

Utilizing ARIMA Model Forecasts to Inform Allocation of Resources to the Maternal and Neonatal Health Program in Guatemala

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Abstract - Neonatal mortality continues to be an important public health issue in Guatemala especially in the rural areas where deliveries are sometimes conducted by lay midwives who lack skills of conducting safe deliveries. Failure to identify high risk pregnancies and late referrals significantly contributes to mortality among newborn babies. This study uses annual time series data on neonatal mortality rate (NMR) for Guatemala from 1964 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 (4,2,2) model. The findings of this study indicate that neonatal mortality will gradually decline from approximately 12 in 2020 to around 9 deaths per 1000 live births by the end of 2030. Hence, authorities are encouraged to promote institutional deliveries particularly in the rural areas to keep neonatal mortality under control.

Keywords: ARIMA, Forecasting, NMR.

I. INTRODUCTION

According to WHO reports, 2.5 million neonates die every year around the world with the majority occurring during the first week of life (WHO, 2018). Guatemala is among the Latin American countries which continue to face the challenge of mortality of children under 5 years of age. Rural areas have been found to be reporting worrying trends of neonatal mortality (World Bank, 2019). The majority of deliveries in rural Guatemala are home deliveries under the care of lay midwives (World Bank, 2019; Juarez *et al.* 2019). It is reported that most neonates die from preventable causes hence it is critical for the government to address the quality of health services from antenatal care, delivery and postnatal periods. Training of lay midwives has been found to be helpful in the reduction of maternal and neonatal deaths (Miller & Smith, 2017). However it is important for the health authorities to promote institutional deliveries as this has been found to be very effective in dealing with late referrals, infections and failure to recognize complications at home especially in Sub-Saharan African countries (Adu *et al.* 2018; Kyei-Nimakoh *et al.* 2017; Gitimu *et al.* 2015; Tekelab *et al.* 2015). The aim of this study is to model and project neonatal mortality rate for Guatemala using the popular Box-Jenkins ARIMA methodology. The technique has been proven to be useful in analyzing linear time series data (Nyoni, 2018; Box & Jenkins, 1970). This econometric forecasting technique is underutilized in public health programming in low-middle income countries, hence the researchers are advocating for its use as it will inform public health policy, decision making and allocation of resources. Forecast results from this study are envisioned to help track the country's progress towards achieving set sustainable development goal 3 target 3.2 by 2030 and inform neonatal policies that will enable effective control of neonatal deaths in Guatemala.

II. LITERATURE REVIEW

Juarez *et al.* (2020) conducted a quality improvement study to increase the detection of neonatal complications by lay midwives in rural Guatemala, thereby increasing referrals to a higher level of care. A quality improvement team in Guatemala reviewed drivers of neonatal health services provided by lay midwives. Improvement interventions included training on neonatal warning signs, optimized mobile health technology to standardize assessments and financial incentives for providers. The primary quality outcome was the rate of neonatal referral to a higher level of care. It was found that structured improvement interventions, including mobile health decision support and financial incentives, significantly increased the detection of neonatal complications and referral of neonates to higher levels of care by lay midwives operating in rural home-based settings in Guatemala. Raymondville *et al.* (2020) conducted a convergent, mixed methods study to assess barriers and facilitators to facility based

childbirth at Hôpital Universitaire de Mirebalais (HUM) in Mirebalais, Haiti. A secondary analyses of a prospective cohort of pregnant women seeking antenatal care at HUM was performed and quantitatively assessed predictors of not having a facility-based childbirth at HUM. The study also prospectively enrolled 30 pregnant women and interviewed them about their experiences delivering at home or at HUM. It was found that living further from the hospital, poverty and household hunger were associated with not having a facility-based childbirth. Primigravid women were more likely to have a facility-based childbirth. In 2019, Souza *et al* investigated the determinants of neonatal mortality in Foz do Iguassu in Brazil. The authors analyzed all neonatal deaths that occurred in Foz do Iguassu from 2012 to 2016. Birth and mortality data were extracted from two national governmental databases (SINASC and SIM). It was found that high rate of neonatal death in Foz do Iguassu is strongly associated with newborn characteristics and not associated with maternal socio-demographic characteristics. Boulos *et al.*(2017) investigated the aetiology of severe bacterial infections in neonates. Researchers conducted a secondary retrospective analysis of a de-identified database from the Neonatal Intensive Care Unit (NICU) at Nos Petit Frères et Soeurs-St. Damien Hospital (NPFS-SDH). Records from 1292 neonates admitted to the NICU at NPFS-SDH in Port-au-Prince Haiti from 2013 to 2015 were reviewed. Sepsis accounted for 708 of 1292 (54.8%) of all admissions to the NICU. The most common organism cultured was *Streptococcus agalactiae*, followed by *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Enterobacter aerogenes*, *Staphylococcus aureus* and *Proteus mirabilis*.

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 Guatemala for the period 1964 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

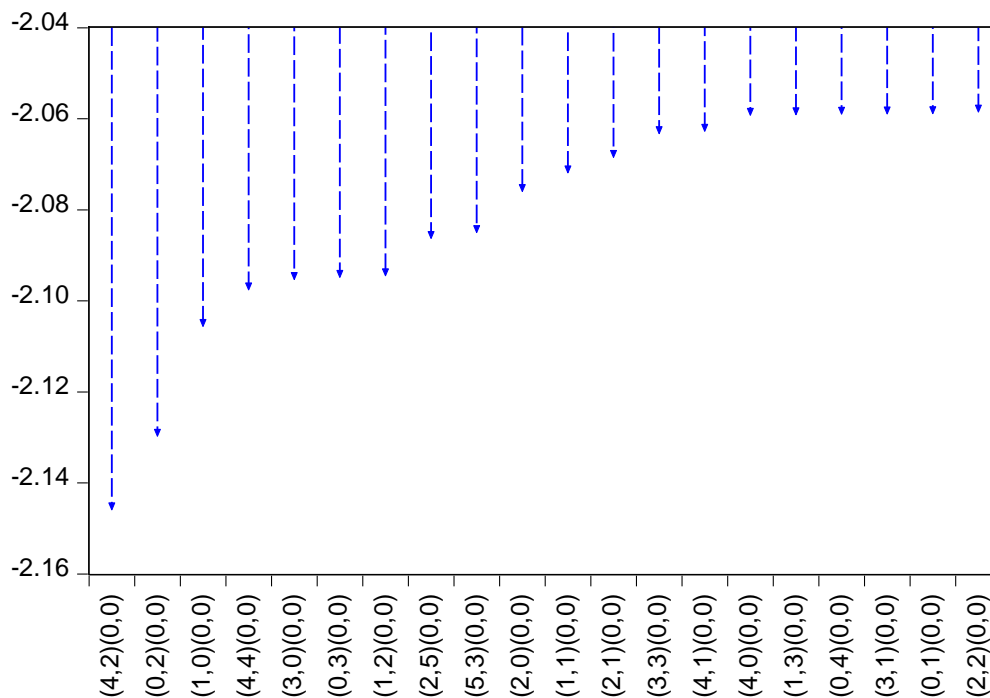
Model Selection Criteria Table			
Dependent Variable: D(G, 2)			
Date: 01/22/22 Time: 14:19			
Sample: 1964 2019			
Included observations: 54			
Model	LogL	AIC*	BIC
(4,2)(0,0)	65.916155	-2.145043	-1.850378
(0,2)(0,0)	61.479114	-2.128856	-1.981524
(1,0)(0,0)	59.828507	-2.104760	-1.994260
(4,4)(0,0)	66.611116	-2.096708	-1.728378
(3,0)(0,0)	61.550068	-2.094447	-1.910282
(0,3)(0,0)	61.536947	-2.093961	-1.909796
(1,2)(0,0)	61.526968	-2.093591	-1.909426

(2,5)(0,0)	65.306643	-2.085431	-1.753934
(5,3)(0,0)	66.271857	-2.084143	-1.715812
(2,0)(0,0)	60.028503	-2.075130	-1.927798
(1,1)(0,0)	59.917182	-2.071007	-1.923675
(2,1)(0,0)	60.825994	-2.067629	-1.883464
(3,3)(0,0)	63.685235	-2.062416	-1.767752
(4,1)(0,0)	62.670023	-2.061853	-1.804021
(4,0)(0,0)	61.575140	-2.058339	-1.837340
(1,3)(0,0)	61.572074	-2.058225	-1.837227
(0,4)(0,0)	61.569262	-2.058121	-1.837123
(3,1)(0,0)	61.568150	-2.058080	-1.837081
(0,1)(0,0)	58.566957	-2.058035	-1.947536
(2,2)(0,0)	61.557078	-2.057670	-1.836671

Criteria Graph

Figure 1: Criteria Graph

Akaike Information Criteria (top 20 models)



Forecast Comparison Graph

Figure 2: Forecast Comparison Graph

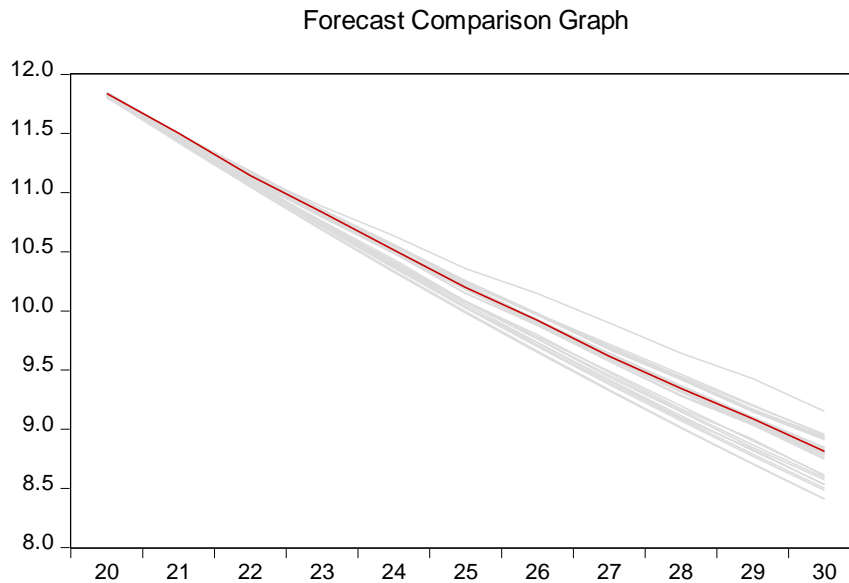


Table 1 and Figure 1 indicate that the optimal model is the ARIMA (4,2,2) model. Figure 2 is a combined forecast comparison graph showing the out-of-sample forecasts of the top 25 models evaluated based on the AIC criterion. The red line shows the forecast line graph of the optimal model, the ARIMA (4,2,2) model.

IV. RESULTS

ARIMA () Model Forecast

Tabulated Out of Sample Forecasts

Table 2: Tabulated Out of Sample Forecasts

Year	Forecasts
2020	11.83721538323212
2021	11.5015974789063
2022	11.14414641209036
2023	10.8342030537414
2024	10.51490425245995
2025	10.19753251119138
2026	9.920507166178843
2027	9.617477156047038
2028	9.345262341761641
2029	9.087805882429116
2030	8.812079661293209

Table 2 clearly shows that neonatal mortality will gradually decline from approximately 12 in 2020 to around 9 deaths per 1000 live births by the end of 2030.

V. POLICY IMPLICATION & CONCLUSION

Death of neonates continues to be a public health concern in Guatemala especially in rural areas where worrying trends of neonatal mortality is being reported mainly as a result of home deliveries which are conducted by lay-midwives. Training of lay-midwives has helped improve pregnancy and neonatal outcomes. This study proposed the Box-Jenkins ARIMA technique to model and project NMR for Guatemala and it established that neonatal mortality will gradually decline from approximately 12 in 2020 to around 9 deaths per 1000 live births by the end of 2030. Hence, the authorities are encouraged to promote institutional deliveries especially in the rural areas to keep neonatal mortality under control.

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