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Forecasting Maternal Deaths in Nigeria Using the Arima Model

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***Abstract* - Nigeria is among the African countries with very high maternal mortality ratios and there is need to utilize early surveillance tools to understand the future trends of maternal deaths so as to put in place preventive and control measures. In this research article, the ARIMA technique was applied to analyze maternal deaths in Nigeria. The employed data covers the period 2000-2017 and the out-of-sample period ranges over the period 2018-2022. The residuals and forecast evaluation criteria (Error, MSE and MAE) of the applied model indicate that the model is stable in forecasting maternal deaths in Nigeria. The results of the study suggest that the Nigerian government is ought to allocate more human and financial resources towards maternal and child health to address gaps which exist in the rural and some of the urban healthcare facilities and continuous health education among communities to promote institutional deliveries on the other hand discouraging home deliveries.**

Keywords: ANN, forecasting, maternal mortality.

I. INTRODUCTION

Maternal mortality refers to any loss of woman's life resulting from pregnancy complications or death within 42 days post-delivery regardless of the period or site of the pregnancy resulting from tissues that are associated or propagated by the management of the pregnancy but not from accident or incidental factors (Nyoni & Nyoni, 2019; Ibrahim, 2016). Maternal mortality in Nigeria is due to several factors which include medical, social, economic and cultural factors. These factors have a direct bearing on maternal mortality (Muoghalu, 2016).The majority of maternal deaths in Nigeria's rural areas are caused by poverty, low level of education and harmful cultural practices among others (Ibrahim, 2016). Nigeria's maternal mortality ratio was estimated to be 948 maternal deaths per 100 000 live births and the country contributes about 10% of the global deaths (Ikeako et al, 2017; NPC, 2009; Adamu et al, 2003). Most maternal deaths are avoidable or preventable. Obstetric causes of maternal deaths include obstetric haemorrhage, hypertensive disorders in pregnancy and prolonged or obstructed labour (Nyoni, 2019; Ikeako et al, 2017; Lanre-Abass, 2017; Omo-aghoja, 2010).

Maternal mortality in Nigeria remains high despite measures which were implemented by the government. The main cause of these deaths is the poor management of obstetric complications (Aikpitanyi et al, 2019; Sageer et al, 2019; Ntiomo et al, 2018; Okonofua et al, 2017; Hofman & Mohammed, 2014). The Nigeria Ministry of Health in 2013 recommended that all maternity health facilities should carry out maternal audits, surveillance and response using the technical guidance document. This was anticipated to help identify causes of maternal deaths and then institute corrective measures (Okonofua et al, 2017; FMOH, 2015; Knight et al, 2013).

In this paper we aim to model and forecast the maternal mortality ratio (MMR) in Nigeria using the Multilayer Perceptron (MLP) neural network. The model is composed of 3 layers of neurons which are the input, hidden and output layers which are connected by acyclic links called connection weights. It is a feed forward neural network framework (Nyoni et al, 2020; Zhao et al, 2020; Kaushik & Sahi, 2018; Yan et al, 2018; Zhang, 2003). The findings of this piece of work are expected to reveal the future trends of maternal mortality ratio (MMR) in Nigeria. This will act as an early surveillance tool that will guide policy makers in the development of policies and plans in order to prevent maternal deaths in the country.

II. LITERATURE REVIEW

Nyoni & Nyoni (2020) modelled and forecasted maternal deaths at Chitungwiza Central Hospital in Zimbabwe using artificial neural networks. The study utilized monthly maternal deaths covering the period January 2012 to December 2019 and the out of sample forecast covered the period January 2020 to December 2021.The ANN (12,12,1) model predicted an upward trajectory of

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maternal deaths over the out of sample period. In another similar study, Nyoni (2019) modelled and forecasted maternal deaths and maternal mortality ratio (MMR) for Zimbabwe using Box-Jenkins ARIMA models and the study utilized annual time series data for both maternal deaths and MMR. The optimal models based on AIC were ARIMA (0, 2, 2) and (2, 2, 0) respectively. The results of the study revealed that both maternal deaths and MMR are likely to increase over the period 2016-2025. Okereke et al (2019) designed a study to assess stakeholders' perceptions about the performance of community health workers and the feasibility of introducing and using community midwifery to address the high maternal and newborn mortality within the Nigerian healthcare system. The study was undertaken in two human resources for health (HRH) project focal states (Bauchi and Cross River States) in Nigeria, utilizing a qualitative research design. Interviews were conducted with 44 purposively selected key informants. Key informants were selected based on their knowledge and experience working with different cadres of frontline health workers at primary healthcare level. The qualitative data were audio-recorded, transcribed and then thematically analyzed. The authors concluded that applying community midwifery within the Nigerian healthcare system has the potential to increase the availability of skilled care during pregnancy, at birth and within postpartum periods, especially in rural communities. However, there needs to be broader stakeholder engagement, more awareness creation and the careful consideration of modalities for introducing and strengthening community midwifery training and practice within the Nigerian health system as well as within the health systems of other developing countries. In another study, Meh et al (2019) assessed differences in the levels and determinants of maternal mortality in women of childbearing age (15–49years) in the North and South of Nigeria. The Nigeria Demographic and Health Surveys (2008 and 2013) were used. The association between maternal mortality (outcome) and relevant sociocultural, economic and health factors was tested using multivariable logistic regression in a sample of 51,492 living or deceased women who had given birth. The study results indicated that there were variations in the levels of maternal mortality between the two regions. Maternal mortality was more pronounced in the North and increased in 2013 compared to 2008. For the South, the levels slightly decreased. Media exposure and education were associated with maternal mortality in the North while contraceptive method, residence type and wealth index were associated with maternal death in the South. In both regions, age and community wealth were significantly associated with maternal mortality. Aikpitanyi et al (2019) did a research to identify through the MPDSR process, the medical causes and contributory factors of maternal mortality, and to elucidate the policy response that took place after the dissemination of the results. The study was conducted at the Central Hospital, Benin between October 1, 2017, and May 31, 2019. The researchers first developed a strategic plan with the objective to reduce maternal mortality by 50% in the hospital in two years. An MPDSR committee was established and the members and all staff of the Maternity Department of the hospital were trained to use the nationally approved protocol. All consecutive cases of maternal deaths in the hospital were then reviewed using the MPDSR protocol. The results were submitted to the hospital Management and its supporting agencies for administrative action to correct the identified deficiencies. The authors concluded that the results of MPDSR, when acted upon by hospital managers and policymakers can lead to an improvement in quality of care and a consequent decline in maternal mortality ratio in referral hospitals. Olonade et al (2019) focused on cogent issues affecting maternal mortality by unpacking its precipitating factors and examining the maternal health care system in Nigeria. Contemporary works of literature were reviewed, and the functionalist perspective served as a theoretical guide to examine the interrelated functions of several sectors of the society to the outcome of maternal mortality. It was noted that apart from the medical related causes (direct and indirect) of maternal mortality, certain socio-cultural and socioeconomic factors influence the outcome of pregnancy. Also, a poor health care system, which is a consequent of weak social structure, is a contributing factor.

III. METHODODOLOGY

The ARIMA technique

The first step towards model selection is to difference the series in order to achieve stationarity. Once this process is over, the researcher will then examine the correlogram in order to decide on the appropriate orders of the AR and MA components. It is important to highlight the fact that this procedure (of choosing the AR and MA components) is biased towards the use of personal judgement because there are no clear – cut rules on how to decide on the appropriate AR and MA components. Therefore, experience plays a pivotal role in this regard. The next step is the estimation of the tentative model, after which diagnostic testing shall follow. Diagnostic checking is usually done by generating the set of residuals and testing whether they satisfy the characteristics of a white noise process. If not, there would be need for model re – specification and repetition of the same process; this time from the second stage. The process may go on and on until an appropriate model is identified (Nyoni, 2018c). This approach will be used to analyze N, the maternal mortality ratio series under consideration.

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Data Collection

This study is based on annual observations (that is, from 2000 – 2017) of the Nigerian maternal mortality ratios (MMR) (used as the proxy for maternal deaths) [denoted as N]. According to the World Bank (2021), maternal mortality ratio is the number of women who die from pregnancy-related causes while pregnant or within 42 days of pregnancy termination per 100 000 live births. Out-of-sample forecasts will cover the period 2018 – 2022. All the data was gathered from the World Bank online database.

Evaluation of ARIMA models (with a constant)

Guided by stationarity tests (not here presented), it was discovered that the N series is an I (2) variable. Therefore, the following evaluations were carried out in order to select to final model.

Table 1: Evaluation of ARIMA Models (without a constant)

Model	AIC	U	ME	RMSE	MAPE
ARIMA (1, 2, 1)	129.2073	0.4643	-0.50903	11.38	0.81047
ARIMA (1, 2, 0)	127.2841	0.46381	-0.50498	11.401	0.80446
ARIMA (0, 2, 1)	127.2848	0.46373	-0.50366	11.401	0.80412
ARIMA (2, 2, 0)	128.745	0.45818	-0.37476	11.236	0.82275

A model with a lower AIC value is better than the one with a higher AIC value (Nyoni, 2018b) Similarly, the U statistic can be used to find a better model in the sense that it must lie between 0 and 1, of which the closer it is to 0, the better the forecast method (Nyoni, 2018a). In this research paper, only the AIC is used to select the optimal model. Therefore, the ARIMA (1, 2, 0) model is finally chosen.

Stability Tests

Correlogram of the Residuals of the ARIMA (1, 2, 0) Model

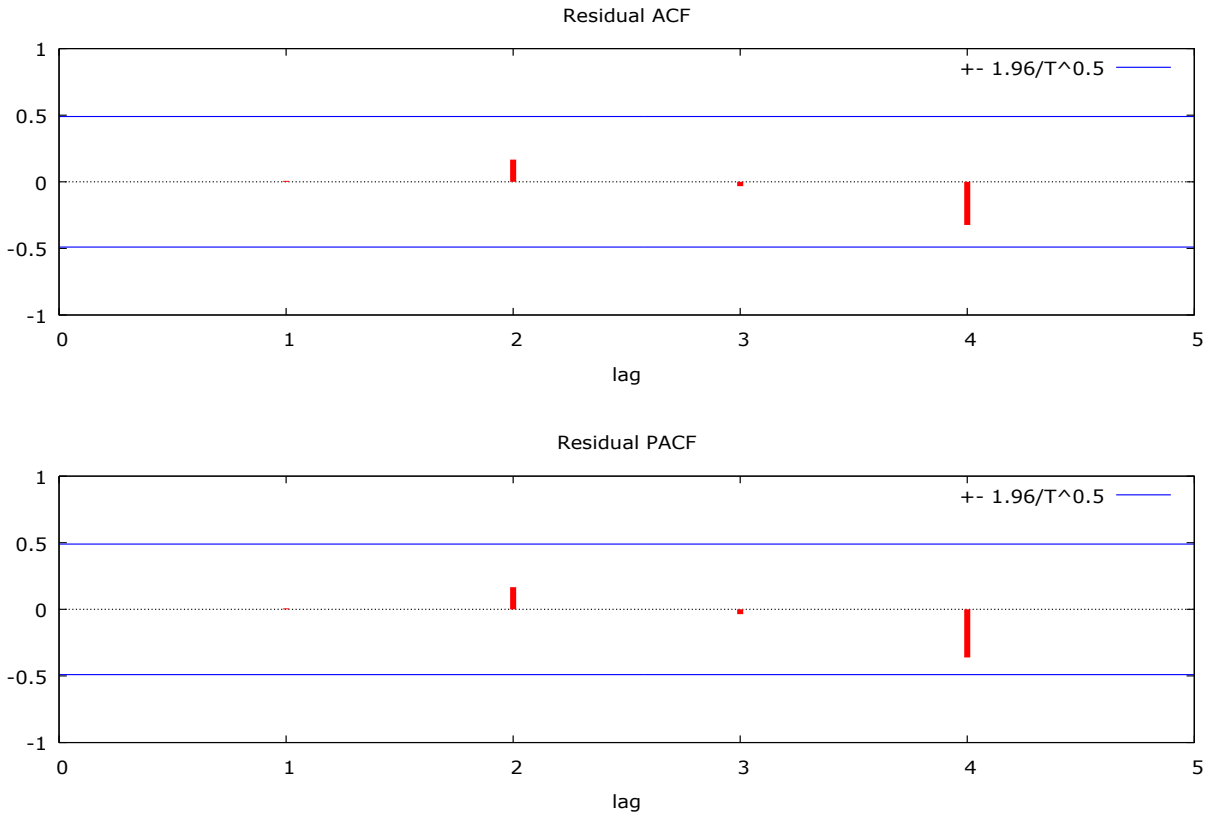

Figure 1: Correlogram of the Residuals

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Figure 1 indicates that the estimated optimal model is adequate since ACF and PACF lags are quite short and within the bands. This implies that the "no autocorrelation" assumption is not violated in this piece of work.

Normality Test of the Residuals of the ARIMA (1, 2, 0) Model

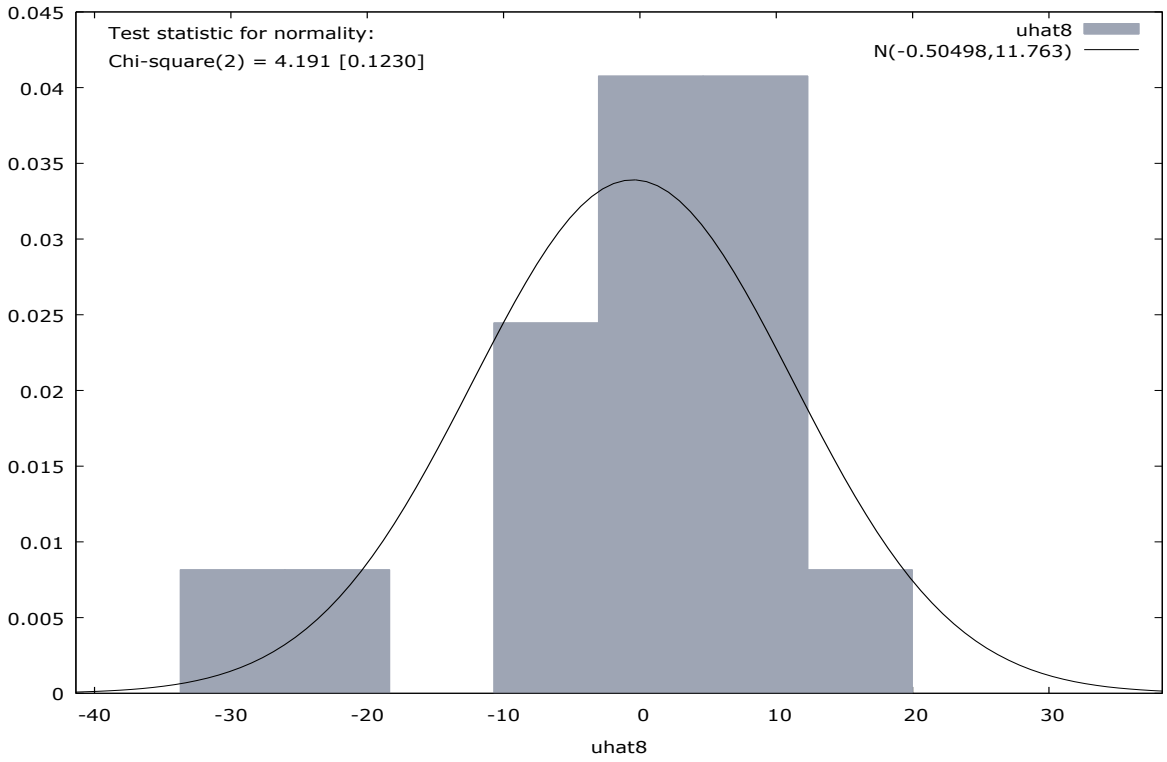

Figure 2: Normality Test

Since the probability value of the chi-square statistic is insignificant, we therefore reject the null hypothesis and conclude that the residuals of the ARIMA (1, 2, 0) model are normally distributed.

IV. FINDINGS

Table 2: Main Results

ARIMA (1, 2, 0) Model:				
Variable	Coefficient	Standard Error	z	p-value
β_1	-0.013289	0.25022	-0.5311	0.9576

Table 2 shows the main results of the ARIMA (1, 2, 0) model.

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Forecast Graph

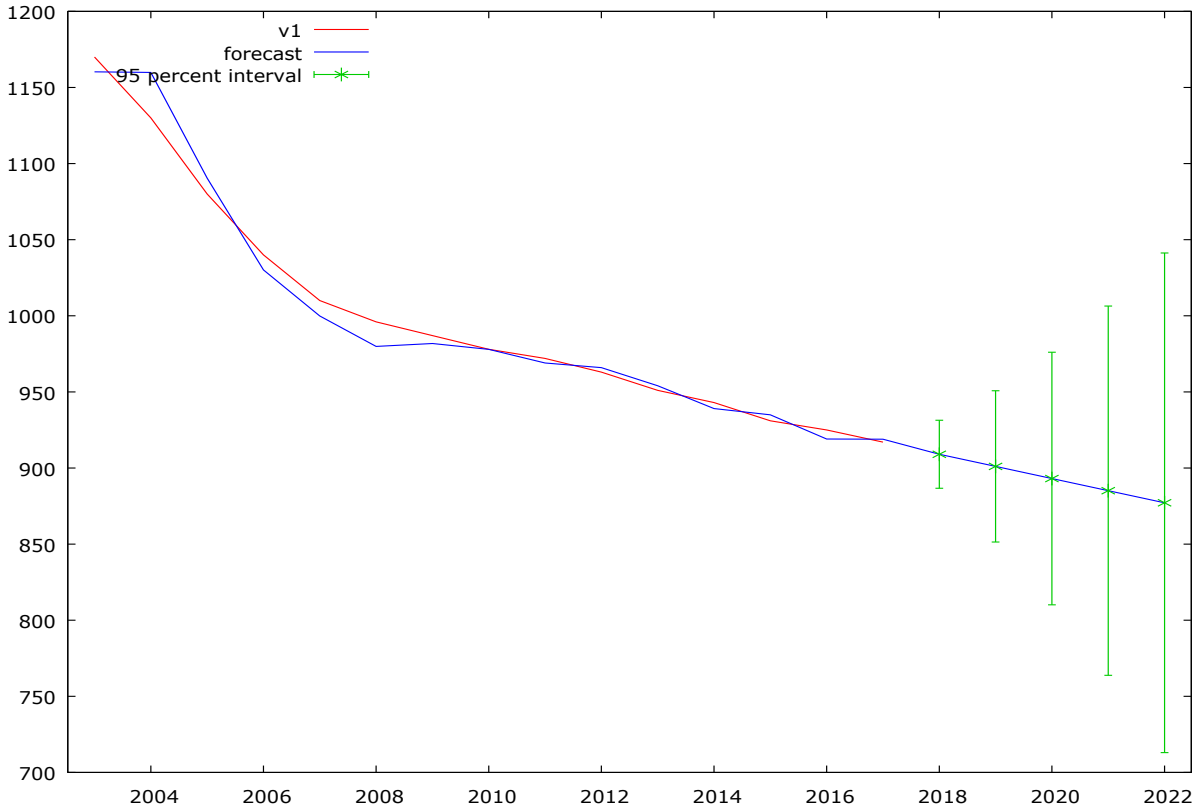

Figure 3: Forecast Graph – In & Out-of-Sample Forecasts

Figure 3 shows the in-and-out-of-sample forecasts of the N series. The out-of-sample forecasts cover the period 2018 – 2023.

Predicted N– Out-of-Sample Forecasts Only

Table 3: Predicted N

Year	Predicted	Standard Error	Lower Limit	Upper Limit
2018	909	11	887	913
2019	901	25	851	951
2020	893	42	810	976
2021	885	61	764	1006
2022	877	84	713	1041

Table 3 and figure 3 show the out-of-sample forecasts only while table shows the main results of the chosen model. Maternal mortality in Nigeria is generally projected to continue on a downwards trajectory over the out-of-sample period. However, our forecasts also indicate that maternal mortality will still be acceptably high in the country as already highlighted by Sageer et al. (2019) and Mohammed et al. (2019).

V. CONCLUSION & RECOMMENDATIONS

Maternal death is one of the most important public health and developmental problems worldwide, particularly in developing countries where maternal mortality is persistently very high (WHO, 2004). In Nigeria, maternal death was estimated to be 58,000 in 2015 contributing about 14% of the global maternal deaths (Hussein et al, 2016). Maternal mortality in Nigeria remains high despite several measures such as maternal and perinatal death audits put in place by the government (Sageer et al, 2019; Mohammed et al, 2019). A large percentage of maternal deaths in Nigeria as in many low-resource countries result from poorly managed deliveries, in particular when obstetrical complications occur (Hofman & Mohammed, 2014; Okonofua et al, 2017;

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Ntiomo et al, 2018). Management of these complications are well established and appropriate emergency obstetric care can prevent most maternal deaths (Singh et al, 2018). Maternal death has devastating effects on the family and long-term consequences for socio-economic development. Women in developing countries lose more disability-adjusted life years from maternal health-related causes than to any other cause (Teka & Yibrah, 2018). Therefore, an understanding of factors which lead to maternal deaths is vital for targeted actions at all levels of the health delivery system (Dumont et al, 2006; Mpumelelo et al, 2019). In this paper we modelled and forecasted MMR in Nigeria and results are envisioned to be used as an early surveillance mechanism of maternal deaths in the country. The government of Nigeria is encouraged to allocate more financial resources for maternal and child health to cater for health care labour force, medical drugs & equipment and health education among the communities to promote institutional deliveries.

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