POLAC ECONOMIC REVIEW (PER)
DEPARTMENT OF ECONOMICS
NIGERIA POLICE ACADEMY, WUDIL-KANO

FEMALE EDUCATION, HOUSEHOLD INCOME, AND INFANT MORTALITY IN NIGERIA

Yaji, Williams Nyijime — Department of Economics, Faculty of Social Sciences, Federal University of Lafia

Garba, Dauda — Department of Economics, Faculty of Social Sciences, Federal University of Lafia

Abstract

This study examines the effects of female education and household income on infant mortality in Nigeria, controlling for physician density and public health expenditure. Using annual data from 1980 to 2021 and an Autoregressive Distributed Lag (ARDL) framework, the paper tests whether household socioeconomic conditions and health-system capacity jointly explain infant survival outcomes. The bounds test confirms a long-run relationship among the variables. The results show that household income, physician density, and public health expenditure significantly reduce infant mortality in the long run. Female education has a negative short-run effect but a positive long-run coefficient, suggesting that literacy gains may not improve infant survival unless they translate into practical maternal health knowledge and access to care. Granger causality results show bidirectional causality between infant mortality and both household income and physician density. The findings indicate that infant mortality in Nigeria is not driven by health financing alone, but by the interaction of household welfare, maternal capability, and healthcare access. The study recommends strengthening female health education, improving household welfare, expanding physician availability, and targeting health expenditure toward primary and neonatal care.

Keywords: Female Education; Household Income; Infant Mortality; Physician Density; Public Health Expenditure; ARDL

JEL Classification: *I12; I14; I15; I25; C32*

1. Introduction

Infant mortality remains one of the most sensitive indicators of socioeconomic wellbeing, healthcare access, and state capacity. It refers specifically to the death of a child before the first birthday, usually measured per 1,000 live births. Unlike under-five mortality, which covers deaths before age five, infant mortality captures mortality risks concentrated in the first year of life, when children are especially vulnerable to neonatal complications, malnutrition, infectious diseases, poor sanitation, and delayed access to care (World Bank, 2022; Grossman, 1972).

Nigeria presents a severe child-survival challenge. Although infant mortality has declined over time, the rate remains high relative to many developing economies. This persistence reflects not only weaknesses in the health system but also deeper socioeconomic constraints, including low household income, uneven maternal education, limited access to medical personnel, and inadequate public health financing. Studies on Nigeria and Sub-Saharan Africa consistently show that child survival is shaped by both household-level conditions and health-system capacity (Anyanwu & Erhijakpor, 2009; Antai, 2011; Akinlo & Sulola, 2019).

This paper shifts attention from a narrow public-health-expenditure framing to a broader socioeconomic explanation of infant mortality. The central argument is that infant mortality in Nigeria is shaped fundamentally by female education and household income. Female education improves maternal health knowledge, hygiene practices, nutrition choices, immunisation uptake, antenatal-care use, and timely care-seeking. This argument is consistent with evidence that parental and maternal education are strongly associated with child survival outcomes across countries and within Nigeria (Balaj et al., 2021; Antai, 2011; Osonwa et al., 2012).

Household income is equally important because infant survival depends on the resources available to protect the child during the first year of life. Higher income improves the ability to afford food, safe housing, transport to health facilities, medicines, sanitation, and supplementary care. Conversely, poverty exposes infants to malnutrition, delayed treatment, unsafe environments, and preventable mortality risks. Earlier studies show that income and household welfare conditions are central to explaining variations in infant and child mortality, often more strongly than public spending alone (Filmer & Pritchett, 1997; Roberts & Bogg, 2004; Taylor-Robinson et al., 2019).

Public health expenditure and physician density remain important health-system controls. For instance, public health expenditure may reduce mortality when it improves primary healthcare, immunisation, maternal and neonatal services, and access to essential medicines. Physician density captures the availability of trained medical personnel, which is crucial for diagnosis, treatment, referral, and emergency care. However, health-system resources may not reduce infant mortality effectively if households lack the income, knowledge, and access required to use available services (Berger & Messer, 2002; Bokhari et al., 2007; Liang et al., 2019; Rajkumar & Swaroop, 2008).

The Nigerian context makes this study particularly important. Many infant deaths are linked to preventable or treatable conditions, but survival depends on whether mothers and households can recognise risks, seek care promptly, afford associated costs, and access competent medical personnel. Expanding public health expenditure alone may therefore be insufficient unless household socioeconomic capacity and healthcare access improve simultaneously. This paper consequently examines female education and household income as the main socioeconomic determinants of infant mortality, while controlling for physician density and public health expenditure.

The broad objective is to examine the effect of female education and household income on infant mortality in Nigeria. Specifically, the paper investigates whether a long-run relationship exists among infant mortality, female education, household income, physician density, and public health expenditure; estimates the short-run and long-run effects of these variables; and examines the direction of causality among them. The rest of the paper is organised as follows. Section 2 provides the conceptual clarification, theoretical, and empirical literature. Section 3 presents the methodology. Section 4 discusses the empirical results. Section 5 concludes and provides policy implications.

2. Literature Review and Theoretical Framework

2.1 Conceptual Review

Infant mortality refers to the probability that a child born in a specific year or period dies before reaching the age of one, expressed per 1,000 live births. The World Health Organization (2024) provides this definition in its Global Health Observatory indicator metadata. This differs from under-five mortality, which measures the probability of dying before age five. The distinction is important because this paper is concerned specifically with mortality risks within the first year of life, not childhood mortality more broadly. Operationally, infant mortality is measured as infant deaths before age one per 1,000 live births and denoted as IFMO. Female education refers to the acquisition of literacy, knowledge, skills, and cognitive capacity by women through formal or informal learning. In the child-health literature, female education is important because it affects maternal health knowledge, reproductive behaviour, hygiene practices, nutrition decisions, immunisation uptake, and care-seeking behaviour. Balaj et al. (2021) show that parental education is strongly associated with child mortality inequalities, while Antai (2011) links maternal and household characteristics to child survival outcomes in Nigeria. In this paper, female education is operationalised as female literacy rate and denoted as HHES. This proxy captures the minimum educational capability required for women to read, understand, and act on basic health-related information. Household income refers to the economic resources available to households for consumption, welfare, healthcare, nutrition, housing, sanitation, and other basic needs. Roberts and Bogg (2004) associate household income with health opportunities and constraints across the life course, while Filmer and Pritchett (1997) show that income and household welfare conditions explain important variations in child mortality. In this paper, household income is operationalised as income per capita at constant 2005 US dollars and denoted as

HHDI. It captures the household welfare and affordability channel through which families are able to protect infant health. Physician density refers to the availability of medical doctors relative to the population. It is a standard health-system capacity indicator because it captures the extent to which trained medical personnel are available to provide diagnosis, treatment, referral, emergency care, and preventive services. Liang et al. (2019) show that healthcare workforce availability matters for child mortality outcomes, while Liebert and Mäder (2022) emphasise the contribution of physicians to health production during mortality transitions. In this paper, physician density is operationalised as physicians per 1,000 people and denoted as PHDE. It is included as a health-system access control. Public health expenditure refers to public resources devoted to financing health services, facilities, personnel, medicines, preventive care, and health-system administration. Berger and Messer (2002) and Bokhari et al. (2007) show that health financing can influence mortality outcomes, while Anyanwu and Erhijakpor (2009) find that health expenditure is associated with infant and child mortality outcomes in Africa. In this paper, public health expenditure is operationalised as current health expenditure as a percentage of GDP and denoted as PHEX. It is treated as a health-system financing control rather than the main variable of interest.

Conceptually, this paper argues that infant mortality in Nigeria is shaped primarily by household socioeconomic conditions, especially female education and household income, while physician density and public health expenditure condition the health-system environment within which households seek care. The empirical model therefore examines whether female education and household income reduce infant mortality after controlling for physician availability and public health financing.

2.2 Theoretical Framework

The theoretical foundation of this paper rests on Grossman's health demand model and the health production-function approach. Grossman (1972) treats health as a durable form of capital that individuals and households inherit, maintain, and improve through investment. Health is therefore not produced by medical care alone. It is shaped by a combination of knowledge, income, time, behaviour, healthcare access, and the wider social environment. This framework is particularly useful for analysing infant mortality because infant survival depends not only on the availability of health services, but also on the capacity of mothers and households to recognise risk, seek care, afford treatment, and maintain healthy living conditions.

Within this framework, female education operates as a maternal capability channel. Education improves a mother's ability to process health information, understand nutrition and hygiene practices, comply with immunisation schedules, use antenatal and postnatal services, and respond promptly to childhood illness. Its relevance is not merely that educated women have attended school, but that education increases the effectiveness with which households can convert available health resources into improved infant survival. Household income operates through the welfare and affordability channel. Even where health services exist, poor households may be unable to afford transport, drugs, adequate nutrition, safe housing, clean water, or timely treatment. Income therefore affects infant mortality by shaping the material conditions under which infants are born, fed, protected, and treated. In low-income settings, this channel is especially important because out-of-pocket costs and indirect access costs often determine whether care is actually used. Physician density and public health expenditure represent the health-system side of the survival process. Physician density captures the availability of trained medical personnel, while public health expenditure captures the financing capacity of the health system. These variables matter because household capability alone cannot reduce infant mortality where medical personnel, essential services, and public health infrastructure are inadequate. However, their effectiveness also depends on whether services are accessible, geographically distributed, and usable by households most exposed to infant mortality risk.

The health production logic can be expressed generally as:

$$H = f(E, Y, M, G) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where H denotes health outcomes, E represents education, Y captures income or household resources, M denotes medical-care access, and G represents public health-system support. Since infant mortality is an adverse health outcome, improvements in maternal education, household welfare, healthcare personnel availability, and health-system financing are expected to reduce mortality risk. This theoretical footing supports the central argument of our paper: infant mortality in Nigeria should not be understood as a health-expenditure problem alone. It is better explained as the outcome of interaction between maternal capability, household welfare, and health-system access. Female education and household income constitute the primary socioeconomic channels, while physician density and public health expenditure condition the health-system environment through which those household capabilities are converted into infant survival.

2.3 Empirical Review

The empirical literature on infant mortality can be read through three connected strands. The first strand emphasises household socioeconomic conditions, especially income and maternal education. The second examines health-system capacity, including physician availability and health financing. The third questions whether public health expenditure alone can explain mortality outcomes without considering governance, access, and household capability. These strands are not competing explanations; they are complementary channels through which infant survival is produced.

The socioeconomic strand provides the strongest foundation for our paper. Filmer and Pritchett (1997) show that public spending explains only a limited share of cross-country differences in child mortality once income, female education, and income distribution are taken into account. Their finding is important because it shifts attention from budgetary inputs to household capability. In other words, health expenditure may create supply, but household income and maternal education shape whether that supply is understood, reached, and used. Within this socioeconomic channel, maternal education has received sustained empirical support. Antai (2011), using Nigerian evidence, shows that under-five mortality varies with both individual and community-level characteristics, including maternal and household factors. Osonwa, Iyam, and Osonwa (2012) similarly highlight the role of perceptions, maternal characteristics, and social context in child mortality outcomes in Rivers State, Nigeria. Extending this evidence beyond Nigeria, Balaj et al. (2021), in a global systematic review and meta-analysis, report a strong association between parental education and child mortality inequalities. In all, these studies suggest that education improves child survival not simply by raising schooling levels, but by improving health knowledge, care-seeking behaviour, and the ability to act on medical advice. Income constitutes the second major socioeconomic pathway. Roberts and Bogg (2004) argue that income structures health opportunities and constraints across the life course, while Taylor-Robinson et al. (2019) show that rising child poverty can be associated with adverse infant mortality outcomes. The relevance for Nigeria is direct: low-income households are more likely to face poor nutrition, unsafe housing, inadequate sanitation, delayed treatment, and inability to afford transport or medicines. Thus, household income is not merely a control variable; it captures the material capacity through which families protect infants during the most vulnerable stage of life.

The second strand of the literature focuses on health-system capacity. Berger and Messer (2002) find that public financing of health expenditure and insurance arrangements influence mortality outcomes, while Bokhari, Gai, and Gottret (2007) show that both government health expenditure and income affect health outcomes in developing countries. Anyanwu and Erhijakpor (2009), using African evidence, also find that health expenditure is inversely related to infant and under-five mortality. These studies justify retaining public health expenditure in the model. However, they also imply that expenditure is best understood as part of a wider health-production process, not as a stand-alone explanation. Physician availability sharpens this health-system argument. Liang, Macinko, Yue, and Meng (2019) show that healthcare workforce availability affects under-five mortality, while Liebert and Mäder (2022) provide evidence that physicians contribute to health production during mortality transitions. The implication is straightforward: public spending may be ineffective if it does not translate into personnel, facilities, and accessible services. For Nigeria, where medical personnel are unevenly distributed across regions and between urban and rural areas, physician density is a necessary control for the actual availability of care.

The third strand introduces an important institutional qualification. Rajkumar and Swaroop (2008) demonstrate that the effectiveness of public spending depends on governance quality, while Yaqub, Ojapinwa, and Yussuff (2012) show that governance conditions mediate the relationship between public health expenditure and health outcomes in Nigeria. This matters because higher expenditure does not automatically produce better health outcomes. Funds must be allocated efficiently, protected from leakage, converted into services, and made accessible to households at risk. Recent Nigerian evidence reinforces this point. Yaji, Mihályi, and Williams-Yaji (2026), using Nigerian data from 1980 to 2021 and an ARDL framework, find that public health expenditure significantly reduces infant mortality, while household disposable income and physician density exhibit bidirectional causality with infant mortality. Their evidence is useful for the present paper because it confirms the relevance of health financing while also showing that mortality outcomes are tied to household welfare and healthcare personnel availability. It therefore supports the decision to treat public health expenditure as a health-system control rather than the sole centre of analysis.

The literature therefore points to a clear gap. Many studies examine infant or child mortality through either household socioeconomic conditions or health expenditure, but fewer integrate these channels while explicitly placing female education and household income at the centre of the analysis. This paper addresses that gap by examining whether female education and household income reduce infant mortality in Nigeria after controlling for physician density and public health expenditure. The contribution lies in shifting the emphasis from health spending alone to the interaction between maternal capability, household welfare, and health-system access.

3. Methodology

3.1 Data Source and Variables

This study uses annual time-series data for Nigeria covering 1980 to 2021. The data are sourced mainly from the World Development Indicators, with supplementary reference from Central Bank of Nigeria publications. The dependent variable is infant mortality rate (IFMO), measured as deaths per 1,000 live births. The key explanatory variables are household education status (HHES) and household disposable income (HHDI). Household education status is proxied by female literacy rate, while household disposable income is proxied by income per capita at constant 2005 US dollars. The control variables are physician density (PHDE) and public health expenditure (PHEX). Physician density is measured as the number of physicians per 1,000 inhabitants, while public health expenditure is measured as current health expenditure as a percentage of GDP.

3.2 Model Specification

The functional model of child survival is specified as:

$$\mathrm{IFMO} = f(\mathrm{HHES}, \mathrm{HHDI}, \mathrm{PHDE}, \mathrm{PHEX}) \ldots . (2)$$

The econometric model is expressed as:

$$\mathrm{IFMO}_t = \beta_0 + \beta_1 \mathrm{HHES}_t + \beta_2 \mathrm{HHDI}_t + \beta_3 \mathrm{PHDE}_t + \beta_4 \mathrm{PHEX}_t + \varepsilon_t \ldots \ldots (3)$$

Where IFMO_t denotes infant mortality, HHES_t denotes female education, HHDI_t denotes household disposable income, PHDE_t denotes physician density, PHEX_t denotes public health expenditure, and ε_t is the stochastic error term.

A priori, the expected signs are:

$$\beta_1 < \mathbf{0}, \quad \beta_2 < \mathbf{0}, \quad \beta_3 < \mathbf{0}, \quad \beta_4 < \mathbf{0}$$

This implies that higher female education, higher household income, greater physician density, and increased public health expenditure are expected to reduce infant mortality.

3.3 Method of Data Analysis

The empirical analysis proceeds in four stages. At the first instance, the Phillips-Perron unit root test is used to examine the stationarity properties of the variables. Secondly, the ARDL bounds test is applied to determine whether a long-run relationship exists among the variables. Thirdly, the ARDL long-run model and short-run error correction model are estimated. Finally, Granger causality tests are conducted to examine predictive direction among the variables. The ARDL approach is appropriate because it accommodates variables integrated at I(0), I(1), or a mixture of both, provided none is integrated at I(2). It is also suitable for relatively small samples and allows simultaneous estimation of short-run and long-run relationships.

4. Results and Discussion

4.1 Descriptive Statistics

Table 1: 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 Computation, 2026.

The descriptive statistics show that infant mortality averaged 103.76 deaths per 1,000 live births during the study period. This confirms the severity of Nigeria's child-survival challenge. Female literacy averaged 55.69, while household disposable income averaged 3,286.90. Physician density averaged only 0.28 physicians per 1,000 inhabitants, indicating weak healthcare personnel availability. Public health expenditure averaged 3.34 per cent of GDP, suggesting limited health-financing intensity relative to the scale of Nigeria's health burden.

4.2 Unit Root and Bounds Test Results

Table 2: 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 Computation, 2026.

The Phillips-Perron unit root results show that infant mortality and female education are stationary at level, while household disposable income, physician density, and public health expenditure become stationary after first differencing. This mixed order of integration validates the ARDL approach. Additionally, the ARDL bounds test produces an F-statistic of 16.80610, which exceeds the upper-bound critical values at all conventional significance levels. This confirms a long-run relationship among infant mortality, female education, household disposable income, physician density, and public health expenditure. The result means that child mortality in Nigeria is jointly linked to socioeconomic and health-system factors over the long run.

4.3 Long-Run Estimates

Table 3: 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 Computation, 2026

The long-run results show that household disposable income has a negative and statistically significant effect on infant mortality. This supports the paper's central argument that household welfare is a crucial child-survival channel. Higher income improves access to nutrition, sanitation, transport, medication, and healthcare services, thereby reducing mortality risk. Physician density also has a negative and statistically significant effect on infant mortality. This indicates that greater availability of medical personnel reduces mortality in the long run. The result confirms that household socioeconomic capacity must be complemented by health-system access. Public health expenditure has a strong negative and statistically significant effect on infant mortality. Conversely, female education has a positive and statistically significant long-run coefficient which suggest that education gains have not been evenly translated into healthcare access, income security, or child-survival behaviour.

4.4 Short-Run Dynamics

Table 4: 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 Computation, 2026.

In the short run, female education has a negative effect on infant mortality and is significant at the 10 per cent level. This result aligns with the theoretical expectation that improvements in female education can reduce mortality by improving maternal knowledge, care-seeking behaviour, and child-health practices. Public health expenditure also has a negative short-run effect, although it is statistically insignificant. This suggests that increases in health expenditure may reduce infant mortality, but the effect may take time to materialise because expenditure must pass through implementation, facility improvement, personnel deployment, and service delivery before affecting health outcomes. Household disposable income and physician density show positive but statistically insignificant short-run effects. These results should be interpreted cautiously. In the short run, income and physician availability may not immediately translate into lower mortality if health-system access, regional inequality, and service quality remain weak. The error correction term is negative and statistically significant, with a coefficient of -0.183249. This means that about 18.3 per cent of short-run disequilibrium is corrected annually. The adjustment speed is modest, implying that improvements in socioeconomic and health-system conditions reduce mortality gradually rather than immediately.

4.5 Diagnostic and Causality Results

Table 5: 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 computation, 2026.

The diagnostic tests support the reliability of the estimated model. The serial correlation LM test, normality test, heteroskedasticity test, and CUSUM stability test indicate that the model is statistically adequate.

Table 6: 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 computation, 2026.

The Granger causality results show bidirectional causality between infant mortality and household disposable income, and between infant mortality and physician density. This means that household income and physician availability help predict infant mortality, while infant mortality also contains predictive information about these variables. The result reinforces the view that child survival, household welfare, and healthcare access are mutually connected. No strong causality is found from public health expenditure to infant mortality. It suggests that public spending alone may not be the immediate causal driver of mortality outcomes unless it translates into household access, physician availability, and effective service delivery.

4.6 Discussion of Findings

The results support a socioeconomic interpretation of infant mortality in Nigeria. Household disposable income significantly reduces infant mortality in the long run, confirming that child survival is strongly tied to household welfare. Poor households face greater exposure to malnutrition, delayed treatment, unsafe environments, and limited healthcare access. The physician-density result shows that healthcare access remains essential. Even where households have income and education, child survival depends on the availability of trained health personnel. This is particularly relevant in Nigeria, where rural and disadvantaged areas often face severe shortages of medical professionals. Public health expenditure matters, but the causality results suggest that spending alone is not enough. Health expenditure must be converted into accessible, high-quality services before it can reduce mortality. This strengthens the paper's argument: child survival depends on the interaction between household socioeconomic capacity and health-system delivery. The female education result is mixed. Its negative short-run effect supports the expected maternal-education channel, but its positive long-run coefficient suggests that female literacy, as measured in the data, may not fully capture the quality of maternal health knowledge or the ability of women to act on that knowledge. Thus, education policy must therefore be linked to reproductive health education, household empowerment, and access to primary healthcare.

5. Conclusion and Policy Implications

This paper examined whether female education and household income help explain infant mortality in Nigeria after accounting for physician density and public health expenditure. The motivation was deliberately narrower than a general health-spending question. Infant survival is produced inside households as well as inside health facilities; mothers and families must possess the information, resources, and access required to convert health services into survival outcomes. The results support that interpretation, but with important qualifications. Household disposable income has a negative and statistically significant long-run effect on infant mortality, indicating that improvements in household welfare are associated with lower infant deaths. Physician density and public health expenditure also reduce infant mortality in the long run, showing that socioeconomic capacity must be complemented by accessible health-system resources. The causality results further show interdependence between infant mortality, household income, and physician density. These findings imply that infant mortality is not explained by one channel alone. It reflects the joint operation of household welfare, medical access, and public health financing.

The female education result is more complex. Its short-run coefficient is negative, consistent with the expected maternal-capability channel, but the long-run coefficient is positive and statistically significant. This suggest that literacy may improve survival only when it is linked to maternal health knowledge, autonomy, timely care-seeking, and actual access to services. This result is therefore a warning against treating schooling indicators as automatic measures of effective maternal capability.

The policy implication is straightforward. Reducing infant mortality in Nigeria requires a combined socioeconomic and health-system strategy. First and foremost, household welfare matters. Policies that raise household income, reduce poverty, improve food security, expand sanitation, and lower the indirect costs of seeking care can reduce infant mortality risk. Secondly, female education should be made more health relevant. Literacy programmes and girls' education should incorporate maternal health, nutrition, immunisation, hygiene, reproductive health, and early recognition of neonatal danger signs. Thirdly, physician availability must improve, especially in rural and underserved areas where infant mortality risks are highest. Finally, public health expenditure should be targeted toward primary healthcare, neonatal care, immunisation, essential medicines, and community-level service delivery rather than absorbed by administrative expenditure.

The central conclusion is that infant mortality in Nigeria is not simply a budgetary health-sector problem. Public health spending is necessary, but it is not sufficient. Infant survival improves when households have the income to seek care, mothers have usable health knowledge, physicians and facilities are physically available, and public expenditure is converted into effective frontline services. Policy should therefore focus less on isolated spending increases and more on the transmission chain through which resources, knowledge, and access become actual infant survival.

References

Akinlo, A. E., & Sulola, A. O. (2019). Health care expenditure and infant mortality in sub-Saharan Africa. *Journal of Policy Modeling, 41*(1), 168-178.

Antai, D. (2011). Regional inequalities in under-5 mortality in Nigeria: A population-based analysis of individual- and community-level determinants. *Population Health Metrics, 9*, Article 6.

Anyanwu, J. C., & Erhijakpor, A. E. O. (2009). Health expenditures and health outcomes in Africa. *African Development Review, 21*(2), 400-433.

Balaj, M., York, H. W., Sripada, K., Besnier, E., Vonen, H. D., Aravkin, A., Friedman, J., Griswold, M., Jensen, M. R., Mohammad, T., Mullany, E. C., Solhaug, S., Sorensen, R. J. D., Stonkute, D., Tallaksen, A., Whisnant, J. L., Zheng, P., Gakidou, E., & Eikemo, T. A. (2021). Parental education and inequalities in child mortality: A global systematic review and meta-analysis. *The Lancet, 398*(10300), 608-620.

Bello, R. A., & Joseph, A. I. (2014). Determinants of child mortality in Oyo State, Nigeria. *African Research Review, 8*(1), 252-272.

Berger, M. C., & Messer, J. (2002). Public financing of health expenditures, insurance, and health outcomes. *Applied Economics, 34*(17), 2105-2113.

Bokhari, F. A. S., Gai, Y., & Gottret, P. (2007). Government health expenditures and health outcomes. *Health Economics, 16*(3), 257-273.

Dhrifi, A. (2018). Health-care expenditures, economic growth and infant mortality: Evidence from developed and developing countries. *CEPAL Review*.

Eboh, A., Abba, J. Y., & Fatoye, H. A. (2018). Impact assessment of the public health expenditure on the health outcome in Nigeria. *International Journal of Social and Administrative Sciences, 3*(2), 62-72.

Edeme, R. K., Emecheta, C., & Omeje, M. O. (2017). Public health expenditure and health outcomes in Nigeria. *American Journal of Biomedical and Life Sciences, 5*(5), 96-102.

Filmer, D., & Pritchett, L. (1997). *Child mortality and public spending on health: How much does money matter?* World Bank.

Grossman, M. (1972). On the concept of health capital and the demand for health. *Journal of Political Economy, 80*(2), 223-255.

Khaleghian, P., & Gupta, M. D. (2005). Public management and the essential public health functions. *World Development, 33*(7), 1083-1099.

Liang, S., Macinko, J., Yue, D., & Meng, Q. (2019). The impact of the health care workforce on under-five mortality in rural China. *Human Resources for Health, 17*, Article 21.

Liebert, H., & Mäder, B. (2022). *Physicians and the production of health: Returns to health care during the mortality transition* (IZA Discussion Paper No. 15220). IZA Institute of Labor Economics.

Osonwa, O. K., Iyam, M. A., & Osonwa, R. H. (2012). Under-five mortality in Nigeria: Perception and attitudes of the Ikwerres in Rivers State towards the existence of "Ogba-Nje". *Journal of Sociological Research, 3*(2), 587-598.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics, 16*(3), 289-326.

Rajkumar, A. S., & Swaroop, V. (2008). Public spending and outcomes: Does governance matter? *Journal of Development Economics, 86*(1), 96-111.

Taylor-Robinson, D., Lai, E. T. C., Wickham, S., Rose, T., Norman, P., Bambra, C., Whitehead, M., & Barr, B. (2019). Assessing the impact of rising child poverty on the unprecedented rise in infant mortality in England, 2000–2017: Time trend analysis. *BMJ Open, 9*(10), e029424.

World Bank. (2022). *World Development Indicators*. World Bank.

World Health Organization. (2024). *Infant mortality rate (between birth and 11 months per 1,000 live births): Global Health Observatory Indicator Metadata Registry*. World Health Organization.

Yaji, W. N., Mihályi, P., & Williams-Yaji, V. O. (2026). Public health expenditure and infant mortality rate in Nigeria: New empirical insight from the ARDL model. *International Journal of Economic Development Research and Investment, 15*(3), 119-139.

Yaqub, J. O., Ojapinwa, T. V., & Yussuff, R. O. (2012). Public health expenditure and health outcome in Nigeria: The impact of governance. *European Scientific Journal, 8*(13), 189-201.