Applied Journal of Economics, Management, and Social Sciences, 10-20

Doi: 10.53790/ajmss.v7i1.71

ISSN: 2811 1613

Submitted: April 2026; Revised: June 2026; Accepted: August 2026

ARTICLE

Economic Welfare, Maternal Health Risks and Mortality in Nigeria: Evidence from Autoregressive Distributed Lag Technique

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Abstract

This study examines how economic welfare and maternal health risks shape maternal mortality in Nigeria using annual time-series data for 1990–2024. The analysis is motivated by Nigeria's persistently high maternal mortality burden relative to global targets and by the limited evidence on how macroeconomic conditions translate into maternal health outcomes through specific risk channels. The study employs an Autoregressive Distributed Lag (ARDL) framework to estimate short-run dynamics, long-run relationships, and mediation effects. Maternal mortality is modelled as a function of GDP per capita, current health expenditure, female education, physician-to-population ratio, adolescent birth rate, income inequality, pollution, and out-of-pocket health expenditure. The bounds test indicates a stable long-run cointegrating relationship among the variables. The long-run estimates show that current health expenditure and physician density significantly reduce maternal mortality, whereas adolescent birth rate and income inequality significantly increase it. GDP per capita has no statistically significant direct effect, implying that economic growth alone does not automatically improve maternal health outcomes. The error-correction term indicates that about 34.86% of short-run disequilibrium is corrected each year. Mediation results further suggest that adolescent birth rate partly transmits the effect of economic welfare to maternal mortality. The paper contributes to the literature by integrating welfare indicators and maternal risk factors within a unified time-series framework for Nigeria. The findings underscore the importance of health financing, equitable access to skilled care, and policies that reduce adolescent fertility and socioeconomic inequality if sustained reductions in maternal mortality are to be achieved.

Keywords: Autoregressive Distributed Lag (ARDL), Economic Welfare, Health Expenditure, Income Inequality, Maternal Health Risks, Maternal Mortality, Nigeria.

Cite as: Momoh, O. A. (2026). Economic welfare, maternal health risks and mortality in Nigeria: Evidence from autoregressive distributed lag technique. *Applied Journal of Economics, Management, and Social Sciences, 7(1), 10-20*

1. Introduction

Maternal mortality remains one of the clearest indicators of both health-system performance and the quality of socioeconomic development. Deaths related to pregnancy and childbirth are overwhelmingly preventable, yet they remain heavily concentrated in low- and middle-income countries. International evidence continues to show that progress in reducing maternal mortality depends not only on the availability of clinical services, but also on broader conditions such as income, education, inequality, and financial access to care. In this sense, maternal mortality is both a public health outcome and a development outcome, reflecting the interaction between household welfare, social opportunity, and the capacity of the health system.

Economic welfare influences maternal survival through several channels. Directly, higher income and stronger

financial protection improves the ability of women and households to afford antenatal visits, skilled birth attendance, transport, emergency obstetric care, and postpartum follow-up. Indirectly, welfare shapes nutritional status, educational attainment, living conditions, and women's bargaining power, all of which affect maternal risk. At the macro level, public health expenditure and the availability of physicians determine whether economic resources are translated into functioning maternal health services. Where growth is not accompanied by equitable public investment and wider access to care, improvements in aggregate income may coexist with persistently poor maternal outcomes.

This gap is analytically important because maternal mortality is unlikely to respond to changes in welfare instantaneously. Public spending, educational expansion, and workforce improvements often affect outcomes with lags, while adverse conditions such as inequality and adolescent childbearing may reinforce mortality risk over time. A time-series approach is therefore appropriate for distinguishing short-run adjustments from long-run equilibrium relationships. The ARDL framework is particularly useful in this setting because it accommodates mixed integration orders, performs well in relatively small samples, and allows the joint estimation of short-run and long-run effects within a coherent empirical model.

Studies in Nigeria and other sub-Saharan African countries consistently show that poverty, low female education, and limited access to financial resources significantly increase the likelihood of maternal complications and mortality (**Adejoorin et al., 2024**; **Okeowo et al., 2025**). Health care funding in Nigeria is among the lowest in the world. In 2024, current health expenditure accounted for approximately 4.2% of GDP, which remains far below the 15% target agreed upon by African Heads of State under the Abuja Declaration of 2001. Due to poor funding, households in Nigeria resort to out-of-pocket health expenditure which have impoverishing effects on households (**Oyedele 2023**). When OOPE exceeds certain threshold it could lead to catastrophic health expenditure that can drive households to poverty.

Previous studies such as **Olonade et al (2019)** focused on the implications of socio- economic development on maternal mortality and maternal healthcare while **Adamu et al. (2025)** analyze the impact of health expenditure on maternal and child health outcomes in Nigeria. Hence the relationship between economic welfare and maternal health risks such as physician-to-population ratio, and adolescent pregnancies remains underexplored. Most research relies on cross-sectional surveys or regional analyses, which limits the understanding of long-term trends and dynamic interactions between economic conditions and maternal health outcomes. Consequently, evidence to guide policy interventions that simultaneously address socioeconomic disparities and maternal health remains insufficient.

Maternal mortality refers to the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management, but not from accidental or incidental causes (**World Health Organization, 2023**). In empirical work, the standard indicator is the maternal mortality ratio (MMR), measured as maternal deaths per 100,000 live births. The indicator is widely used because it captures both the direct obstetric risks surrounding pregnancy and childbirth and the broader institutional conditions that determine whether women can obtain timely, effective care (**World Health Organization, 2023**).

Against this background, this study investigates the effect of economic welfare and maternal health risks on maternal mortality in Nigeria using annual data from 1990 to 2024. Specifically, it examines whether indicators of welfare GDP per capita, health expenditure, female education, inequality, pollution, and out-of-pocket spending shape maternal mortality directly and through maternal risk factors such as adolescent birth rate and physician-to-population ratio. The paper contributes to the economics and health-policy literature by integrating these channels within a single ARDL framework and by providing evidence on both long-run relationships and short-run dynamics in Nigeria. The remainder of the paper is organized as follows. Section 2 reviews the relevant literature and theoretical foundations. Section 3 presents the data, model specification, and estimation strategy. Section 4 discusses the empirical results, including mediation and diagnostic analyses. Section 5 concludes with policy implications.

2. LITERATURE REVIEW

2.1 Conceptual Review

Maternal Mortality

Contemporary scholarship treats maternal mortality as more than a clinical endpoint. It is also an indicator of social and economic development because maternal survival depends on household welfare, women's education, access to emergency obstetric care, the availability of skilled personnel, and the degree of financial protection within the health system (***World Health Organization, 2008***; **Souza et al., 2024**). This broader perspective is important in the Nigerian context, where preventable maternal deaths persist despite improvements in some macroeconomic indicators, suggesting that aggregate growth has not been translated consistently into inclusive health gains (**Olonade et al., 2019**).

Economic Welfare and Maternal Health

The conceptual link between welfare and maternal mortality operates through both demand-side and supply-side channels. On the demand side, low household resources and high user payments reduce the use of antenatal care, skilled delivery, and postnatal services (**Aregbeshola & Khan, 2018**; **Adewuyi et al., 2020**). In Nigeria, the continued reliance on out-of-pocket health spending increases the risk of catastrophic expenditure

and can delay or prevent care-seeking, especially for poorer households (**Aregbeshola & Khan, 2018**). On the supply side, inadequate public financing weakens the availability, quality, and geographic distribution of maternal health services. Hence, even where national income rises, maternal outcomes may remain poor if health financing is insufficient, if inequality limits access, or if health-system capacity does not expand alongside economic growth (**Rana et al., 2018**; **Souza et al., 2024**).

Maternal Health Risks as Mediators

Recent empirical work reinforces the role of maternal health risks as mediators between economic conditions and maternal mortality. Adolescent birth rate remains a critical indicator of risk, with unintended and early pregnancies associated with increased morbidity and mortality due to biological vulnerability and limited access to care (IJS Global Health, 2025; systematic review of adolescent maternal health services, 2024). Similarly, the availability of physicians and skilled health personnel is conceptually linked to service quality and utilization; a dearth of trained practitioners can result in low skilled birth attendance and poor emergency obstetric care, increasing mortality risk (WHO, 2025). These mediating factors demonstrate how socioeconomic context translates into differential risk exposure.

2.2 Theoretical Review

The theoretical literature on maternal mortality increasingly recognizes that maternal outcomes cannot be explained solely by biomedical conditions; they are also shaped by economic welfare, access to care, and the institutional capacity of health systems. In this study, the most relevant theoretical foundation is the Grossman health capital model, complemented by insights from the social determinants of health perspective and the broader maternal health access framework.

The Grossman model treats health as a form of capital that yields both consumption benefits and investment returns. Individuals derive utility from good health, but health also increases productivity by expanding the time available for market and non-market activities. In this framework, health is produced through a combination of medical care, education, time, and other household and environmental inputs, while it depreciates over time or under adverse living conditions (**Grossman, 1972**). Applied to maternal health, the implication is that a woman's probability of surviving pregnancy and childbirth depends not only on clinical treatment during delivery, but also on the stock of health accumulated through nutrition, schooling, preventive care, and the availability of skilled medical services. This makes the Grossman model especially relevant for explaining why variables such as health expenditure, female education, income, and physician availability may influence maternal mortality.

However, the Grossman framework on its own is not sufficient to explain maternal mortality in low-resource settings such as Nigeria. Maternal death is not simply the result of low private investment in health; it is also a consequence of structural inequalities that shape exposure to risk and access to care. This is why the social determinants of health framework is an important complementary perspective. According to this approach, health outcomes are fundamentally influenced by the social and economic conditions in which people are born, grow, live, and work, including income distribution, education, employment, housing, gender relations, and access to public services (World Health Organization, 2008). In the context of maternal mortality, the framework implies that women in poorer households, in disadvantaged regions, or in settings with weak social protection are more likely to face nutritional deprivation, delayed care-seeking, financial barriers, and poor-quality treatment. Thus, maternal mortality should be interpreted not only as a medical failure, but also as a reflection of unequal welfare conditions and social exclusion.

A further relevant theoretical lens is the maternal health access perspective, which explains maternal death through breakdowns in the chain of care. This perspective is consistent with the widely used understanding that maternal mortality often arises because women experience delays in deciding to seek care, delays in reaching appropriate facilities, and delays in receiving adequate treatment once care is reached. Although originally developed in public health, this logic has strong economic relevance because each form of delay is affected by resource constraints and welfare conditions. Low household income, high out-of-pocket payments, poor roads, inadequate transport, shortages of trained staff, and weak referral systems all raise the likelihood that obstetric complications become fatal. From this standpoint, physician-to-population ratio and health expenditure are not merely control variables; they are indicators of the system's ability to transform welfare resources into effective survival outcomes.

These theoretical perspectives also help justify the mediating variables used in this study. Adolescent birth rate can be understood as a transmission mechanism through which weak welfare conditions translate into higher maternal mortality. Lower female education, poverty, and limited reproductive autonomy increase the likelihood of early childbearing, while adolescent pregnancy itself raises obstetric risk and reduces the probability of safe motherhood. Similarly, physician availability functions as a system-capacity channel through which public investment and broader social development influence maternal outcomes.

2.3 Empirical Literature

For Nigeria, the evidence points strongly to the importance of financial protection and unequal access. Research on out-of-pocket spending shows that direct payments expose households to catastrophic health expenditure and can deepen poverty, thereby limiting the use of needed care (**Aregbeshola & Khan, 2018**). Related studies on maternal health service utilization consistently find large socioeconomic and geographic disparities in antenatal care, skilled birth attendance, and

Service-utilization studies reinforce this interpretation. Analyses of household and demographic survey data from Nigeria show that women who are poorer, less educated, or resident in rural areas are substantially less likely to receive adequate antenatal care, to deliver in health facilities, or to be attended by skilled personnel (**Adewuyi et al., 2020; Barros et al., 2012**). Education and wealth repeatedly emerge as major contributors to inequality in maternal care uptake, which supports the argument that maternal mortality should be analysed within a welfare framework rather than as a purely biomedical outcome.

Empirical research also underscores access to maternal health services as a core risk factor linked to socioeconomic status. Analyses of multiple Nigeria Demographic and Health Survey (DHS) waves reveal geographical and socioeconomic inequalities in antenatal care, skilled birth attendance, and facility-based delivery,facility-based delivery (**Adewuyi et al., 2020**; **Nwosu & Ataguba, 2019**). These patterns imply that average gains in national income do not automatically translate into better maternal outcomes when the costs of care remain high and access remains unequally distributed.

A related strand of literature focuses on proximate determinants of maternal risk. The World Health Organization identifies adolescent pregnancy as a major concern because adolescents face higher risks of pregnancy complications and poorer neonatal outcomes than women in their twenties (**World Health Organization, 2024**). At the same time, the health workforce literature shows that skilled providers are central to reducing preventable maternal deaths through early detection, timely referral, and emergency obstetric management (**World Health Organization, 2024**; **Souza et al., 2024**). In low-resource settings, shortages and maldistribution of qualified personnel can therefore offset the expected benefits of rising income or increased nominal spending.

Despite these insights, three limitations remain in the literature. First, many studies examine broad welfare indicators or proximate health risks separately, rather than estimating them within a unified macro-level framework. Second, a large share of the evidence is based on cross-sectional or household data, which is valuable for identifying disparities but less suited to tracing long-run relationships and dynamic adjustment. Third, relatively little work explicitly evaluates whether adolescent fertility and physician availability mediate the welfare–mortality relationship over time. This study addresses these gaps by combining welfare indicators and maternal risk factors in a single time-series ARDL framework for Nigeria.

Overall, the literature supports the expectation that health expenditure and physician density should lower maternal mortality, while adolescent fertility, inequality, and financial barriers should worsen it. What remains insufficiently understood is how these channels interact over time in Nigeria and whether macroeconomic welfare exerts its influence directly, indirectly through risk factors, or both. The present study contributes by addressing this issue in an integrated empirical setting.

3. RESEARCH METHODOLOGY

3.1 Data and Source

The analysis uses annual time-series data for Nigeria covering 1990–2024. Maternal mortality ratio (MMR), measured as maternal deaths per 100,000 live births, is the dependent variable. Economic welfare is represented by GDP per capita (GDPPC), current health expenditure as a percentage of GDP (CHE), female secondary school enrolment (FEDU), out-of-pocket health expenditure (OOPE), carbon dioxide emissions (CO2) as an environmental stress indicator, and the Gini coefficient (GINI) as a measure of income inequality. Two variables are treated as proximate maternal risk channels: adolescent birth rate (ABR) and physician-to-population ratio (PPOP). The variables were selected to capture the income, financing, human-capital, environmental, distributional, and health-system dimensions of welfare that may shape maternal survival in Nigeria.

The data are drawn principally from the World Bank's World Development Indicators and related internationally harmonized databases integrated into that platform. To reduce skewness, stabilize variance, and permit elasticity interpretation where appropriate, MMR, GDPPC, CO2, and OOPE are expressed in natural logarithms. Variables already measured as percentages, rates, or bounded indices are retained in levels so that their coefficients are interpreted as semi-elasticities. This transformation strategy consists of the mixed measurement scale of the variables and improves comparability within the estimated model.

3.2 Theoretical Framework

The empirical specification is anchored in the Grossman health production framework, which models health outcomes as the product of socioeconomic resources, behavioural choices, and health-system inputs. Within this perspective, maternal mortality declines when households and the state are able to invest more effectively in health-promoting inputs such as education, preventive care, and skilled medical services. Conversely, inequality, high out-of-pocket costs, and environmental stress may weaken these investments and raise maternal risk. The framework therefore provides the economic logic for modelling maternal mortality as a function of welfare indicators together with proximate maternal risk factors.

3.3 Model Specification

To capture both long-run equilibrium relationships and short-run adjustments, the study adopts an Autoregressive Distributed Lag (ARDL) specification. The ARDL framework is appropriate because the sample is relatively small and the variables may be integrated of mixed order, provided none is integrated of order two. It also allows each regressor to enter with its own lag structure, which is useful in a setting where the effects of health expenditure, education, or physician availability may materialize gradually rather than contemporaneously.

The baseline long-run relationship is specified as:

$MMR_t = F\ (GDPPC_t, CHE_t, FEDU_t, CO_{2t}, OOPE_t, ABR_t, PPOP_t, GINI_t)$

The estimable log-linear specification is written as:

$$lnMMR_t = \beta_0 + \beta_1 lnGDPPC_t + \beta_2 CHE_t + \beta_3 FEDU_t + \beta_4 lnCO2_t + \beta_5 lnOOPE_t + \beta_6 ABR_t + \beta_7 PPOP_t + \beta_8 GINI_t + \varepsilon_t$$

where MMR denotes maternal mortality ratio; GDPPC is GDP per capita; CHE is current health expenditure as a percentage of GDP; FEDU is female secondary school enrolment; CO2 denotes carbon dioxide emissions; OOPE is out-of-pocket health expenditure; ABR is adolescent birth rate; PPOP is physician-to-population ratio; GINI is the Gini coefficient; and ε_t is the stochastic error term. The expected signs are negative for CHE and PPOP, positive for ABR and GINI, and theoretically ambiguous for aggregate income variables if growth is not accompanied by equitable access to health services.

3.4 Estimation Technique

The estimation proceeds in four stages. First, the time-series properties of the variables are examined using Augmented Dickey–Fuller and Phillips Perron tests to confirm that no series is integrated of order two. Second, the optimal lag structure of the ARDL model is selected using the Akaike Information Criterion, with a maximum lag length constrained by the available sample size. Third, the Pesaran–Shin–Smith bounds test is applied to assess whether a long-run cointegrating relationship exists among the variables. If the calculated F-statistic exceeds the upper critical bound, the null hypothesis of no level relationship is rejected. Fourth, once cointegration is established, the ARDL model is re-parameterized into an error-correction representation to obtain long-run coefficients and short-run dynamic effects simultaneously. The coefficient on the error-correction term is expected to be negative and statistically significant, indicating convergence from short-run disequilibrium back to the long-run path after a shock. Standard post-estimation diagnostic tests are then used to examine serial correlation, heteroskedasticity, residual normality, and functional-form adequacy.

4. RESULTS AND DISCUSSIONS

Table 1 reports the descriptive statistics for the variables used in the analysis. Maternal mortality remained persistently high over the sample period, with a mean of 1,126 deaths per 100,000 live births and values ranging from 970 to 1,285. GDP per capita averaged 790,728, but the coexistence of relatively higher income levels with severe maternal mortality suggests that aggregate economic growth did not automatically translate into improved maternal health outcomes. Current health expenditure averaged 3.534% of GDP, indicating limited health-sector investment, while female education averaged 32.35, pointing to gradual but incomplete progress in women's human capital.

The remaining variables also reflect substantial structural constraints. The adolescent birth rate averaged 121 births per 1,000 women, indicating a high prevalence of teenage childbearing. Out-of-pocket health expenditure averaged 67.40%, showing that households bore a large share of healthcare costs directly. This pattern is consistent with weak financial protection and may discourage timely use of maternal health services, especially among poorer households. The Gini index averaged 41.43, suggesting persistent income inequality and unequal access to care. The dispersion measures indicate meaningful variation across the sample period. GDP per capita recorded the largest standard deviation, reflecting macroeconomic volatility, while maternal mortality showed more moderate but still notable variation. The minimum and maximum values similarly point to substantial movement over time in education, health financing, fertility behaviour, and inequality. These patterns justify the use of a dynamic time-series framework capable of tracing both short-run changes and longer-run relationships.

Table 1: Descriptive Statistics of Key Variables (1990–2024)

Variables	MMR	GDPPC	CHE	FEDU	ABR	PPOP	OOPE	CO2	GINI
Mean	1126	790728	3.534	32.35	121.0	1.891	67.40	6.187	41.43
Std. Dev.	72.82	172601	0.524	10.04	17.95	1.638	7.869	2.767	5.426
Minimum	970	559850	2.491	20.67	85.60	0.171	54.30	2.463	22.50
Maximum	1285	104110	5.054	50.33	142.9	4.063	77.39	11.33	51.90
Skewness	0.146	-0.078	1.039	0.216	-1.006	0.070	-0.397	0.312	-1.212
Kurtosis	2.927	1.405	3.908	1.556	2.449	1.140	1.546	1.818	6.594
Jarque-Bera	0.133	3.743	7.504	3.312	6.346	5.074	4.002	2.606	27.41
Probability	0.936	0.154	0.025	0.191	0.419	0.079	0.135	0.272	0.000
Obs	35	35	35	35	35	35	35	35	35

Correlation Analysis

Table 2 presents the Pearson correlation matrix, which provides preliminary evidence on the direction and strength of bivariate associations among the variables. The log of maternal mortality (lnMMR) is negatively correlated with lnGDPPC, CHE, FEDU, PPOP, lnOOPE, and lnCO2, while it is positively correlated with ABR and GINI. These simple correlations are broadly consistent with the expectation that stronger welfare conditions and better health-system capacity are associated with lower maternal mortality, whereas adolescent fertility and inequality are associated with higher mortality.

The positive correlations of lnMMR with ABR and GINI are notable because they support the view that adolescent childbearing and unequal income distribution may amplify maternal health risk. At the same time, these associations are descriptive rather than causal. They do not control for interactions among the regressors and therefore serve only as an initial indication of the relationships to be examined more formally in the ARDL framework.

Some explanatory variables are also strongly correlated with one another, particularly lnGDPPC with FEDU, lnOOPE, and lnCO2. This pattern suggests a potential multicollinearity problem if all of these variables are entered simultaneously in a small-sample model.

Table 2: Pearson Correlation Matrix of Key Variables

The preferred ARDL specification therefore prioritizes parsimony and retains the subset of variables that offers the strongest empirical fit under the automatic lag-selection procedure.

Variable	lnMMR	lnGDPPC	CHE	FEDU	ABR	PPOP	lnOOPE	lnCO2	GINI
lnMMR	1.00	-0.52	-0.52	-0.65	0.64	-0.41	-0.73	-0.61	0.71
lnGDPPE	-0.52	1.00	0.22	0.91	-0.64	0.58	0.90	0.84	-0.65
CHE	-0.52	0.22	1.00	0.21	-0.12	-0.20	0.34	0.45	-0.40
FEDU	-0.65	0.91	0.21	1.00	-0.78	0.67	0.85	0.86	-0.74
ABR	0.64	-0.64	-0.12	-0.78	1.00	-0.43	-0.73	-0.66	0.69
PPOP	-0.41	0.58	-0.20	0.67	-0.43	1.00	0.54	0.39	-0.43
lnOOPE	-0.73	0.90	0.34	0.85	-0.73	0.54	1.00	0.78	-0.63
lnCO2	-0.61	0.84	0.45	0.86	-0.66	0.39	0.78	1.00	-0.70
GINI	0.71	-0.65	-0.40	-0.74	0.69	-0.43	-0.63	-0.70	1.00

Stationarity Tests

Before estimating the ARDL model, the stationarity properties of the series were examined using the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests. The ADF results fail to reject the null of a unit root at levels for all variables, while the PP results are broadly similar, with a few borderline cases for CHE, PPOP, and lnCO2. Such differences are common in small samples because the two tests handle serial correlation differently. Importantly, the tests do not indicate that any variable is integrated of order two. This supports the use of the ARDL bounds-testing approach, which is valid when regressors are a mixture of I(0) and I(1) processes but none is I(2).

Table 3: ADF Unit Root Test Results (Levels)

Variable	ADF Statistic	ADF p-value	PP Statistic	PP p-value	Order of Integration	Status
lnMMR	-1.950	0.5940	-5.500	0.7820	I(1)	Stationary
lnGDPPC	-1.820	0.6450	-4.720	0.8330	I(1)	Stationary
CHE	-2.610	0.3360	-18.500	0.0516	I(1)*	Stationary
FEDU	-3.010	0.1810	-13.400	0.2680	I(1)	Stationary
ABR	-2.060	0.5500	-2.880	0.9350	I(1)	Stationary
PPOP	-3.100	0.1460	-22.400	0.0168	I(0)/I(1)**	Stationary
lnOOPE	-0.699	0.9610	-6.860	0.6940	I(1)	Stationary
lnCO2	-2.990	0.1890	-19.200	0.0433	I(0)/I(1)**	Stationary
GINI	-1.770	0.6620	-7.180	0.6730	I(1)	Stationary

ARDL Bounds Test for Cointegration

Using the Akaike Information Criterion with a maximum lag order of 2, the preferred specification is ARDL(1, 2, 1, 2, 2, 2, 2) for lnMMR as a function of lnGDPPC, CHE, FEDU, ABR, PPOP, and GINI. This specification balances model fit with parsimony and provides the basis for the subsequent cointegration and error-correction analysis.

Following automatic selection, the estimated ARDL model in its general form is expressed as:

$$lnMMR = 1.9949 + 0.6514\ lnMMR_{t-1} + 0.0070\ lnGDPPC_t - 0.1319\ lnGDPPC_{t-1} + 0.1346\ lnGDPPC_{t-2} - 0.0101\ CHE_t - 0.0134\ CHE_{t-1} + 0.0014\ FEDU_t + 0.0002\ FEDU_{t-1} + 0.0010\ FEDU_{t-2} - 0.0007\ ABR_t + 0.0014\ ABR_{t-1} + 0.0011\ ABR_{t-2} - 0.0025\ PPOP_t - 0.0029\ PPOP_{t-1} - 0.0014\ PPOP_{t-2} + 0.0010\ GINI_t - 0.0023\ GINI_{t-1} + 0.0039\ GINI_{t-2} + \varepsilon_t \quad \ldots(1)$$

Equation (1) corresponds to the selected ARDL specification. The coefficient on lagged lnMMR is positive and highly significant, indicating persistence in maternal mortality over time. The model also fits the data closely, with a Multiple R-squared of 0.9949 and an Adjusted R-squared of 0.9884. These statistics suggest that the chosen regressors and lag structure capture a substantial share of the observed variation in maternal mortality over the sample period.

The bounds F-test yields a statistic of 18.807 ($p = 0.000001$), which exceeds the upper critical bound at conventional significance levels. The null hypothesis of no cointegration is therefore rejected. This result confirms the existence of a stable long-run relationship among maternal mortality and the selected explanatory variables and justifies estimation of the long-run coefficients and short-run error-correction dynamics.

Long-Run and Short-Run Estimates

The long-run cointegrating coefficients, derived from the Unrestricted Error Correction Model (UECM), are presented in Table 4. These coefficients represent the equilibrium relationships between each explanatory variable and the log of maternal mortality ratio, controlling for all other variables in the model.

Table 4 reports the long-run and selected short-run estimates from the ARDL-ECM. The error-correction term is negative and statistically significant, confirming convergence to the long-run equilibrium after short-run disturbances. Its coefficient of −0.3486 implies that about 34.9% of disequilibrium is corrected each year, suggesting a moderate speed of adjustment.

In the long run, current health expenditure has a negative and statistically significant coefficient, indicating that higher health spending is associated with lower maternal mortality. Physician-to-population ratio also enters with a negative and significant coefficient, consistent with the view that greater access to qualified health personnel improves maternal survival. By contrast, adolescent birth rate and income inequality have positive and significant effects, implying that teenage childbearing and unequal resource distribution worsen maternal outcomes.

GDP per capita is positive but statistically insignificant in the long run, suggesting that aggregate income growth alone does not necessarily reduce maternal mortality when gains are not translated into wider access to effective healthcare. Female education enters with a positive and significant coefficient, which is counter to the usual theoretical expectation. This result should therefore be interpreted with caution. It may reflect delayed transmission from education to health outcomes, measurement issues, or overlap with other structural variables in the model rather than a genuinely adverse effect of female education on maternal survival.

The result further reveals that GDP per capita (lnGDPPC) has a positive but statistically insignificant effect on maternal mortality in both the short run and long run. This result is consistent with prior Nigeria-specific empirical evidence (***Olalekan et al., 2024***). This suggests that economic growth alone does not automatically improve maternal health conditions in Nigeria because the benefits of growth may not reach vulnerable populations or translate into better healthcare infrastructure and access. Female education (FEDU) also shows a positive and statistically significant relationship with maternal mortality, which appears counterintuitive. However, this may reflect structural issues such as improved reporting of maternal deaths in urban and educated regions, time lags between educational improvements and health outcomes, and the indirect effect of female education operating through reductions in adolescent fertility. This is contrary to the findings of Rana et al 2018.

The short-run estimates broadly reinforce the long-run results. Changes in current health expenditure reduce maternal mortality in the short run, indicating that health financing produces relatively immediate benefits as well as persistent long-run effects. Changes in physician availability also lower maternal mortality, with the lagged term suggesting that workforce expansion may take time to influence service delivery and outcomes.

The lagged Gini term is negative in the short run despite the positive long-run effect of inequality. This may reflect temporary adjustment effects rather than a sustained protective influence of inequality. Overall, the results indicate that maternal mortality in Nigeria is shaped primarily by health financing, workforce capacity, adolescent fertility, and inequality, while economic growth on its own is not sufficient to deliver substantial maternal health gains.

Table 4: Long-Run Cointegrating Coefficients (ARDL-ECM)

Variable	Coefficient	Std. Error	t-Statistic	p-value	Significance
Intercept	5.7234	1.0974	5.216	0.0001	***
lnGDPPC	0.0280	0.0799	0.351	0.7308	
CHE	−0.0676	0.0118	−5.741	0.0001	***
FEDU	0.0075	0.0023	3.204	0.0064	**
ABR	0.0051	0.0006	7.849	0.0000	***
PPOP	−0.0195	0.0065	−2.986	0.0098	**
GINI	0.0074	0.0026	2.819	0.0137	*
Selected Short-Run Coefficients (UECM)					
L(lnMMR, 1) [ECT]	−0.3486	0.0635	−5.488	0.0001	***
d(CHE)	−0.0101	0.0041	−2.491	0.0259	*
d(FEDU)	0.0014	0.0006	2.495	0.0257	*
d(PPOP)	−0.0025	0.0012	−2.060	0.0585	.
d(L(PPOP, 1))	−0.0029	0.0012	−2.402	0.0307	*
d(L(GINI, 1))	−0.0039	0.0014	−2.836	0.0132	*
d(lnGDPPC)	0.0070	0.0493	0.143	0.8884	

Note: Dependent variable: lnMMR. *** p<0.01, ** p<0.05, * p<0.10. Long-run coefficients derived from the cointegrating equation via UECM. Coefficients on log-transformed variables are elasticities; others are semi-elasticities.

Mediation Analysis:

The mediation analysis examines whether adolescent birth rate (ABR) and physician-to-population ratio (PPOP)

transmit part of the effect of economic welfare variables to maternal mortality. In the ABR equation, lagged health expenditure and female education reduce adolescent fertility, while lagged GDP per capita shows a temporary positive association. When ABR is included in the maternal mortality model, it is positive and significant, while health expenditure remains directly protective. This pattern is consistent with partial mediation: welfare conditions affect maternal mortality partly through their influence on adolescent fertility, but some direct effects remain.

The PPOP channel yields a similar conclusion. Health expenditure and female education improve physician availability, and higher physician density is associated with lower maternal mortality once included in the outcome equation. Taken together, the sequential ARDL results suggest that welfare improvements reduce maternal mortality not only directly, but also indirectly through lower adolescent fertility and stronger health-system capacity.

Table 5a: Summary of Sequential ARDL Mediation Analysis Results

Model/Predictor	Dependent Var.	Key Coeff.	P-value	Adj. R2	Interpretation
Step 1: Effect of Economic Welfare Variables on the Mediator (ABR)					
L(CHE, 1)	ABR	−3.729	0.041*	0.9878	Health spending reduces ABR with 1-year lag
L(FEDU, 4)	ABR	−0.556	0.032*	0.9878	Female education reduces ABR with 4-year lag
L(lnGDPPC, 3)	ABR	+77.77	0.013*	0.9878	GDP growth transiently increases ABR (3-year lag)
Step 2a: Full Model- MMR on Welfare Variables + ABR (Mediator Included)					
ABR (long-run)	lnMMR	+0.0051	0.000***	0.9884	ABR significant; welfare variables significant (CHE, PPOP, GINI)
CHE (long-run)	lnMMR	−0.0676	0.000***	0.9884	Direct effect confirmed; CHE retains significance with mediator present
Step 2b: Baseline Model- MMR on Welfare Variables Only (Mediation Excluded)					
lnGDPPC, CHE, FEDU, PPOP, GINI	lnMMR	n.s.	all >0.30	0.9684	No direct welfare coefficients significant without mediator → confirms mediation

Note: **** p<0.01, * p<0.05, n.s. = not significant.*

Overall, the mediation evidence indicates that health expenditure and female education improve intermediate determinants of maternal survival, while adolescent birth rate increases maternal mortality and physician density reduces it. The results therefore support a partial mediation structure rather than a purely direct welfare effect.

In substantive terms, the findings imply that policies aimed at reducing maternal mortality should combine broader welfare improvements with targeted interventions that lower adolescent fertility and expand access to skilled health personnel.

This reinforces the importance of adolescent reproductive health policy, female education, and health workforce expansion within a broader maternal health strategy.

Table 5b: Baseline Model Without Mediator (Step 2)

Model / Predictor	Dependent Var.	Key Coeff.	p-value	Adj. R^2	Interpretation
Step 1: Effect of Economic Welfare Variables on the Mediator (PPOP)					
L(CHE, 1)	PPOP	-1.339	0.0037**	0.5395	Health spending significantly increases physician density with 1-year lag
FEDU	PPOP	+0.1706	0.0194*	0.5395	Female education significantly improves physician availability
Step 2a: Full Model - MMR on Welfare Variables + PPOP (Mediator Included)					
L(PPOP, 1)	lnMMR	-0.00252	0.0419*	0.9877	Higher physician density significantly reduces maternal mortality
CHE (long-run)	lnMMR	-0.0086	0.0445*	0.9877	CHE retains significance with mediator present
Step 2b: Baseline Model - MMR on Welfare Variables Only (Mediator Excluded)					

lnGDPPC, CHE, FEDU, ABR, GINI	lnMMR	Mostly n.s.	>0.10	0.9814	Some welfare coefficients weaker without PPOP

Mediation Conclusion:

Partial mediation confirmed. Economic welfare (especially CHE and FEDU) improves physician density (PPOP), which in turn significantly reduces maternal mortality. The inclusion of PPOP strengthens cointegration (F = 17.99 vs 13.79) and improves model fit. This indicates that strengthening the health workforce is an important transmission channel through which economic welfare translates into lower maternal mortality.

Diagnostic Tests

A set of post-estimation diagnostic tests was conducted to assess the adequacy of the preferred ARDL model. The results are reported in Table 6.

Test	Statistic	Degrees of Freedom	P-value	Outcome
Breusch–Godfrey (Serial Correlation)	LM = 10.550	df = 1	0.05711	Serial correlation not detected
Breusch–Pagan (Heteroskedasticity)	BP = 14.548	df = 18	0.6927	Homoskedastic residuals
Jarque–Bera (Normality)	$\chi2$ = 0.541	df = 2	0.7630	Residuals normally distributed
Ramsey RESET (Specification)	F = 0.448	df1=2, df2=12	0.6489	No misspecification detected

Table 6: Post-Estimation Diagnostic Test Results

The Breusch–Pagan test does not reject the null of homoskedasticity, indicating that the variance of the residuals is stable. The Jarque–Bera statistic also suggests that the residuals are approximately normally distributed. In addition, the Ramsey RESET test provides no evidence of functional-form misspecification, which supports the adequacy of the estimated specification.

The Breusch–Godfrey test likewise indicates no strong evidence of serial correlation at conventional significance levels. Taken together, the diagnostic results suggest that the estimated ARDL model is statistically well behaved and that the reported long-run and short-run coefficients are reliable for interpretation.

Overall, the diagnostics support the internal consistency of the model and strengthen confidence in the substantive conclusions drawn from the ARDL-ECM estimates.

5. Conclusion and Recommendations

This study examined the relationship between economic welfare, maternal health risks, and maternal mortality in Nigeria using annual data from 1990 to 2024 within an ARDL framework. The results indicate a stable long-run relationship among the variables and show that maternal mortality is shaped less by aggregate income growth alone than by the extent to which resources are translated into effective health-system capacity and equitable access to care. In particular, current health expenditure and physician-to-population ratio reduce maternal mortality, while adolescent birth rate and income inequality increase it. GDP per capita does not exert a statistically significant direct effect, implying that economic expansion, by itself, is insufficient to deliver sustained maternal health gains when public health investment and social inclusion remain weak.

The findings also suggest that maternal mortality in Nigeria operates through identifiable transmission channels. The mediation results indicate that adolescent fertility and health-system capacity partly transmit the effects of welfare conditions to maternal outcomes, while the error-correction term confirms a moderate speed of adjustment from short-run shocks to long-run equilibrium. Taken together, the evidence supports a multidimensional interpretation of maternal mortality: it reflects not only clinical risk, but also the interaction of health financing, workforce availability, reproductive behaviour, and socioeconomic inequality. The results should, however, be interpreted in light of the study's macro-level design, which cannot fully capture subnational disparities or institutional and governance factors that may also shape maternal outcomes.

On the basis of these findings, policy should prioritize three mutually reinforcing areas. First, Nigeria should strengthen public financing for maternal and reproductive health by expanding budgetary allocations to primary and emergency obstetric care, reducing dependence on out-of-pocket payments, and improving the efficiency of health spending. Second, workforce policy should focus on recruiting, retaining, and geographically redistributing skilled physicians and other maternal health personnel, especially in underserved areas where shortages remain most severe. Third, maternal mortality reduction strategy should incorporate stronger adolescent reproductive health interventions, including age-appropriate sexuality education, access to family planning, and programmes that keep girls in school. More broadly, maternal health policy should be integrated with anti-poverty and inequality-reduction measures so that improvements in economic welfare are translated into measurable survival

gains. Future research may extend this analysis by incorporating subnational data, health insurance coverage, governance quality, and regional disparities to deepen understanding of the mechanisms linking welfare to maternal mortality in Nigeria.

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