

Government Health Expenditure, Exchange Rate Instability and Neonatal Mortality in Nigeria: A 25-Year Time-Series Analysis

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Abstract

Background:

Neonatal mortality remains a significant public health concern in Nigeria, with persistent rates despite various health interventions. While medical causes are well documented, the role of macroeconomic factors, particularly government health expenditure and exchange rate instability, requires deeper investigation. This study examined the association between government health expenditure, exchange rate fluctuations, inflation, out-of-pocket health spending, and neonatal mortality in Nigeria over a 25-year period, with a view to informing fiscal and healthcare policy reforms.

Methods:

A retrospective quantitative time-series study design was adopted using annual secondary data from the World Development Indicators for the period 2000–2024. Variables analysed included neonatal mortality rate, government health expenditure as a percentage of gross domestic product, exchange rate, inflation measured by the Consumer Price Index, out-of-pocket health expenditure as a percentage of current health expenditure, and adjusted GDP per capita growth. Statistical methods included descriptive analysis, Pearson and Spearman correlation analyses, t-tests, analysis of variance, multiple linear regression, polynomial regression, and multicollinearity diagnostics using variance inflation factors. Additional time-series diagnostic and sensitivity analyses included Augmented Dickey-Fuller stationarity testing, autocorrelation assessment, and a time-adjusted regression model.

Results:

Neonatal mortality declined over the study period, while exchange rate depreciation and out-of-pocket health expenditure increased. In the primary multiple linear regression model, exchange rate and out-of-pocket expenditure were significantly associated with neonatal mortality, while government health expenditure and inflation were not statistically significant predictors. Correlation analysis showed strong inverse associations between neonatal mortality and both exchange rate and out-of-pocket expenditure, reflecting the opposing secular trends between declining neonatal mortality and rising macroeconomic pressures. Multicollinearity diagnostics for the primary model showed acceptable variance inflation factor values below the conventional threshold of 5. Time-series diagnostics showed that several variables were non-stationary at level, suggesting that some observed associations may be influenced by underlying time trends. In the time-adjusted sensitivity model, exchange rate became positively associated with neonatal mortality, although this finding was interpreted cautiously because collinearity increased due to the strong relationship between year and exchange rate.

Conclusion:

This study suggests that neonatal mortality trends in Nigeria are associated with broader macroeconomic conditions, particularly exchange rate instability and high reliance on out-of-pocket health financing. However, the findings should be interpreted as ecological associations rather than

direct causal effects because several variables showed strong time trends. Government health expenditure remains essential, but its potential impact depends on efficient allocation, timely disbursement, and effective implementation. Policies aimed at exchange rate stability, improved public health financing, reduced household health spending, local production of essential neonatal commodities, and expansion of Universal Health Coverage are needed to support progress toward Sustainable Development Goal 3.2.

Background

Neonatal mortality, defined as death within the first 28 days of life, remains a critical public health concern in Nigeria. Despite concerted global efforts to improve maternal and child health, Nigeria continues to rank among the countries with the highest neonatal mortality rates worldwide. According to the 2023–2024 Nigeria Demographic and Health Survey, approximately 41 neonates per 1,000 live births die within the first month of life, more than double the global average of 17 per 1,000 live births [1, 2]. This figure significantly exceeds the Sustainable Development Goal 3.2 target of 12 neonatal deaths per 1,000 live births by 2030 [2].

Economic disparities compound the crisis. Neonatal mortality among Nigeria's poorest households reaches 45 deaths per 1,000 live births, compared with 30 per 1,000 live births among wealthier households [1]. Regional inequities are also stark, with states such as Kano reporting rates as high as 59 per 1,000 live births, while the Southwest region records notably lower mortality rates [1]. Such contrasts reveal how economic access, infrastructural deficits, and systemic inefficiencies shape neonatal survival outcomes.

Medical causes of neonatal death, such as prematurity, birth asphyxia, and infections, are well documented. However, economic and fiscal barriers play an increasingly critical role in undermining access to neonatal health services. Nigeria's healthcare financing remains disproportionately reliant on private expenditure, with out-of-pocket spending accounting for a substantial share of total health expenditure [3]. Compounding this, frequent currency devaluation can raise the cost of imported neonatal equipment, medications, and other essential health commodities [4]. Although government health expenditure has increased modestly in nominal terms, inefficiencies in allocation, disbursement, and implementation may limit its potential impact [5, 6].

More recent evidence also highlights the persistent challenge of translating research, financing, and policy attention into substantial neonatal survival gains in low- and middle-income countries. A recent systematic review focusing on neonatal survival in LMICs emphasised that decades of academic and policy effort have not consistently produced proportional reductions in neonatal mortality, underscoring the need to examine wider systems and macroeconomic constraints [19]. In Nigeria, time-series evidence has also shown that the relationship between government health expenditure and health outcomes is complex and may depend on the structure, efficiency, and responsiveness of spending rather than expenditure volume alone [20].

Despite growing recognition of the economic determinants of health, empirical evidence linking macroeconomic factors directly to neonatal mortality in Nigeria remains limited. Existing studies often aggregate child health outcomes or focus on general mortality, thereby neglecting the specific vulnerabilities of the neonatal period [6, 7]. This study therefore addresses the underexplored link between macroeconomic instability and neonatal mortality in Nigeria by examining the influence of government health expenditure, exchange rate fluctuations, inflationary trends, out-of-pocket health spending, and household income over a 25-year period.

Methods

Study design and theoretical framework

This study adopted a retrospective quantitative time-series design using annual secondary data for Nigeria from 2000 to 2024. The study was rooted in a positivist paradigm, which supports hypothesis-driven investigation using objective empirical data to examine relationships between measurable variables [8, 9]. The analysis was guided by the Health Production Function and macroeconomic theory frameworks, which link health outcomes to the availability, allocation, and use of economic resources, as well as to broader macroeconomic conditions such as inflation, exchange rate movements, and household purchasing power [10–12].

Data sources and variables

Secondary data spanning 25 years, from 2000 to 2024, were extracted from the World Development Indicators database. The dependent variable was neonatal mortality rate, measured as deaths within the first 28 days of life per 1,000 live births. The independent variables were government health expenditure as a percentage of gross domestic product, exchange rate, out-of-pocket health expenditure as a percentage of current health expenditure, inflation measured by the Consumer Price Index, and adjusted GDP per capita growth.

For clarity, neonatal mortality rate was treated as a population-level health outcome, while the macroeconomic and health financing variables were treated as annual national-level exposures. The variables were selected based on their theoretical relevance to neonatal survival, health system financing, household affordability, and access to essential maternal and newborn health services.

Sampling and data validity

A purposive non-probability sampling approach was used to select relevant annual time-series data that met the study criteria. These criteria included availability of annual records for the study period, relevance to the study objectives, and credibility of the data source. The World Development Indicators

database was selected because it provides internationally standardised and comparable development indicators across countries and over time.

Data validity was strengthened through consistency checks across the extracted variables. All variables were reviewed for plausibility before analysis. Where minor data gaps existed in the original data source, values were checked against available trend patterns and treated cautiously to preserve continuity in the time series.

Statistical analysis

Data analysis was conducted using STATA and Microsoft Excel. Descriptive statistics were used to summarise the distribution, central tendency, and dispersion of the study variables. Pearson correlation analysis was used to examine linear relationships between neonatal mortality and selected macroeconomic variables, while Spearman correlation analysis was used to assess monotonic associations.

Independent sample t-tests were used to compare mean neonatal mortality before and after 2015, given the major exchange rate and macroeconomic shifts that occurred around that period. One-way analysis of variance was used to examine differences in neonatal mortality across levels of government health expenditure.

Regression analyses were then conducted to examine the association between neonatal mortality and the selected explanatory variables. Simple linear regression was used to estimate bivariate relationships between neonatal mortality and key predictors. Multiple linear regression was used to assess the combined association of government health expenditure, exchange rate, out-of-pocket expenditure, inflation, and adjusted GDP per capita growth with neonatal mortality. Polynomial regression was used to explore possible non-linear relationships, particularly between exchange rate and neonatal mortality.

Multicollinearity diagnostics were assessed using the variance inflation factor. Variance inflation factor values below 5 were interpreted as indicating acceptable levels of independence among predictors in the primary multiple regression model.

Because the study used annual time-series data, additional diagnostic and sensitivity analyses were conducted to assess the robustness of the findings. The Augmented Dickey-Fuller test was used to assess stationarity of the variables. Autocorrelation was assessed using the Durbin-Watson statistic and the Breusch-Godfrey test. A time-adjusted regression model including year as a covariate was fitted to examine whether observed associations were influenced by underlying secular trends. Where appropriate, Newey-West heteroskedasticity and autocorrelation-consistent standard errors were considered to improve the reliability of statistical inference.

Given the ecological and time-series nature of the study, all findings were interpreted as associations rather than direct causal effects. This cautious interpretation was necessary because national-level

annual data may be influenced by time trends, policy changes, health system factors, and other unmeasured confounders.

Ethical considerations

This study used publicly available aggregate secondary data and did not involve individual-level human participants, personal identifiers, or confidential records. Ethical approval and informed consent were therefore not required. Data use adhered to principles of transparency, attribution, and responsible research conduct.

Results

The analysis included annual data from 2000 to 2024 and examined trends in neonatal mortality alongside selected macroeconomic and health financing indicators in Nigeria. Figure 1 provides an overview of the trends in the key economic and health indicators over the study period. The neonatal mortality rate declined from 46.50 deaths per 1,000 live births in 2000 to 34.43 deaths per 1,000 live births in 2024, although minor fluctuations were observed in the later years of the study period. The neonatal mortality trend is shown separately in Fig. 2. Descriptive statistics for the study variables are presented in Table 1.

Table 1
Summary statistics for key variables, 2000–2024

Statistic	NMR	GHE_GDP	EXR	OPExp	AP_GDPPC	INFR_CPI
Count	25	25	25	25	25	25
Mean	38.47	0.63	216.51	71.80	2.28	13.47
Standard deviation	3.39	0.21	113.16	4.87	3.39	4.70
Minimum	34.30	0.45	102.11	60.16	-4.16	5.39
Maximum	46.50	1.20	425.98	77.39	12.28	24.66
25th percentile	36.30	0.50	129.36	70.93	0.44	10.83
50th percentile	37.50	0.53	157.31	72.81	2.44	12.88
75th percentile	39.90	0.66	306.08	75.46	3.83	16.50

Data source

World Development Indicators database.

The mean neonatal mortality rate was 38.47 deaths per 1,000 live births, with a standard deviation of 3.39. The highest neonatal mortality rate was recorded in 2000, while the lowest value was recorded in

2022. This overall pattern suggests a gradual decline in neonatal mortality over the 25-year period, although the rate remained above the Sustainable Development Goal 3.2 target.

Government health expenditure as a percentage of GDP averaged 0.63%, with values ranging from 0.45% to 1.20%. This indicates persistently low public health expenditure throughout the study period. The trend in government health expenditure is shown in Fig. 3. The exchange rate averaged ₦216.51 per US dollar, with a large standard deviation of 113.16, reflecting substantial exchange rate variability. The exchange rate rose from ₦102.11/USD in 2000 to ₦419.55/USD in 2024, with the highest value recorded in 2022. The exchange rate trend is shown in Fig. 4.

Out-of-pocket health expenditure accounted for an average of 71.80% of current health expenditure, with values ranging from 60.16% to 77.39%. Although the standard deviation was relatively modest, the consistently high level of out-of-pocket expenditure suggests a sustained reliance on household financing for healthcare. The trend in out-of-pocket health expenditure is shown in Fig. 5. Adjusted GDP per capita growth averaged 2.28%, but showed considerable variation, ranging from – 4.16% to 12.28%. Inflation averaged 13.47%, with a peak of 24.66%, indicating recurrent macroeconomic pressure during the study period.

Time-series trend analysis showed three broad patterns. First, neonatal mortality declined gradually across the study period. Second, exchange rate depreciation became more pronounced after 2015. Third, out-of-pocket health expenditure remained persistently high, suggesting continued household financial burden in accessing healthcare. Together, these descriptive trends suggest that neonatal mortality outcomes in Nigeria occurred within a broader context of low public health expenditure, exchange rate instability, high private health spending, fluctuating income growth, and inflationary pressure.

Correlation analysis

Correlation analysis was conducted to examine the direction and strength of association between neonatal mortality and the selected macroeconomic and health financing indicators. Pearson correlation was used to assess linear relationships, while Spearman correlation was used to assess monotonic relationships. The Pearson correlation matrix is presented in Table 2 and displayed visually in Fig. 6.

Table 2
Pearson correlation matrix for neonatal mortality and selected macroeconomic variables, 2000–2024

Variable	NMR	GHE_GDP	EXR	OPExp	AP_GDPPC	INFR_CPI
NMR	1.000	0.537	-0.776	-0.862	0.591	-0.281
GHE_GDP	0.537	1.000	-0.439	-0.550	0.345	0.064
EXR	-0.776	-0.439	1.000	0.609	-0.620	0.606
OPExp	-0.862	-0.550	0.609	1.000	-0.481	0.221
AP_GDPPC	0.591	0.345	-0.620	-0.481	1.000	-0.197
INFR_CPI	-0.281	0.064	0.606	0.221	-0.197	1.000

need, delayed policy response, or broader fiscal changes rather than a direct adverse effect of public spending.

Exchange rate showed a strong inverse correlation with neonatal mortality ($r = -0.776$, $p < 0.001$), while out-of-pocket expenditure also showed a strong inverse correlation with neonatal mortality ($r = -0.862$, $p < 0.001$). These inverse associations reflect the fact that neonatal mortality declined over the study period while exchange rate depreciation and out-of-pocket expenditure increased. Therefore, the direction of these correlations should not be interpreted as evidence that exchange rate depreciation or higher household spending directly reduces neonatal mortality.

Adjusted GDP per capita growth showed a moderate positive correlation with neonatal mortality ($r = 0.591$, $p = 0.002$), while inflation showed a weak inverse and statistically non-significant correlation with neonatal mortality ($r = -0.281$, $p = 0.173$). Exchange rate was positively correlated with inflation ($r = 0.606$, $p = 0.001$) and out-of-pocket expenditure ($r = 0.609$, $p = 0.001$), suggesting that macroeconomic and household financing pressures may be interconnected.

Spearman correlation analysis broadly supported the Pearson findings, particularly the strong monotonic inverse associations between neonatal mortality and exchange rate, and between neonatal mortality and out-of-pocket expenditure. The consistency between Pearson and Spearman results suggests that the observed associations were not limited to strictly linear relationships. However, given the strong secular trends in the data, these findings were interpreted as descriptive associations requiring further assessment through regression and time-series sensitivity analyses.

Regression analysis

Regression analysis was conducted to examine the association between neonatal mortality and selected macroeconomic and health financing variables. Simple linear regression was first used to assess bivariate relationships, followed by multiple linear regression to assess the combined association of all explanatory variables with neonatal mortality.

The simple linear regression results are presented in Table 3.

Table 3
Simple linear regression models for predictors of neonatal mortality, 2000–2024

Predictor	Coefficient	p-value	R ²	Interpretation
GHE_GDP	8.55	0.006	0.288	Significant positive association
EXR	-0.023	< 0.001	0.603	Significant inverse association
OPExp	-0.599	< 0.001	0.742	Significant inverse association
AP_GDPPC	0.590	0.002	0.350	Significant positive association
INFR_CPI	-0.203	0.173	0.079	Not statistically significant

In the simple linear regression models, government health expenditure as a percentage of GDP showed a statistically significant positive association with neonatal mortality ($\beta = 8.55$, $p = 0.006$), although it explained only 28.8% of the variation in neonatal mortality. This finding should not be interpreted as evidence that public health spending increases neonatal mortality, but may reflect the timing, targeting, or efficiency of spending, as well as the possibility that higher spending occurred in response to greater health system need.

Exchange rate showed a statistically significant inverse association with neonatal mortality ($\beta = -0.023$, $p < 0.001$), explaining 60.3% of the variation in neonatal mortality in the bivariate model. Out-of-pocket

expenditure also showed a strong inverse association with neonatal mortality ($\beta = -0.599$, $p < 0.001$), with an R^2 of 0.742. These inverse associations should be interpreted cautiously because neonatal mortality declined over time while exchange rate and out-of-pocket expenditure increased.

Adjusted GDP per capita growth was positively associated with neonatal mortality in the simple regression model ($\beta = 0.590$, $p = 0.002$), while inflation was not statistically significant ($\beta = -0.203$, $p = 0.173$).

The multiple linear regression results are presented in Table 4.

Table 4
Multiple linear regression model for neonatal mortality, 2000–2024

Variable	Coefficient	p-value	Interpretation
GHE_GDP	-0.563	0.761	Not statistically significant
EXR	-0.015	0.007	Statistically significant inverse association
OPExp	-0.409	< 0.001	Statistically significant inverse association
AP_GDPPC	0.035	0.766	Not statistically significant
INFR_CPI	0.123	0.194	Not statistically significant

Model $R^2 = 0.860$; Adjusted $R^2 = 0.824$; $p < 0.001$

In the multiple linear regression model, the selected macroeconomic and health financing variables jointly explained 86.0% of the variation in neonatal mortality. Exchange rate remained a statistically significant predictor of neonatal mortality ($\beta = -0.015$, $p = 0.007$), as did out-of-pocket health expenditure ($\beta = -0.409$, $p < 0.001$). Government health expenditure, adjusted GDP per capita growth, and inflation were not statistically significant predictors in the multivariable model.

The inverse association between exchange rate and neonatal mortality in the primary model should be interpreted in the context of the study period, during which neonatal mortality declined while exchange rate depreciation intensified. Similarly, the inverse association between out-of-pocket expenditure and neonatal mortality may reflect improved access among households able to pay for care, but also raises equity concerns because high reliance on household financing may exclude poorer families from essential neonatal services.

Polynomial regression

Polynomial regression was used to explore a possible non-linear relationship between exchange rate and neonatal mortality. The quadratic model improved explanatory power compared with the simple linear exchange rate model, with an R^2 of 0.696 and adjusted R^2 of 0.669.

The polynomial regression results are presented in Table 5.

Table 5
Polynomial regression
model of exchange rate
and neonatal mortality

Variable	Coefficient	p-value
EXR	-0.0917	0.002
EXR ²	0.0001	0.016

Both the linear and quadratic exchange rate terms were statistically significant. This suggests that the relationship between exchange rate and neonatal mortality may not be strictly linear. However, because exchange rate changed substantially over time, this non-linear association should be interpreted cautiously and considered alongside the time-series sensitivity analysis.

Multicollinearity diagnostics

Multicollinearity was assessed using variance inflation factors in the primary multiple regression model. The variance inflation factor results are presented in Table 6.

Table 6
Variance
inflation factor
analysis for the
primary
regression
model

Variable	VIF
GHE_GDP	1.78
EXR	3.98
OPExp	1.92
AP_GDPPC	1.80
INFR_CPI	2.17

All variance inflation factor values were below the conventional threshold of 5, indicating acceptable levels of independence among predictors in the primary multiple regression model. Exchange rate had the highest VIF value, suggesting some relationship with other macroeconomic indicators, but not at a level that would invalidate the primary model.

Time-series diagnostics and sensitivity analysis

Because the study used annual time-series data, additional diagnostic and sensitivity analyses were conducted to assess whether the observed associations were influenced by underlying time trends, non-stationarity, or autocorrelation.

Stationarity testing

The Augmented Dickey-Fuller test showed that several variables were non-stationary at level. Exchange rate, government health expenditure, adjusted GDP per capita growth, and inflation were non-stationary, while neonatal mortality was borderline non-stationary. Out-of-pocket expenditure was stationary at level.

The Augmented Dickey-Fuller stationarity results are presented in Table 7.

Table 7
Augmented Dickey-Fuller stationarity test results

Variable	ADF p-value	Interpretation
NMR	0.065	Borderline non-stationary
GHE_GDP	0.474	Non-stationary
EXR	0.996	Non-stationary
OPExp	0.028	Stationary
AP_GDPPC	0.110	Borderline/non-stationary
INFR_CPI	0.944	Non-stationary

These findings indicate that some of the variables, particularly exchange rate and inflation, had strong underlying time trends. This supports the need for cautious interpretation of the correlation and regression findings, as some observed associations may partly reflect secular movement over time rather than direct causal relationships.

Autocorrelation assessment

Autocorrelation was assessed using the Durbin-Watson statistic and the Breusch-Godfrey test. In the primary multiple linear regression model, the Durbin-Watson statistic was 1.34, suggesting possible mild

positive autocorrelation. However, the Breusch-Godfrey test for first-order autocorrelation was not statistically significant.

The autocorrelation diagnostic results are presented in Table 8.

Table 8
Autocorrelation diagnostics for the primary regression model

Test	Result	Interpretation
Durbin-Watson statistic	1.34	Possible mild positive autocorrelation
Breusch-Godfrey test	p = 0.132	Not statistically significant

Overall, autocorrelation did not appear to be a major threat to the primary regression model, although the annual time-series structure justified cautious interpretation and additional sensitivity testing.

Time-adjusted sensitivity model

A time-adjusted regression model was fitted by including year as an additional covariate. This was done to assess whether the observed relationships were influenced by the general passage of time, especially because neonatal mortality declined steadily over the study period while exchange rate depreciation intensified.

The time-adjusted model showed a substantially improved model fit, with an R^2 of 0.980 and adjusted R^2 of 0.973. In this model, exchange rate became positively associated with neonatal mortality after accounting for year. This suggests that, after adjusting for the secular decline in neonatal mortality, exchange rate depreciation may be associated with higher neonatal mortality risk.

However, this sensitivity finding should be interpreted cautiously because year and exchange rate were strongly related, leading to increased collinearity in the time-adjusted model. Therefore, the time-adjusted analysis was used as a robustness check rather than as the primary model.

The time-adjusted sensitivity analysis is summarised in Table 9.

Table 9
Summary of time-adjusted sensitivity analysis

Model	R^2	Adjusted R^2	Key interpretation
Primary multiple linear regression model	0.860	0.824	EXR and OPExp were significantly inversely associated with NMR
Time-adjusted regression model	0.980	0.973	EXR became positively associated with NMR after adjustment for year

Taken together, the diagnostic analyses suggest that the primary findings are informative but should be interpreted as ecological associations rather than direct causal effects. The inverse associations observed in the primary model appear to be influenced partly by underlying time trends, particularly the simultaneous decline in neonatal mortality and increase in exchange rate over the study period. The time-adjusted sensitivity model supports the policy relevance of exchange rate instability, but its interpretation is limited by collinearity between year and exchange rate.

Overall results summary

Overall, the results show that neonatal mortality in Nigeria declined over the 25-year study period, while exchange rate depreciation, out-of-pocket health expenditure, and inflationary pressures increased. Government health expenditure as a percentage of GDP remained low throughout the period, suggesting persistent fiscal constraints in public health financing.

In the primary correlation and regression analyses, exchange rate and out-of-pocket expenditure were significantly associated with neonatal mortality. However, both variables showed inverse associations with neonatal mortality, reflecting the fact that neonatal mortality declined over time while exchange rate depreciation and out-of-pocket expenditure increased. These findings therefore require cautious interpretation and should not be taken to mean that exchange rate depreciation or high household health spending directly improves neonatal survival.

Government health expenditure was not a statistically significant predictor of neonatal mortality in the primary multivariable model, despite its theoretical importance. This may suggest that the effect of public health spending depends not only on the amount allocated, but also on the efficiency, timing, targeting, and implementation of such expenditure. Inflation was also not a statistically significant predictor in the multivariable model, although its indirect effects on household purchasing power, healthcare affordability, transport costs, food security, and access to care remain policy-relevant. The time-series diagnostic and sensitivity analyses further showed that some observed associations were influenced by underlying time trends. Several variables were non-stationary at level, while the time-adjusted model changed the direction of the exchange rate association after controlling for year. These findings support the interpretation of the results as ecological associations rather than direct causal effects.

Taken together, the findings suggest that neonatal mortality trends in Nigeria are situated within a broader macroeconomic and health financing context. Exchange rate instability, high reliance on out-of-pocket expenditure, low public health spending, and inflationary pressure may interact with health system weaknesses to influence access to essential maternal and neonatal services. These results provide a basis for further discussion on the need for improved health financing, exchange rate-sensitive procurement planning, financial protection for households, and stronger alignment between economic policy and neonatal survival goals.

Discussion

Principal findings

This study examined the association between government health expenditure, exchange rate instability, out-of-pocket health expenditure, inflation, adjusted GDP per capita growth, and neonatal mortality in Nigeria over a 25-year period. The findings show that neonatal mortality declined between 2000 and 2024, while exchange rate depreciation, out-of-pocket health expenditure, and inflationary pressures increased. Government health expenditure as a percentage of GDP remained low throughout the study period.

In the primary correlation and regression analyses, exchange rate and out-of-pocket health expenditure were significantly associated with neonatal mortality. However, both variables showed inverse associations with neonatal mortality, reflecting the opposing secular trends between declining neonatal mortality and rising macroeconomic pressures. Time-series diagnostics showed that several variables were non-stationary at level, while the time-adjusted sensitivity model changed the direction of the exchange rate association after controlling for year. These findings suggest that the observed

associations should be interpreted cautiously as ecological associations rather than direct causal effects.

Government health expenditure and neonatal mortality

Government health expenditure was not a statistically significant predictor of neonatal mortality in the primary multivariable model. This finding suggests that the relationship between public health spending and neonatal survival may depend not only on the amount allocated, but also on the efficiency, timing, targeting, and implementation of expenditure. In settings where public financial management is weak, increased health expenditure may not translate directly into improved service delivery or better health outcomes.

This finding is consistent with studies showing that the effectiveness of government health expenditure depends on governance quality, absorptive capacity, and the extent to which funds reach frontline services [13, 14]. In Nigeria, public health expenditure has historically remained low relative to need, and even where allocations increase, delays in release, weak procurement systems, and uneven implementation may limit measurable impact on neonatal outcomes [5, 6]. Therefore, increasing government health expenditure is necessary but insufficient unless accompanied by stronger accountability, timely disbursement, and targeted investment in maternal and newborn health services.

This interpretation is also consistent with broader evidence on mortality determinants and health financing, which suggests that health outcomes are shaped by more than health expenditure alone. Public spending must be converted into effective coverage, quality services, and financial protection before measurable mortality improvements can occur [21]. Estimates on domestic government health expenditure for Universal Health Coverage further suggest that countries should aspire to substantially higher levels of public health spending than those observed in this study, reinforcing the need not only for increased allocation but also for efficient and equitable use of resources [22].

Exchange rate instability and neonatal mortality

Exchange rate depreciation was significantly associated with neonatal mortality in the primary regression model, although the direction of association was inverse before adjustment for time. This inverse association should not be interpreted as evidence that exchange rate depreciation improves neonatal survival. Rather, it reflects the opposing secular trends observed during the study period: neonatal mortality declined gradually, while exchange rate depreciation worsened substantially, particularly after 2015.

The time-adjusted sensitivity model provided a more policy-relevant interpretation. After accounting for the general decline in neonatal mortality over time, the direction of association changed, and exchange rate depreciation became positively associated with neonatal mortality. Although this finding must be interpreted cautiously because of increased collinearity between year and exchange rate, it suggests that worsening exchange rates may have adverse implications for neonatal survival.

This finding is biologically and health-system plausible. Depreciation of the local currency can increase the cost of imported medicines, vaccines, antibiotics, oxygen delivery systems, incubator components, laboratory supplies, and other essential neonatal commodities. It can also disrupt procurement planning and reduce the purchasing power of health facilities and households. For neonatal care, where timely access to antibiotics, oxygen, thermal care equipment, resuscitation devices, and other lifesaving supplies is critical, exchange rate instability may therefore affect service availability, affordability, and quality of care.

This interpretation aligns with evidence that exchange rate fluctuations can affect health sector purchasing power, especially in countries that depend heavily on imported medicines, equipment, and donor-supported commodities [4, 15, 16]. Evidence from other settings also suggests that adverse macroeconomic conditions can affect newborn health. For example, analysis of the Greek economic recession showed measurable associations between economic downturns and newborn outcomes, including birth weight, pregnancy duration, and risks of low birth weight and prematurity [23]. Although the Nigerian context differs, this supports the broader argument that macroeconomic shocks can affect perinatal and newborn health through affordability, service access, household welfare, and health system resilience.

Out-of-pocket expenditure and equity concerns

Out-of-pocket health expenditure showed a strong inverse association with neonatal mortality in both correlation and regression analyses. This pattern may reflect the fact that households able to pay for care may access better-quality facilities, timely interventions, and essential newborn services. However, this finding raises an important equity concern. High reliance on out-of-pocket spending means that access to neonatal care may depend heavily on household ability to pay.

In Nigeria, where health insurance coverage remains limited, out-of-pocket expenditure can delay care-seeking, increase catastrophic health expenditure, and exclude poorer households from essential maternal and newborn services. This is particularly important for neonatal conditions such as prematurity, birth asphyxia, and sepsis, where delays in accessing care can rapidly worsen outcomes. Previous studies have shown that socioeconomic disadvantage and limited access to maternal health services are closely linked to neonatal mortality and adverse birth outcomes [7, 17]. Therefore, although higher private spending may be associated with better outcomes among households able to afford care, it may also deepen inequities for poorer families.

Evidence from studies on household financial burden and catastrophic health expenditure further supports this concern. Out-of-pocket payments can impose substantial financial hardship on households, particularly those with low income or recurrent health needs, and may delay or prevent access to essential services [25, 26]. In neonatal care, where timely intervention is often critical, financial barriers may therefore worsen inequities even when aggregate private health expenditure appears statistically associated with improved survival.

These findings support the need to expand financial protection mechanisms, strengthen health insurance coverage, and reduce household dependence on direct payment at the point of care. Universal Health Coverage policies should prioritise pregnant women, newborns, and emergency neonatal services to reduce preventable deaths and improve equity.

Inflation, income growth, and indirect pathways

Inflation was not a statistically significant predictor of neonatal mortality in the multivariable model. However, this does not mean that inflation is unimportant for neonatal health. Inflation can influence neonatal outcomes indirectly by reducing household purchasing power, increasing food and transport costs, raising the cost of medicines, and limiting the ability of families to afford antenatal, delivery, and newborn care. It may also affect health facilities by increasing operating costs and weakening procurement capacity.

Recent Nigerian evidence on global inflation and economic crisis similarly suggests that rising prices and economic instability place pressure on the healthcare system by increasing the costs of care, reducing affordability, and worsening the capacity of households and facilities to respond to health needs [24]. Therefore, although inflation was not a statistically significant direct predictor in the present model, it remains an important indirect pathway through which macroeconomic instability may affect maternal and newborn health.

Adjusted GDP per capita growth was also not statistically significant in the multivariable model, despite showing an association in the bivariate analysis. This suggests that broad national income changes may not translate directly into improved neonatal survival unless economic gains are distributed equitably and accompanied by improvements in health service access, quality, and affordability. Neonatal mortality is therefore influenced not only by national economic performance, but also by how resources are distributed and converted into effective maternal and newborn health services.

Policy implications

The findings of this study highlight the need for stronger alignment between macroeconomic policy and health sector planning. Neonatal survival should not be viewed solely as a clinical or health system issue, but also as a development outcome shaped by fiscal stability, exchange rate management, household purchasing power, and the affordability of essential health services.

This is particularly important because economic adjustment policies and macroeconomic shocks may disproportionately affect vulnerable populations, including women, children, and low-income households [27]. Integrating neonatal survival into fiscal, monetary, and health financing decisions may therefore help reduce the unintended health consequences of economic instability and strengthen progress toward Sustainable Development Goal 3.2.

First, government health expenditure should be increased and better targeted toward high-impact maternal and newborn interventions, including skilled birth attendance, emergency obstetric care, neonatal resuscitation, infection prevention, oxygen access, thermal care, and care for small and sick newborns. Second, public financial management reforms are needed to ensure timely disbursement, transparent procurement, and efficient use of funds. Third, exchange rate-sensitive procurement planning should be introduced for essential neonatal commodities, particularly where these commodities are imported. Fourth, local production of essential medicines, consumables, and appropriate neonatal technologies should be encouraged to reduce vulnerability to exchange rate shocks [18]. Finally, financial protection policies should reduce reliance on out-of-pocket payments and expand access to affordable neonatal care.

Strengths and limitations

This study has several strengths. It focuses on the neonatal period, which is often neglected in studies that aggregate child mortality outcomes. It uses a 25-year national dataset and examines multiple macroeconomic and health financing variables simultaneously. It also includes additional diagnostic and sensitivity analyses, including stationarity testing, autocorrelation assessment, multicollinearity diagnostics, and a time-adjusted model.

However, the study also has limitations. First, it used aggregate national-level data and therefore cannot make individual-level inferences. Second, the number of annual observations was relatively small, limiting the complexity of the statistical models that could be reliably fitted. Third, several variables were non-stationary at level, indicating that some observed associations may be influenced by underlying time trends. Fourth, the time-adjusted model introduced increased collinearity between year and exchange rate, requiring cautious interpretation. Fifth, the analysis did not include all potential determinants of neonatal mortality, such as health workforce density, facility delivery rates, antenatal care coverage, neonatal intensive care availability, immunisation, poverty distribution, insecurity, and regional health system variation.

Despite these limitations, the study provides useful exploratory evidence on the relationship between macroeconomic instability, health financing, and neonatal mortality in Nigeria. The findings support further research using more granular data, including subnational analyses, facility-level indicators, lagged models, and mixed-methods approaches to better understand the pathways linking economic conditions to newborn survival.

Conclusion of the discussion

Overall, this study suggests that neonatal mortality trends in Nigeria are embedded within a broader macroeconomic and health financing context. Exchange rate instability, high out-of-pocket expenditure, low public health spending, and inflationary pressure may interact with health system weaknesses to influence access to essential maternal and neonatal services. While the findings should be interpreted as ecological associations rather than direct causal effects, they underscore the importance of

integrating economic stability, efficient public health financing, financial protection, and neonatal health priorities into national strategies for achieving Sustainable Development Goal 3.2.

Conclusion and recommendations

This study examined the association between government health expenditure, exchange rate instability, out-of-pocket health expenditure, inflation, adjusted GDP per capita growth, and neonatal mortality in Nigeria over a 25-year period. The findings suggest that neonatal mortality trends in Nigeria are shaped within a broader macroeconomic and health financing context. Although neonatal mortality declined between 2000 and 2024, this decline occurred alongside worsening exchange rate instability, persistently high out-of-pocket health expenditure, low government health expenditure as a percentage of GDP, and recurrent inflationary pressure.

In the primary regression model, exchange rate and out-of-pocket health expenditure were significantly associated with neonatal mortality. However, these associations were influenced by underlying time trends and should therefore be interpreted cautiously as ecological associations rather than direct causal effects. The time-adjusted sensitivity analysis suggests that exchange rate depreciation may have adverse implications for neonatal survival after accounting for the secular decline in neonatal mortality, although this finding was limited by increased collinearity between year and exchange rate.

Government health expenditure was not a statistically significant predictor of neonatal mortality in the primary multivariable model. This does not imply that public health spending is unimportant. Rather, it suggests that the effect of government health expenditure depends on the efficiency, timing, targeting, and implementation of spending. Public investment in maternal and neonatal health must therefore go beyond budgetary allocation to include timely disbursement, transparent procurement, effective service delivery, and accountability at frontline levels.

High reliance on out-of-pocket health expenditure remains a major equity concern. Although households able to pay for care may access better-quality services and timely neonatal interventions, poorer households may face delayed care-seeking, catastrophic expenditure, or exclusion from essential services. Reducing neonatal mortality in Nigeria therefore requires not only improved clinical care, but also stronger financial protection for pregnant women, newborns, and vulnerable households.

Based on the findings, the following recommendations are proposed:

1. Improve efficiency and targeting of government health expenditure

Government health expenditure should be increased and more deliberately targeted toward high-impact maternal and neonatal health interventions. Priority areas should include skilled birth attendance, emergency obstetric care, neonatal resuscitation, management of prematurity, oxygen access, infection prevention, newborn sepsis treatment, thermal care, and care for small and sick newborns.

2. Strengthen public financial management in the health sector

Health financing reforms should focus on timely fund release, transparent procurement, efficient resource allocation, and accountability in implementation. Increased expenditure is unlikely to improve neonatal outcomes unless funds reach frontline maternal and newborn health services.

3. Develop exchange rate-sensitive procurement strategies

Given Nigeria's dependence on imported medicines, equipment, and neonatal commodities, procurement planning should account for exchange rate volatility. Strategic reserves, pooled procurement, forward purchasing, and targeted protection for essential neonatal supplies may help reduce the effect of currency instability on service delivery.

4. Promote local production of essential neonatal commodities

Local production of essential medicines, consumables, oxygen-related equipment, neonatal devices, and appropriate health technologies should be strengthened to reduce dependence on foreign exchange and improve affordability of neonatal care.

5. Reduce reliance on out-of-pocket health expenditure

Financial protection mechanisms should be expanded to reduce direct payment at the point of care. Health insurance and publicly funded schemes should prioritise pregnant women, newborns, emergency obstetric care, and neonatal intensive or special care services.

6. Expand Universal Health Coverage for maternal and newborn health

Universal Health Coverage reforms should explicitly include essential maternal and newborn services, especially for poor and rural households. Coverage should not only enrol households but also ensure real access to quality care without financial hardship.

7. Integrate macroeconomic policy and health planning

Economic policy decisions, including exchange rate management, inflation control, and public expenditure planning, should be assessed for their potential downstream effects on healthcare affordability, commodity availability, and neonatal survival.

8. Encourage further research using more granular data

Future studies should use subnational, household-level, and facility-level data to better examine the pathways linking macroeconomic instability to neonatal outcomes. Further research should also consider lagged effects, regional variation, health workforce availability, service coverage, poverty distribution, insecurity, and neonatal care capacity.

In conclusion, this study affirms that neonatal mortality in Nigeria cannot be separated from the wider economic and health financing environment. Achieving Sustainable Development Goal 3.2 will require coordinated action that combines efficient public health financing, exchange rate-sensitive health sector planning, reduced household financial burden, local production of essential neonatal commodities, and sustained investment in quality maternal and newborn care.

Abbreviations

ADF

Augmented Dickey-Fuller

AP_GDPPC

adjusted GDP per capita growth

CPI

Consumer Price Index

EXR

exchange rate

GDP

gross domestic product

GHE_GDP

government health expenditure as a percentage of gross domestic product

INFR_CPI

inflation measured by the Consumer Price Index

IRB

institutional review board

LMICs

low- and middle-income countries

NMR

neonatal mortality rate

OPExp

out-of-pocket health expenditure

SDG

Sustainable Development Goal

UHC

Universal Health Coverage

USD

United States dollar

WDI

World Development Indicators.

Declarations

Ethics approval and consent to participate

This study used only publicly available, aggregate, de-identified country-level secondary data from the World Development Indicators database. It did not involve human participants, human biological material, identifiable personal data, clinical records, or any intervention. The study was therefore not submitted to a local ethics committee or institutional review board, and ethics approval was deemed unnecessary. No ethics reference number is applicable. Consent to participate was not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

OBE conceptualised the study, contributed to the study design, interpretation of findings, manuscript drafting, and critical revision of the manuscript. EE contributed to data interpretation, manuscript drafting, and revision. CIA contributed to the economic framing, data analysis, interpretation of macroeconomic variables, and revision of the manuscript. OE contributed to literature review, manuscript drafting, and revision. OO contributed to manuscript review, policy interpretation, and revision. EC contributed to manuscript review, health systems interpretation, and revision. UO contributed to manuscript review, policy interpretation, and revision. All authors read and approved the final manuscript

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Data Availability

The datasets analysed during the current study are publicly available from the World Development Indicators database. The data used for the analysis are available from the corresponding author on The authors acknowledge the World Bank for making the World Development Indicators database publicly accessible. The authors also acknowledge all contributors whose scholarly work informed the conceptual and empirical framing of this study.request.

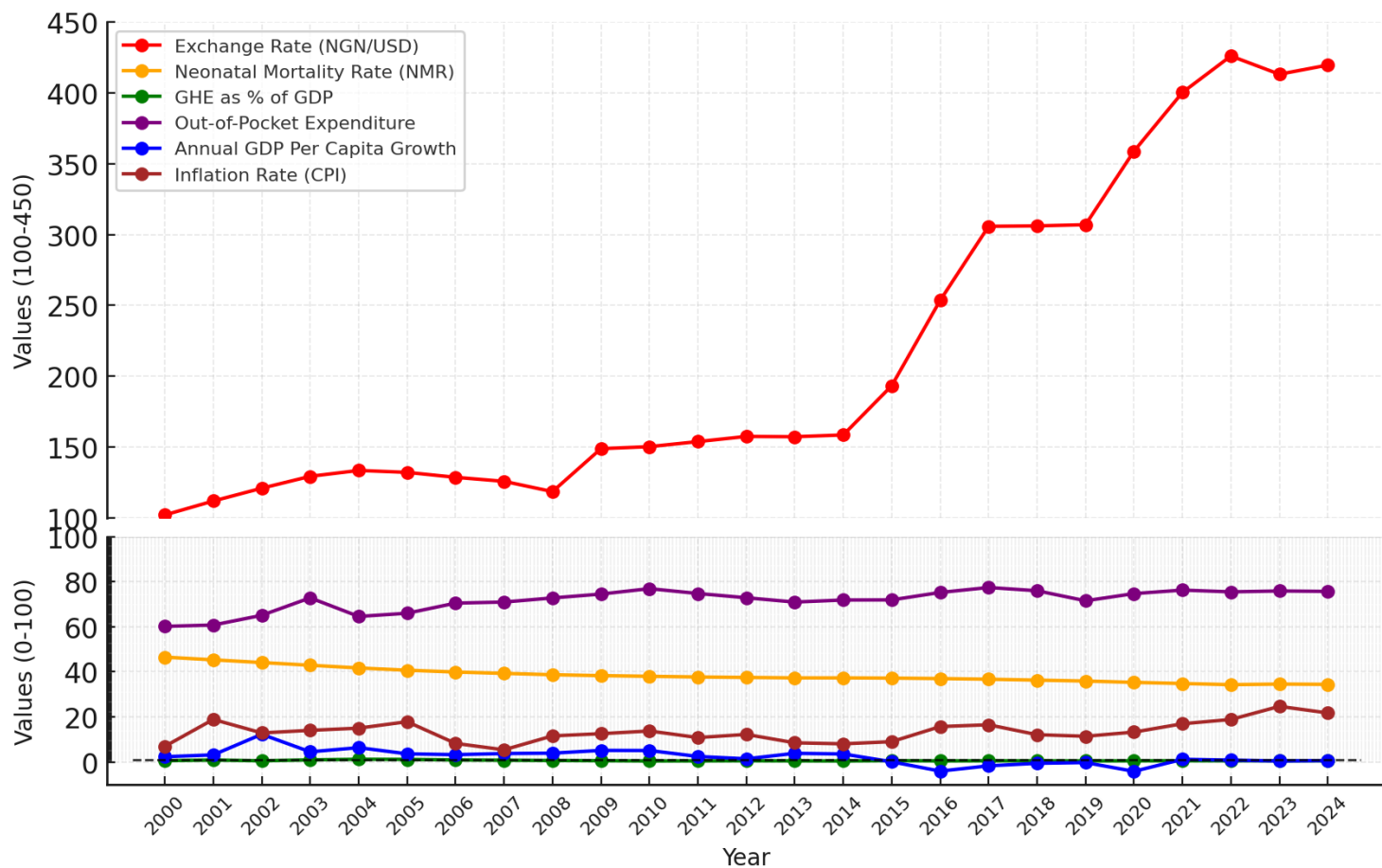
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Figures

Trends of Key Economic and Health Indicators in Nigeria (2000–2024)



Data Source: World Development Indicators (WDI) Database, 2024

Figure 1

Trends of Key Economic and Health Indicators in Nigeria, 2000–2024

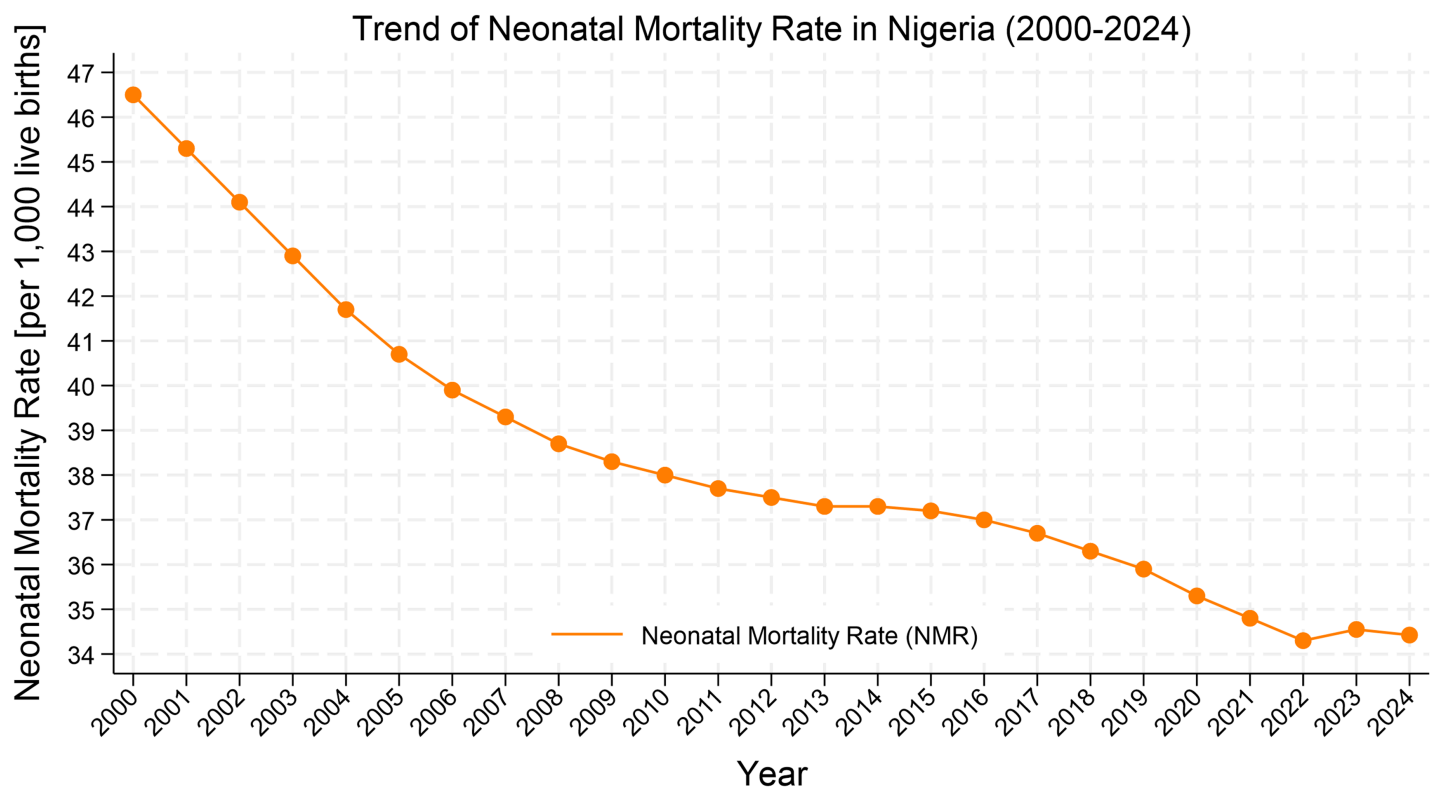


Figure 2

Trend of Neonatal Mortality Rate in Nigeria, 2000–2024

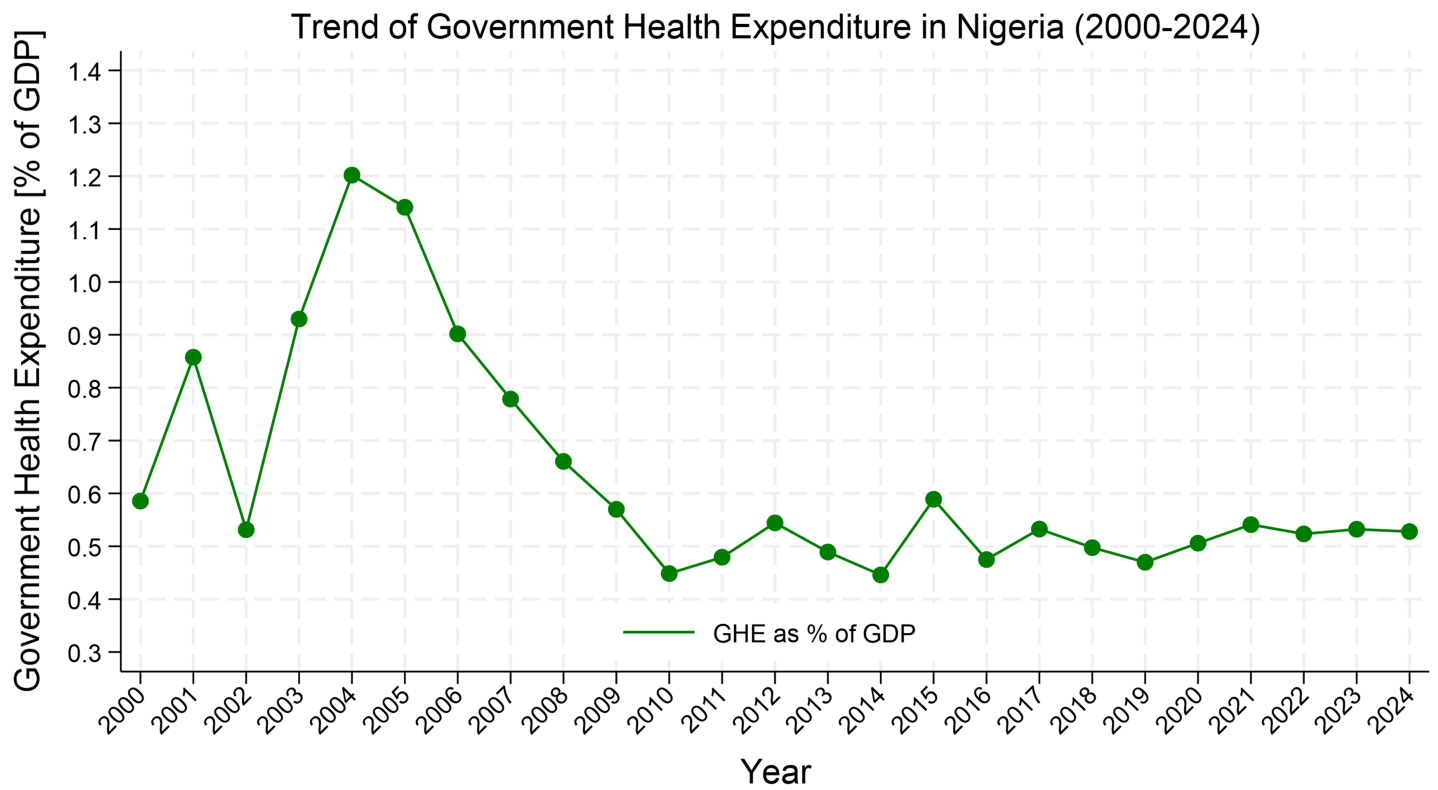


Figure 3

Trend of Government Health Expenditure as a Percentage of GDP in Nigeria, 2000–2024

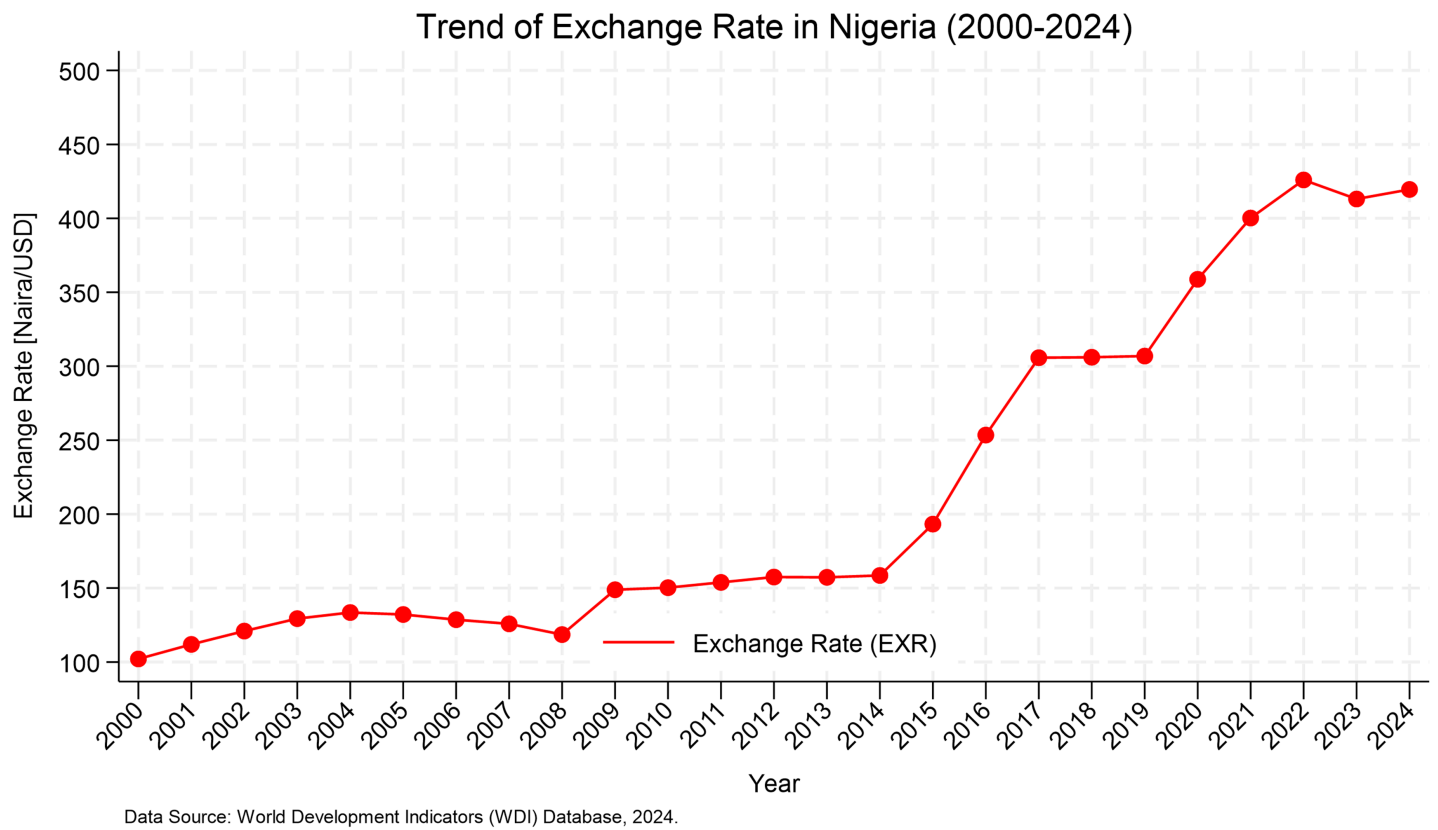


Figure 4

Trend of Exchange Rate in Nigeria, 2000–2024

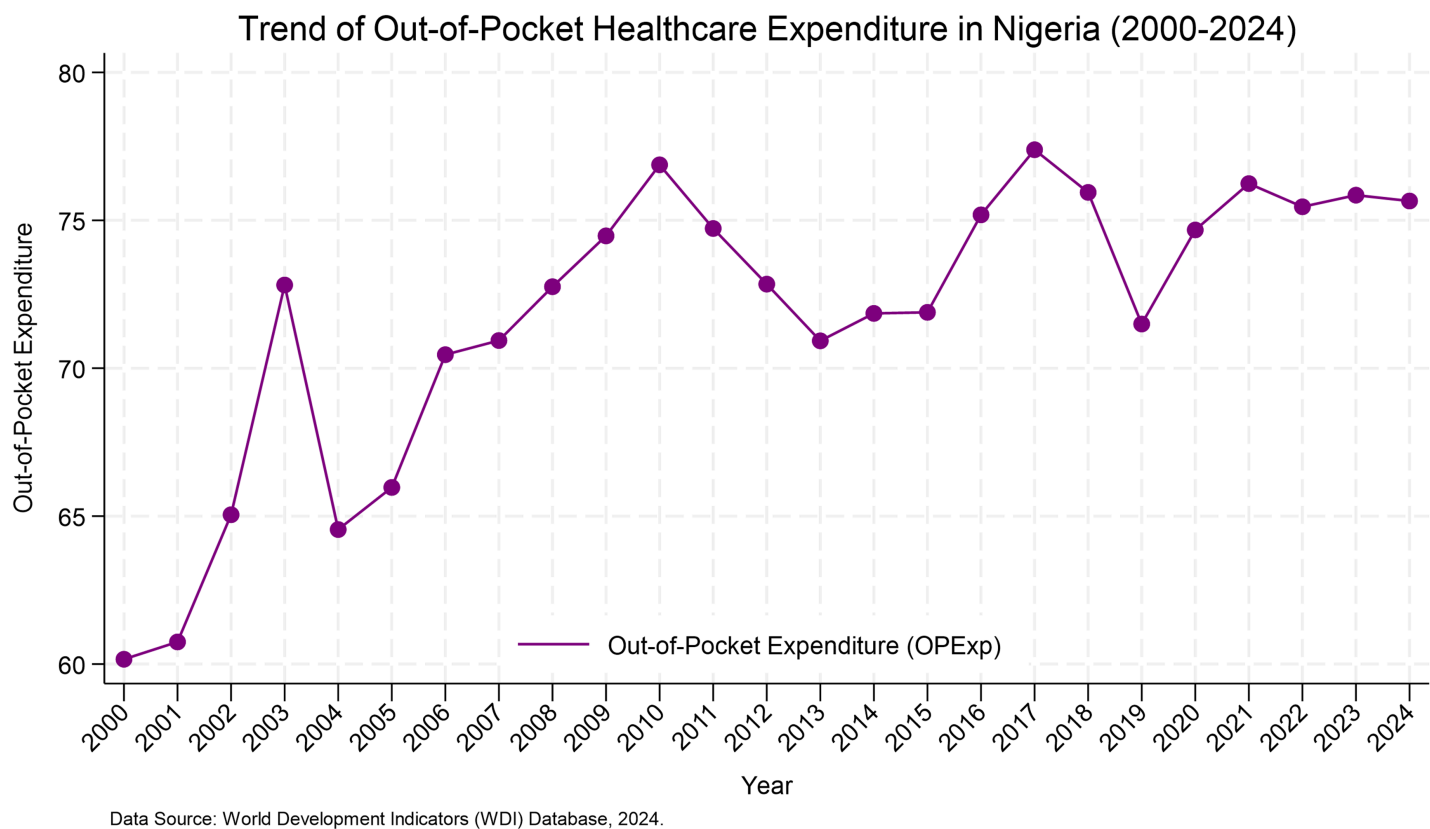


Figure 5

Trend of Out-of-Pocket Health Expenditure in Nigeria, 2000–2024

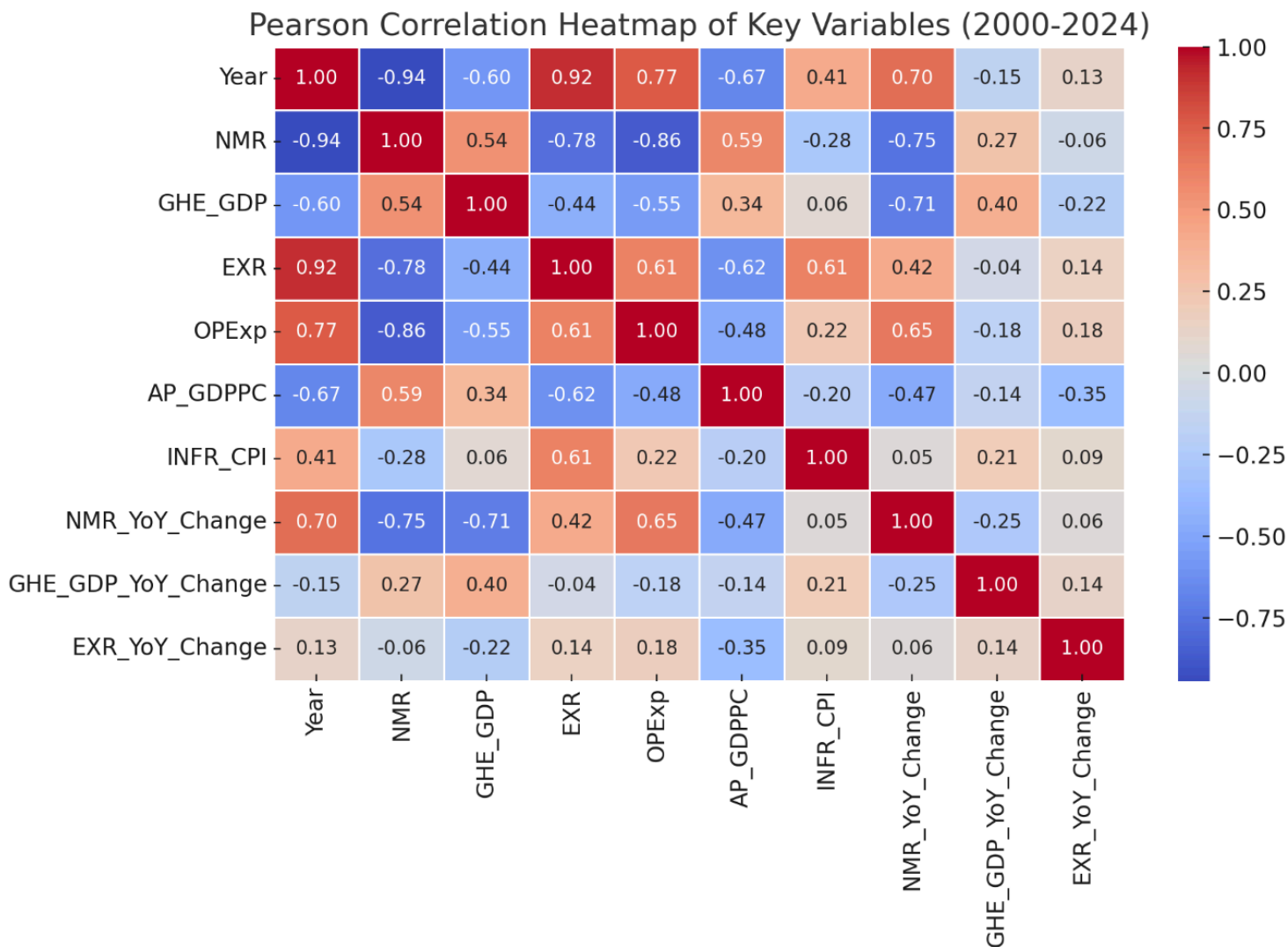


Figure 6

Pearson Correlation Matrix/Heatmap for Neonatal Mortality and Selected Macroeconomic Variables, 2000–2024