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INVESTIGATING THE LINK BETWEEN BIRTH RATE AND MATERNAL MORTALITY, ACCOUNTING FOR NIGERIA'S HEALTH CARE SPENDING AND POPULATION GROWTH

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Abstract: Maternal mortality refers to fatalities resulting from pregnancy or childbirth, whereas the birth rate is defined as the number of live births per 1,000 individuals, both of which are prevalent in Nigeria and other worldwide economies. This work is unprecedented because it offers a fresh analysis of the link between birth rate and maternal mortality, considering Nigeria' Health care spending and population growth, aspects that previous studies have not explored. We collected secondary data from 1990 to 2023 using World Bank development indicators. The unit root test was used to eliminate the potential for unit roots to generate spurious results. The FMOLS indicates that birth rate positively affects maternal mortality in the long term; however, the OLS regression reveals that birth rate significantly increases maternal mortality, whereas population growth negatively and significantly impacts maternal mortality. The correlation study revealed modest negative relationship between maternal mortality rate and health care spending. The graphical method illustrates the inverse relationship between maternal mortality and health care spending. Consequently, to enhance the professional management of pregnancy-related issues and to render family planning accessible for low-income Nigerians, the Nigerian government should allocate an adequate budget for health care services and medical personnel. This will assist in regulating the birth rate; hence, mitigating excessive population expansion and reducing the nation's maternal mortality rate.

Keywords: Birth Rate, Maternal Mortality, Health care Spending, Unit Root Test, OLS Regression, FMOLS

1. Introduction

Maternal mortality denotes fatalities resulting from difficulties associated with pregnancy or childbirth, whereas the birth rate is defined as the total number of live human births per 1,000 inhabitants in a particular population over a designated time frame divided by the duration of that period in years (World Factbook, 2023). Maternal mortality has recently risen, adversely affecting the nation's socioeconomic development; however, maternal death cases cannot occur without pregnancy or childbirth (Olonade et al, 2019). Based on UN inter-agency figures, the worldwide mother mortality ratio dropped by 44% from 1990 to 2015, from 525,000 live births to 216 deaths per 100,000 live births. This leads to an average annual decline of 2.3%. Although admirable, this statistic is less than 50% of the 5.5% annual rate needed to achieve the three-quarter decrease in mother mortality targeted for 2015 in the UN Development Goal 5. Of more significance is the classification of maternal mortality, defined as the death of women during the perinatal period due to pregnancy-related complications, as a preventable death and a significant social indicator in Nigeria (Nwokocha, 2008; Okeke et al., 2016).

Increased birth rates in developing nations, such as Nigeria, have led to a surge in population growth, which in turn has increased maternal mortality due to inadequate maternal health care for newborns and a shortage of qualified health practitioners in the country. China, a developed nation with a dense population, has projected a population reduction from 1.41 billion to less than 1.39 billion by 2035 due to strict government policies aimed at reducing the number of newborns and increasing the number of deaths from its aging population (Economist Intelligence Unit, 2024). Moreover, a limited number of recent studies have examined the trend in maternal mortality in a global context, with some focusing on risk factors associated with the maternal mortality rate through correlation analysis. However, these studies did not investigate the predictive factors that can impact the maternal mortality rate using appropriate predictive models (Douthard et al., 2021; Souza et al., 2024), resulting in a significant gap that our study aims to fill. Our study aimed to explore the impact of predictor variables on maternal mortality based on the theory of maternal adaptive capacity that encompasses women of childbearing age. The primary goal of this theory is to enhance maternal health (Mollard & Cottrell, 2023). Therefore, our study makes a unique contribution in two ways. First, we investigated impact of childbirth rate on maternal mortality rate, considering population growth and health care spending in Nigeria. Second this study also examines the relationship between maternal mortality rate, childbirth rate, population growth, and health care spending.

2. Literature review

Empirical data on the relationship between public health expenditure and health indicators, such as maternal health, remain uncertain (Novignon et al., 2012). The question arises of how public health spending might improve the health of the population. Some authors (Arthur & Oaikhenan, 2017; Novignon & Lawanson, 2017) have noted that public health spending improves health outcomes. Others (Hitiris & Posnett, 1992) have found either a negative or significant impact of public health expenditure on maternal health. Empirical data on the relationship between public health expenditure and health indicators remain uncertain (Novignon et al., 2012). The influence of public health initiatives on improving the health of the population is currently under debate. Some scholars (Arthur & Oaikhenan, 2017; Novignon & Lawanson, 2017) have noted that public health spending improves health outcomes.

Most of the data came from developing countries, and the area of mother mortality displayed the biggest variation in health statistics acquired by the World Health Organization between developed and undeveloped countries. Like many other Sub-Saharan African countries, at the conclusion of the Millennium Development Goals (MDGs), Nigeria had not only missed the targets but also had high rates of maternal and perinatal disease and death. As most deaths occur in developing countries, problems during pregnancy, delivery, or the postpartum period kill millions of women globally annually (World Bank Group, 2000). These trends over the past few decades have been judged as unsatisfactory because they still constitute a major public health concern that calls for the attention of all the players engaged in maternal and child health care. Maternal mortality, defined as the loss of life in the maternity stage due to pregnancy complications, falls under the category of preventable deaths and is a significant social indicator in Nigeria (Nwokocha, 2008; Okeke et al., 2016).

With 14% of all maternal deaths globally, Nigeria ranked second globally for yearly maternal mortality in 2010, according to the World Health Organization (WHO). Nigeria boasts a mother death ratio of approximately 814 per 100,000 live deliveries as of 2015 (World Health Organization, 2015). Although data from the National Demographic and Health Survey (NDHS) shows that southwestern Nigeria has one of the lowest rates of preventable maternity and perinatal deaths, maternal mortality rate (MMR) figures vary throughout geopolitical zones within Nigeria. Federal Ministry of Health, FMOH (2004). Different ramifications for maternal health follow from the Nigerian population increase (Adesola et al., 2024). A nation's population increase influences the health of its people and the consequent reasons for mother mortality (Aliyu & Amadu, 2017). Furthermore, Nelson et al. (2018) asserted that population-level factors are correlated with the rise in maternal death rates in the United States. Boundioa and Thiombiano (2024) reported that population density significantly positively affects maternal mortality in West African nations.

The escalation in birth rates in developing nations, as shown by Nigeria, has resulted in significant population growth, hence worsening maternal death rates. This is due to the insufficient provision of health care for babies and the scarcity of qualified health care professionals in the country. Some recent research has examined the trend of maternal mortality from a worldwide perspective, while other studies employ correlation analysis to explore the risk factors linked to maternal death rates; however, they fail to evaluate the predictive elements that may affect maternal mortality rates through appropriate prediction models (Douthard et al., 2021; Souza et al., 2024). This led to a substantial discrepancy that our study sought to address. Additionally, our research expands upon the theory of maternal adaptive capacity, which includes women of reproductive age, to enhance maternal health (Mollard & Cottrell, 2023). Our study aimed to investigate the influence of predictor variables on maternal mortality, a concept rooted in theory.

3. Research Methodology

3.1 Data Description

Table 1 provides a detailed account of the variables used in the study on maternal mortality modeling in Nigeria, highlighting the acronyms and units of measurement. The maternal mortality rate (MMR), expressed as deaths per 100,000 live births, is sourced from the World Bank and serves as the dependent variable in this study, acting as an indicator of maternal health. The birth rate (BR) represents the number of human births per 1,000 individuals within a designated period, and it functions as the principal independent variable. The control variables include healthcare spending (HCS), which is denoted as a percentage of GDP dedicated to healthcare services in Nigeria, and population growth (PG), which is measured as a percentage indicating the annual rise in Nigeria's population. The dataset was sourced from the World Bank's development indicators spanning 1990 to 2023 via purposive sampling based on data availability.

3.2 Methodology

Considering Nigeria's population growth and health care spending, this study employed a quantitative research methodology to investigate the relationship between the childbirth rate and maternal mortality. Population growth was chosen because it takes into account the nation's yearly population increase, while healthcare spending represents the national funds allotted for Nigerian healthcare facilities and services, both of which have a major influence on maternal mortality in the nation. To determine the stationarity of the series by removing unit roots that could lead to incorrect conclusions, this study uses unit root tests and other quantitative methods such as descriptive statistics to summarize the dataset, ordinary least squares (OLS) regression, fully modified least squares (FMOLS), and correlation analysis (Souza et al., 2024) to examine the direction and strength of the relationships among maternal mortality rate, childbirth rate, population growth, and healthcare expenditure. The statistical software used for this study included SPSS, EViews, and STATA.

3.3 OLS regression Model and FMOLS

In a linear regression model, ordinary least squares (OLS) regression is a method for estimating unknown parameters, therefore enabling the investigation of the effect of predictor variables on the dependent variable. This method lowers the total of the squared deviations—residuals—between the actual dependent variable and those projected using the linear function of the independent variables. The aim is to find the line that most precisely reflects the data. The OLS regression model is mathematically defined as follows:

$$Y = X\beta + \varepsilon \qquad (1)$$

where:

Y denotes the vector of the dependent variable.

X is the matrix of independent variables,

β is the vector of the coefficient estimates, and

ε is the vector of residuals.

The OLS estimator of β can be written as

$$\hat{\beta} = (X'X)^{-1}X'Y \qquad (2)$$

An econometric technique intended to produce the best estimates for co-integrating regressions is fully modified least squares (FMOLS). Usually seen in time-series data, FMOLS modifies the OLS estimator to handle endogeneity in the regressors and serial correlation. FMOLS modifies the OLS estimator to rectify these difficulties, hence enhancing the reliability of estimations, particularly in the context of cointegrate connections (Adebanjo et al., 2024).

FMOLS involves:

- Including leads and lags of independent variables helps adjust for endogeneity.
- non-parametric method of serial correlation correction.

The FMOLS estimator can be written as follows:

$$\hat{\beta} = (X'X)^{-1}X'(Y + \Delta) \qquad (3)$$

where Δ indicates adjustments for endogeneity and serial correlation.

3.3.1 Differences between OLS and FMOLS:

1. **Handling Serial Correlation and Endogeneity:**

o **OLS:** We assume that there is no serial correlation in the residuals and that the regressors are exogenous (not correlated with the error term).

o **FMOLS:** FMOLS explicitly adjusts for serial correlation and endogeneity, making it more suitable for time series data where these issues are prevalent.

2. **Asymptotic Properties:**

- **OLS:** Consistent and unbiased if the assumptions of the classic linear regression model hold (i.e., no multicollinearity, no autocorrelation, homoscedasticity, and exogeneity).
- **FMOLS:** Provides consistent and unbiased estimates even when there is serial correlation and endogeneity, thus offering better asymptotic properties in co-integrated systems.

3. **Model Equations:**

- While the basic form of the model equations may appear similar, the estimators differ due to the FMOLS adjustments. The primary mathematical distinction lies in the correction terms that FMOLS includes to adjust for serial correlation and endogeneity.

This paper used OLS regression to find the linear link between the variables and FMOLS to investigate the long-term consequences of the predictor variables on the dependent variable using the functional model approach proposed by Adebanjo et al. (2024). The functional link between the two can be characterized as follows:

$$MMR = f(BR, HCS, PG) \quad (4)$$

The OLS regression model specification takes the following form:

$$MMR_t = \beta_0 + \beta_1(BR)_t + \beta_2(HCS)_t + \beta_3(PG)_t + \varepsilon_t \quad (5)$$

Where $\varepsilon_t \sim N(0, \sigma^2)$

The maternal mortality rate (MMR) is the dependent variable and is a proxy for maternal health. The birth rate (BR) was the main independent variable whereas the control variables include health care spending (HCS) and population growth (PG). The intercept or constant term is β_0, the coefficient estimates of the predictor variables are denoted by β_1 through β_3, and the error term is denoted by ε_t , while t is the period in years.

3.4 Diagnostic Tests

As part of the study, diagnostic tests will be run on the models used. These include the multicollinearity test using variance inflation factors (VIF), the cumulative sum (CUSUM) test for the stability of the model parameters, the serial correlation test, the heteroscedasticity test, and the normality test of the regression model residuals. The normality test of the model residuals will also be used as a diagnostic test for the FMOLS.

Table 1: Variable's description

Variables	Abbreviation	Units of Measurement
Maternal Mortality Rate	MMR	Deaths per 100,000 Live Births
Birth rate	BR	Births per 1000 people
Health care spending	HCS	Percentage of GDP (%)
Population growth	PG	Percentage (%)

Source: World Bank.

4. Results and Discussion

4.1 Results

Table 2: Descriptive Statistics

	N	Mean	Std. Deviation
Maternal mortality	34	93.057	24.896
Birthrate	34	41.352	2.497
Health care Spending	34	3.509	0.515
Population growth	34	2.626	0.113

Valid N	34

Source: Authors' Computation

Table 2 shows that the average maternal mortality during the period under review is about 93 deaths per 100,000 live births, the average birth rate is about 41 births per 1000 people with a variability of about 2 births per 1000 people during the period under review, the average healthcare spending is about 3.5% of GDP with a variability of about 0.5% of GDP, and the average population growth during the period under review is about 2.6% with a variability of about 0.1%.

Table 3: Unit Root Test

Differenced Series	Test-Statistic	P-value	Order Level
Maternal mortality	-5.457	0.0001	Order 1
Birthrate	-5.433	0.0001	Order 1
Health care Spending	-7.435	0.0000	Order 1
Population growth	-6.226	0.0000	Order 1

Source: Authors' Computation

Table 3 reveals that series including maternal mortality, birth rate, healthcare spending, and population growth are statistically significant at the 1% level after the first difference and become stationary, indicating that the presence of a unit root that can constitute a misleading conclusion has been eliminated. Therefore, an appropriate analysis can be conducted on the series.

Table 4: OLS Regression

Maternal Mortality	Coefficient	T-Statistic	P-value	VIF
Birthrate	11.225	47.07	0.0000	1.51
Health care Spending	-0.3941	-0.40	0.6940	1.11
Population growth	-71.679	-13.62	0.0000	1.51
Constant	-181.543	-15.47	0.0000	NA
Overall Model P-value	0.000			
R-squared	0.989			
Adj R2	0.988			
Serial Correlation Test				
Durbin–Watson Statistic = 1.5375				
Homoscedasticity Test				
Prob > chi2 = 0.0206.				

Source: Authors' Computation

Table 4 shows that the fitted OLS regression has an overall p-value of less than 0.01 at a significant level, indicating a 1% level of statistical significance for the model. This implies, even with population increase and health care spending considered, a notable linear link between maternal death and birth rate. Assuming that an increase in birth rate instances can help contribute to the rise in maternal mortality in Nigeria, the coefficient estimations of the birth rate have a positive and significant impact on maternal mortality in the country at the 1% level. Nigerian health care spending coefficient estimations show a negative and negligible impact on maternal mortality. Rising population growth can help lower the maternal mortality rate in Nigeria because the coefficient estimates of population growth have a negative and significant impact on maternal mortality. With other factors accounting for the remaining 1.1%, the R2 value of 0.989 implies that birth rate, healthcare spending, and population growth account for 98.9% of the variance in maternal mortality. Because the variance inflation factor (VIF) of every predictor is less than 5, there are no indications of multicollinearity; the R-squared value is high. Furthermore, the fitted OLS regression model is statistically significant, indicating that the model effectively fits the data and may be applied to reasonably project the future maternal mortality rate in Nigeria. The Durbin-Watson statistic value of 1.5375 falls within the two critical levels of 1.5 and 2.5 according to other diagnostic tests, including the serial correlation. Consequently, the regression model satisfies the assumption of autocorrelation by not having the autocorrelation problem. Conversely, the homoscedasticity test reveals that a p-value of 0.0206 exceeds the 0.01 significance level, so the fitted OLS regression model satisfies the condition of constant variance of the error term and avoids the heteroscedasticity issue.

Table 5: FMOLS

Maternal Mortality	Coefficient	T-Statistic	P-value
Birthrate	11.217	35.75	0.0000
Health care Spending	-0.239	-0.19	0.8531
Population growth	-76.779	-11.31	0.0000
Constant	-168.229	-11.09	0.0000
R-squared	0.987		
Adj R2	0.986		

Source: Authors' Computation

Table 5 indicates that the coefficient estimates for the birth rate exhibit a positive and statistically significant long-term impact on maternal mortality at the 1% level, implying that an increase in the birth rate correlates with a rise in maternal mortality over time. Conversely, the coefficient estimates for population growth revealed a negative and statistically significant long-term effect on maternal mortality at the 1% level, suggesting that an increase in population growth is associated with a reduction in maternal mortality in the long-term. The R2 value of the FMOLS is approximately 98.7%, which is relatively high, thereby validating the model's adequacy.

Table 6: Correlation matrix

		Maternal	Birthrate	Health care	Pop-growth
Maternal	Pearson Correlation	1	.954	-.229	.269
	N	34	34	34	34
Birthrate	Pearson Correlation	.954	1	-.150	.530
	N	34	34	34	34
Health care	Pearson Correlation	-.229	-.150	1	.159
	N	34	34	34	34
Pop-growth	Pearson Correlation	.269	.530	.159	1
	N	34	34	34	34

Source: Authors' Computation

Table 6 shows a strong positive association between birth rate and maternal mortality (r = 0.954), suggesting that an increase in the birth rate in Nigeria results in a corresponding increase in maternal mortality in the country.

More so, Table 6 also reveals that there is a weak negative correlation between healthcare spending and maternal mortality (r = -0.229), suggesting that an increase in healthcare spending or expenditure will constitute a decline in maternal mortality, and the results also demonstrate that there is a weak positive relationship between population growth and maternal mortality (r = 0.269), indicating that an increase in population growth results in a corresponding increase in maternal mortality.

Figure 1 illustrates that the p-value of the fitted OLS regression model residuals is approximately 0.4078, surpassing the significance level of 0.01 and indicating that the model residuals are normally distributed, hence fulfilling the assumption of normality for the model residuals. Figure 2 illustrates the CUSUM test for the stability of the OLS regression parameters, indicating that the model parameters reside inside the two 95% confidence intervals, suggesting the stability of the fitted OLS regression model parameters. Figure 3 illustrates the normality of the FMOLS residuals, with a p-value of 0.2947, which is beyond the significance level of 0.01; thus, the fitted FMOLS residuals are normally distributed. Figure 4 illustrates that the graph depicting maternal mortality in relation to the birth rate has an upward trend, indicating that an increase in the birth rate corresponds with an increase in maternal death. Figure 5 illustrates the correlation between maternal mortality and health care expenditures revealing an irregular inverse pattern that suggests an increase in health care spending correlates with a reduction in maternal mortality. Additionally, the graph depicting maternal mortality against population growth also indicates an irregular inverse relationship, implying that an increase in population growth is associated with a decline in maternal mortality (see Figure 6).

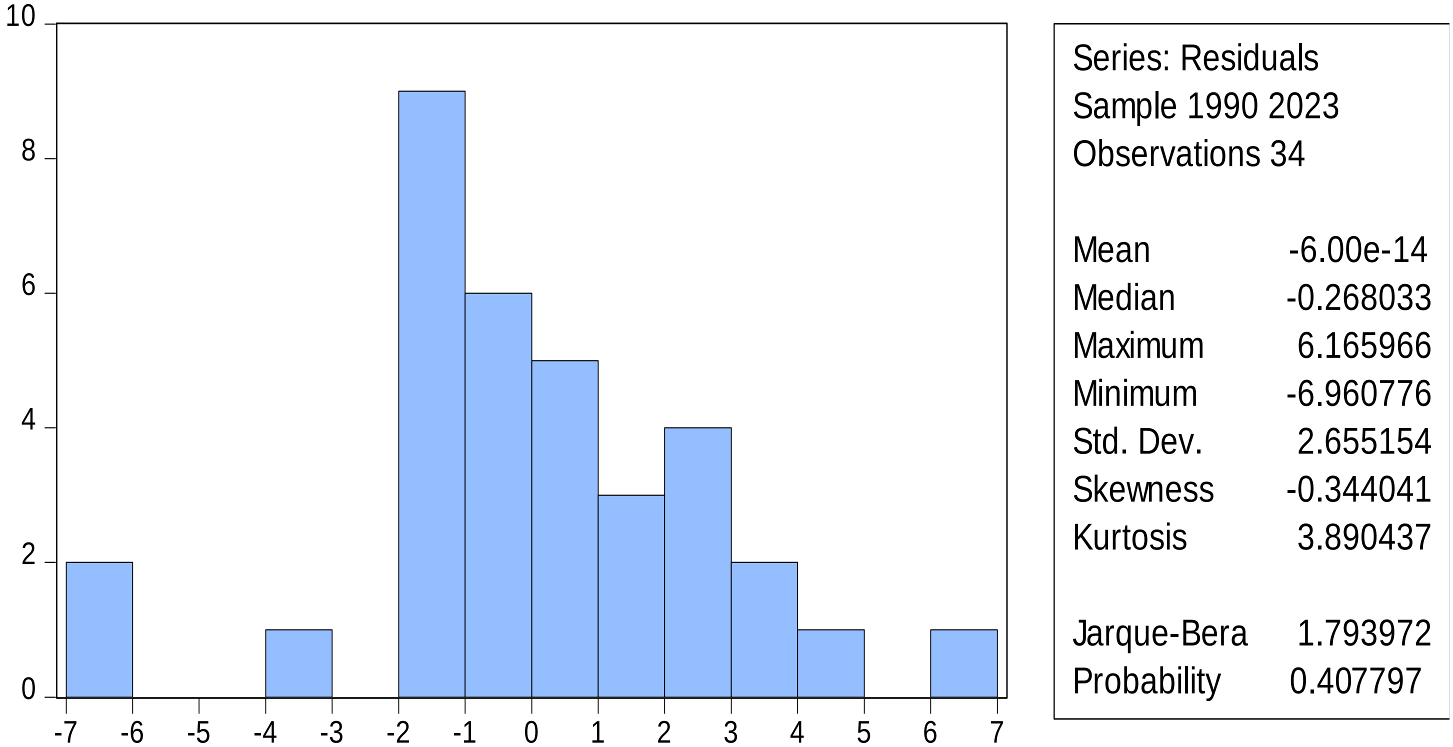

Figure 1: OLS Regression Residuals Normality test

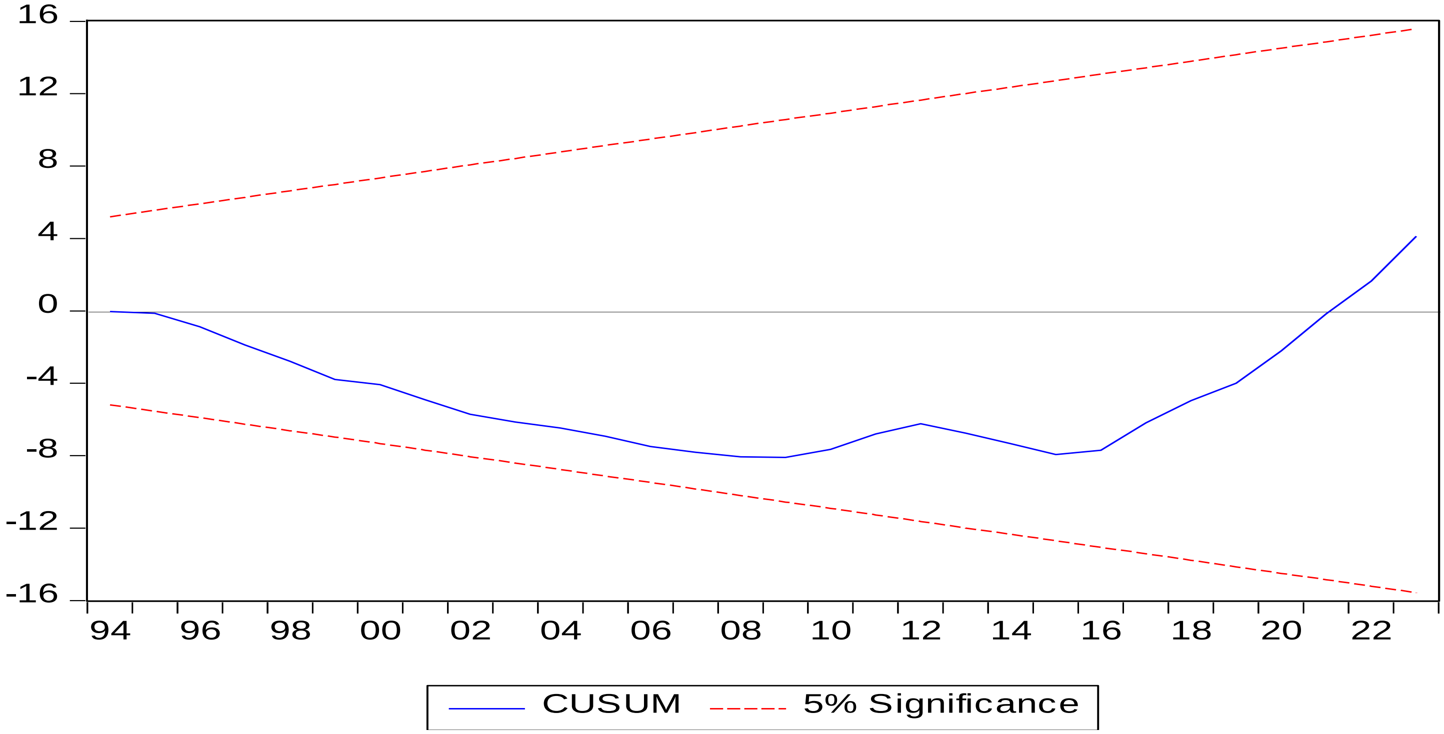

Figure 2: CUSUM Test of the Stability of the OLS Regression Model

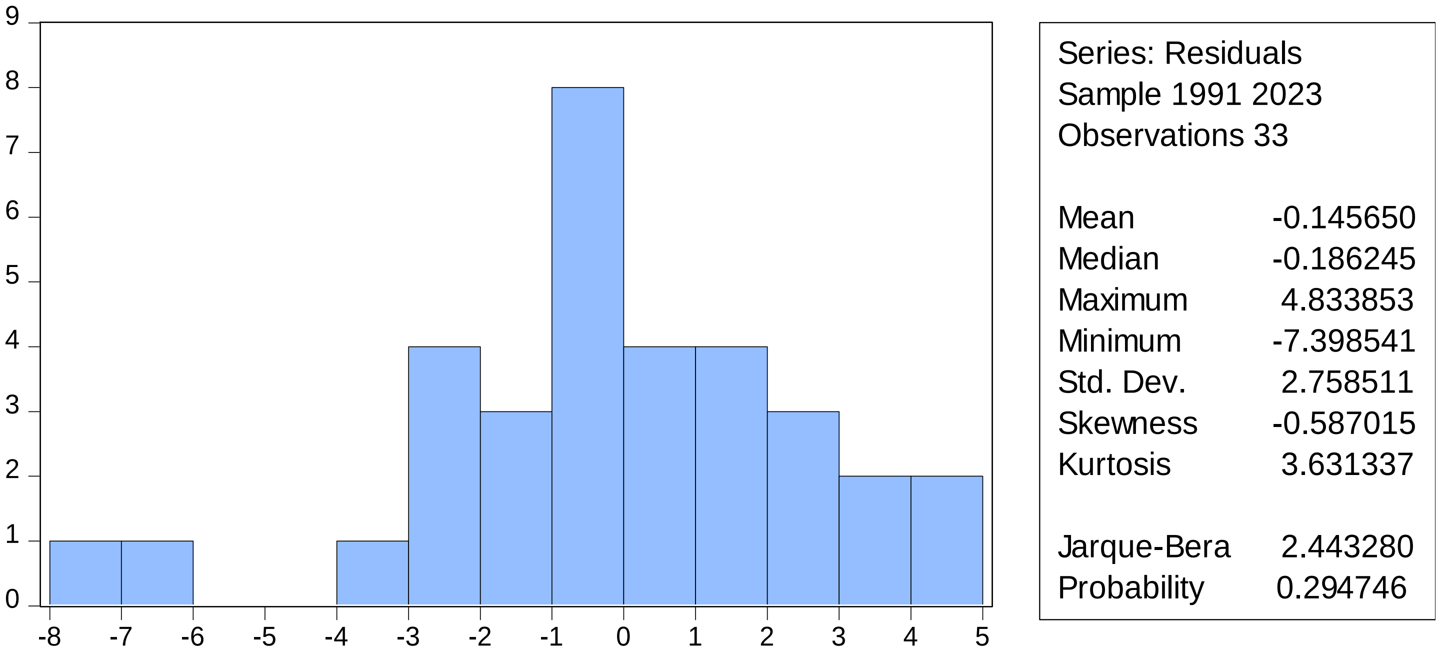

Figure 3: FMOLS Normality Test

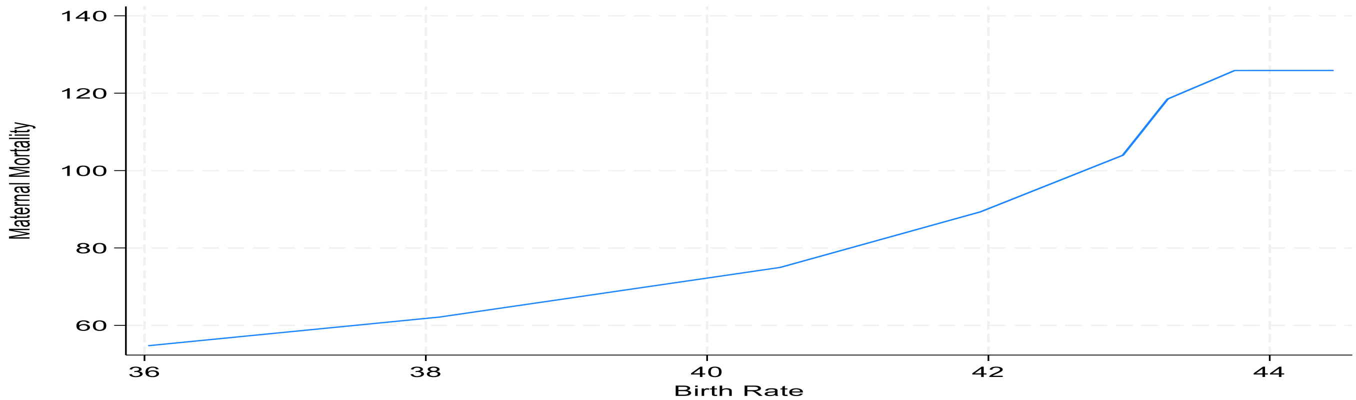

Figure 4: Graph of Maternal Mortality Versus Birth Rate

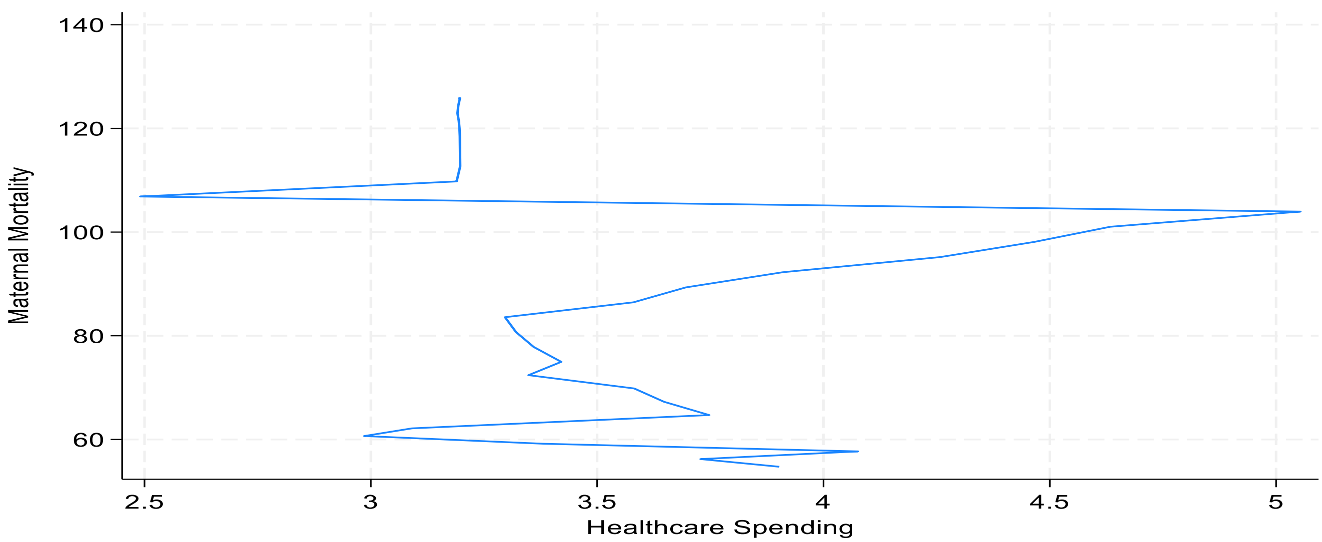

Figure 5: Graph of Maternal Mortality Versus Health care Spending

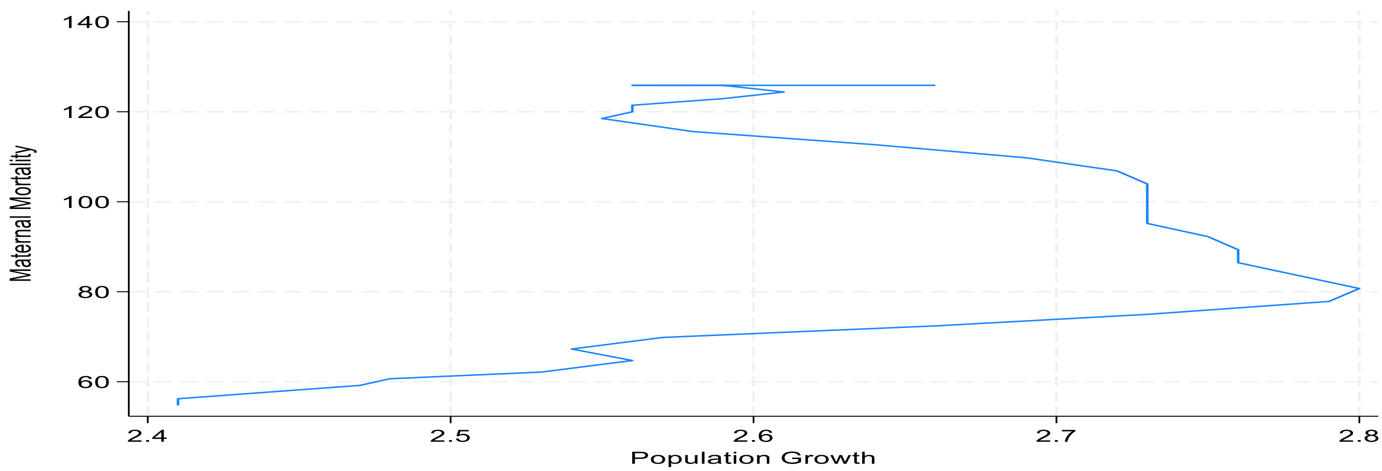

Figure 6: Graph of Maternal Mortality Versus Population Growth

4.2 Discussion

The analytical results indicate that Table 4 reveals a substantial linear relationship between maternal mortality and birth rate, even when controlling for health care expenditure and population increase. The coefficient estimates of the birth rate have a positive and substantial impact on maternal mortality in Nigeria at the 1% level, suggesting that an increase in birth rate occurrences may result in a rise in maternal mortality in the country. The coefficient estimates of healthcare expenditure in Nigeria demonstrate a negative and insignificant influence on maternal mortality, which is consistent with the findings of Hitiris and Posnett (1992), who indicated either a non-significant or negatively significant effect of public health spending on maternal health. This outcome is in contrast with the conclusions of Novignon and Lawanson (2017), who identified a positive effect of public health expenditure on maternal mortality. The coefficient estimates for population growth demonstrate a negative and substantial effect on maternal mortality, indicating that an increase in population growth may lower the maternal mortality rate in Nigeria. This contradicts the findings of Boundioa and Thiombiano (2024), who contended that population density has a favorable and significant impact on maternal mortality rates in West African countries. An R2value of 0.989 indicates that birthrate, health care expenditure, and population growth explain 98.9% of the variance in maternal mortality, whereas other factors contribute to the remaining 1.1%. The additional significant assumptions of the fitted ordinary least squares regression model were also fulfilled, confirming the model's adequacy.

Table 5 demonstrates that the coefficient estimates for the birth rate reveal a positive and statistically significant long-term effect on maternal mortality at the 1% level, suggesting that an increase in the birth rate is associated with an escalation in maternal death over time. In contrast, the coefficient estimate for population growth indicates a negative and substantial long-term impact on maternal mortality at the 1% level, implying that an increase in population growth correlates with a decrease in maternal mortality. The R-squared value of the FMOLS is approximately 98.7%, indicating a high model adequacy.

Furthermore, Table 6 indicates a robust positive correlation between birth rate and maternal mortality, implying that an increase in the birth rate in Nigeria leads to a concomitant rise in maternal death within the nation. Furthermore, Table 6 indicates a weak negative correlation between health care expenditure and maternal mortality, implying that an increase in health care spending may reduce maternal mortality. Additionally, the results show a weak positive relationship between population growth and maternal mortality, suggesting that an increase in population growth correlates with a rise in maternal mortality, consistent with the findings of Nelson et al. (2018), who asserted that population-level factors are linked to an increase in the maternal mortality rate in the United States.

Moreover, Figure 4 demonstrates that the graph representing maternal mortality in relation to the birth rate has an increasing trend, signifying that an increase in the birth rate correlates with a rise in maternal deaths. Figure 5 depicts the relationship between maternal mortality and health care expenditures indicating an uneven negative trend that implies that higher health care spending is associated with decreased maternal mortality. Furthermore, Figure 6, which illustrates maternal mortality in relation to population expansion, reveals an irregular negative correlation, suggesting that an increase in population growth correlates with a decrease in maternal mortality.

5. Conclusion

This study specifically examines the link between birth rate and maternal mortality, considering health care spending and population growth in Nigeria, an area overlooked by recent research. This study demonstrated a significant linear association between maternal mortality and birth rate, even when controlling for health care expenditure and population increase. The findings also indicate that the increase in the birth rate contributes to increased maternal mortality. At the same time, population growth is associated with both a decline and an increase in maternal mortality.

Additionally, health care spending exhibits a negative but insignificant effect on maternal mortality and a negative correlation with it, suggesting that sufficient health care expenditure could alleviate the maternal mortality rate in Nigeria. Furthermore, the findings of this study further reveal that the birth rate has a positive long-term effect on maternal mortality in Nigeria.

Consequently, the Nigerian government should allocate sufficient funding for health care services and health professionals to improve the management of complications related to pregnancy. Additionally, inclusive health provisions should be implemented that render family planning affordable for economically disadvantaged Nigerians, thereby regulating birth rates to alleviate excessive population growth and reduce the maternal mortality rate in Nigeria.

However, the study is limited to Nigeria, and birth rate as well as maternal mortality is a serious issue in West Africa due to poor funding of health care sectors across the region. Therefore, future studies should extend the research to other West African communities to have a broad view of this research study.

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Conflict of Interest

No

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Author's contributions

Fadayomi, Akinwumi Festus: Methodology, Analysis, Literature Review, and Conclusion

Seun Adebanjo: Methodology, Analysis, and Literature Review

Ojeogwu, Okwudili Richard: Literature review

Anyebe, Phoebe Eikojonwa: Methodology, Analysis, and Discussion

Olaleye Adebimpe Tosin: Introduction and Literature review

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