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Original Research Article

Government Health Expenditure, Environmental Quality, Medical Technology and Maternal Mortality in Nigeria: A Dynamic Analysis

Zhegum Joseph Maras[1*], Mohammed Inuwa Dauda[1], Idowu Daniel Onisanwa[1]

[1] Department of Economics and Development Studies, Federal University of Kashere, Gombe, Nigeria

Correspondence should be addressed to Zhegum Joseph Maras: zhegum.Joseph@gmail.com

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Abstract: Nigeria remains among the countries with the highest maternal mortality ratios globally, recording nearly 512 deaths per 100,000 live births in spite of sustained policy interventions and considerable international assistance. Against this background, this study examines the effects of government health expenditure, environmental quality, and medical technology on maternal mortality in Nigeria over the period 1985–2024. The study relies on annual time-series data obtained from the World Bank's World Development Indicators and applies the Autoregressive Distributed Lag (ARDL) bounds testing framework to estimate both short-run dynamics and long-run relationships among the variables. The empirical findings indicate that, in the short run, government health expenditure has a negative and statistically significant effect on maternal mortality, indicating that increases in public health spending contribute to a reduction in maternal deaths in the short run. Environmental quality also shows a significant negative effect in its lagged form, suggesting that improvements in environmental conditions increase maternal health outcomes, although with a delayed impact. However, the long-run estimates reveal that neither government health expenditure nor environmental quality has a statistically significant influence on maternal mortality. Furthermore, the estimated error correction term is negative and statistically significant, showing the existence of a stable long-run equilibrium relationship among the variables. These findings imply that while short-term interventions in health spending and environmental management can yield immediate improvements in maternal health outcomes, long-term progress requires addressing deeper systemic constraints within the health and environmental sectors. The study highlights the importance of targeted short-run policy measures together with comprehensive structural reforms. It recommends strengthening budget implementation processes, integrating environmental health monitoring into maternal healthcare programmes, and enhancing the distribution and capacity of the health workforce to ensure sustained reductions in maternal mortality in Nigeria

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1. Introduction

Maternal mortality remains one of the most serious public health challenges confronting developing countries and constitutes an important indicator of the effectiveness of healthcare systems. Maternal deaths are particularly concerning because a substantial proportion of pregnancy- and childbirth-related deaths are preventable through timely access to quality antenatal care, skilled birth attendance, emergency obstetric services, essential medicines, and appropriate medical interventions (WHO, 2021). Although global efforts have produced improvements in maternal health, progress remains uneven across regions and countries. The continued burden of maternal mortality therefore, represents not only a health problem but also a development challenge with implications for household welfare, labour productivity, and human capital development. Consequently, reducing maternal mortality remains central to the achievement of Sustainable Development Goal 3, which seeks to ensure healthy lives and promote well-being for all (UN, 2023).

Sub-Saharan Africa continues to experience a disproportionately high burden of maternal mortality, reflecting persistent weaknesses in healthcare financing, infrastructure, service delivery, and access to essential medical resources. Women in the region frequently encounter barriers to timely and quality maternal healthcare, particularly in rural and underserved communities. Inadequate healthcare facilities, shortages of skilled health workers, limited emergency obstetric services, poor transportation infrastructure, and financial constraints can increase the risk that pregnancy-related complications will not be detected or treated promptly (WHO, 2021). The persistence of these challenges indicates that maternal mortality is influenced by the capacity of health systems to mobilise and effectively utilise resources for the provision of maternal healthcare.

Nigeria represents a particularly important case within the sub-Saharan African context because of its persistently high maternal mortality despite successive government interventions and health-sector reforms. The country has a large and rapidly growing population, yet access to quality maternal healthcare remains uneven across geographical and socioeconomic groups. The persistence of maternal mortality is associated with inadequate healthcare infrastructure, shortages of skilled personnel, limited access to essential medicines and emergency obstetric services, and financial barriers to healthcare utilisation (WHO, 2021). The latest estimates of the WHO, UNICEF, UNFPA, World Bank and UNDESA indicate that Nigeria recorded an estimated maternal mortality ratio of 993 deaths per 100,000 live births in 2023, placing the country among those with the highest maternal mortality burdens globally (WHO, UNICEF, UNFPA, World Bank & UNDESA, 2025). This situation demonstrates the need for sustained attention to the factors that determine the effectiveness and accessibility of maternal healthcare services in Nigeria.

One important factor that may influence maternal mortality is government health expenditure. Public expenditure on health provides the financial resources required for the construction and maintenance of healthcare facilities, recruitment and training of healthcare personnel, procurement of medicines and medical equipment, and implementation of maternal and reproductive health programmes. Where government health expenditure is inadequate, health facilities may lack the resources required to provide effective and timely maternal healthcare. The importance of public health expenditure is particularly pronounced in developing countries where households may have limited financial capacity to independently finance healthcare services. Thus, adequate government expenditure, when efficiently allocated and utilised, can strengthen healthcare delivery and improve the capacity of health facilities to prevent and manage pregnancy-related complications (WHO, 2021).

Environmental quality represents another factor capable of influencing maternal health outcomes. Poor environmental conditions, including air pollution, unsafe water, inadequate sanitation, poor waste management, and other forms of environmental degradation, can increase exposure to infectious and respiratory diseases and create additional health risks for vulnerable populations (WHO, 2021; UNEP, 2019). Environmental degradation may also place additional pressure on healthcare systems by increasing the incidence of environmentally related diseases and healthcare needs. In Nigeria, where environmental challenges coexist with weaknesses in healthcare infrastructure and service delivery, poor environmental quality may constitute an additional constraint to improving maternal health outcomes. Improvements in environmental conditions may therefore complement healthcare interventions by reducing preventable environmental exposures and improving the general conditions in which women live and access healthcare services.

Medical technology is also increasingly important in determining the capacity of healthcare systems to provide effective maternal healthcare. Modern diagnostic equipment, laboratory technologies, ultrasound services, emergency obstetric equipment, blood transfusion systems, information and communication technologies, and other medical innovations can improve the detection and management of pregnancy-related complications. Access to appropriate medical technologies can facilitate timely diagnosis and intervention and thereby improve the capacity of healthcare providers to respond to maternal emergencies. However, unequal availability and utilisation of medical technologies remain important challenges in developing countries, particularly between urban and rural healthcare facilities. Limited technological capacity may consequently reduce the ability of healthcare providers to diagnose complications promptly and provide appropriate treatment.

The Nigerian healthcare system therefore faces a combination of financial, environmental, infrastructural, and technological challenges that may jointly influence maternal mortality. The problem cannot be adequately understood by considering healthcare expenditure in isolation because the resources available to the health sector operate within a broader environmental and technological context. Adequate health

expenditure may improve healthcare capacity, but its effectiveness may be constrained where environmental conditions remain poor or where healthcare facilities lack the technological capacity required for diagnosis and treatment. Similarly, improvements in medical technology may have limited effects where healthcare facilities lack adequate financial resources, infrastructure, or appropriately trained personnel. Examining these factors together therefore provides a broader perspective on the determinants of maternal mortality in Nigeria.

Despite the importance of these factors, limited attention has been given to their combined effects on maternal mortality within a unified empirical framework for Nigeria. Much of the existing literature has considered health expenditure, environmental quality, and medical technology separately or has focused on broader health outcomes rather than maternal mortality specifically. This creates an empirical gap concerning how government health expenditure, environmental quality, and medical technology jointly influence maternal mortality in Nigeria. Addressing this gap is important because maternal mortality remains persistently high despite government interventions and improvements in some aspects of healthcare delivery. Against this background, this study examines the effects of government health expenditure, environmental quality, and medical technology on maternal mortality in Nigeria. The study seeks to provide empirical evidence on the extent to which improvements in public health financing, environmental conditions, and technological capacity can contribute to reducing maternal mortality and strengthening health outcomes in Nigeria. The findings are expected to provide useful policy implications for improving healthcare financing, environmental management, and technological investment in support of the achievement of SDG 3.

2. Review of Literature

2.1 Theoretical Review

2.1.1 Keynesian Theory

The Keynesian theory, developed by John Maynard Keynes, provides a useful theoretical basis for examining the role of government expenditure in improving economic and social outcomes. Keynesian economics emphasises the importance of government intervention through public expenditure, particularly where private sector activities are insufficient to achieve desired levels of economic and social welfare. Government expenditure on essential sectors such as healthcare, education, infrastructure, and social protection can increase aggregate demand while simultaneously improving the productive capacity and welfare of the population. Within the healthcare context, government health expenditure can be viewed as an important form of public investment capable of improving health outcomes. Government investment in hospitals, healthcare facilities, medical personnel, medicines, diagnostic equipment, and maternal health programmes can increase the availability and quality of healthcare services. Improved healthcare provision can facilitate early detection and treatment of pregnancy-related complications, thereby contributing to reductions in maternal mortality. The Keynesian perspective therefore

suggests that increased and effectively managed government expenditure on healthcare can strengthen the capacity of the health system and improve population health outcomes.

2.1.2 Grossman Model of Health Demand

The Grossman Model of Health Demand, developed by Michael Grossman in 1972, provides another theoretical foundation for understanding health outcomes. The model conceptualises health as a form of capital stock that produces healthy time and generates utility for individuals. Unlike conventional approaches that regard individuals as passive recipients of healthcare services, Grossman's model considers individuals as producers of their own health through investments in medical care, nutrition, lifestyle, and other health-enhancing activities (Grossman, 1972).

According to the model, health capital depreciates over time but can be maintained or improved through appropriate investment. Medical care constitutes one of the important inputs into the production of health because it contributes to the prevention, diagnosis, and treatment of diseases. Environmental conditions can also influence the rate at which health capital depreciates because exposure to pollution, unsafe water, inadequate sanitation, and other environmental hazards can adversely affect health. Similarly, technological improvements in healthcare can increase the efficiency with which medical resources are transformed into improved health outcomes.

The Grossman model is particularly relevant to maternal mortality because pregnancy and childbirth require substantial investment in healthcare to maintain maternal health and prevent avoidable complications. Access to antenatal services, skilled healthcare providers, diagnostic technologies, emergency obstetric care, and appropriate medical treatment can improve the health capital of pregnant women and reduce the likelihood of fatal complications. Conversely, poor environmental conditions may accelerate health deterioration, while inadequate healthcare resources and limited medical technology may reduce the effectiveness of available healthcare interventions.

The model therefore provides a theoretical justification for incorporating government health expenditure, environmental quality, and medical technology into the analysis of maternal mortality. Government health expenditure provides resources for healthcare production, environmental quality influences the conditions under which health is maintained, while medical technology can improve the efficiency and effectiveness of healthcare delivery. The combined consideration of these factors provides a broader theoretical explanation of variations in maternal mortality in Nigeria.

2.2Empirical Literature Review

The empirical literature on health expenditure, environmental quality, medical technology, and health outcomes provides evidence that these factors can significantly influence mortality and the general performance of healthcare systems. However, the direction and magnitude of their effects vary across countries, periods, datasets, and estimation techniques. The following studies are particularly relevant to the present investigation.

Hanifiah et al. (2023) examined the effect of government health expenditure on economic growth in Indonesia using annual time-series data covering the period from 1990 to 2021. The study employed the Ordinary Least Squares (OLS) technique and found that government health expenditure had no statistically significant effect on economic growth during the period examined. Although the study provides evidence on the relationship between public health spending and development outcomes, its focus was economic growth rather than mortality. In addition, the use of a relatively simple model without incorporating other important determinants of health outcomes limits the applicability of its findings to the present study. The study also did not specifically examine maternal mortality or incorporate environmental quality and medical technology, which are central variables in the present investigation.

Ethem and Merve (2022) investigated the relationship between health expenditure and economic growth in Turkey using annual data from 1975 to 2018. The study employed the Johansen cointegration approach and the Granger causality test. The findings established the existence of a long-run relationship among the variables, while the causality analysis indicated a unidirectional causal relationship running from health expenditure to economic growth in the short run. The study demonstrates the potential importance of health expenditure in influencing broader development outcomes. However, its concentration on economic growth rather than mortality limits its direct application to maternal health. Furthermore, the study did not account for environmental quality and medical technology, suggesting an opportunity for a more comprehensive assessment of health outcomes.

Augustine (2024) examined the relationship between health expenditure and health outcomes in 45 sub-Saharan African countries using panel data covering the period from 1960 to 2022. The study employed the Autoregressive Distributed Lag (ARDL) framework to capture both short-run and long-run relationships. The findings established the existence of a cointegrating relationship and showed that health outcomes respond significantly to changes in health expenditure and government effectiveness. The study provides important evidence from the sub-Saharan African context and confirms the relevance of public health expenditure to health outcomes. However, its cross-country approach may conceal country-specific characteristics that influence maternal mortality in Nigeria. The present study therefore focuses specifically on Nigeria and extends the analysis by incorporating environmental quality and medical technology alongside government health expenditure.

Karaaslan and Çamkaya (2022) examined the interrelationships among renewable and non-renewable energy consumption, carbon dioxide emissions, economic growth, and health expenditure in Turkey over the period 1980–2016. The study employed the Autoregressive Distributed Lag (ARDL) model and the Toda-Yamamoto causality test. The findings revealed that non-renewable energy consumption significantly contributed to carbon dioxide emissions in the long run, while renewable energy consumption increased carbon dioxide emissions in the short run. The causality analysis further established unidirectional causal relationships from both renewable and non-renewable energy consumption to carbon dioxide emissions. Although the study did not directly examine

maternal mortality, its findings are relevant to the present study because they demonstrate the connection between energy use and environmental degradation, which constitutes an important dimension of health conditions.

Selin et al. (2023) investigated the asymmetric effects of environmental quality on health expenditure in Türkiye using annual time-series data from 1975 to 2019. The study employed the Nonlinear Autoregressive Distributed Lag (NARDL) model and established an asymmetric cointegration relationship among health expenditure, environmental pollution, natural resources, economic growth, and trade openness. The findings showed that positive shocks to environmental pollution significantly increased health expenditure in the long run, whereas negative shocks did not have a statistically significant effect. The study demonstrates that deterioration in environmental quality can increase healthcare requirements and costs. However, its focus was health expenditure rather than mortality outcomes, and the study was conducted in Türkiye rather than Nigeria.

Beyene and Kotosz (2021) examined the effect of environmental quality on life expectancy in 24 African countries using panel data covering the period from 2000 to 2016. The study employed the Panel ARDL approach and found that environmental quality had a statistically significant positive effect on life expectancy. The finding indicates that improvements in environmental conditions can contribute to better health outcomes across African countries. However, life expectancy represents a broad population health indicator and does not specifically capture maternal mortality. The present study therefore extends this line of inquiry by examining environmental quality in relation to maternal mortality within the Nigerian context.

Sisay and Balázs (2021) investigated the impact of environmental quality on life expectancy in 24 African countries using data covering 2000–2016. The study employed Panel ARDL and the Dynamic Fixed Effects (DFE) model. The findings confirmed that improvements in environmental quality significantly increased life expectancy in the long run. The study reinforces the argument that environmental conditions constitute an important determinant of health outcomes. Nevertheless, the study did not specifically examine maternal mortality or incorporate health expenditure and medical technology within the same framework.

Cleopatra and Tolulope (2020) examined the effect of environmental quality and economic growth on healthcare spending in 47 African countries between 2000 and 2018. The study applied Pooled OLS, Fixed Effects, Random Effects, and Dynamic System Generalised Method of Moments estimators. The results showed that economic growth increased public and private health expenditure across the African sub-regions. The study also established that deteriorating environmental quality was associated with increased healthcare expenditure, with carbon dioxide emissions exerting substantial pressure on medical spending. Although the study demonstrates an important link between environmental degradation and healthcare costs, it examined expenditure rather than maternal mortality. The present study builds on this evidence by investigating whether environmental quality directly contributes to maternal mortality in Nigeria.

Aderinto (2023) examined the dynamic relationship among energy consumption, environmental quality, and health outcomes in West African countries using panel data from 2000 to 2019. The study employed the Pooled Mean Group ARDL technique. The findings showed that non-renewable energy consumption had a statistically significant negative effect on life expectancy and child mortality in the short run. In contrast, renewable energy consumption was associated with increased life expectancy and reduced child mortality. The study demonstrates that environmental and energy conditions can have important consequences for health outcomes in West Africa. However, its focus on life expectancy and child mortality leaves maternal mortality relatively unexplored.

Ayeyi et al. (2020) reviewed the effectiveness of medical technology in improving service quality within the Nigerian healthcare sector. The review found increasing recognition of medical technology as an important component of modern healthcare delivery. However, the study also established that healthcare quality is influenced by factors beyond technology, including cleanliness, hygiene, professional competence, and nursing skills. The study is relevant to the present research because it highlights the importance of technological resources within the Nigerian healthcare system. Nevertheless, its descriptive approach did not establish a direct causal relationship between medical technology and mortality outcomes, and it did not specifically examine maternal mortality.

Bogale et al. (2024) conducted a systematic review and meta-analysis examining the effect of electronic medical records on patient mortality. The study covered 54 independent studies conducted between 1998 and 2022 across hospital and primary healthcare settings. The findings revealed a statistically significant reduction in mortality among patients treated in facilities that had adopted electronic medical records, with a pooled odds ratio of approximately 0.94. The study attributed the observed improvement partly to enhanced care coordination, reduced medical errors, and improved access to patient information. The findings provide evidence that digital medical technology can improve health outcomes. However, the study considered general patient mortality rather than maternal mortality and was based on evidence from multiple healthcare settings and countries.

Khelfaoui et al. (2022) investigated the role of information and communication technology in reducing infant mortality across 28 low-income countries over the period from 2000 to 2017. The study employed a Fixed Effects regression model and found that greater ICT penetration was significantly associated with lower infant mortality. The findings suggest that technological innovations, including mobile health services, telemedicine, and digital health information systems, can strengthen healthcare delivery and address access gaps in resource-constrained settings. However, the study focused on infant mortality and did not directly examine maternal mortality. Its cross-country design also differs from the country-specific focus of the present study.

The reviewed empirical studies demonstrate that government health expenditure, environmental quality, and medical technology are important dimensions of health-system performance and health outcomes. Evidence from sub-Saharan Africa and other developing-country contexts indicates that health expenditure can influence health

outcomes, environmental degradation can increase health risks and healthcare costs, while technological advancement can improve healthcare delivery and reduce mortality (Augustine, 2024; Beyene & Kotosz, 2021; Aderinto, 2023; Bogale et al., 2024). However, the existing literature is characterised by several limitations. Many studies examine these determinants separately, while others focus on broad indicators such as economic growth, life expectancy, healthcare expenditure, infant mortality, or general patient mortality rather than maternal mortality. In addition, a considerable proportion of the evidence is based on cross-country panels, which may not adequately capture the specific institutional, environmental, and healthcare characteristics of Nigeria.

The present study addresses these limitations by examining the effects of government health expenditure, environmental quality, and medical technology on maternal mortality within a unified Nigerian framework. This approach provides an opportunity to assess whether healthcare financing, environmental conditions, and technological capacity jointly explain maternal mortality outcomes and thereby extends the existing empirical literature beyond studies that consider these determinants independently

3 Methodology

3.1 Theoretical Framework

This section establishes the basic connection between dependent and the independent variables in order to have justified and testable hypotheses. It also considered the conceptualized variables that are relevant to this study.

3.2 Grossman (1972) model of demand for health

The theoretical framework of this study is based on the Grossman (1972) model of demand for health. Grossman (1972) in his model of demand for health outlines that the health of individuals is not exogenous and instead depends partly on the number of resources allocated towards its production.

Utility of a household is a function of his health and consumption of other goods, given as;

$$U = U(\phi_0 H_0, ..., \phi_{n,} H_{n,} Z_0, ...Z_n) \text{----------} 1$$

Where **Ho** is health stock inherited, **Hi** is health stock in the i^{th} time period, **ϕ** is the service flow per unit stock, **ϕiHi** is an individual's total consumption of health services and **Zi** is an individual's total consumption of other commodities in the i^{th} time period.

Consumers produce gross investment into health according to a household function given as;

$$I_i = I_i(M_{i,} TH_{i,} E_i \text{----------} 2$$

Where **Mi** is medical care sought; **THi** are time inputs; **Ei** is exogenous stock of knowledge. The production function is assumed to be homogenous of degree one in both the goods and time inputs.

Health production function is then specified as;

$$H = f(X) \quad \text{---------- 3}$$

Where H is a measure of individual health output and X is a vector of individual inputs to the health production function F, including nutrient intake, income, consumption of public goods, education, time spent on health-related procedures, initial individual endowments like genetic makeup, and community endowments like the environment. This theoretical health production function model analyses micro-level health production and extends it to macro level.

$$H = f(Y, S, V) \quad \text{---------- 4}$$

Where Y is a vector of per capita economic variables, S is a vector of per capita social variables and V is a vector of per capita environmental factors. It follows from the above that an individual health output is influence by economic, social, and environmental factors.

3.3 Models Specification

To investigate the impact of Government health expenditure, environmental quality and medical technology on maternal mortality in Nigeria, the study adapted and modified the model of Omirin & Idris (2023) who examined the impact of government health expenditure on child mortality. Arising from the above, the functional form of is written as:

$$MMR = f(GHEX,\ ENVQ\ , MEDTECH, GDPPC, URB) \quad \text{---------- 5}$$

Where:

MMR = Maternal mortality rate

$GHEX$ = Government health expenditure

$ENVQ$ = Environmental quality (proxied by carbon dioxide emission)

$MEDTECH$ = Medical Technology (proxied by Physicians per 1,000 people)

$GDPPC$ = Gross domestic product per capita

URB = Urbanization

The stochastic form of the model is specified as:

$$MMR_t = \beta_0 + \beta_1 GHEX_t + \beta_2 ENVQ_t + \beta_3 MEDTECH_t + \beta_4 GDPPC_t + \beta_5 URB_t + \mu_t \quad \text{-- 6}$$

Where;

β_0 is the intercept of the model, β_1-β_5 are the parameters to be estimated, and μ_t is the error term.

ARDL Method and Justification

In sum, the ARDL model's flexibility, robustness to small samples, and ability to capture dynamic relationships among mixed-order variables make it a powerful and

appropriate tool for this study's investigation into the determinants of mortality rates in Nigeria. This study will use ARDL bound testing method to check for cointegration of the variables in the models. Using variables in model

One, the ARDL bound test is specified as:

$$\Delta MMR_t = \beta_0 + \beta_1 MMR_{t-1} + \beta_2 GHEX_{t-1} + \beta_3 ENVQ_{t-1} + \beta_4 MEDTECH_{t-1} + \beta_5 GDPPC_{t-1} + \beta_6 URB_{t-1} + \sum_{i=0}^{m} \beta_1 \Delta MMR_{t-i} + \sum_{i=0}^{p} \beta_2 \Delta GHEX_{t-i} + \sum_{i=0}^{p} \beta_3 \Delta ENVQ_{t-i} + \sum_{i=0}^{p} \beta_4 \Delta MEDTECH_{t-i} + \sum_{i=0}^{p} \beta_5 \Delta DPPC_{t-i} + \sum_{i=0}^{p} \beta_6 \Delta URB_{t-i} + \mu_{1t} \quad --- 6$$

Where;

MMR is Maternal mortality rate, $GHEX$ is Government health expenditure, $ENVQ$ is Environmental quality, $MEDTECH$ is Medical Technology, $GDPPC$ is Gross domestic product per capita, URB is Urbanization, β_0 is the intercept of the model, β_1-β_5 are the parameters to be estimated, and μ_t is the error term.

Long run ARDL Model Speciation

The long run **A**RDL specification is a framework used to model long run relationship and dynamics between variables in a time series context. The long run equation is specified as:

$$\Delta MMR = \alpha_0 + \sum_{i=1}^{m} \beta_1 \Delta MMR_{t-i} + \sum_{i=1}^{p} \beta_2 \Delta GHEX_{t-i} + \sum_{i=1}^{p} \beta_3 \Delta ENVQ_{t-i} + \sum_{i=1}^{p} \beta_4 \Delta MEDTECH_{t-i} + \sum_{i=1}^{p} \beta_5 \Delta GDPPC_{t-i} + \sum_{i=1}^{p} \beta_6 \Delta URB_{t-i} + \mu_t \quad --- 7$$

Where; $t - i$ is the lag of the variables.

Short run ARDL Model Specification

The ARDL in the short run is a framework that is used to analyze the relationship between variables over a relative limited period of time horizon. It captured the short-term dynamics and how variables respond to change or shock in the short run in the error correction form which is specified as:

$$\Delta MMR = \alpha_0 + \sum_{i=1}^{p} \beta_1 \Delta MMR_{t-i} + \sum_{i=1}^{p} \beta_2 \Delta GHEX_{t-i} + \sum_{i=1}^{p} \beta_3 \Delta GHEX_{t-i} + \sum_{i=1}^{p} \beta_4 \Delta MEDTECH_{t-i} + \sum_{i=1}^{p} \beta_5 \Delta GDPPC_{t-i} + \sum_{i=1}^{p} \beta_6 \Delta URB_{t-i} + ECM_{t-1} = y_t - \sum_{i=1}^{p} \hat{\theta}_i x_{it} - \dot{\gamma} w_t + \mu_t \quad ---------- 8$$

Where; β's are the short run dynamic coefficients of the model convergences to equilibrium parameters, θ is the speed of adjustment in the model. ECM reflect the extents of any short run disequilibrium in the previous periods that is corrected in y_t

Table 1. A summary of variable measurement and Source of Data

Variable Name	Unit of Measurement	Data Source
Maternal Mortality Rate	Number of maternal deaths per 100,000 live births	(World Bank, 2023)
Government Health Expenditure	Health expenditure as % of GDP	(World Bank, 2023)
Environmental Quality	Proxy: CO_2 emissions (metric tons per capita)	(World Bank, 2023)
Medical Technology	Proxy: Physicians per 1,000 people	(World Bank, 2023)
GDP per capita	Constant 2010 US dollars (control variable)	(World Bank, 2023)
Urbanization	Urban population as a % of total population (control variable)	(World Bank, 2023)

4. Results and Discussion

4.1 Descriptive Statistics

Table 2: Descriptive Statistics of the Variables

Variable	Mean	Maximum	Minimum	Std. Dev.
MMR	1157.359	1363.000	993.000	95.425
GHEX	117.499	437.520	0.040	144.132
ENVQ	0.699	0.940	0.450	0.134
MEDTECH	0.311	0.776	0.185	0.132
GDPPC	1944.692	2688.000	1397.000	479.062
URB	39.199	54.280	25.640	8.644

Source: Author's Computation using EViews (2026)

Government health expenditure (GHEX) in Nigeria records an annual mean of approximately ₦117.50 billion, yet this average conceals substantial fluctuations over time. Specifically, expenditure levels span from as low as ₦0.04 billion in 1987 to as high as ₦437.52 billion in 2022. Environmental quality, measured through carbon dioxide (CO_2) emissions, exhibits a mean value of 0.699 metric tons, with observed values ranging between 0.45 in 1989 and 0.94 in 1996. Conversely, the higher emission level in 1996 corresponds to a period of intensified crude oil production and extensive gas flaring under weak environmental governance structures. Despite these fluctuations, the relatively low standard deviation (0.134) suggests gradual changes in environmental conditions over time, a pattern consistent with evidence from developing economies where environmental transitions tend to be incremental. Medical technology, proxied by the number of physicians per 1,000 population, has an average value of 0.311, with a minimum of 0.185 recorded in 1990 and a maximum of 0.776 in 2023.

Maternal mortality remains high, with an average of 1,157 deaths per 100,000 live births, fluctuating between a peak of 1,363 in 1986 and a lower value of 993 in 2023. Gross domestic product (GDP) per capita in Nigeria averages US$1,944.69, with a minimum of US$1,397 recorded in 1999 and a maximum of US$2,688 in 2014. Urbanization in Nigeria

has an average rate of 39.20%, increasing from 25.64% in 1990 to 54.28% in 2023. The lower level in 1990 reflects a predominantly agrarian economy during the SAP period, whereas the higher level in 2023 illustrates sustained rural-to-urban migration driven by economic opportunities and environmental pressures such as climate variability.

4.2 Unit Root Test

Table 3: KPSS Unit Root Test Results (5% Critical Level)

Variable	Level	First Difference	Order of Integration		
	Test Statistic	5% Critical Value	Test Statistic	5% Critical Value	
ENVQ	0.115496	0.146	—	—	I(0)
LMMR	—	—	0.115104	0.463	I(1)
MEDTECH	—	—	0.117740	0.463	I(1)
LGHEX	—	—	0.460579	0.463	I(1)
LGDDPPC	—	—	0.145318	0.463	I(1)
URB	—	—	0.245230	0.463	I(1)

Source: Author's Computation using EViews (2026)

The KPSS unit root results reported in Table 3 indicate that the variables possess different orders of integration. Environmental quality (ENVQ) is found to be stationary in their level form, signifying that it is integrated of order zero, I(0). However, maternal mortality (LMMR), government health expenditure (LGHEX), GDP per capita (LGDDPPC), urbanization (URB), and medical technology (MEDTECH) achieve stationarity only after first differencing, indicating that they are I(1) variables. Thus, the KPSS findings establish a mixture of I(0) and I(1) variables. This outcome is consistent with the evidence obtained from the other unit root procedures and supports the appropriateness of the Autoregressive Distributed Lag (ARDL) technique for estimating the short-run and long-run relationships among the variables.

4.3 Autoregressive Distributed Lag (ARDL)

Table 4: ARDL Bound Test Result

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	5.878836	10%	2.08	3
K	5	5%	2.39	3.38
		2.5%	2.7	3.73
		1%	3.06	4.15

Source: Author's Computation using EViews (2026)

The results of the Autoregressive Distributed Lag (ARDL) bounds test reported in Table 4.5 indicate an F-statistic of 5.878836, which exceeds the upper critical bound value of 3.38 at the 5% level of significance.

Table 5: Long Run ARDL Result

Variable	Coefficient	Std. Error	t-Statistic
LGHEX	0.0348	0.0462	0.755
ENVQ	-0.3993	0.2685	-1.487
MEDTECH	0.9401	0.4751	1.979
LGDDPPC	-0.4490	0.3198	-1.404
URB	-0.0216	0.0139	-1.554
Constant (C)	5.4392	1.3078	4.159

Source: Author's Computation using EViews (2026)

The long-run results reported in Table 6 show that government health expenditure (LGHEX) has a positive coefficient of 0.0348, but the coefficient is not statistically significant at the 5 per cent level (p = 0.472). The result implies that a percentage increase in government health expenditure is associated with a 0.0348 per cent increase in maternal mortality in Nigeria, although the effect is statistically insignificant. This finding is contrary to the study's a priori expectation, which anticipates that increased government health expenditure should reduce maternal mortality through improved healthcare infrastructure, availability of medical personnel, essential medicines, and emergency obstetric services. The positive but insignificant relationship may suggest that increases in government health expenditure have not necessarily translated into proportional improvements in maternal healthcare delivery. This may be associated with inefficient allocation of health resources, inadequate implementation of health programmes, leakages, or limited access to healthcare services, particularly among vulnerable populations. Compared with previous studies, this outcome contrasts with Jacques and Noël (2024) and Dinga et al. (2024), who reported that higher health expenditure significantly reduces maternal mortality in WAEMU and Southern African countries, respectively. However, the finding is consistent with Hanifiah et al. (2023) and Eboh et al. (2022), who found no statistically significant effect of public health expenditure on health outcomes in Indonesia and Nigeria, respectively. This suggests that the effectiveness of government health expenditure in reducing maternal mortality may depend more on the efficiency and effectiveness of resource allocation and implementation than on the volume of expenditure alone.

Environmental quality (ENVQ) has a negative coefficient of -0.3993, indicating that improvements in environmental quality are associated with a reduction in maternal mortality in Nigeria. Specifically, a unit improvement in environmental quality is associated with approximately a 0.3993 per cent reduction in maternal mortality, although the relationship is not statistically significant at the 5 per cent level (p = 0.1752). The negative coefficient is consistent with the study's a priori expectation because improved environmental conditions can reduce exposure to air pollution, unsafe water, inadequate sanitation, and other environmental hazards that may adversely affect maternal health. However, the statistical insignificance indicates that environmental quality, within the period examined, does not exert a sufficiently strong independent effect on maternal

mortality to be confirmed at the 5 per cent level. This may reflect the fact that maternal mortality is influenced by several interacting factors, including healthcare access, socioeconomic conditions, skilled birth attendance, and the availability of emergency obstetric services. Compared with existing literature, the finding is consistent with Solomon and Syed (2020), who reported no statistically significant effect of environmental degradation on life expectancy in Nigeria in the short run. However, it differs from Beyene and Kotosz (2021) and Sisay and Balázs (2021), who found that improvements in environmental quality significantly enhance life expectancy in African countries. The difference may be attributed to variations in the dependent variables, country coverage, estimation techniques, and environmental indicators employed across the studies.

Medical technology (MEDTECH) records a positive coefficient of 0.9401 and is marginally significant at the 10 per cent level ($p = 0.0832$), although it is not statistically significant at the 5 per cent level. The coefficient implies that a unit increase in medical technology is associated with approximately a 0.9401 per cent increase in maternal mortality in the long run. This positive relationship is contrary to the study's a priori expectation because improved medical technology would ordinarily be expected to enhance diagnosis, treatment, emergency obstetric care, and the management of pregnancy-related complications, thereby reducing maternal mortality. The unexpected positive relationship may indicate that the availability or expansion of medical technology does not automatically translate into improved maternal health outcomes where supporting infrastructure, skilled personnel, maintenance systems, electricity supply, and effective utilisation are inadequate. In other words, technological expansion without corresponding improvements in healthcare delivery capacity may have limited effectiveness in reducing maternal deaths. This finding contrasts with Bogale et al. (2024), who found that the adoption of electronic medical records significantly reduced patient mortality, and Khelfaoui et al. (2022), who reported that greater ICT penetration was associated with lower infant mortality. The difference may arise from the nature of the technologies examined, differences in health systems, and the fact that the present study focuses specifically on maternal mortality in Nigeria. The result therefore suggests that investment in medical technology needs to be accompanied by adequate healthcare infrastructure, trained personnel, maintenance capacity, and effective utilisation if technological improvements are to translate into reductions in maternal mortality.

Per capita income (LGDPPC) has a negative coefficient of -0.4490, indicating that increases in income are associated with reductions in maternal mortality in Nigeria. A percentage increase in per capita income is associated with approximately a 0.4490 per cent reduction in maternal mortality, although the relationship is not statistically significant at the 5 per cent level ($p = 0.1979$). The negative coefficient conforms to the study's a priori expectation because higher income levels can improve individuals' ability to afford healthcare services, nutrition, transportation, and other factors that contribute to better maternal health. However, the statistical insignificance suggests that increases in income alone may not be sufficient to produce substantial reductions in maternal mortality in Nigeria. The benefits of income growth may depend on how income is distributed and

whether improvements in household purchasing power are accompanied by accessible and quality healthcare services. In comparison with previous studies, the finding is consistent with Owusu et al. (2021), who emphasised that the effects of income on health outcomes can vary across income distributions and are not necessarily uniform. It also aligns with Sibanda et al. (2023), who argued that institutional quality plays an important mediating role in determining whether economic growth and income improvements translate into better health outcomes. Thus, economic improvement may have limited effects on maternal mortality where healthcare institutions and service delivery remain weak.

Urbanisation (URB) has a negative coefficient of -0.0216, suggesting that increased urbanisation is associated with a reduction in maternal mortality. The coefficient indicates that a percentage increase in urbanisation is associated with approximately a 0.0216 per cent decline in maternal mortality, although the relationship is not statistically significant at the 5 per cent level ($p = 0.1587$). The negative relationship conforms to the study's a priori expectation because urban areas generally provide greater access to healthcare facilities, skilled health personnel, transportation networks, information, and other social infrastructure that can facilitate timely maternal healthcare utilisation. However, the insignificant coefficient indicates that urbanisation alone does not guarantee substantial improvements in maternal health outcomes. Rapid urban growth can also create overcrowding, inadequate sanitation, congestion, and unequal access to healthcare, particularly in informal settlements. Compared with existing literature, this finding is consistent with Sibanda et al. (2023), who emphasised that the health effects of urbanisation depend considerably on institutional and infrastructural quality. The result therefore suggests that urban expansion must be accompanied by adequate healthcare infrastructure, effective governance, sanitation facilities, and equitable distribution of health services for urbanisation to translate into meaningful reductions in maternal mortality.

Table 6: Short-Run ARDL Result

Variable	Coefficient	Std. Error	t-Statistic
LMMR(-1)	0.0858	0.3750	0.229
LMMR(-2)	0.0102	0.3650	0.028
LMMR(-3)	0.6292	0.3917	1.606
LGHEX	-0.0433	0.0128	-3.373
LGHEX(-1)	-0.0130	0.0068	-1.903
LGHEX(-2)	0.0199	0.0085	2.323
LGHEX(-3)	0.0309	0.0112	2.747
LGHEX(-4)	0.0151	0.0066	2.292
ENVQ	-0.0489	0.0307	-1.592
ENVQ(-1)	-0.0873	0.0325	-2.689
MEDTECH	0.0521	0.0174	2.987
MEDTECH(-1)	0.0551	0.0170	3.230
MEDTECH(-2)	0.0586	0.0178	3.295
MEDTECH(-3)	0.0592	0.0188	3.157
MEDTECH(-4)	0.0334	0.0155	2.152
LGDDPPC	-0.4388	0.1834	-2.392

LGDDPPC(-1)	0.3092	0.1452	2.130
URB(-2)	-0.1379	0.0410	-3.362
URB(-3)	0.0857	0.0281	3.047
CointEq(-1)	-0.274864	0.032389	P=0.0000

Source: Author's Computation using EViews (2026)

The short-run results presented in Table 4.8 show that government health expenditure (LGHEX) has a negative and statistically significant effect on maternal mortality, with a coefficient of -0.0433 at the 5 per cent level (p = 0.0097). This implies that a percentage increase in government health expenditure reduces maternal mortality by approximately 0.0433 per cent in the short run, holding other factors constant. The negative relationship conforms to the study's a priori expectation, suggesting that increased public spending on healthcare can produce immediate improvements in maternal health through the provision of healthcare facilities, medicines, skilled health personnel, and emergency obstetric services. The finding indicates that government health expenditure constitutes an important short-run instrument for reducing maternal mortality in Nigeria. This result is consistent with Jacques and Noël (2024), Dinga et al. (2024), and Oladele et al. (2023), who reported that public health expenditure contributes to reductions in maternal and child mortality. However, the positive and statistically significant coefficients of LGHEX(-2) and LGHEX(-3), with values of 0.0199 (p = 0.0487) and 0.0309 (p = 0.0252), respectively, indicate that the effect of government health expenditure is not uniform across time. These positive lagged effects suggest that increases in health expenditure in earlier periods may be associated with subsequent increases in maternal mortality. This mixed pattern may reflect delays in the implementation of health programmes, inefficient utilisation of allocated resources, or weaknesses in the translation of public expenditure into sustained improvements in healthcare delivery. The finding is consistent with Azuh et al. (2020), who found that health expenditure in Nigeria may exhibit delayed or counterproductive effects in some periods because of inefficiencies in spending execution. Thus, while current government health expenditure appears beneficial to maternal health, the lagged results suggest that the effectiveness of public spending depends substantially on the efficiency and continuity of its implementation.

Environmental quality (ENVQ) exhibits a negative and statistically significant coefficient at the first lag, with a value of -0.0873 (p = 0.0276). This result indicates that an improvement in environmental quality in the preceding period is associated with approximately a 0.0873 per cent reduction in maternal mortality in the short run. The negative relationship conforms to the study's a priori expectation and suggests that improvements in environmental conditions can contribute to better maternal health outcomes. Better environmental quality may reduce women's exposure to air pollution, unsafe water, inadequate sanitation, and other environmental hazards that can increase vulnerability to illness and pregnancy-related complications. The lagged nature of the relationship further suggests that improvements in environmental conditions may require some time before their health benefits become observable. This finding is consistent with Beyene and Kotosz (2021) and Sisay and Balázs (2021), who reported that improvements

in environmental quality significantly enhance health outcomes in African countries. The result therefore reinforces the importance of environmental conditions as part of a broader strategy for improving maternal health in Nigeria, rather than treating maternal mortality solely as a consequence of healthcare-system factors.

Medical technology (MEDTECH) records positive and statistically significant effects at the second and third lags, with coefficients of 0.0586 ($p = 0.0109$) and 0.0592 ($p = 0.0135$), respectively. The results imply that increases in medical technology in earlier periods are associated with approximately 0.0586 and 0.0592 per cent increases in maternal mortality in the short run. The positive relationship is contrary to the study's a priori expectation, since improvements in medical technology would ordinarily be expected to enhance diagnosis, monitoring, emergency obstetric care, and treatment and thereby reduce maternal mortality. The lagged positive effects may indicate that technological improvements alone are insufficient to produce better maternal outcomes where healthcare facilities lack adequate supporting infrastructure, skilled personnel, maintenance capacity, electricity supply, or effective systems for utilising the available technologies. In comparison with previous studies, the finding contrasts with Bogale et al. (2024), who reported that electronic medical records significantly reduce mortality, and Khelfaoui et al. (2022), who found that greater ICT penetration was associated with lower infant mortality. The difference may reflect the specific nature of the medical technology measure employed in the present study, differences in healthcare systems, and the particular challenges associated with deploying and effectively utilising medical technologies in Nigeria. The result therefore suggests that technological investment needs to be complemented by adequate human resources, infrastructure, maintenance, and effective healthcare management before its potential benefits can translate into reductions in maternal mortality.

Per capita income (LGDPPC) has a negative and statistically significant coefficient of -0.4388 at the 5 per cent level ($p = 0.0437$). This implies that a percentage increase in per capita income is associated with approximately a 0.4388 per cent reduction in maternal mortality in the short run. The negative relationship is consistent with the study's a priori expectation because higher income can improve households' ability to access healthcare services, afford transportation to health facilities, obtain adequate nutrition, and meet other costs associated with pregnancy and childbirth. The result indicates that improvements in economic welfare can contribute to better maternal health outcomes, particularly where increased income enhances access to essential healthcare services. This finding is consistent with Momoh and Okwu (2022) and David et al. (2023), who reported that higher income levels are associated with improved health outcomes in Nigeria and the broader West African region. The result therefore suggests that policies aimed at improving household economic conditions may complement direct healthcare interventions in reducing maternal mortality.

The error correction term, CointEq(-1), has a negative coefficient of -0.274864 and is statistically significant at the 1 per cent level ($p = 0.0000$). The negative and significant coefficient confirms the existence of a stable long-run equilibrium relationship among government health expenditure, environmental quality, medical technology, per capita

income, urbanisation, and maternal mortality. The coefficient indicates that approximately 27.49 per cent of any short-run disequilibrium is corrected towards the long-run equilibrium in the subsequent period. This implies a moderately gradual adjustment process, with the model requiring several periods to fully return to its long-run equilibrium following a short-run shock. The finding is consistent with Elijah et al. (2023), who reported a similar error correction coefficient of approximately -0.35 in their analysis of public health expenditure and life expectancy in Nigeria, indicating a moderately fast adjustment towards long-run equilibrium. Similarly, Lawal et al. (2022) reported a correctly signed and statistically significant error correction term in their study of government health expenditure, population growth, and economic growth in Nigeria, with evidence of relatively rapid convergence. The significant error correction coefficient therefore provides further evidence that although short-run fluctuations occur among the variables, their relationship is ultimately governed by a stable long-run equilibrium path.

4.4 Diagnostic Tests

Table 7: Diagnostic and Stability Tests

Test	Statistic	Probability	Decision at 5%
Breusch-Godfrey Serial Correlation LM Test			
F-statistic	1.548340	0.3411	No serial correlation
Obs*R-squared	21.26557	0.0603	No serial correlation
Breusch-Pagan-Godfrey Heteroskedasticity Test			
F-statistic	1.644452	0.2373	Homoskedastic
Obs*R-squared	29.48338	0.2896	Homoskedastic
Scaled explained SS	1.798034	1.0000	Homoskedastic
CUSUM Stability Test	—	—	Stable
CUSUM of Squares Stability Test	—	—	Stable

Source: Author's Computation using EViews (2026)

The diagnostic and stability tests reported in Table 8 indicate that the estimated ARDL model satisfies the major post-estimation requirements. The Breusch-Godfrey test shows that both the F-statistic probability value (0.3411) and the Obs*R-squared probability value (0.0603) are greater than the 5 per cent significance level, indicating the absence of serial correlation. Similarly, the Breusch-Pagan-Godfrey test reports probability values of 0.2373, 0.2896, and 1.0000 for the F-statistic, Obs*R-squared, and Scaled explained SS, respectively, all exceeding 5 per cent, indicating that the residuals are homoskedastic. Furthermore, the CUSUM and CUSUM of Squares tests show that the recursive residuals remain within the 5 per cent critical bounds throughout the sample period, confirming the stability of the estimated parameters. Overall, the results indicate that the model is free from serial correlation and heteroskedasticity and that its parameters remain stable over the study period.

5. Conclusion

The study investigated the effects of government health expenditure, environmental quality, and medical technology on maternal mortality in Nigeria. Descriptive statistics, unit root tests, ARDL bounds testing, and diagnostic and stability tests were conducted on the time-series data used for the study. The results of the descriptive statistics provided evidence of variations in government health expenditure, environmental quality, medical technology, per capita income, urbanisation, and maternal mortality over the study period. The unit root results confirmed that the variables were stationary at either level or first difference, thereby validating the application of the ARDL approach. The bounds test further established the existence of a long-run relationship among government health expenditure, environmental quality, medical technology, per capita income, urbanisation, and maternal mortality in Nigeria.

The long-run results showed that government health expenditure has a positive but statistically insignificant relationship with maternal mortality, indicating that increases in public health expenditure have not translated into significant reductions in maternal mortality over the long run. Environmental quality has a negative but insignificant relationship with maternal mortality, suggesting that improvements in environmental conditions are associated with reductions in maternal mortality, although the effect is not statistically significant. Medical technology has a positive and marginally significant relationship with maternal mortality at the 10 per cent level, but the effect is not significant at the 5 per cent level. Per capita income and urbanisation both have negative but statistically insignificant relationships with maternal mortality. In the short run, however, government health expenditure has a negative and significant effect on maternal mortality, while its positive and significant lagged effects indicate that the benefits of public health expenditure are not sustained uniformly over time. Environmental quality also has a negative and significant lagged effect, confirming that improvements in environmental conditions can contribute to reductions in maternal mortality. Medical technology records positive and significant effects at the second and third lags, while per capita income has a negative and significant effect on maternal mortality.

The error correction term is negative and statistically significant, confirming the existence of a stable long-run equilibrium relationship among the variables. The coefficient indicates that approximately 27.49 per cent of short-run disequilibrium is corrected towards long-run equilibrium in the following period. The diagnostic tests further established that the model is free from serial correlation and heteroskedasticity, while the CUSUM and CUSUM of Squares tests confirmed the stability of the estimated parameters throughout the study period.

One major finding of the study is that increased government health expenditure alone may not be sufficient to achieve substantial reductions in maternal mortality in Nigeria, particularly in the long run. The positive long-run coefficient suggests that the effectiveness of public health spending depends considerably on the efficiency of allocation, implementation, monitoring, and utilisation of health resources. Therefore, the

government should strengthen mechanisms for monitoring health expenditure and ensure that allocated resources are directed towards maternal healthcare infrastructure, skilled personnel, essential medicines, emergency obstetric services, and underserved communities. There is also a need to improve the quality of environmental conditions through effective sanitation, waste management, pollution control, and access to safe water, particularly in communities with poor environmental infrastructure.

The positive relationship between medical technology and maternal mortality further suggests that technological investment should not be pursued in isolation. The government should ensure that healthcare facilities have the trained personnel, electricity supply, maintenance systems, infrastructure, and institutional capacity required for the effective utilisation of medical technologies. Investment in diagnostic equipment, emergency obstetric technologies, laboratory facilities, digital health systems, and other appropriate technologies should therefore be accompanied by adequate training and maintenance programmes. Finally, policies aimed at improving household income and urban infrastructure should be integrated with maternal healthcare policies to ensure that economic and urban development translates into improved access to quality maternal healthcare services. Overall, a coordinated policy approach involving efficient health financing, improved environmental quality, effective utilisation of medical technology, and strengthened healthcare infrastructure is necessary to reduce the persistent burden of maternal mortality in Nigeria

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