Proposing Ways to Address Adverse Neonatal Health Outcomes in Madagascar Using Empirical Evidence from the ARIMA Model

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Abstract - This study uses annual time series data on neonatal mortality rate (NMR) for Madagascar from 1969 to 2019 to predict future trends of NMR over the period 2020 to 2030. Unit root tests have shown that the series under consideration is an I (2) variable. The optimal model based on AIC is the ARIMA (2,2,5) model. The study found out that neonatal mortality will gradually decline from approximately 20 in 2020 to around 16 deaths per 1000 live births by the end of 2030. Hence, the government of Madagascar should craft neonatal healthcare policies which are country specific to address the problem of mortality in neonates. Authorities should prioritize availing adequate human resources through use of staff retention incentives, ensuring enough medical supplies in primary healthcare facilities and establishing good roads in rural areas to improve accessibility of healthcare services.

Keywords: ARIMA, Forecasting, NMR.

I. INTRODUCTION

Madagascar is a Sub-Saharan country in the SADC region with a poverty rate of 70.5% (UN, 2020). Access to health is still a challenge in this country. The majority of primary health care facilities are not easily accessible with 25.8% of the population living approximately 10km away from medical facilities (Madagascar, 2018). Persistent stock out of essential medical supplies is affecting the quality of health services being offered in healthcare facilities (Lang *et al.* 2018; Mattern, 2017; Morris *et al.* 2014). Neonatal mortality rate (NMR) for the country is high (INSTAT *et al.* 2010) and is being aggravated by previously mentioned challenges. The aim of this study is to model and forecast NMR for Madagascar using the widely applied Box-Jenkins ARIMA technique which is ideal for modelling linear time series data (Nyoni, 2018; Box-Jenkins, 1970). This methodology has not been fully utilized by public health practitioners to inform their policies and decisions in public health programming. This study will be the first of its kind in the country to apply ARIMA models in the analysis of neonatal mortality rate. The results from this piece of work are expected to guide policy, decision making and resource mobilization for maternal and child health (MNCH) programs with the aim of substantially reducing neonatal mortality rate in Madagascar. In addition, forecast results will help in assessing the feasibility of achieving the sustainable development goal 3 target 3.2 by 2030 which aims to reduce neonatal mortality rate to at least 12 per 1000 live births by 2030 (UNICEF, 2019; WHO, 2019, IOM, 2019; UNFPA, 2018).

II. LITERATURE REVIEW

Andrianantoandro *et al.*(2021) carried out a mixed methods study in Madagascar to identify and analyze factors that influence the utilization of maternal services, specifically, the use of antenatal care (ANC) during pregnancy and the use of skilled birth attendants (SBAs) at delivery.. Data was collected for the period October 2016 to July 2017. A total of 245 pregnant women were included and followed up in the quantitative survey, and among them, 35 participated in in-depth interviews (IDIs). Logistic regression was applied to explore the influencing factors of antenatal and delivery healthcare seeking practices through thematic qualitative analysis. The study results showed that school level; the frequency of ANCs; the origin region; and the preference between modern or traditional care influenced the use of SBAs at delivery. Masaba & Phetoe (2020) described the trends of neonatal mortality within the two sub-Saharan countries. The study concluded that in 2018, the neonatal mortality rate for Kenya was 19.6 deaths per 1000 live births. The neonatal mortality rate had fallen gradually from 35.4 deaths per 1000 live births in 1975. On the other hand, South Africa had its neonatal mortality rate fall from 27.9 deaths per 1000 live births in 1975 to 10.7 deaths per 1000 live births in 2018. Kayode *et al.*(2017) conducted an ecological study which revealed that there is a wide variation in neonatal mortality in SSA. A substantial part of this variation can be explained by differences in the quality of healthcare governance, prevalence of HIV and socioeconomic deprivation. Rhoda *et al.*(2018) reviewed efforts made by the South

African government to reduce neonatal mortality. Indications from the study showed that high-impact interventions, providing an adequate number of appropriately trained healthcare providers and a more active role played by ward-based community health workers and district clinical specialist teams was pivotal to achieve substantial reduction in neonatal deaths. In a descriptive study Indongo (2014) examined the common causes and risk factors of neonatal deaths in facilities in five regions in Namibia. The researcher found out that mortality rate was high in low birth weight neonates.

III. METHODOLOGY

The Box – Jenkins Approach

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, 2018). The Box – Jenkins technique was proposed by Box & Jenkins (1970) and is widely used in many forecasting contexts.

Data Issues

This study is based on annual NMR in Madagascar for the period 1969 to 2019. The out-of-sample forecast covers the period 2020 to 2030. All the data employed in this research paper was gathered from the World Bank online database.

**Evaluation of ARIMA Models**

Criteria Table

Table 1: Criteria Table

Model Selection Criteria Table			
Dependent Variable: D(M, 2)			
Date: 01/23/22 Time: 17:39			
Sample: 1969 2019			
Included observations: 49			
Model	LogL	AIC*	BIC
(2,5)(0,0)	51.103852	-1.718525	-1.371047
(5,4)(0,0)	53.099924	-1.718364	-1.293670
(2,4)(0,0)	50.091458	-1.718019	-1.409150
(0,4)(0,0)	48.058650	-1.716680	-1.485028
(1,2)(0,0)	46.964076	-1.712819	-1.519777
(2,2)(0,0)	47.931633	-1.711495	-1.479844
(5,5)(0,0)	53.738101	-1.703596	-1.240293
(1,3)(0,0)	47.678859	-1.701178	-1.469526
(0,3)(0,0)	46.424964	-1.690815	-1.497772
(0,5)(0,0)	48.226867	-1.682729	-1.412469
(1,4)(0,0)	48.121699	-1.678437	-1.408177
(3,0)(0,0)	45.943539	-1.671165	-1.478122
(3,2)(0,0)	47.937555	-1.670921	-1.400661
(2,3)(0,0)	47.933596	-1.670759	-1.400499
(4,2)(0,0)	48.876276	-1.668419	-1.359551
(5,3)(0,0)	50.539400	-1.654669	-1.268584
(1,5)(0,0)	48.517640	-1.653781	-1.344913

(2,1)(0,0)	45.269248	-1.643643	-1.450600
(3,4)(0,0)	49.227770	-1.641950	-1.294473
(3,3)(0,0)	47.952724	-1.630723	-1.321855

Criteria Graph

Figure 1: Criteria Graph
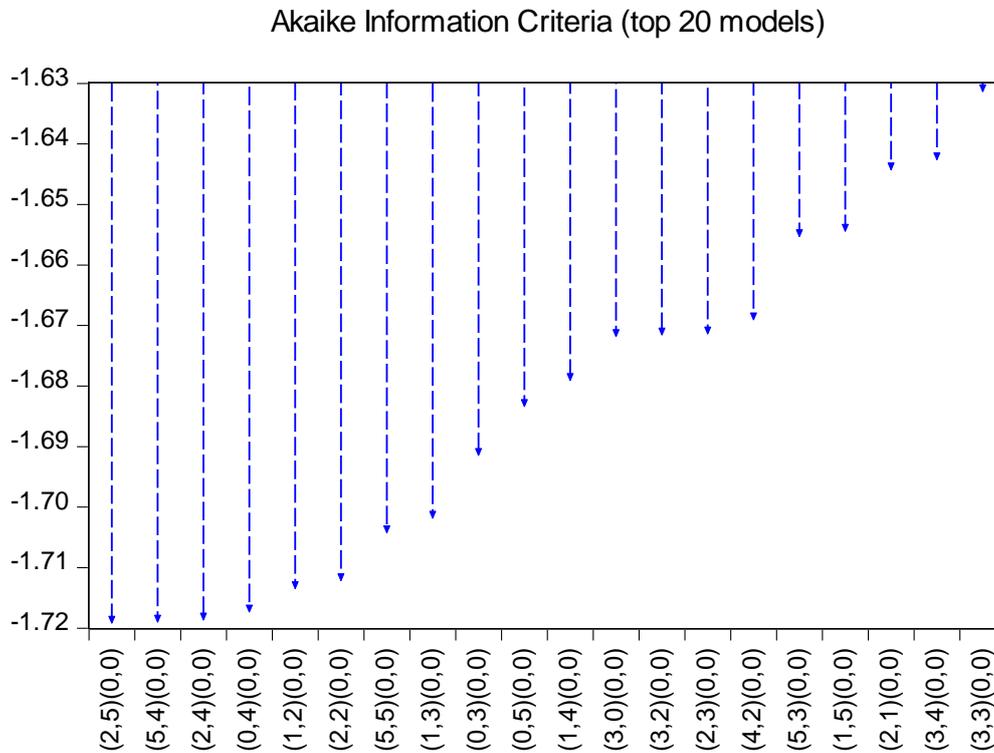
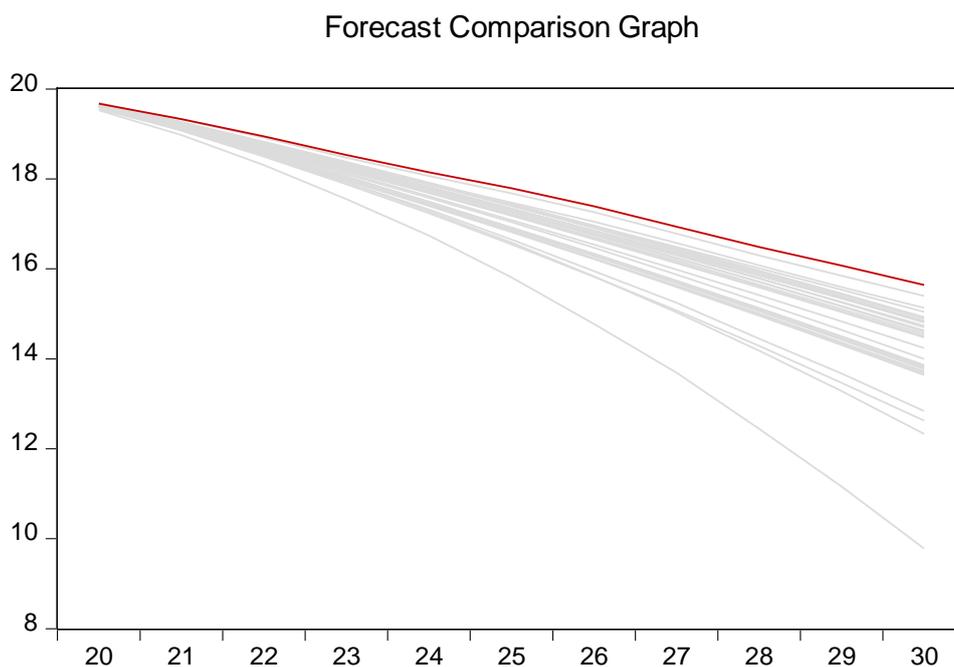**Forecast Comparison Graph**

Figure 2: Forecast Comparison Graph

Table 1 and Figure 1 indicate that the optimal model is the ARIMA (2,2,5) model. Figure 2 is a combined forecast comparison graph showing the out-of-sample forecasts of the top 25 models evaluated based on the AIC criterion. The red line shows the forecast line graph of the optimal model, the ARIMA (2,2,5) model.

IV. RESULTS

ARIMA () Model Forecast

Tabulated Out of Sample Forecasts

Table 2: Tabulated Out of Sample Forecasts

Year	Forecasts
2020	19.67199908879888
2021	19.3269702900549
2022	18.94345626656418
2023	18.52825464435318
2024	18.14868269414825
2025	17.79058879354319
2026	17.38826216343769
2027	16.93466946121021
2028	16.48762583636241
2029	16.0710958488492
2030	15.63960666363334

Table 2 clearly indicates that neonatal mortality will gradually decline from approximately 20 in 2020 to around 16 deaths per 1000 live births by the end of 2030.

V. POLICY IMPLICATION & CONCLUSION

Several challenges being experienced by Madagascar contribute significantly to high absolute numbers of neonatal deaths being reported by the health authorities. Most primary health care facilities are not easily accessible and natural disasters continue to hit the country hard. In this paper we proposed the Box-Jenkins ARIMA approach to forecast NMR for Madagascar and the findings indicate that neonatal mortality will gradually decline from approximately 20 in 2020 to around 16 deaths per 1000 live births by the end of 2030. Hence, the government of Madagascar should craft neonatal policies which are country specific to address the problem of mortality in neonates. Authorities should prioritize availing adequate human resources through use of staff retention incentives, ensuring enough medical supplies in primary healthcare facilities and establishing good roads in rural areas to improve accessibility of healthcare services.

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