ARIMA Modelling of Neonatal Mortality in Abia State of Nigeria

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Authors contributions

This work was carried out in collaboration among all authors. CNC designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. OM and COB managed the analyses of the study. OUO and COC managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

Abstract

In this study, the incidence neonatal mortality in Abia State of Nigeria was considered using data from January 2014 to December 2018. The data was obtained from the Federal Medical Centre, Umuahia in Abia State of Nigeria. The time plot of the data and the ADF test conducted confirmed the series to be stationary. The plots of the ACF and PACF cut off after lags 4 and 1 respectively which suggested ARIMA (1, 0, 4). However, diagnostic checks led us to select ARIMA (1, 0, 1) as the best model to fit the data and it was used to make forecast. Our forecasted values indicate there will be a continous decline in the incidence of neonatal mortality in Abia State of Nigeria. Much should be done to even expedite the decrease.

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1 Introduction

Neonatal mortality is the death of a child under 28 days of age. Its measure, the Neonatal Mortality Ratio (NMR) is the number of children under 28 years of age who die, divided by the number of live births in a given year. In Abia State which is our case study, NMR stood at 0.037 (that is, 37 neonate deaths out of every 1000 live births), [1]. According to statistics from UNICEF, as at September of 2018, Nigeria's estimated number of neonate deaths was in a range of 23.1 and 47.1 with 32.9 as mean. The estimated actual number of deaths was in the range of 169116 and 344954. Also, according to UNICEF, the global neonatal mortality fell by 51% from 37 deaths per 1000 in 1990 to 18 in 2017. In the year 2010 alone, 7.6 million children died all over the world before reaching age 5. However, since year 2000, there has been a decline from 100 in 1000 in 1999 to 72 in 1000 in 2010, [2,3].

The Federal Medical Centre where the data was obtained is located in the metropolis of Umuahia, which is the capital of Abia State. Majority of its inhabitants are civil servants, public servants, politicians, traders, contractors and farmers. It is the only federal medical centre in the entire state so it serves as both a general and referral health centre. [4] reports that a good number of children who visit the health facility were coming as their first contact with a health facility following their sickness. They claim that it is the only fully fuctional public hospital with adequate doctors and specialists in various fields of medicine.

Neonatal mortality is of serious concern to the society and concerted efforts are continuously made to combat it. The developement and evaluation of effective programmes and initiatives to tackle neonatal mortality requires a detailed knowledge of mortality distribution and the policies to be made should be based on appropriate and reliable statistics especially bothering on the causes.

In [5], the authors modelled and forecasted murder crimes in Nigeria using the Autoregressive Integrated Moving Average model. They fitted ARIMA (0, 1, 0) to the time series. Thier forecasts suggest that there would a slight increase in murder crimes in future if present conditions persist. [6] fitted a SARIMA $(0,0,0)(0,1,1)_{12}$ to model frequency of rainfall in Umuahia, Abia State of Nigeria. This result is in agreement with [7] though they actually compared SARIMA and Holt-Winters Exponential Smoothening and found that SARIMA was a better forecsting model though no significant differences abound in the forecasts made by both models. The Seasonal Autoregressive Integrated Moving Average (SARIMA) model is a generalization of the ARIMA model which can be used to model seasonal time series. In [8], ARIMA (1, 0, 2) was fitted and used to forecast quarterly maternal mortality ratios in Okomfo Anokye Teaching Hospital in Kumasi, Ghana. The study shows that the hospital's Maternal Mortality Ratio (MMR) was relatively stable. However, it had an alamrming quarterly average of 967.7 per 100,000 live births which was about twice the national ratio of 451 per 100, 000 live births. [9] modelled neonatal mortality in Nigeria from 1990 - 2017 using ARIMA (1, 1, 1). Thier study shows that there was 17.8% decrease in the incidence of neonatal mortality and their forecast values suggest a steady decrease in the incidence of neonatal mortality.

There also exist works in the literature bothering on neonatal mortality particularly in Abia State. According to [4], the major diseases in neonatal period were asphyxia, prematurity and neonatal sepsis. Others include jaundice and low birth weight. Also, [10] concluded that surgical care of neonate with a wide range of pathologies is still a major challenge in Abia State. Good political will, capacity building in the form of manpower development and procurement of appropriate equipment will make for better outcomes.

It is the hope of the authors that this work will shed light on this important issue and thus serve as a veritable tool by which government, individuals and NGOs alike can rely on in making policies to further combat neonatal mortality.

2 Methodology

For this study, secondary data was used. By secondary data, we mean that the data has already been collected and recorded by someone else for a different purpose(s). The source of the data was recorded cases of neonatal deaths from the Federal Medical Centre, Umuahia, Abia State of Nigeria from January 2014 to December 2018. This gave a total of 60 months. The medical centre was on an industrial action for months 12, 13, 33, 37, 41, 44 and 53. During this period, the facility was not operating and thus there were no records for these months. For each missing data, the average neonate death in the year it fell was imputed to complete the series. All the graphs and analysis in this study was conducted using Gnu Regression Econometrics and Time Series Library (GRETL).

According to [11], A *time series* is a sequence of observations taken sequentially in time. Since data used for this study was recorded chronologically over time, our choice of using a time series model is justified.

The Autoregressive Integrated Moving Average (ARIMA (p, d, q)) model was used to model the series especially since the dataset qualifies as a time series. This linear nonstationary time series was made popular by Box and Jenkins in 1976. It describes how a series is statistically related to its own past observations. It is especially suited for short term forecasting.

The ARIMA (p, d, q) model is given by:

$$\phi_p(B)(1-B)^d X_t = \theta_0 + \theta_q(B)e_t \tag{2.1}$$

In the model above, $\phi_p(B)$ is a characteristic polynomial of order p, $\theta_q(B)$ is a characteristic polynomial of order q, d is the order of the non-seasonal differencing, $(1-B)$ is the differencing operator, X_t is the observation value at time t, θ_0 is a constant term and e_t is a white noise process. When $d = 0$, the ARIMA model becomes a typical Autoregressive Moving Average (ARMA (p, q)) Model.

2.1 Steps to ARIMA modelling

Box and Jenkins established a four step iterative procedure to be used while carrying out ARIMA modelling. They Include:

a. Model Identification

b. Estimation of Parameters of the chosen model

c. Diagnostic Checks

d. Forecasting

The last step is most times not included in plenty of works in literature since the end point of every time series modelling is to make forecasts.

3 Results and Discussion

The series was stationary and thus needed no differencing (i.e $d = 0$). This conclusion was reached at with the help of the time plot of the series and confirmed using the Augmented Dickey-Fuller (ADF) test which returned a p-value of 0.01387. The ADF test is done with the hypotheses; H_0:

The data has Unit root and thus not stationary. Since the p-value of 0.01387 is less than 0.05, we fail to accept H_0 and conclude the series is stationary. Since the series is stationary, there is no need for differencing and thus $d = 0$
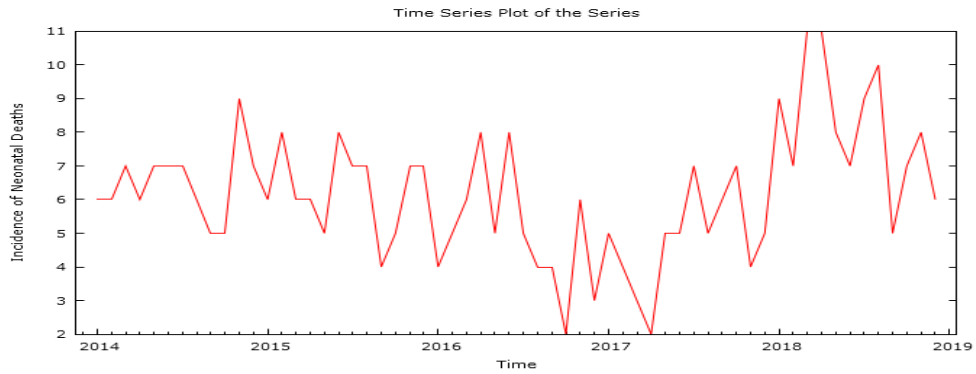

Fig. 1. Time Series Plot of Neonatal Mortality (2014 - 2018)

Table 1. ADF test

TEST	TEST STATISTIC	P-VALUE
Dickey-Fuller	-3.32402	0.01387

The next step is to observe the graph of the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF). The helps to suggest the values of p and q.
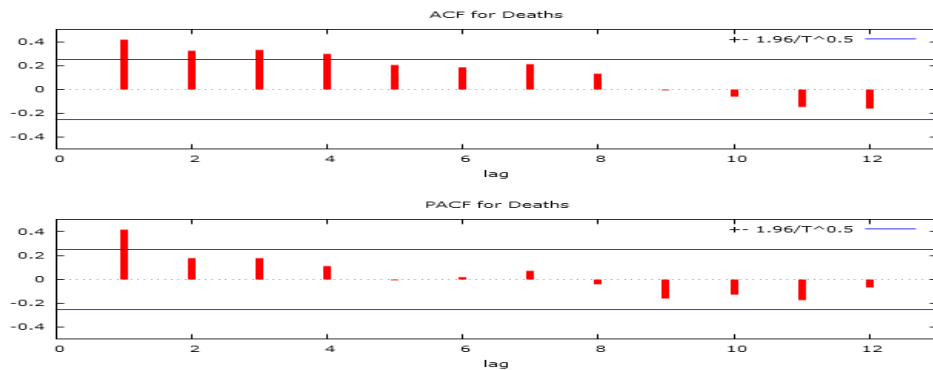

Fig. 2. Graphical illustration of the ACF and PACF of the Series

Since the PACF cuts off after lag 1, it can be assumed that $p = 1$ and since ACF cuts off after lag 4, we can assume $q = 4$. So the suggested ARIMA model is ARIMA(1, 0, 4). However, to justify this parsimony, eight other tentative models were suggested and subjected to test using the Akaike Information Criterion (AIC), Schwarz Criterion (SC) and Hannan-Quinn Criterion (HQC). The optimal model is the one which has the least value in these criteria. Table 2 is a cross-tabulation of the tentative models and their respective AIC, SC and HQC values. The optimal model is in bold letters.

Table 2. A cross-tabulation of tentative models and selection criteria values

Tentative ARIMA Model	AIC	SC	HQC
(1, 0, 4)	245.28	259.94	251.01
(1, 0, 1)	**239.96**	**248.34**	**243.24**
(1, 0, 2)	241.95	252.42	246.05
(1, 0, 3)	243.50	256.06	248.41
(1, 1, 1)	240.38	248.69	243.62
(2, 0, 1)	241.95	252.43	246.05
(3, 0, 1)	243.54	256.10	248.45
(4, 0, 1)	245.43	260.07	251.16
(1, 2, 1)	251.49	259.72	254.70

Consequently, ARIMA (1, 0, 1) is the best to model the series. The next step is to check the adequecy of the model. It is expected that the residuals, e_t, follow a white noise process. The adequacy check can achieved by looking at the time plot, ACF and PACF, Histogram and Normal Q-Q plot of the residuals as well as the Ljung-Box Chi-Square test.
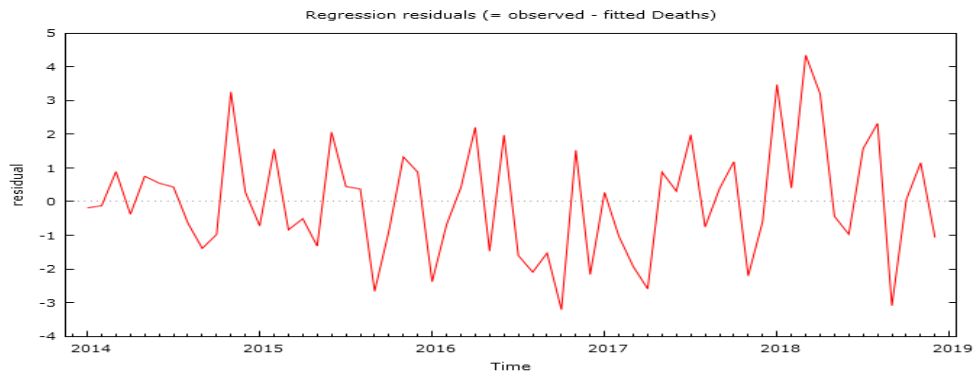
Fig. 3. Time Plot of the Residuals
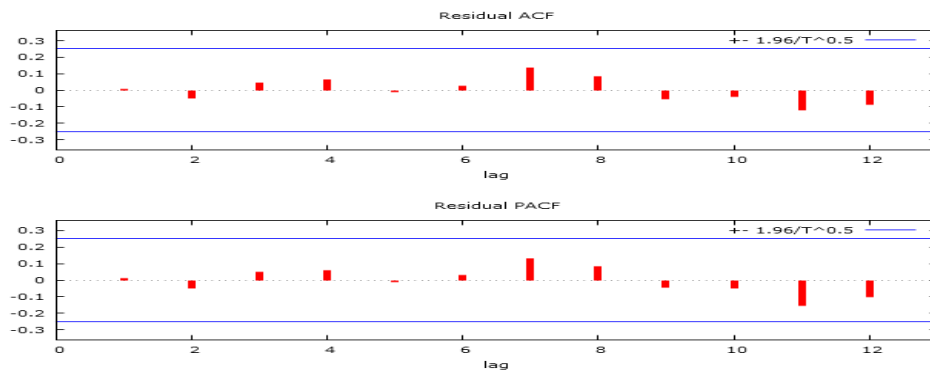
Fig. 4. ACF and PACF plot of the Residuals

Figure 3 clearly shows that the residuals fluctuate around zero which as an indicator that they have a zero mean and constant variance which is expected of a white noise process. Also, the ACF and PACF as seen in figure 4 has all spikes within bounds which indicates that none is significant and thus are not auto-correlated. Finally, we examine the normal q-q plot of the residuals and the histogram.
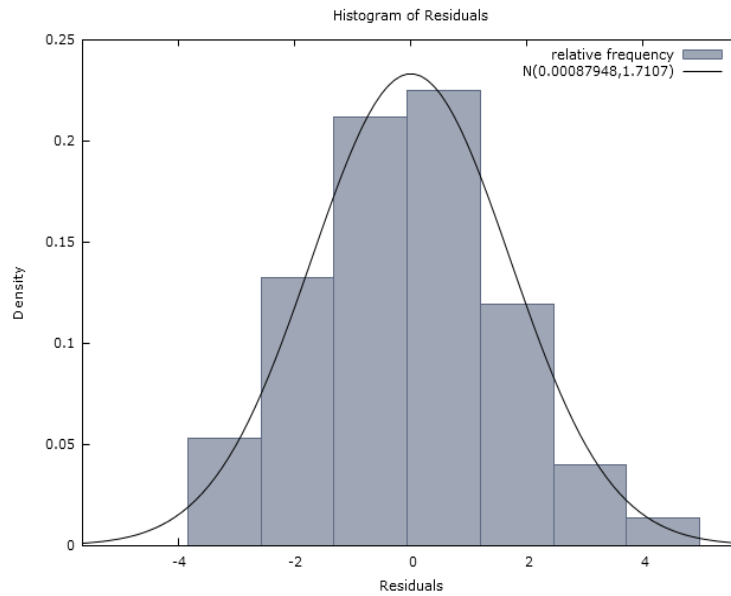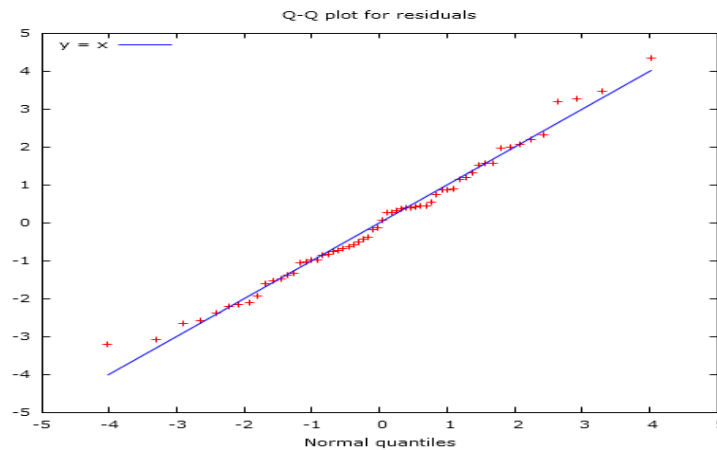

Fig. 5. Histogram of the Residuals

Fig. 6. Normal Q-Q Plot of the Residuals

Figures 5 and 6 indicate that the residuals follow the normal distribution. This is further confirmed by the Ljung-Box Chi-Square test which gave a value of 1.159 and a p-value of 0.5601. Since the

p-value of 0.5601 is greater than 0.05, we conclude that the residuals are normally distributed. Lastly, we present the graph of forecast.
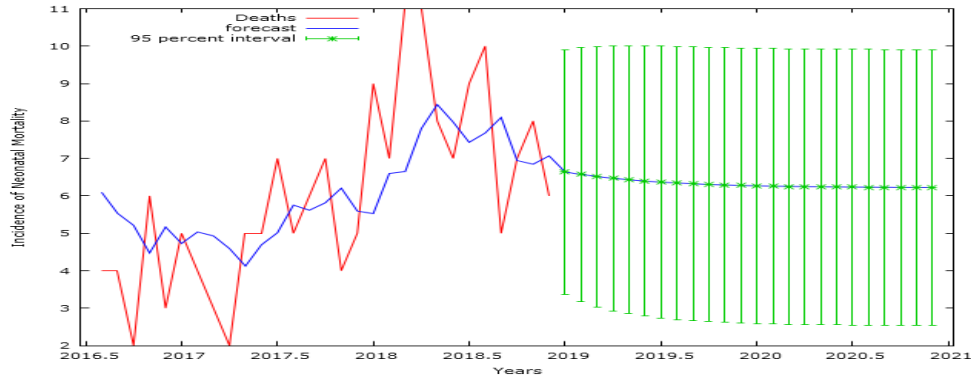
Fig. 7. Graph of Forecasts

The forecast graph suggests that neonatal mortality will drop slightly in 2019 and 2020. This is very similar to the result from [9]. When the data for 2019 is available, it could be compared with the forecast values too. The forecast values are as shown below:

Table 3. For 95% confidence intervals, $z(0.025) = 1.96$

Year/Month	observed	prediction	std. error	95% interval	
2019:01		6.64	1.667	3.37	9.91
2019:02		6.57	1.731	3.18	9.96
2019:03		6.52	1.774	3.04	9.99
2019:04		6.47	1.805	2.93	10.01
2019:05		6.43	1.827	2.85	10.01
2019:06		6.40	1.842	2.79	10.01
2019:07		6.37	1.853	2.74	10.00
2019:08		6.34	1.860	2.70	9.99
2019:09		6.32	1.866	2.67	9.98
2019:10		6.31	1.869	2.64	9.97
2019:11		6.29	1.872	2.62	9.96
2019:12		6.28	1.874	2.61	9.95
2020:01		6.27	1.876	2.59	9.95
2020:02		6.26	1.877	2.58	9.94
2020:03		6.25	1.877	2.57	9.93
2020:04		6.25	1.878	2.57	9.93
2020:05		6.24	1.878	2.56	9.92
2020:06		6.24	1.878	2.56	9.92
2020:07		6.23	1.879	2.55	9.92
2020:08		6.23	1.879	2.55	9.91
2020:09		6.23	1.879	2.54	9.91
2020:10		6.23	1.879	2.54	9.91
2020:11		6.22	1.879	2.54	9.91
2020:12		6.22	1.879	2.54	9.90

4   Conclusions

In this study, ARIMA (1, 0, 1) has been successfully used to model Neonatal Mortality in Abia State of Nigeria using data on incidence of neonatal mortality at Federal Medical Centre, Umuahia from January 2014 to December 2018. The monthly average of neonatal deaths was 6.5, 6.3, 5, 4.8 and 8.2 for 2014, 2015, 2016, 2017 and 2018 respectively. It could be seen that there was a slow but steady decrease from 2014 to 2017. 2018 witnessed a rise in the incidence of neonate deaths but our model forecasts a drop in 2019 and 2020. This is similar to the finding of [9]. Since the neonatal mortality series had no trend nor seasonal pattern, it could be concluded that neonatal mortality in Abia state has no trend nor yearly pattern, suggesting that policies for pediatric management in the state are effective and should be maintained. It could be said that the fight against child mortality is gradually been won especially in the area of neonatal mortality. However, much more attention should paid to this fight to engender even a rapid decline than is currently witnessed.

Acknowledgement

Competing Interests

Authors have declared that no competing interests exist.

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