British Journal of Global Ecology and Sustainable Development
Volume-20, Sep., 2023
ISSN (E): 2754-9291

MODELING OF NEONATAL MORTALITY RATES IN NIGERIA: AN INSIGHT TO THE UNITED NATIONS SUSTAINABLE DEVELOPMENT GOAL

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Abstract
The third Sustainable Development Goal (SDG) explicitly states that it is a priority to reduce neonatal mortality rate to 12 deaths per 1,000 live births due to its importance to population dynamics. Comparing Nigeria to other Sub-Saharan African countries, the neonatal mortality rate remains unacceptably high. Nigeria has the highest rate of neonatal deaths in all of Africa. The objective of this research is to model and generate projections of NMR in Nigeria using a time series approach in order to ascertain if Nigeria will achieve the SDG target of NMR by 2030. Using data from UN-IGME 2022, STATA version 12 was used for this study's data analysis. According to the forecasts, Nigeria's Neonatal Mortality Rate (NMR) would drop to about 27 deaths per 1,000 live births by 2030. Even while this would represent a significant improvement over earlier rates, the overall NMR aim would still be greatly missed. The Annual Reduction Rate (ARR) of NMR in Nigeria would need to be significantly raised in order to reach the stated reduction in NMR mentioned in the Sustainable Development Goal of the United Nations by the year 2030.

Keywords: Neonatal death, Mortality, Rates, Time series, models.

1.0 Introduction

Neonatal death, or the death of a newborn within the first 28 days of life, is defined as the death of a child under the age of one month. According to the 2014 UNICEF Annual Report, perinatal mortality remains a severe hazard to global public health, particularly in poor countries in Sub-Saharan Africa. Every day, over 6,700 newborn deaths occur, with approximately one-third of all neonatal deaths occurring during the first day of life and almost three-quarters occurring within the first week (UNICEF, 2020). In 2019, 2.4 million children died in their first month of birth throughout the world. In 2013, there were an estimated 6.3 million child deaths globally. 44% of these fatalities occurred during the neonatal phase (the first 28 days of life), and 75% occurred throughout the neonatal period. Nigerian Neonatal Mortality Rate (NMR) dropped by 20.4% from 49 fatalities per 1000 live infants in 1990 to 39 in 2011 (Ochaga *et al.,* 2014), 37 in 2013, and 34 in 2015. Different chances of survival begin at very young ages.

Sub-Saharan Africa had the highest NMR in the world, at 27 (24-32) fatalities per 1,000 live births, whereas the global NMR in 2021 was 18 (17-19) deaths per 1,000 live births. Child born in Australia and New Zealand, which has the lowest regional NMR in the world, is 11 times more likely to die in the first month of life than a child born in Sub-Saharan Africa. Central Africa follows Sub-Saharan Africa. Notably, when split down by sub-region, the Southern Asia sub-region leads the Central and Southern Asia region's high NMR, with 22 (20-25) fatalities per 1,000 new births in 2021, compared to Central Asia's 10 (6-13) deaths per 1,000 live births. A high-income child has a one-tenth reduced likelihood of dying in the first month of life than a low-income youngster. In 2021, NMRs varied from less than one death per 1,000 live births in the lowest mortality nation to roughly 53 times greater for a child born in the highest mortality country who died within the first 28 days of life. Nigeria's neonatal death rate has remained disconcertingly high when compared to other Sub-Saharan African countries. Nigeria has the highest rate of neonatal mortality in Africa (Onazi S. O. *et. al.*, 2021, Usman A. *et.al.* 2019).

The awareness that reliable and accurate NMR projections are both required and vital for the implementation of appropriate intervention programs and preventative measures for NMR reduction in Nigeria is what prompted the researchers to conduct this study in the first place. This will assist Nigeria in meeting the SDG objective of 2030. The purpose of this research is to model and forecast NMR in Nigeria using a time series approach in order to evaluate if Nigeria will meet the SDG target of NMR by 2030. The Nigerian federal government will be able to utilize this study to guide policy adjustments and policy implementation as it strives to fulfill the SDGs objective by 2030. It will also assist people active in the health industry and add to the organized body of knowledge (United Nations Sustainable Development Goals (SDG), (2015)).

2.0 Methodology

Nigeria is the major topic of this research, which includes the North Central, North East, North West, South-East, South-South, and South-West geopolitical zones, as well as 36 states and the Federal Capital Territory (FCT). This study relied on World Bank data and estimates from the United Nations Inter-Agency Group for Childhood Mortality Estimation (UN-IGME, 2022). The data in this study was analyzed using STATA software, version 12.

3.0 Results and Discussions

Table 1 presents the data, which is the NMR estimations for Nigeria, precisely 1972 to 2021.

ISSN (E): 2754-9291

Table 1: Estimate of NMR and IMR in Nigeria (1972 - 2021).

S/NO	YEAR	NMR	S/NO	YEAR	NMR
1.	1972	63.72	28	1999	47.37
2.	1973	62.39	29	2000	46.43
3.	1974	61.02	30	2001	45.35
4.	1975	59.66	31	2002	44.18
5.	1976	58.30	32	2003	43.04
6.	1977	57.02	33	2004	41.91
7.	1978	55.78	34	2005	40.93
8.	1979	54.55	35	2006	40.07
9.	1980	53.44	36	2007	39.39
10.	1981	52.36	37	2008	38.90
11.	1982	51.48	38	2009	38.47
12.	1983	50.79	39	2010	38.10
13.	1984	50.22	40	2011	37.80
14.	1985	49.81	41	2012	37.59
15.	1986	49.55	42	2013	37.43
16.	1987	49.51	43	2014	37.37
17.	1988	49.59	44	2015	37.22
18.	1989	49.67	45	2016	37.02
19.	1990	49.77	46	2017	36.74
20.	1991	49.82	47	2018	36.39
21.	1992	49.88	48	2019	35.94
22.	1993	49.88	49	2020	35.48
23.	1994	49.86	50	2021	34.92
24.	1995	49.68			
25.	1996	49.34			
26.	1997	48.83			
27.	1998	48.17			

Source: UN-IGME 2022.

Time series analysis and the Auto Regressive Integrated Moving Average (ARIMA) approach, created by Box and Jenkins (1976) were used to make the forecast. The absence of stationary in the data in Table 1 was investigated.

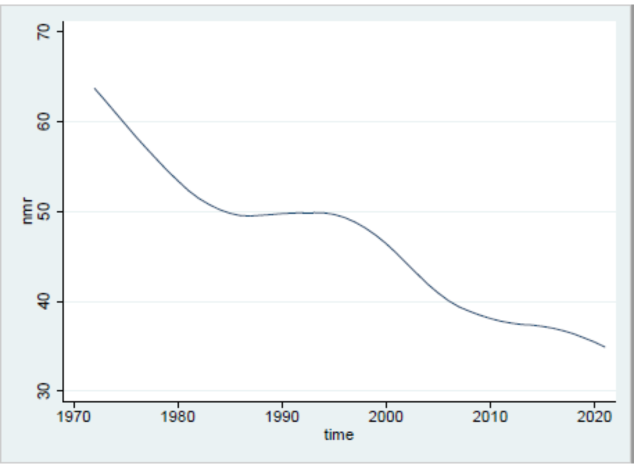

Figure 1: The Time Series plot of NMR in Nigeria from 1972 to 2021

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Figure 1 depicts a time series plot of NMR in Nigeria from 1972 to 2021. A visual examination of the time series plot in Figure 1 reveals that the series is non-stationary since it drops at a constant pace and displays patterns and seasonality. The correlogram, which depicts autocorrelation and partial autocorrelation function plots, demonstrated a high significant ACF for time delays that gradually diminish in magnitude but do not decay to zero (slow decay). As seen in Figure 2, the ACF follows a pattern similar to that of a non-stationary time series.

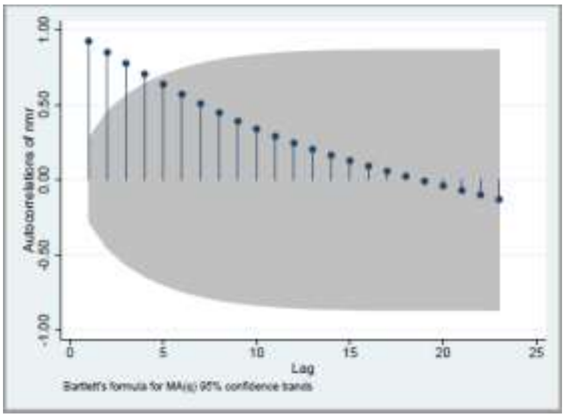

Figure 2: ACF Exhibiting Pattern

The time series plot in Figure 1 shows that the series was non-stationary, as determined by the Augmented Dickey Fuller test (Dickey and Fuller, 1979). The series is transformed into a stationary series by using the third difference from the time series data and generating the time plot illustrated in Figure 3.

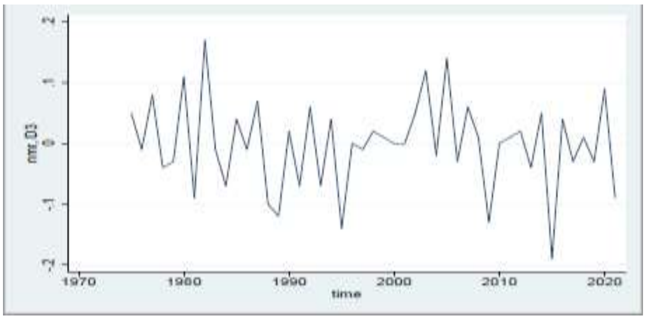

Figure 3: Visual Inspection of Time Plot

A visual examination of the time plot of the differenced series in Figure 3 shows that it seems stable and devoid of trend, implying that the mean and variance are now constant through time. For stationarity, we use the unit root test. If the series has a unit root, it is non-stationary because it fails the primary condition of time series modeling, which is a zero mean and constant variance (Dickey and Fuller, 1979).
To test for stationary in the time series data, we adopt the following hypothesis:
H_0: the series contains a unit root
H_1: there is no unit root in the series

We shall reject the null hypothesis and conclude that the alternative hypothesis is true if the p-value is less than the significance level 0.05.

Table 2. Augmented Dickey-Fuller Tests.

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z (t)	-9.628	-4.187	-3.516	-3.190

MacKinnon approximate p-value for Z (t) = 0.0000

We reject the null hypothesis since the estimated p-value = 0.000 in Table 2 is less than 0.01, and we infer that the alternative hypothesis H1 is true, meaning that the series is stationary after calculating the third difference (d = 3). Plots of the autocorrelation and partial autocorrelation functions at several time delays provide additional evidence that the series is stable. These plots are often used to identify plausible models. The autocorrelation plot and partial autocorrelation plot for the differenced NMR are shown in Figures 4 and 5.

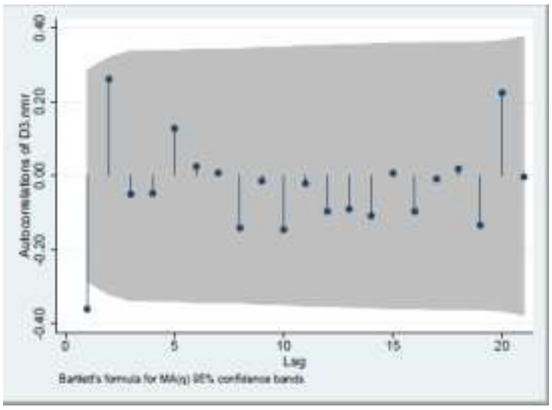

Figure 4: MA (1) model

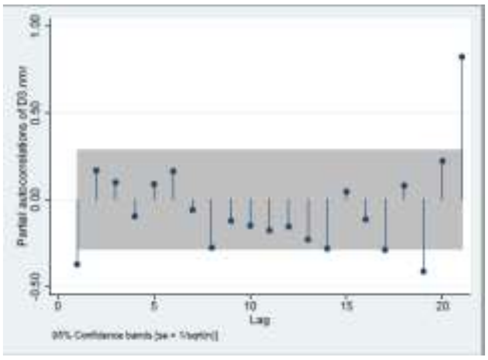

Figure 5: ARIMA models

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British Journal of Global Ecology and Sustainable Development
Volume-20, Sep., 2023
ISSN (E): 2754-9291

Figure 4 shows that just one major time lag error bound, which signals an MA (1) model, surpasses the significant threshold. Other time delays are all within acceptable limits. It is obvious that an AR (3) model exists since three significant time delays exceed the considerable threshold, which is the error bound. Other time delays are all within acceptable limits. (As illustrated in figure 5, the order of the AR component might be 1, 2, or 3. According to the study, three ARIMA models have been found as viable candidates: ARIMA (1, 3, 1), ARIMA (2, 3, 1), and ARIMA (3, 3, 1).

In order to identify the best ARIMA model to fit the NMR series, the log likelihood value, the Akaike's Information Criterion (AIC), and the Bayesian Information Criterion (BIC) are calculated and compared for a set of ARIMA models chosen based on the principle of parsimony and recognizable patterns of the ACF and PACF of the time series data.

Table 3: ARIMA models for NMR

Criteria	Model			Best model
	Model A ARIMA (1,3,1)	Model B ARIMA (2,3,1)	Model C ARIMA (3,3,1)	
AR & MA	2/2	2/2	2/2	=
Log Likelihood	59.99113	60.38538	60.64473	A
Akaike	-113.9823	-112.7708	-111.2895	A
Bayesian	-108.4318	-105.3702	-102.0387	A
Best Model				A

When the three alternative models are compared, it becomes clear that ARIMA (1,3,1) is the best model for NMR in Nigeria since it has the lowest AIC, BIC, and LOG Likelihood values. If the only thing left after fitting the model is white noise residuals, the model is correct. In this case, the residuals must have a constant variance and be uncorrelated. Table 4 shows the results of the Portmanteau test for white noise. This shows that the residuals are white noise, and the residual plots in figure 6 show that there is no trend, allowing us to forecast using the selected model.

Table 4: Portmanteau test for white noise

Portmanteau (Q) statistic =	18.8325
Prob > chi2(21) =	0.5959

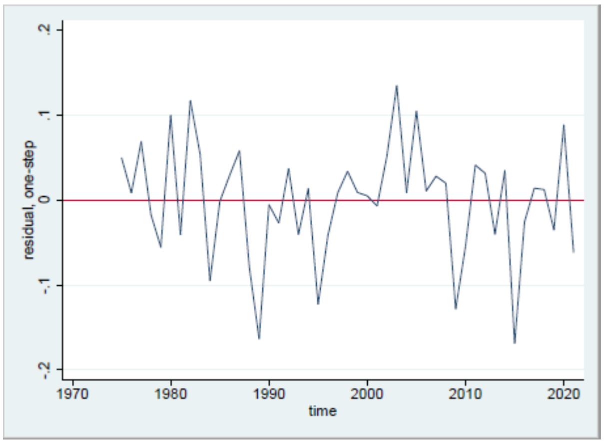

Figure 6: Residual plots

After fitting the ARIMA (1, 3, 1) model to forecast for the future values of NMR up to year 2030, the following forecast estimates in Table 5 are obtained.

Table 5: Forecast of NMR in Nigeria.

Year	NMR	Forecast	Year	NMR	Forecast
2010	38.1	38.14388	2021	34.92	34.97625
2011	37.8	37.77948	2022		34.29894
2012	37.59	37.5691	2023		33.59414
2013	37.43	37.46336	2024		32.8188
2014	37.37	37.3353	2025		31.96524
2015	37.22	37.38919	2026		31.03793
2016	37.02	37.05011	2027		30.03427
2017	36.74	36.73948	2028		28.95578
2018	36.39	36.3976	2029		27.80156
2019	35.94	35.96235	2030		26.57214
2020	35.48	35.40211			

According to the estimates, the annual reduction rate (ARR) will be 1.24% by 2030, representing a 24% drop in the incidence of NMR. We were able to compare the first ten projected values (2017-2021) of NMR in Nigeria with the observed values after fitting the time series data using the ARIMA (1, 3, 1) model. This allowed us to establish the forecast error distribution, which is given in Table 6.

Table 6: Distribution of the forecast error of NMR in Nigeria

Year	Observed value	Forecast	Forecast error
2017	36.74	36.74	0
2018	36.39	36.39	-0.01
2019	35.94	35.96	-0.02
2020	35.48	35.40	0.08
2021	34.92	34.98	-0.06

Because the forecast errors are so small, we also examine the plot of the predicted NMR versus NMR and find that their movement patterns are identical, which makes the forecast plausible.

4.0 Conclusion

Based on the projected estimate, Nigeria is expected to reduce its Neonatal Mortality Rate (NMR) to approximately 27 deaths per 1,000 live births by 2030. While this represents progress compared to previous rates, it remains notably below the overarching NMR target. To reach the reduction goal for NMR outlined in the United

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Nations' Sustainable Development Goal by 2030, there would need to for a substantial increase in the Annual Reduction Rate (ARR) of NMR in Nigeria.

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