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STATISTICAL MODELLING OF THE IMPACT OF MALARIA CONTROL INTERVENTIONS ON ECONOMIC GROWTH IN NIGERIA

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ABSTRACT

Malaria remains a major public health concern in Nigeria and continues to impose significant economic costs through reduced labour productivity, increased healthcare expenditure, and constrained investment outcomes. This study examines the short-run and long-run effects of malaria control interventions and selected health indicators on economic growth in Nigeria using annual time-series data from 1988 to 2024. The Autoregressive Distributed Lag (ARDL) bounds testing approach is employed to accommodate variables integrated of mixed orders and to estimate both equilibrium relationships and dynamic adjustments. Unit root tests confirm mixed integration orders, while bounds test results indicate the existence of long-run relationships among the variables. Short-run estimates reveal that a 1% reduction in malaria incidence is associated with an approximate 0.35% increase in GDP, reflecting immediate productivity gains. Life expectancy exerts a negative short-run effect on output, while fertility rate remains statistically insignificant. In the long run, the direct effects of health indicators are weak; however, a negative and statistically significant error correction term confirms rapid convergence to equilibrium. The findings provide empirical support for the economic justification of malaria control interventions and underscore the need for sustained financing and efficient allocation of health-sector resources within Nigeria's broader development strategy.

1. Introduction

Malaria remains one of the most persistent public health challenges in sub-Saharan Africa, with Nigeria accounting for a substantial proportion of global malaria cases and related deaths. Beyond its health implications, malaria exerts significant economic costs by reducing labour productivity, increasing household and government healthcare expenditures, and discouraging domestic and foreign investment. These effects collectively constrain economic performance and undermine long-term development prospects, particularly in low- and middle-income economies.

From a macroeconomic perspective, health is increasingly recognised as a critical component of human capital formation and economic growth. Improved population health enhances labour efficiency, increases life-cycle productivity, and supports capital accumulation. Conversely, high disease burdens such as malaria can trap economies in cycles of low productivity and weak growth. Despite this theoretical linkage, empirical evidence on the growth effects of malaria control interventions remains mixed, particularly in country-specific contexts such as Nigeria where institutional, demographic, and fiscal conditions differ markedly from those of developed economies. Nigeria has implemented several malaria control strategies over the past decades, including the distribution of insecticide-treated nets, indoor residual spraying, improved diagnostic testing, and subsidised access to antimalarial drugs. These interventions have contributed to notable reductions in malaria incidence and mortality rates. However, the extent to which these health improvements translate into measurable macroeconomic gains remains insufficiently explored. Existing studies often focus on micro-level health outcomes which may obscure country-specific dynamics and policy-relevant insights.

This study contributes to the literature by empirically examining the relationship between malaria control interventions, selected health indicators, government expenditure, and economic growth in Nigeria using a time-series

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framework. Specifically, the study employs the Autoregressive Distributed Lag (ARDL) bounds testing approach to investigate both short-run dynamics and long-run relationships over the period 1988–2024. By integrating health indicators and fiscal variables within a unified econometric framework, the study provides policy-relevant evidence on the economic benefits of sustained malaria control efforts and complementary investment strategies.

2. Literature Review

The relationship between health outcomes and economic growth has received increasing attention in the development economics and health economics literature. Early theoretical contributions emphasize health as a fundamental component of human capital, arguing that improvements in population health enhance labour productivity, extend working life, and stimulate investment and savings, thereby promoting economic growth. Conversely, a high disease burden can reduce effective labour supply and constrain long-term development.

Malaria has been identified as one of the most economically damaging diseases in tropical and sub-tropical regions. Nmadu, *et al*. (2015) conducted a descriptive survey to analyze the prevalence of malaria in children aged 2-15 who visited Gwarinpa General Hospital Life-Camp, Abuja, Nigeria. The study revealed that 128 out of 200 children (64%) were infected with the malaria parasite. Among the infected children, those aged 2-5 had the highest infection rate at 29%, followed by children aged 6-10, and then those aged 11-15. Their findings suggest that malaria reduces growth through channels such as lower worker productivity, increased absenteeism, and higher healthcare costs. Similarly, Adepoju and Akpan (2017) examined the historical trend and anomalies of malaria cases and mortality in Nigeria over a span of sixty years. The results showed a significant increase in malaria prevalence between 2000 and 2015, with most cases occurring among children and women. The study also suggested that malaria distribution in Nigeria might shift towards the North-Central region due to a combination of environmental, social, and demographic factors. malaria discourages foreign investment and tourism, thereby weakening capital accumulation and trade performance.

At the country level, however, the empirical evidence is less extensive and often mixed. Some studies report strong short-run economic gains from malaria control interventions, while long-run effects remain weak or statistically insignificant. This divergence may reflect differences in institutional quality, financing consistency, and complementarities with other growth-enhancing investments. For instance, Yusuf *et al*. (2020) investigated the dynamics of health expenditure, malaria incidence, and GDP in Nigeria between 1990 and 2018. Applying a VECM with cointegration analysis, they identified a long-run negative effect of malaria on GDP, with causality running from malaria incidence to economic growth. In contrast, more recent studies in developing economies find that health improvements alone may be insufficient to generate sustained growth without complementary investments in education and physical capital.

Beyond malaria-specific indicators, broader health measures such as life expectancy and fertility rates have also been examined in growth models. Higher life expectancy is generally associated with improved productivity and human capital accumulation; however, its short-run effects on growth may be ambiguous due to increased dependency ratios and public expenditure pressures.

Methodologically, many earlier studies rely on cross-sectional or panel data approaches, which may obscure country-specific dynamics and short-run adjustments. Time-series studies using cointegration and error-correction frameworks offer a more suitable approach for analyzing long-run equilibrium relationships and short-run dynamics within individual economies. The Autoregressive Distributed Lag (ARDL) bounds testing approach, developed by Pesaran *et al*. (2001), has become particularly popular due to its flexibility in handling variables integrated of mixed orders and its suitability for small samples.

Despite the growing literature, there remains a gap in country-specific time-series studies that jointly examine malaria control interventions, health indicators, government expenditure, and economic growth within a unified econometric framework for Nigeria. Most existing Nigerian studies either focus on health outcomes without explicitly linking them to macroeconomic performance or examine public expenditure effects without isolating the role of malaria-related variables. This study addresses this gap by applying the ARDL bounds testing approach to assess both the short-run and long-run economic impacts of malaria control interventions in Nigeria.

3. Materials and Methods

3.1 Data Description

This study utilizes annual time-series data covering the period 1988–2024 to examine the relationship between malaria control interventions, health indicators, government expenditure, and economic growth in Nigeria. Real Gross Domestic Product (GDP) is used as the measure of economic growth. Malaria incidence rate serves as a proxy for malaria control outcomes, while life expectancy at birth and fertility rate captures broader population health and demographic dynamics. To account for fiscal and investment effects, government health expenditure, government education expenditure, and gross fixed capital formation are included as explanatory variables.

The data were obtained from secondary sources, including publications of the World Bank, World Health Organization, and the Central Bank of Nigeria. All variables were transformed into natural logarithms to reduce scale effects, stabilize variance, and allow coefficient interpretation as elasticities.

3.2 Model Specification

The Autoregressive Distributed Lag (ARDL) bounds testing approach developed by Pesaran, Shin, and Smith (2001) is employed to estimate both models. The ARDL methodology is particularly suitable when variables are integrated of mixed orders, I(0) and I(1), but not I(2). It also performs well in small sample settings and allows for the simultaneous estimation of short-run dynamics and long-run equilibrium relationships.

The ARDL representation of the model is expressed as:

$$GDP_t = \beta_0 + \beta_1 LER_t + \beta_2 FER_t + \beta_3 MIR_t + \beta_4 GHE_t + \beta_5 GEE_t + \beta_6 OOPEX_t + \beta_7 GFCF_t + \beta_8 SES_t + e_t$$

Where:

GDP_t= Gross Domestic Product at time t (dependent variable)

LERt = Life Expectancy Rate at time t, FER_t = Fertility Rate at time t, MIR_t = Malaria Incidence Rate at time t, GHE_t = Government Health Expenditure at time t, GEE_t = Government Education Expenditure at time t, $OOPEX_t$ = Out-of-Pocket Health Expenditure at time t, $GFCF_t$ = Gross Fixed Capital Formation at time t, SES_t = Secondary School Enrolment at time t, β_0 = Intercept term, β_1, β_2, ...β_8 = Slope coefficients, e_t = Error term at time t, t = Time period (1988-2024)

The model captures the relationship between Nigeria's economic growth (measured by GDP) and various health indicators, government expenditure patterns, and investment variables over the 37-year period from 1988 to 2024.

To capture the macroeconomic effects of malaria control interventions, two complementary models are specified. The first model focuses on the direct effects of health indicators on economic growth, while the second incorporates government expenditure and capital formation to account for fiscal and investment channels.

The first long-run model is specified as:

$$DRGDP_t = b_{01} + \sum_{i=1}^{p} b_{1i} DRGDP_{t-1} + \sum_{i=1}^{q} b_{2i} DLR_{t-1} + \sum_{i=1}^{q} b_{3i} DFR_{t-1} + \sum_{i=1}^{q} b_{4i} DMIR_{t-1} + l ECM_{t-1} + e_{1t}$$

where

$RGDP_t$=Real Gross Domestic Product, MIR =Malaria Incidence Rate, LR =Life Expectancy Rate, FR =Fertility Rate, and also, b_0 =Constant/Intercept, b_1 =Coefficient of Real Gross Domestic Product, b_2 =Coefficient of Life Expectancy Rate, b_3 =Coefficient of Fertility Rate, b_4 =Coefficient of Malaria Incidence Rate, D represents the first difference while l is the coefficient of Error correction model (ECM) for short-run dynamics. ECM shows the speed of adjustment in long-run equilibrium after a shock in the short run.

The second model extends the framework to include government expenditure and investment variables:

$$DRGDP_t = b_{01} + \sum_{i=1}^{p} b_{1i} DRGDP_{t-1} + \sum_{i=1}^{q} b_{2i} DGEE_{t-1} + \sum_{i=1}^{q} b_{3i} DGFCF_{t-1} + \sum_{i=1}^{q} b_{4i} DGHE_{t-1} + \sum_{i=1}^{q} b_{5i} DOOPEX_{t-1} + \sum_{i=1}^{q} b_{6i} DSES_{t-1} + l ECM_{t-1} + e_{1t}$$

where

RGDP =Real Gross Domestic Product, GEE = Government Education Expenditure, GHE = Government health spending as percentage (%) of total government spending, OOPEX = Out of pocket health expenditures as a percentage (%) total government spending, SSE = Secondary School Enrolment, GFCF = Gross Fixed Capital Formation, b_0 = Constant/Intercept, b_1 = Coefficient of Real Gross Domestic Product, b_2 = Coefficient of Government Education Expenditure (GEE), b_3 = Coefficient of Gross Fixed Capital Formation (GFCF), b_4= Coefficient of Government health spending as percentage (%) of total government spending (GHE), b_5= Coefficient of Out of pocket health expenditures as a percentage (%) total government spending, b_6 = Coefficient of Secondary School Enrolment

3.3 Unit Root and Cointegration Tests

Prior to estimation, the stationarity properties of the variables are examined using the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) unit root tests. These tests are employed to determine the order of integration of each variable and to ensure that none is integrated of order two, which would invalidate the ARDL approach.

The existence of long-run relationships among the variables is tested using the ARDL bounds testing procedure. The computed F-statistic is compared with the critical bound values. If the F-statistic exceeds the upper bound, the null hypothesis of no cointegration is rejected, confirming the presence of a long-run equilibrium relationship.

3.4 Error Correction Model

Once cointegration is established, the short-run dynamics are estimated using an error correction model (ECM) derived from the ARDL specification. The ECM captures the speed at which deviations from long-run equilibrium are corrected following short-run shocks. A negative and statistically significant error correction term indicates convergence toward long-run equilibrium and validates the stability of the estimated model.

4. Results and Discussion

The results indicate that reductions in malaria incidence significantly increase GDP in the short run. Life expectancy shows a negative short-run effect, while fertility is insignificant. Capital formation consistently drives growth in both the short and long run.

4.1 Time Series Model Development and Appropriate Relationships between Variables

The development of appropriate time series models to describe the relationships between health indicators and Nigeria's economic growth required comprehensive analysis of data characteristics and model selection procedures. The descriptive statistics presented in Table 1 reveals that Life Expectancy Rate (LR) demonstrates a relatively high mean of 50 years with a standard deviation of 5.21571, indicating moderate dispersion around the central tendency. This variation reflects the gradual improvement in healthcare outcomes and living standards over the study period. The Fertility Rate (FR) exhibits low skewness of 0.398, suggesting a nearly symmetric distribution that indicates stable demographic patterns with gradual transitions typical of developing economies.

The Gross Domestic Product (GDP) shows high standard deviation values, indicating significant variation across observations, which reflects the volatile nature of Nigeria's economic performance influenced by oil price, policy changes, and external economic shocks. Government health expenditure (GHE) and government education expenditure (GEE) both demonstrate negative skewness values of -0.113, The Malaria Incidence Rate (MIR) also shows slightly negative skew (-0.450), indicating that lower incidence rates have become more common over time, reflecting successful public health interventions and improved disease control measures.

Table 1: Descriptive Statistic

Series	Mean	Standard Deviation	Skewness	Kurtosis
LR	50.0989	5.21571	2.755	2.755
FR	5.8319	0.53527	0.398	0.398
GDP	40925464.8438	22260942.13743	0.133	0.133
GHE (%)	3.9091	1.59693	-0.113	-0.113
OOPEX (%)	65.5299	8.57334	-0.237	-0.237
GFCF	8271150.6031	1963335.35924	-1.346	-1.346
MIR (per 1000 population)	404.1214	77.51289	-0.450	-0.450
GEE (%)	3.9091	1.59693	-0.113	-0.113

The time series plots presented in Figures 1 and 2 reveal distinct temporal patterns across all variables that inform model specification decisions. Life expectancy demonstrates a consistent upward trajectory from 46 years in 1988 to 53 years in 2019, indicating sustained improvements in healthcare delivery and overall population well-being. However, the data shows an unprecedented sharp rise to 62 years in 2023 and further to 73 years in 2024, which may reflect data quality issues or significant methodological changes in measurement.

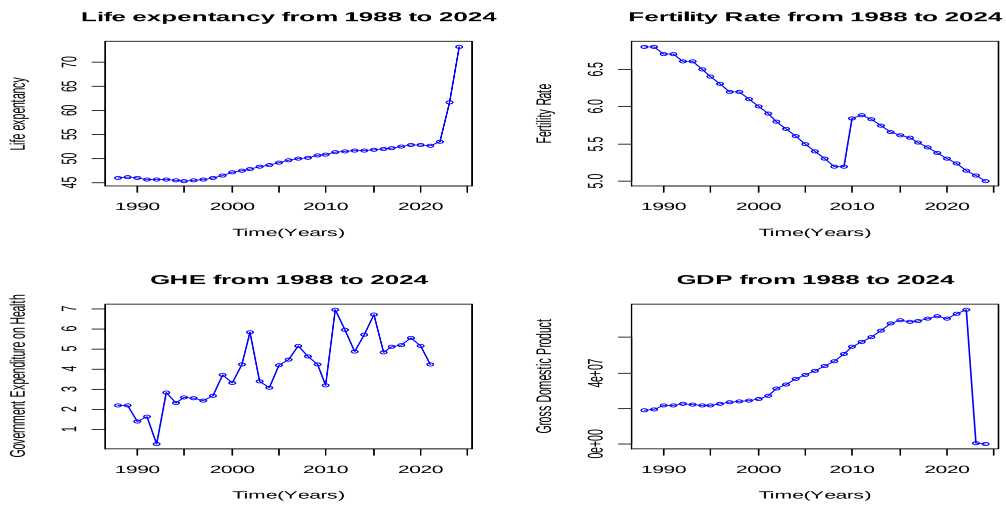

Figure 1: Time series plot for LR, FR, GHE and GDP from 1988 to 2024

The fertility rate follows a declining trend from 7 children per woman in 1988 to 5 in 2024, consistent with demographic transition patterns observed in developing countries. This decline suggests improvements in family planning services, enhanced educational attainment particularly among women, and economic development that typically accompanies reduced birth rates. The GDP trajectory shows general upward movement from $19 million in 1988 to $75.7 million in 2022, reflecting long-term economic growth despite periodic volatility. However, the dramatic decline to $234,426 in 2023 and $201,157 in 2024 represents an unprecedented contraction that may indicate significant economic disruption, measurement errors, or fundamental structural.

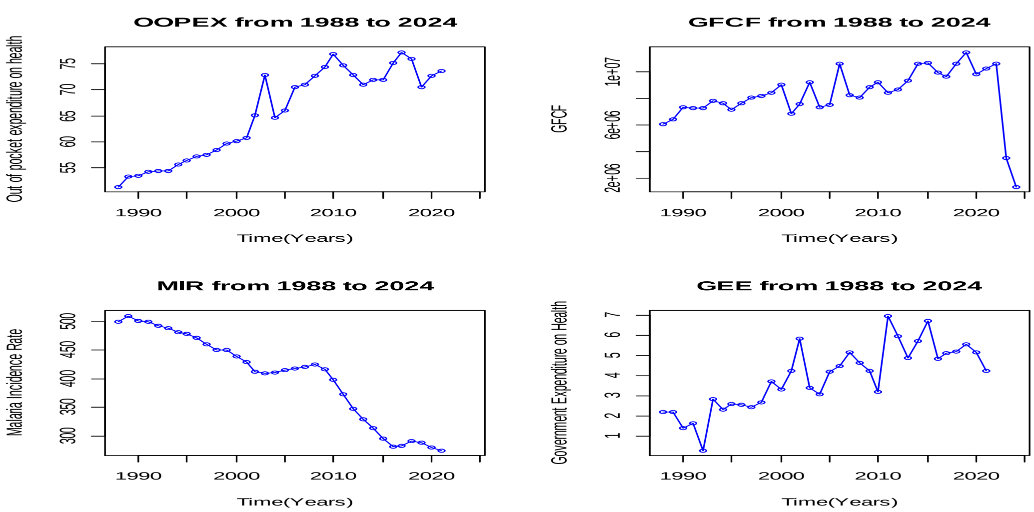

Figure 2: Time series plot for OOPEX, GFCF, MIR and GEE from 1988 to 2024

Government health expenditure exhibits considerable fluctuation throughout the period, reaching peaks of 6.99% in 2011 and 6.73% in 2015 before stabilizing between 4.22% and 5.55% in later years. These variations suggest shifting government priorities, budgetary constraints. The malaria incidence rate demonstrates encouraging trends with steady decline from 500 cases per 100,000 populations in 1988 to approximately 275 cases per 100,000 in 2021, representing a 45% reduction. This improvement reflects successful implementation of malaria control strategies including distribution of insecticide-treated nets, improved case management, and enhanced surveillance systems.

Table 2: Test for stationarity using Augmented Dickey-Fuller (ADF) and Phillips-Perron unit root test

Series	Augmented Dickey-Fuller (ADF) Test		Phillips-Perron (PP) Test		Remark
	Test Statistic	P-Value	Test Statistic	P-Value	
Fertility rate (FR)	-4.6763	0.0006	-4.6401	0.0007	Stationary at level I(0)
Gross domestic product (GDP)	-5.7116	0.0000	-5.7116	0.0000	Stationary at level I(0)
Life expectancy (LR)	-3.0749	0.0387	-3.8648	0.0056	Stationary at first differencing I(1)
Malaria incidence rate (MIR)	-8.0846	0.0000	-19.1359	0.0001	Stationary at second differencing I(2)
Government education spending (GEE)	-6.0440	0.0000	-17.2892	0.0001	Stationary at level I(0)
Gross fixed capital formation (GFCF)	-4.6199	0.0007	-4.7357	0.0005	Stationary at level I(0)
Government health spending as a percentage of total government spending (GHE)	-6.1156	0.0000	-22.4754	0.0001	Stationary at level I(0)
Out of pocket health expenditure as a percentage of total government spending (OOPEX)	-6.5107	0.0000	-6.9259	0.0000	Stationary at level I(0)
Secondary school enrolment (SES)	-6.0857	0.0000	-6.0846	0.0000	Stationary at level I(0)

The stationarity analysis conducted through Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests which reveals varying integration orders across variables, which is crucial for appropriate model specification. The results presented in Table 2 indicate that Life Expectancy (LR) achieves stationarity only after first differencing I(1), indicating the presence of a single unit root and suggesting that life expectancy follows a random walk process with drift. This finding aligns with expectations since life expectancy typically exhibits persistent upward trends over time. Most significantly, Malaria Incidence Rate (MIR) requires second differencing I(2) to achieve stationarity, suggesting the presence of two unit roots and indicating that malaria incidence exhibits strong trend components that may influence long-term economic and health policy modelling approaches. Other variables are all stationary at level I(0), meaning they do not require differencing for stability. This finding suggests these variables fluctuate around stable long-term means without persistent trends that would violate stationarity assumptions.

Following appropriate differencing transformations, the ACF and PACF plots for the transformed data demonstrate the quick cut off patterns which is characteristic of stationary processes. This transformation success confirms that the differenced series are suitable for ARDL modelling procedures and that

4.2 Long-term and Short-term Relationships between Health Indicators and Economic Growth and the adequacy of the developed model for the purpose of prediction

The analysis of long-term and short-term relationships between health indicators and Nigeria's economic growth utilized the Autoregressive Distributed Lag (ARDL) bounds testing approach, which is particularly suitable for variables with mixed integration orders. The bounds test results presented in Table 3 provide strong evidence for long-run cointegration relationships between GDP, life expectancy, fertility rate, and malaria incidence rate.

Table 3: Bounds Test for GDP, LR, FR and MIR Relationship

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Significance Value	I (0)	I (1)
F-Statistic	14.5145	10% Critical Value	2.676	3.586
K (Number of Regressors)	3	5% Critical Value	3.272	4.194
		1% Critical Value	4.614	5.966

The F-statistic value of 14.5145 substantially exceeds the upper-bound critical values at all conventional significance levels (10%, 5%, and 1%), providing conclusive evidence against the null hypothesis of no long-run relationship. This finding confirms that GDP, life expectancy, fertility rate, and malaria incidence are cointegrated, meaning these variables share a common long-term equilibrium relationship despite short-term deviations. The presence of cointegration implies that changes in any one variable will have lasting effects on the others, supporting the theoretical expectation that health and economic outcomes are fundamentally interconnected over extended periods.
The model selection process detailed in Table 4 employed multiple information criteria to identify the most appropriate ARDL specification. The selected model ARDL(1,0,2,1) achieves the lowest Akaike Information Criterion (AIC) value of -0.0128, indicating optimal balance between goodness-of-fit and model complexity. This specification suggests that GDP responds to its own lagged values with a one-period lag, fertility rate has immediate contemporaneous effects, life expectancy influences GDP with up to two-period lags, and malaria incidence affects economic growth with a one-period lag structure.

Table 4: Model Selection Criteria Table for Model A of Health variables (ARDL for GDP on LR, FR and MIR)

Model	**LogL**	**AIC**	**BIC**	**HQ**	**Specification**
47	8.2183	-0.0128	0.3463	0.1096	ARDL(1,0,2,1)*
48	6.8497	0.0088	0.3231	0.1160	ARDL(1,0,2,0)
38	8.6673	0.0196	0.4236	0.1574	ARDL(1,1,2,1)
50	6.5790	0.0248	0.3390	0.1319	ARDL(1,0,1,1)

** Best fit model*

The estimated ARDL model results presented in Table 5 reveal the specific nature of long-term and short-term relationships between health indicators and economic growth. The error correction coefficient of -1.6794 ($p = 0.0000$) is both statistically significant and appropriately negative, indicating that approximately 168% of any deviation from long-run equilibrium is corrected within each time period. While this coefficient magnitude exceeds unity, suggesting rapid overshooting adjustment, it confirms the existence of a stable long-run relationship with strong equilibrium-restoring forces.

Table 5: Conditional Error Correction for Health Variables (Model A)

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**P-value**
GDP(-1)*	-1.67939	0.21152	-7.93945	0.00000
FR**	0.68333	1.77282	0.38545	0.70304
LR(-1)	-7.61161	8.64097	-0.88087	0.38646
MIR(-1)	1.03600	1.73247	0.59799	0.55502
C	0.12820	0.06854	1.87037	0.07273
D(LR)	-42.25473	2.73007	-15.47752	0.00000
D(LR(-1))	-17.66980	10.89158	-1.62234	0.11680
D(MIR)	3.78882	1.54338	2.45488	0.02110

Model selection method: Akaike info criterion (AIC)
Number of models evaluated: 54
Selected model: ARDL(1,0,2,1)

The long-run coefficient estimates reveal nuanced relationships between health indicators and economic performance. Life expectancy demonstrates a negative long-run coefficient (-7.6116) but lacks statistical significance ($p = 0.38646$), suggesting that while increased longevity might be associated with economic challenges such as higher dependency ratios or increased social security costs, this relationship is not statistically robust over the long term. The malaria incidence rate shows a small positive long-run coefficient (1.03600, $p = 0.55502$), which is also statistically insignificant, indicating that the direct long-term impact of malaria on GDP may be offset by other factors or measurement issues.
The fertility rate exhibits a positive long-run coefficient (0.68333) but again lacks statistical significance ($p = 0.70304$), suggesting that demographic dynamics do not exert strong direct effects on long-term economic growth within this model specification. These findings indicate that while health indicators may influence economic outcomes, their isolated long-run effects are not sufficiently strong or consistent to achieve statistical significance, possibly reflecting complex interactions and competing mechanisms that offset direct relationships.
Conversely, malaria incidence rate changes show a positive and significant short-term effect on GDP (3.7888, p =

0.0061). This seemingly counterintuitive result may reflect several mechanisms: increased healthcare sector activity during malaria outbreaks that temporarily boosts economic output, emergency resource mobilization that stimulates short-term economic activity,

The investigation of model adequacy for prediction purposes requires comprehensive diagnostic testing to ensure that estimated relationships provide reliable foundations for forecasting and policy analysis. The diagnostic test results for model reveal important information about its suitability for predictive applications and policy guidance.

Table 6: Diagnostic Test for Health Variables Model (GDP on LR, FR and MIR)

Test	F-Statistic	P-Value
Breusch-Godfrey test for serial correlation	2.5026	0.1029
Ljung-Box Test for the autocorrelation in residuals	0.8591	0.3611
Breusch-Pagan Test for the homoskedasticity of residuals	0.9748	0.4699
Shapiro-Wilk test of normality of residuals	1.1594	0.5601

In table 6 diagnostic testing demonstrates strong adequacy for prediction purposes across multiple statistical criteria. The Breusch-Godfrey test for serial correlation yields an F-statistic of 2.5026 with p-value of 0.1029, indicating absence of significant serial correlation in model residuals. This finding confirms that error terms are not systematically related over time, ensuring that coefficient estimates are unbiased and that the model can reliably capture the underlying relationships between health indicators and economic growth.

The Ljung-Box test for autocorrelation produces consistent results with F-statistic of 0.8591 and p-value of 0.3611, further confirming that residuals do not exhibit problematic autocorrelation patterns. This independence of error terms strengthens confidence in the model's ability to generate reliable predictions.

Homoskedasticity testing through the Breusch-Pagan procedure yields F-statistic of 0.9748 with p-value of 0.4699, indicating that residual variance remains constant across different levels of independent variables. This finding ensures prediction intervals will be appropriately sized across the entire range of explanatory variables.

The Shapiro-Wilk test for normality of residuals produces F-statistic of 1.1594 with p-value of 0.5601, confirming that error terms follow normal distribution patterns. Normality of residuals is crucial for valid statistical inference, confidence interval construction, and prediction interval estimation,

Conclusion

The findings reveal a complex relationship between economic growth, health outcomes, and government spending. GDP, life expectancy, and malaria incidence share a long-term connection, though their individual effects vary in significance. The bidirectional link between GDP and life expectancy indicates a reinforcing cycle, where better health boosts economic growth, and economic advancement supports improved health. Similarly, the relationship between GDP and malaria incidence highlights the economic toll of disease while emphasizing the role of financial resources in disease control. The ARDL modeling approach assumes linear relationships and may not fully capture complex non-linear interactions between health indicators and economic growth. The models are also sensitive to structural breaks from Nigeria's economic volatility due to oil price fluctuations and political transitions. The study period encompasses significant changes including structural adjustment programs and COVID-19 impacts during 2020-2024, creating potential confounding factors. The causal interpretation is limited by the observational nature of data and potential omitted variable bias, Future research could explore how different components of government health expenditure impact economic growth to identify areas where spending inefficiencies may exist, exploring other econometric models, such as Vector Error Correction Models (VECM) or Generalized Method of Moments (GMM), may help refine causality analysis and improve robustness in estimating relationships among economic and health variables. The research contributes new empirical evidence by validating bidirectional causality between malaria incidence and economic growth, providing quantitative support for self-reinforcing cycles predicted by endogenous growth theory.

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