO_{t-i} + \sum_{i=1}^{p} \theta iPHEX_{t-i} + E_t \quad \dots \quad (xv)$$

$$PHEX = a_3 + \sum_{i=1}^{p} \beta iIFMO_{t-i} + \sum_{i=1}^{p} \theta iPHEX_{t-i} + E_t \quad \dots \quad (xvi)$$

There are three cases of causality

Case One: Unidirectional causality

Infant Mortality Rate granger causes Household Education Status if $\sum\theta_1^{HHES} \neq 0$
Household Education Status granger causes Infant Mortality Rate if $\sum B_1^{IFMO} \neq 0$
Infant Mortality Rate granger causes Household Disposable Income if $\sum\theta_2^{HHDI} \neq 0$
Household Disposable Income granger causes Infant Mortality Rate if $\sum\theta_2^{IFMO} \neq 0$
Infant Mortality Rate granger causes Physician Density if $\sum\theta_3^{PHDE} \neq 0$
Physician Density granger causes Infant Mortality Rate if $\sum\theta_3^{IFMO} \neq 0$
Infant Mortality Rate granger causes Public Health Expenditure if $\sum\theta_4^{PHEX} \neq 0$
Public Health Expenditure granger causes Infant Mortality Rate if $\sum\theta_4^{IFMO} \neq 0$

Case Two: Bidirectional causality

There exists a bidirectional relationship between the variables if; $\sum B_1^{IFMO} \neq 0$ and $\sum\theta_1^{HHES} \neq 0$; $\sum B_2^{IFMO} \neq 0$ and $\sum\theta_2^{HHDI} \neq 0$; $\sum B_3^{IFMO} \neq 0$ and $\sum\theta_3^{PHDE} \neq 0$; and $\sum B_4^{IFMO} \neq 0$ and $\sum\theta_4^{PHEX} \neq 0$.

Case Three: No causality

There is no relationship between the variables if; $\sum\theta_1^{HHES} = 0$ and $\sum B_1^{IFMO} = 0$; $\sum\theta_2^{HHDI} = 0$ and $\sum B_2^{IFMO} = 0$; $\sum\theta_3^{PHDE} = 0$ and $\sum B_3^{IFMO} = 0$; and $\sum\theta_4^{PHEX} = 0$ and $\sum B_4^{IFMO} = 0$.

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4. RESULT AND DISCUSSION

Descriptive Statistics

Table 2: Descriptive Statistics

	IFMO	HHES	HHDI	PHDE	PHEX
Mean	103.7611	55.68648	3286.895	0.275229	3.338270
Median	108.3000	55.44675	2368.196	0.262200	3.090662
Maximum	126.2000	70.19835	5507.169	0.449400	5.053609
Minimum	72.20000	51.07766	2056.868	0.113000	2.490640
Skewness	-0.263228	1.767685	0.533687	0.188928	1.798267
Kurtosis	1.397113	6.576633	1.532441	1.665590	6.171234
Jarque-Bera	4.981202	44.25950	5.762776	3.365995	40.23561
Probability	0.082860	0.000000	0.056057	0.185816	0.000000

Source: Author's compilation, 2025.

The summary of the statistics used in this empirical study is presented in table 2. As observed from the table, the dependent variable which is Infant Mortality rate (IFMO) has a mean of 103.7611 per 1000, Household Education Status (HHES) has a mean of 55.68648, Household Disposable Income (HHDI) has a mean of 3286.895, Physician Density (PHDE) has a mean of 0.275229 per 1000 while Public Health Expenditure (PHEX) has a mean of 3.338270 percent of GDP. The result for Kurtosis shows that IFMO, HHDI and PHDE with value of 1,40, 1.53 and 1.67 respectively are platykurtic in nature as their value is approximately less than 3.0 while HHES and PHEX with values of 6.58 and 6.17 are leptokurtic as their values are approximately greater than 3.0.

Stationarity Test

To prevent the problem of spurious regression occasioned by non-stationarity of time-series data, the Phillips-Perron (PP) tests of stationarity was carried out to test for unit root in the variables. The results are presented below.

Table 3: Unit Root Tests Result

Variables	At Level		At First Difference		Order of Integration
	Adj. t-Stat	Prob. Value	Adj. t-Stat	Prob. Value	
IFMO	-2.988837	0.0037			I(0)
HHES	-3.229091	0.0253			I(0)
HHDI	0.396162	0.9804	-3.221636	0.0260	I(1)
PHDE	1.974725	0.9871	-5.785580	0.0000	I(1)
PHEX	-3.402229	0.0650	-8.863341	0.0000	I(1)

Source: Author's compilation, 2025.

From the table 3, the PP result shows that IFMO and HHES are stationary at level while HHDI, PHDE, and PHEX are stationary at first difference at 5% significance level. The results indicate mixed order of intergration.

The study goes further to ascertain the presence of either a long-run or short-run relationship between the variables using the ARDL bounds test.

Table 4: The Bounds Test Results

TEST STATISTICS	**VALUE**	**K**
F-statistic	16.80610	4
CRITICAL VALUE BOUNDS		
SIGNIFICANCE	I(0) BOUND	I(1) BOUND
10%	2.20	3.09
5%	2.56	3.49
2.5%	2.88	3.87
1%	3.29	4.37

Source: Author's Compilation, 2025.

The Peseran and Shin (2001) criteria stipulates that, for cointegration or a long-run relationship, the F-statistic of the bounds test must be greater than the upper bounds (the I(1) bound) at all significance levels (1%, 2.5%, 5%, 10%). On the other hand, if the F-statistic lies below the lower bounds (the I(0) bound) at all level of significance, then there is a no-cointegration condition or short-run relationship among the variables. If the F-statistic falls between the I(0) and I(1) bounds at all significance levels, then the result is inconclusive. With the F-statistic value of 16.80610 which is greater than the upper bounds (I(1)) bounds at all significance level, there exists a Long-run relationship between IFMO and HHES, HHDI, PHDE and PHEX. Therefore, a Long-run model and an Error Correction Model (ECM) is estimated for the variables as stipulated by Peseran and Shin (1999).

Table 5: The ARDL Long-run Models Results

Dependent Variable	**IFMO**			
Independent Variables	Coefficients	Standard Error	T-Statistics	Probability
HHES	0.401199	0.161653	2.481848	0.0212
HHDI	-0.004975	0.001764	-2.820358	0.0100
PHDE	-2.151210	0.781432	-2.752907	0.0116
PHEX	-111.8879	25.06288	-4.464287	0.0002

Source: Author's Compilation, 2025.

The long run estimates from table 5, indicates that HHES and IFMO has a positive and significant relationship in the long run, it implies that a 1% increase in Household

Education will lead to a 0.40 unit per 1000 increase in Infant Mortality rate and vice versa. HHDI and IFMO has a negative but insignificant relationship in the long run, it implies that a 1 unit increase in Household Disposable Income will lead to a 0.005 unit per 1000 decrease in Infant Mortality rate and vice versa. PHDE and IFMO on the other hand also has a negative and significant relationship in the long run, it implies that a 1 unit per 1000 increase in Physician Density will lead to a 2.15 unit per 1000 decrease in Infant Mortality rate and vice versa While PHEX and IFMO has a negative and significant relationship in the long run, it implies that a 1% increase in Public Health Expenditure will lead to a 111.89 unit per 1000 decrease in Infant Mortality rate and vice versa.

Table 6: The ARDL Short-run (ECM) Results

Dependent Variable		**IFMO**		
Independent Variables	Coefficients	Standard Error	T-Statistics	Probability
HHES	-0.017875	0.009490	-1.883586	0.0729
HHDI	0.000433	0.000419	1.033970	0.3124
PHDE	0.044273	0.085781	0.516119	0.6109
PHEX	-2.819945	1.907388	-1.478433	0.1535
ECM(-1)	-0.183249	0.016473	-11.12448	0.0000
R-squared	0.975732			
Adjusted R-squared	0.966743			
Durbin-Watson stat	2.246534			

Source: Author’s Compilation, 2025.

The short run estimates from table 6 indicates that HHES and IFMO has a negative and significant relationship at 10% level of significance in the short run, it implies that a 1% increase in Household Education will lead to a 0.02 unit per 1000 decrease in Infant Mortality rate and vice versa. HHDI and IFMO has a positive relationship in the short run, it implies that a 1unit increase in Household Disposable Income will lead to a 0.0004 unit per 1000 increase in Infant Mortality rate and vice versa. PHDE and IFMO also has a positive relationship in the short run, it implies that a 1 unit per 1000 increase in PHDE will lead to a 0.04 unit per 1000 increase in Infant Mortality rate and vice versa while PHEX and IFMO has a negative and insignificant relationship in the short run, it implies that a 1% increase in PHEX will lead to a 2.82 unit per 1000 decrease in I Infant Mortality rate and vice versa. As expected, the coefficient of error correction term is significant with the expected negative sign and below unity (-0.183249). The negative sign of the error correction term indicates a backward movement toward long run equilibrium from short run disequilibrium The coefficient of the error correction term been below unity (-0.183249) simply means that the model corrects itself as 18.32% annually. In other words, the speed of adjustment to long run equilibrium is 18.32% annually.

The coefficient of multiple determination (R^2) shows that the explanatory variable captured in the model has jointly explained 97.57% of the movement in the dependent variable with the R^2adjusted (0.966743) of 96.67%. The efficiency, linearity, unbiaseness and the size of the coefficients, standard-errors and the reliability of the t-stats depend on the assumption of no autocorrelation and spuriosity of the test results. The Durbin Watson (DW) test is the most common test for autocorrelation and is based on the assumption that the structure of the autocorrelation is of first order. The Durbin Watson Statistics in the model is 2.25 (approximately 2), indicating that the model is free from the problem of serial auto-correlation. Thus, there is no evidence of first order auto-correlation

Table 7: The Post-Estimation Tests Results

Test	F-Statistics	Prob
Serial Correlation LM Test	0.564186	0.5776
Normality Test	1.953173	0.3766
Heteroskedasticity Test	0.782731	0.6829
Cusum Test	Stable	

Source: Author's compilation, 2025.

From table 7 the Serial Correlation LM test probability value of 0.5776>0.05, implies that the model is not serially correlated thus confirming the Durbin Watson result of no first order autocorrelation. The Jarque-Bera test for normality has a probability value of 0.3766>0.05 which implies that the residuals of the model are normally distributed. The Heteroskedasticity test probability value of 0.6829>0.05 implies that the variation of the residuals in the model are free from Heteroskedasticity. The cusum test indicates that the model is stable.

Table 8: Granger Causality Test Results

Null Hypothesis:	Obs	F-statistic	Prob.
HHES does not Granger Cause IFMO	38	2.23201	0.0901
IFMO does not Granger Cause HHES		0.43200	0.7843
HHDI does not Granger Cause IFMO	38	2.93525	0.0375
IFMO does not Granger Cause HHDI		7.04988	0.0004
PHEX does not Granger Cause IFMO	38	0.91194	0.4701
IFMO does not Granger Cause HHDI		1.70561	0.1757
PHDE does not Granger Cause IFMO	38	7.59881	0.0003
IFMO does not Granger Cause PHDE		5.10641	0.0031

Source: Author's compilation, 2025.

The pairwise granger causality test result shows that there is a bi-directional causal relationship between IFMO and HHDI on one hand and IFMO and PHDE on the other hand. Thus Household Disposable Income and Physician Density have a direct effect on Infant Mortality rate and vice versa. This implies that improved standard of living and improvement in the number of health personnel has a direct impact on Infant Mortality in Nigeria.

Discussion of Findings

As obtained from the ARDL estimations, it can be deduced that there exists a significant long-run relationship between Infant Mortality rate and the variables of Household Education Status, Household Disposable Income, Physician Density and Public Health Expenditure in Nigeria. Household Education Status has a negative short run relationship This suggests that greater sensitization regarding the causes of infant mortality can reduce the infant mortality rate and yield positive long-term outcomes This finding is in line with that of Smith et al (2018), Balaj et al (2021) and Patel et al (2021), but in contrast to the findings of Kiross et al (2019) who found educational status not to be significantly related to Infant Mortality. Household Disposable Income on the other hand has a negative impact on Infant Mortality rate only in the long-run. This implies that household with higher disposable income are less likely to have infant mortality and those household with less disposable income have higher chances of infant mortality in Nigeria. This is in line with the finding of Smith et al (2018) and Taylor-Robinson et al (2019). Physician Density also has a negative relationship with Infant Mortality rate in the long-run. This implies that an increase in health personnel's will lead to a reduction in Infant mortality in Nigeria. This is in line with the findings of Liebert and Mäder (2022) and Liang et al (2019), while Public Health Expenditure (PHEX) which is our variable of interest conforms to apriori expectation as it has a negative significant long run relationship with Infant Mortality rate in Nigeria. The magnitude of PHEX on IFMO as expressed in the results shows that a 1% increase in Public Health Expenditure will lead to a 111.89 unit per 1000 decrease in Infant Mortality rate thus making PHEX a major variable of concern in tackling IFMO in Nigeria. These finding of this study is in line with the findings of Yaqub et al (2012), Edeme et al (2017), Eboh et al (2018), Kouassi et al (2021) and Byaro (2021) but in contrast with Sari and Prasetyani (2021) who found Public health expenditure to have no effect on infant mortality in the Association of Southeast Asian Nations, (ASEAN).

5. CONCLUSION AND RECOMMENDATIONS

This study examined the relationship between Public Health Expenditure and Infant Mortality Rate in Nigeria. The study observed that Public Health Expenditure is a major influencer of the infant mortality rate in Nigeria. Therefore, the study posits that the Nigerian government should increase expenditure on health, as it will help improve the health sector and as such reduce infant mortality. This increase in expenditure can be directed towards increasing the number of health care personnel, construction and renovation of health care facilities, especially those in rural areas, establishment of maternity clinics in all primary health care facilities, to bring health care closer to the grassroots.

The study, therefore, recommends that the government should increase its expenditure in public health, especially in socially and economically disadvantaged areas, to improve the health status of the citizens and reduce the mortality rate while also improving the standard of living to enable them to access health care.

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