Maternal deaths in Zimbabwe: Is it a crime to be a woman in Zimbabwe?

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18 October 2019

MATERNAL DEATHS IN ZIMBABWE: IS IT A CRIME TO BE A WOMAN IN ZIMBABWE?

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Abstract:

Is it a crime to be a woman in Zimbabwe? Is it normal to have at least 6 women dying each day of pregnancy related complications? The time to deal with maternal health problems in Zimbabwe is now! This study uses annual time series data on maternal deaths and Maternal Mortality Ratio (MMR) in Zimbabwe from 1990 to 2015, to model and forecast both maternal deaths and MMR using the Box-Jenkins ARIMA technique. Diagnostic tests indicate that both M_t and MMR_t are I (2) variables. Based on minimum AIC statistics, the study presents the ARIMA (0, 2, 2) model and the ARIMA (2, 2, 0) model as the parsimonious models for forecasting maternal deaths and MMR respectively. The diagnostic tests further show that these models are stable and hence suitable for forecasting maternal deaths and MMR respectively. The selected optimal models prove beyond any reasonable doubt that in the next decade (2016 – 2025), maternal deaths and MMR in Zimbabwe are likely to increase. This is a serious warning signal on the need to give maternal health the attention it deserves. The study boasts of three policy prescriptions that are envisaged to reverse the predictions of the selected optimal models.

Keywords: maternal deaths, maternal mortality ratio

JEL Classification: H51, H75, I11, I12, I14, I18

1. Introduction

Is Zimbabwe blessed or cursed? Zimbabwe is cursed in the sense that it is still amongst the world's least developed countries, in spite of all her abundant natural resource endowments, most of which are not only lying idle but also mature for exploitation (Nyoni & Bonga, 2017). Zimbabwe's natural resource endowment must actually give her a natural competitive advantage over many developing countries across the globe. The most shocking truth is that the opposite is true! Zimbabwe must take advantage of her endowments especially in light of improving maternal health service delivery. The health situation in Zimbabwe cannot be undermined if sustainable growth and development are anything to go by in Zimbabwe. WHO (1948) defined health as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity. Human capital is a catalyst to economic growth and development at the micro and macro levels (Becker, 1964; Wilson & Briscoe, 2004). In fact, health capital development contributes to growth through increase in healthy time for both market and non-market activities (Grossman, 1972; Muurinen, 1982). Health, especially maternal health, occupies a special position in sustainable economic development because it is a precondition for and an outcome of economic development. The health situation in Zimbabwe is quite disturbing.

Zimbabwe's much celebrated "Vision 2030" cannot be achieved without giving maternal health the attention it deserves. The Monetary Policy objective of achieving sustainable economic growth will remain a pipeline dream unless maternal health is given the attention it deserves. Many studies, for example, Thompson & Sofo (2015) and Klobodu *et al* (2018); strongly argue that a positive relationship exists between maternal health and economic growth. Is it a crime to be woman in Zimbabwe? If your answer is "No", then there is need to improve the maternal health situation in Zimbabwe.

Issues of maternal health have continuously received attention globally and nationally since the 1980s (Adedia *et al*, 2018). The importance of maternal and childhood health goes beyond human rights and morality (Saggynbekov, 2018). It was the thought provoking paper by Rosenfield & Maine (1985) which raised the eyebrows of many policy makers and researchers and they immediately began paying more attention to maternal mortality issues. Maternal mortality (maternal deaths) is defined as the death of a woman while she is pregnant or within 42 days after delivery from any cause related to or aggravated by the pregnancy or its management but from accidental or incidental causes (Harrison, 1985; Conde-Agudelo & Belizan, 2000; WHO, 2005; Shah & Say, 2007; Hogan *et al*, 2010; Fabayo, 2010). Obstructed labour, maternal hemorrhage, postpartum sepsis, eclampsia, unsafe abortion and anemia are among the listed causes of maternal mortality (Harrison, 1985; Abou-Zahr, 2003; WHO & UNICEF, 2014). Maternal mortality is an essential indicator of maternal health in both developed and developing countries (Hoj *et al*, 2003). The Maternal Mortality Ratio (MMR) is defined as the number of maternal deaths in a population per 100000 live births (Alkema *et al*, 2015).

Women in developing countries such as Zimbabwe on an average have more pregnancies than their counterparts in developed countries; hence, their lifetime risk of death due to pregnancy is higher. A woman's lifetime risk of maternal death, the probability that a 15-year-old woman will eventually die from maternal cause is, 1 in 3700 in developed countries, versus 1 in 160 in developing countries (WHO, 2014). Maternal mortality is the 5^{th} goal of the United Nations (UN) Millennium Development Goals (MDGs): all the countries that gathered at the UN Millennium Summit in 2000 agreed to prioritize maternal mortality and hence try to reduce it, especially by improving maternal health. Attainment of the MDG target of reducing maternal mortality by three-quarters will require accelerated efforts and stronger political backing for women and children. Improving maternal health is another key to achieving MDG 4 of reducing child mortality (UN, 2014; Asia, 2013). Subjecting women to poor maternal health situations is a violation of their rights. Globally, an estimated 289000 women die annually and, 800 of these vulnerable women lose their lives daily from complications which are pregnancy related (UN, 2018). Sub-Saharan Africa (SSA) has the highest proportion of maternal deaths, it accounts for 56% of global maternal deaths (UNFPA, 2012). Currently, Zimbabwe experiences one of the highest maternal mortality rates in the region (960 per 100000), with 6 women dying each day of pregnancy related complications. 75% of these deaths are preventable, with the most common causes being postpartum hemorrhage, infection, pregnancy related hypertension and malaria (USAID, 2014).

Objectives of the Study

i. To construct an optimal ARIMA model depicting maternal deaths trends in Zimbabwe.
ii. To develop an optimal ARIMA model depicting the pattern of Maternal Mortality Ratio (MMR) in Zimbabwe.

iii. To forecast maternal deaths in Zimbabwe for the period 2016 – 2025.
iv. To forecast MMR in Zimbabwe for the period 2016 – 2025.

Statement of the Problem

Despite the commitment set out in the MDGs, maternal mortality remains unacceptably high in many parts of the world (UN, 2013; Klobodu *et al*, 2018). Maternal health remains a public health challenge in most developing countries (WHO, 2007; Hogan *et al*, 2010; WHO, 2015), especially in Sub-Saharan Africa (WHO, 2008; USAID, 2014; Machira, 2017). Maternal mortality remains disturbingly high in Zimbabwe (Mlambo *et al*, 2013). Zimbabwe is ranked among the 40 countries in the world with high maternal mortality rate of 960 maternal deaths per 100000 live births (WHO, UNICEF, UNFPA & WB, 2012). An estimated 3000 women die every year in Zimbabwe during child birth and at least 1.23% of GDP is lost annually due to maternal complications (UN, 2013). Is it a curse to be a woman in Zimbabwe? This study will go a long way in drawing more attention to maternal mortality issues in Zimbabwe and also enhancing maternal health policy effectiveness in Zimbabwe.

2. Literature Review

Related Previous Studies

Sarpong (2013) modeled and forecasted maternal mortality at the Okomfo Anokye Teaching Hospital (Ghana) using time series data covering the period January 2010 to December 2010 and employed the ARIMA framework; the study found out that the ARIMA (1, 0, 2) model is adequate for forecasting quarterly maternal mortality ratios at the hospital. Lado (2015) forecasted maternal mortality ratio in Juba Teaching Hospital (South Sudan) using time series data covering the period January 2008 to December 2014 and employed the ARIMA technique; the study found out that the ARIMA (3, 0, 1) model adequately fitted maternal mortality ratio data and was able to forecast monthly maternal mortality ratio at Juba Teaching Hospital for the period January 2015 to December 2015. Quarcco (2015) analyzed maternal mortality in Ghana at the Korle-bu Teaching Hospital over the period 2001 to 2013 using ARMA models and found out that the MMR data has a platykurtic distribution and is better modeled by an ARMA model. Adedia *et al* (2018) predicted maternal mortality records from a public health facility in Ghana using time series data covering the period January 2000 to December 2013 and employed the ARIMA approach; the study found out that the ARIMA (1, 1, 1) modeled was the most appropriate model for predicting monthly maternal cases.

3. Materials & Methods

The Autoregressive (AR) Model

A process M_t (annual maternal deaths [maternal mortality] at time t) is thought of, as an autoregressive process of order p, i.e AR (p) if it is a weighted sum of the past p values plus a random shock (Z_t) such that:

$$M_t = \emptyset_1 M_{t-1} + \emptyset_2 M_{t-2} + \emptyset_3 M_{t-3} + \cdots + \emptyset_p M_{t-p} + Z_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

Using the backward shift operator, B, such that $BM_t = M_{t-1}$, the AR (p) model can be expressed as follows:

$$Z_t = \emptyset(B) M_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [2]$$

where $\emptyset(B) = 1 - \emptyset_1 B - \emptyset_2 B^2 - \emptyset_3 B^3 - \cdots - \emptyset_p B^p$

The 1[st] order AR (p) process, AR (1) may be expressed as follows:

$$M_t = \emptyset M_{t-1} + Z_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots [3]$$

Given $\emptyset = 1$, then equation [3] becomes a random walk model, a process that is very unpopular when modeling and forecasting maternal deaths. If $|\emptyset| > 1$, then the series becomes explosive, hence non-stationary. Most time series are explosive. If $|\emptyset| < 1$, then the series is said to be stationary and therefore its ACF (autocorrelation function) decreases exponentially.

The Moving Average (MA) Model

A process is reffered to as a moving average process of order q, MA (q) if it is a weighted sum of the last random shocks, i.e:

$$M_t = Z_t + \theta_1 Z_{t-1} + \theta_2 Z_{t-2} + \cdots + \theta_q Z_{t-q} \ldots \ldots \ldots \ldots \ldots \ldots [4]$$

Using the backward shift operator, B, equation [4] can be expressed as follows:

$$M_t = \theta(B) Z_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots [5]$$

where $\theta(B) = 1 + \theta_1 B + \theta_2 B^2 + \cdots + \theta_q B^q$

Equation [4] can also be expressed as follows:

$$M_t - \sum_{j \leq 1} \pi_j M_{t-j} = Z_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots [6]$$

for some constant π_j such that:

$$\sum_{j \leq 1} |\pi_j| < \infty$$

The implication is that it is possible to invert the function taking the Z_t sequence to the M_t sequence and recover Z_t from present and past values of M_t by a convergent sum.

The Autoregressive Moving Average (ARMA) Model

While the AR and MA processes are good models, a more parsimonious model is the ARMA model. Before we go any further, it is imperative to note that the AR, MA and ARMA models are applied on stationary time series only. The ARMA model is a mixture of AR (p) and MA (q) terms, hence the name ARMA (p, q). This can be expressed as follows:

$$\emptyset(B) M_t = \theta(B) Z_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots [7]$$

Thus:

$$M_t\left(1 - \emptyset_1 B - \emptyset_2 B^2 - \cdots - \emptyset_p B^p\right) = Z_t\left(1 + \theta_1 B + \theta_2 B^2 + \cdots + \theta_q B^q\right) \ldots \ldots \ldots [8]$$

where $\emptyset(B)$ and $\theta(B)$ are polynomials in B of finite order p, q respectively.

The Autoregressive Integrated Moving Average (ARIMA) Model

The AR, MA and ARMA processes are usually not applied in practice just because many time series are not stationary. Hence the need for differencing until stationarity is achieved.

$$\left.\begin{array}{c} The\ first\ difference\ is\ given\ by: \\ M_t - M_{t-1} = M_t - BM_t \\ The\ second\ difference\ is\ given\ by: \\ M_t(1-B) - M_{t-1}(1-B) = M_t(1-B) - BM_t(1-B) = M_t(1-B)(1-B) = M_t(1-B)^2 \\ The\ third\ difference\ is\ given\ by: \\ M_t(1-B)^2 - M_{t-1}(1-B)^2 = M_t(1-B)^2 - BM_t(1-B)^2 = M_t(1-B)^2(1-B) = M_t(1-B)^3 \\ The\ d^{th}\ difference\ is\ given\ by: \\ M_t(1-B)^d \end{array}\right\} \ldots [9]$$

Given the simple algebraic manipulations above, it can be inferred that when the actual data series is differenced "d" times before fitting an ARMA (p, q) process, then the model for the actual undifferenced series is reffered to as an ARIMA (p, d, q) model. Thus equation [7] is now generalized as follows:

$$\emptyset(B)(1-B)^d M_t = \theta(B)Z_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [10]$$

Therefore, in the case of modeling MMR (maternal mortality ratio), equation [10] can be written as follows:

$$\emptyset(B)(1-B)^d MMR_t = \theta(B)Z_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [11]$$

The Mechanics of the Box – Jenkins Methodology

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, 2018i). The Box – Jenkins technique was proposed by Box & Jenkins (1970) and is widely used in many forecasting contexts, especially in Financial Economics. However, many researchers around the world, after realizing the forecast ability of this approach, have begun to use the Box – Jenkins technique in other areas such as weather forecasting, electricity demand forecasting and so on. In this paper, we will use it for forecasting maternal deaths and maternal mortality ratio in Zimbabwe over the period 1990 – 2015.

Data Collection

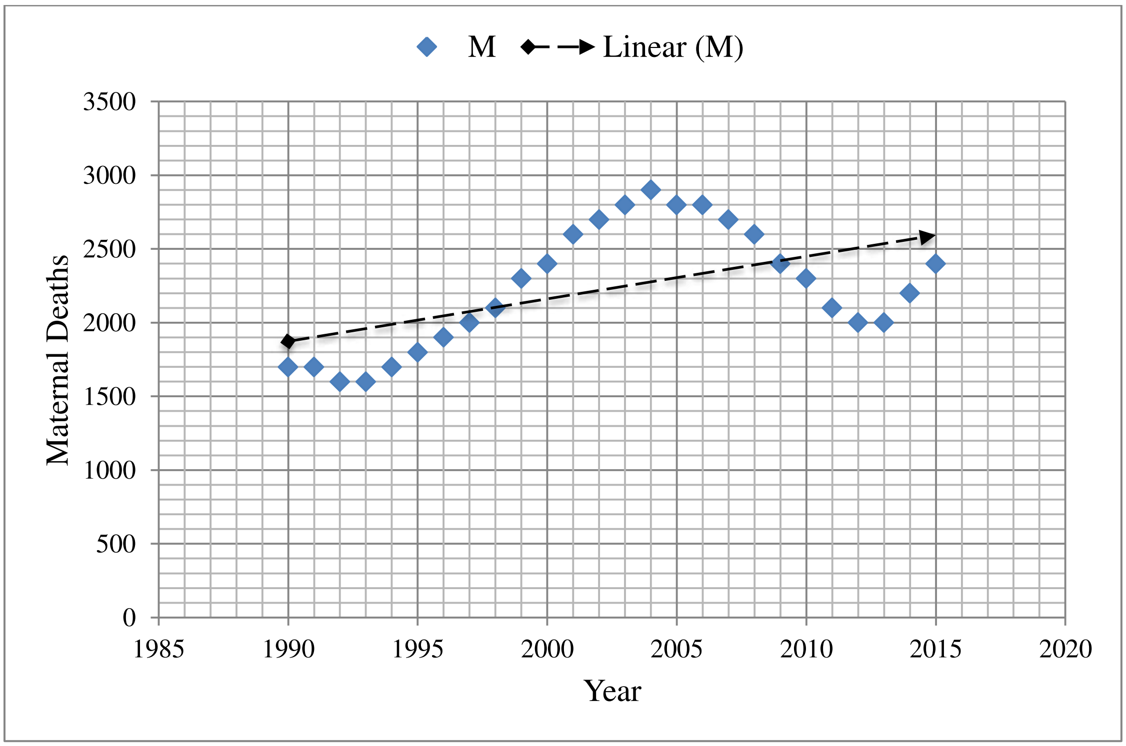
All the data (maternal deaths and MMR: 1990 – 2015) used in this study was extracted from the World Bank online database. Maternal deaths (or maternal mortality), in this paper, is measured as the number of maternal deaths per year. MMR in this study is accounted for by the formula:

$$MMR_t = \frac{Total\ Maternal\ Deaths}{Total\ livebirths} x100\ 000\ livebirths \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . . \ldots [12]$$

<u>Diagnostic Tests and Model Evaluation (for Maternal Deaths)</u>

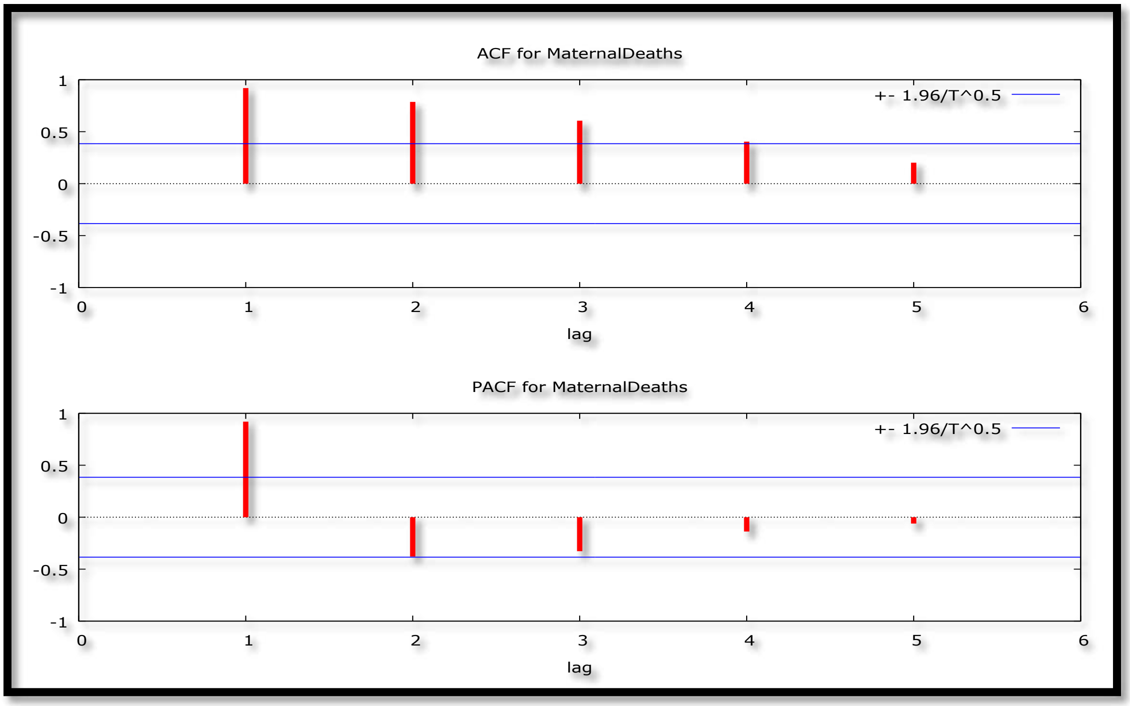
Stationarity Tests: Graphical Analysis

Figure 1: Graphical Analysis



The Correlogram in Levels

Figure 2: Correlogram in Levels



The ADF Test

Table 1: Levels-intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
M	-3.209909	0.0324	-3.752946	@1%	Not stationary
			-2.998064	@5%	Stationary
			-2.638752	@10%	Stationary

Table 2: Levels-trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
M	-3.736204	0.0410	-4.440739	@1%	Not stationary
			-3.632896	@5%	Stationary
			-3.254671	@10%	Stationary

Table 3: without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
M	-0.578707	0.8336	-2.674290	@1%	Not stationary
			-1.957204	@5%	Not stationary
			-1.608175	@10%	Not stationary

The Correlogram at 1st Differences

Figure 3: Correlogram at 1st Differences

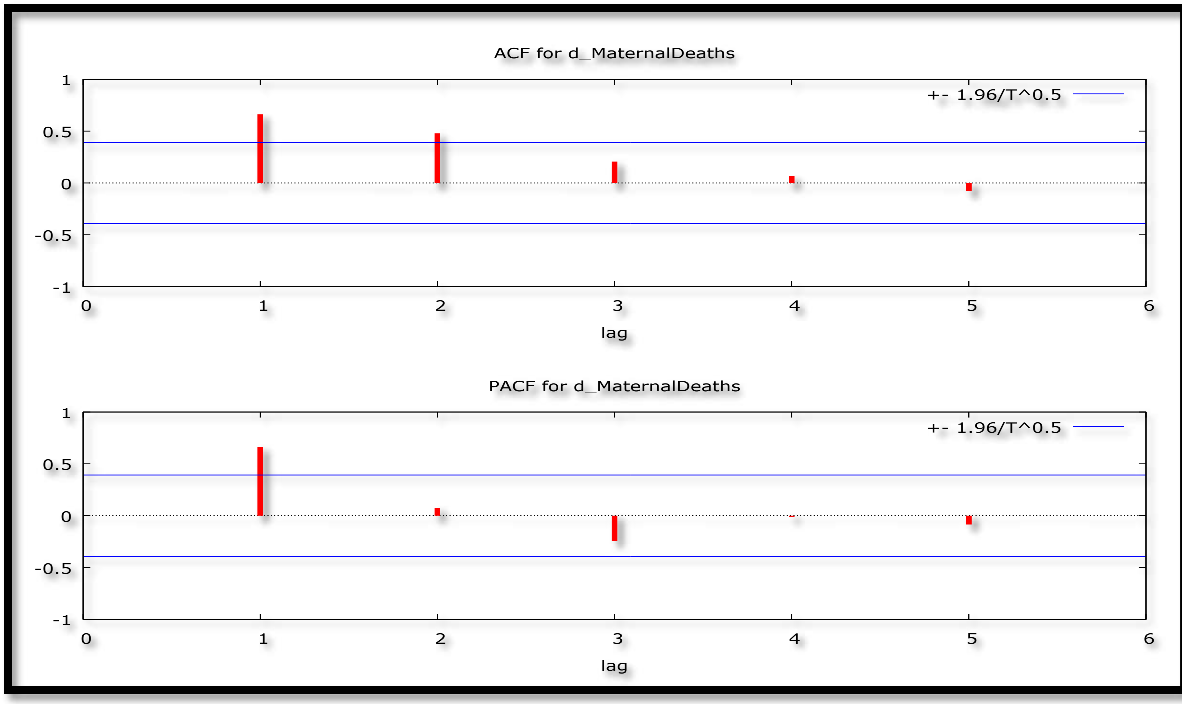


Table 4: 1st Difference-intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
M	-2.139780	0.2323	-3.788030	@1%	Not stationary
			-3.012363	@5%	Not stationary
			-2.646119	@10%	Not stationary

Table 5: 1st Difference-trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
M	-1.304701	0.8582	-4.467895	@1%	Not stationary
			-3.644963	@5%	Not stationary
			-3.261452	@10%	Not stationary

Table 6: 1st Difference-without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
M	-1.682046	0.0869	-2.674290	@1%	Not stationary
			-1.957204	@5%	Not stationary
			-1.608175	@10%	Stationary

Correlogram at 2nd Differences

Figure 4: Correlogram at 2nd Differences

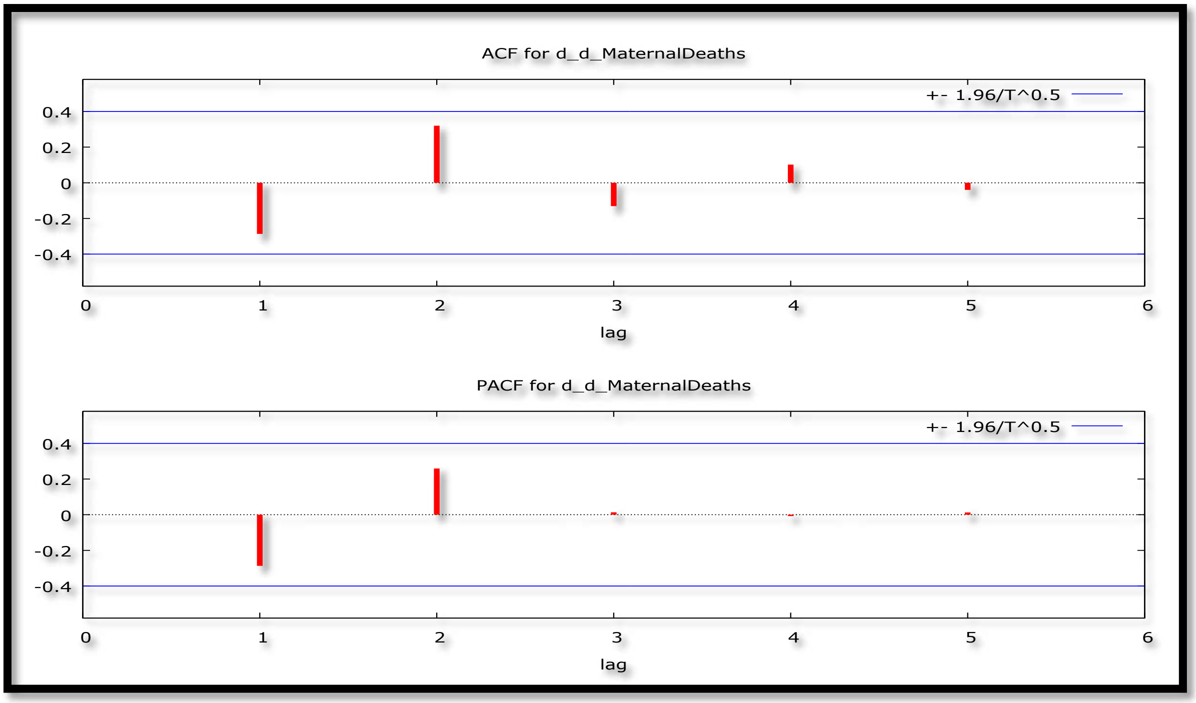


Table 7: 2nd Difference-intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
M	-2.259417	0.1928	-3.769597	@1%	Not stationary
			-3.004861	@5%	Not stationary
			-2.642242	@10%	Not stationary

Table 8: 2nd Difference-trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
M	-6.209698	0.0002	-4.416345	@1%	Stationary
			-3.622033	@5%	Stationary
			-3.248592	@10%	Stationary

Table 9: 2nd Difference-without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
M	-2.248491	0.0267	-2.674290	@1%	Not stationary
			-1.957204	@5%	Stationary
			-1.608175	@10%	Stationary

In figure 1 above, it is clear that the maternal deaths trend is generally upwards sloping and it is quite reasonable to suspect that it is non-stationary. Figures 2 – 4 and tables 1 – 9 are formal tests for stationarity and as illustrated, variable M (maternal deaths per year) is an I (2) variable.

Evaluation of ARIMA Models (without a constant)

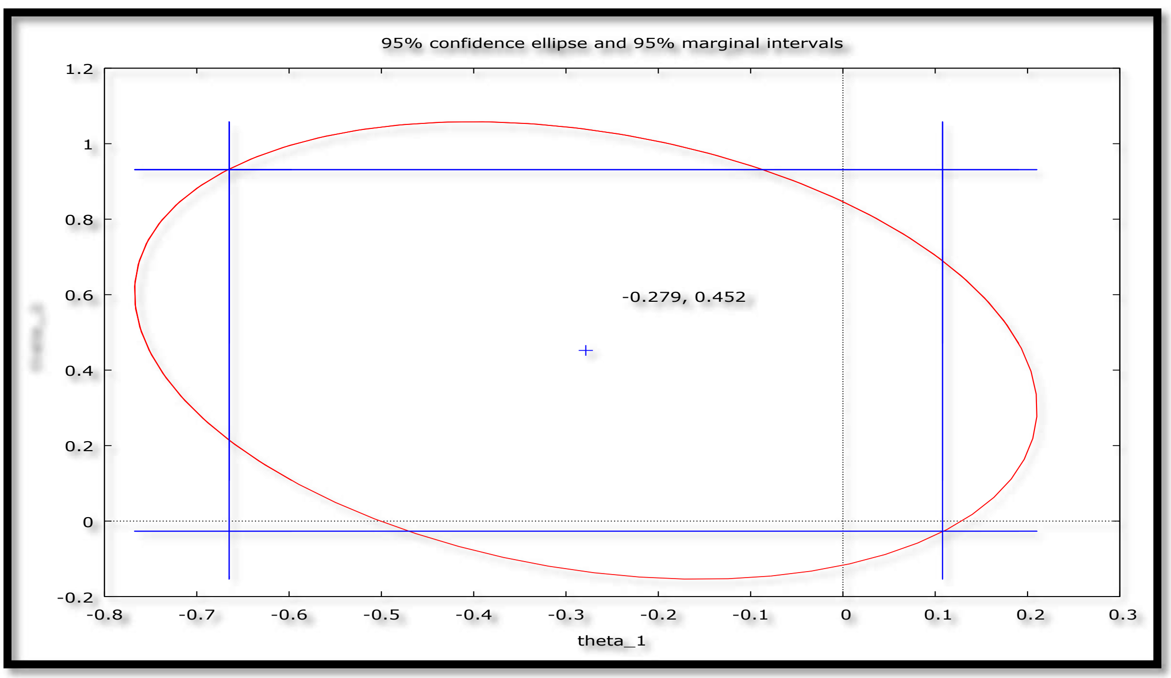
Table 10: Evaluation of ARIMA Models (without an constant)

Model	AIC	U	ME	MAE	RMSE	MAPE
ARIMA (1, 2, 1)	290.0232	0.71806	10.293	70.892	89.888	3.2159
ARIMA (1, 2, 0)	289.2034	0.73432	10.615	72.718	92.113	3.3141
ARIMA (2, 2, 0)	288.8678	0.7106	9.5082	68.653	87.707	3.1532
ARIMA (3, 2, 0)	290.6093	0.71686	10.283	67.388	87.287	3.1223
ARIMA (4, 2, 0)	292.6092	0.71686	10.25	67.414	87.286	3.1235
ARIMA (5, 2, 0)	294.4119	0.71395	9.7906	67.8	86.947	3.14
ARIMA (2, 2, 2)	292.4299	0.72295	10.831	68.302	87.13	3.1878
ARIMA (2, 2, 3)	294.2177	0.71932	10.668	68.009	86.703	3.1664
ARIMA (3, 2, 1)	292.6093	0.71686	10.271	67.398	87.286	3.228
ARIMA (0, 2, 1)	289.8876	0.73457	9.8139	74.632	93.423	3.386
ARIMA (2, 2, 1)	290.6851	0.71406	10.193	67.827	87.392	3.1333
ARIMA (3, 2, 1)	292.6093	0.71686	10.271	67.398	87.286	3.1228
ARIMA (0, 2, 2)	**288.7786**	0.72112	10.192	67.591	87.674	3.1536

A model with a lower AIC value is better than the one with a higher AIC value (Nyoni, 2018n). Theil's U must lie between 0 and 1, of which the closer it is to 0, the better the forecast method (Nyoni, 2018l). The study will only consider the AIC as the criteria for choosing the best model and thus, in the case of maternal deaths; the ARIMA (0, 2, 2) model is selected.

Confidence Ellipse of the ARIMA (0, 2, 2) model for Maternal Deaths

Figure 5: Confidence Ellipse of the ARIMA (0, 2, 2) Model for Maternal Deaths

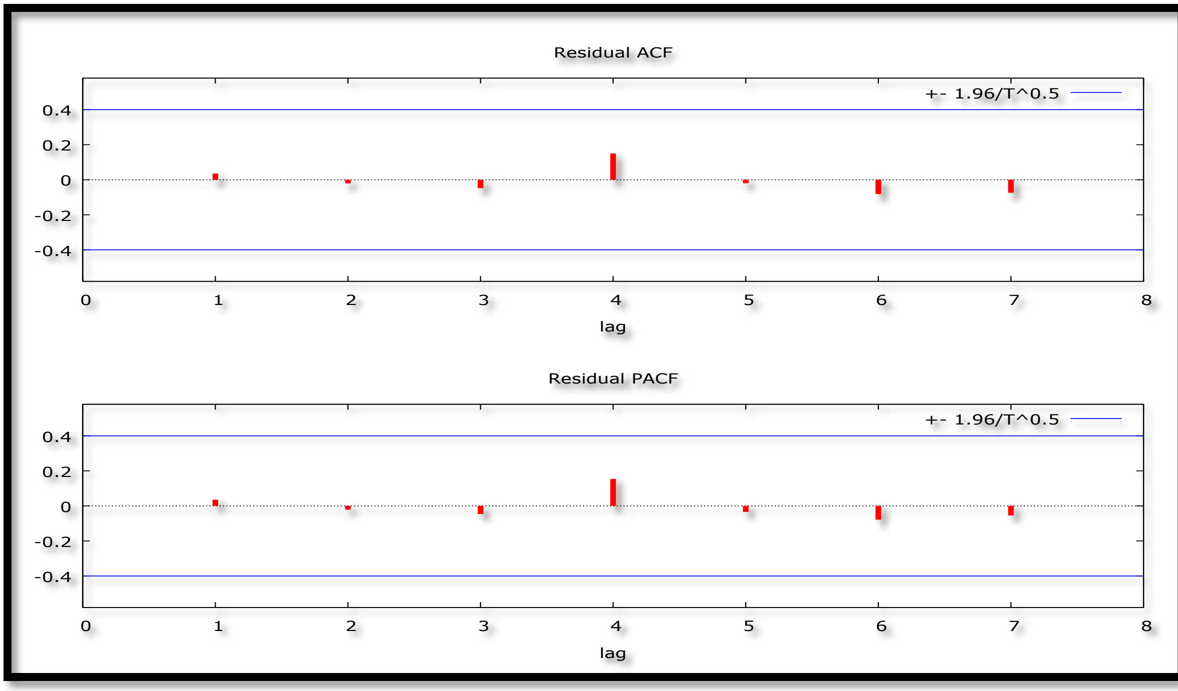


The graph above shows the region in which the realization of the two test statistics must lie for the researcher not to reject the null hypothesis. The graph absolutely confirms the accuracy of the ARIMA (0, 2, 2) model in forecasting maternal deaths in Zimbabwe.

Residual & Stability Tests

Residual Correlogram of the ARIMA (0, 2, 2) Model for Maternal Deaths

Figure 6: Residual Correlogram of the ARIMA (0, 2, 2) Model for Maternal Deaths



ADF Tests of the Residuals of the ARIMA (0, 2, 2) Model for Maternal Deaths

Table 11: Levels-intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
R_t	-4.085455	0.0047	-3.752946	@1%	Stationary
			-2.998064	@5%	Stationary
			-2.638752	@10%	Stationary

Table 12: Levels-trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
R_t	-4.420133	0.0099	-4.416345	@1%	Stationary
			-3.622033	@5%	Stationary
			-3.248592	@10%	Stationary

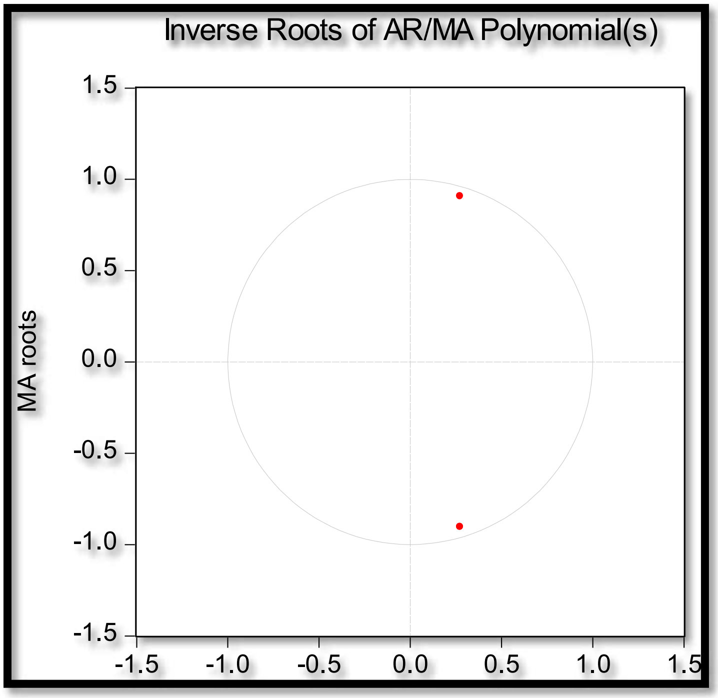
Table 13: without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
R_t	-4.166683	0.0002	-2.669359	@1%	Stationary
			-1.956406	@5%	Stationary
			-1.608495	@10%	Stationary

Figure 6 and tables 11 to 13 show that the residuals of the ARIMA (0, 2, 2) model are stationary.

Stability Test of the ARIMA (0, 2, 2) Model for Maternal Deaths

Figure 7: Inverse Roots of the ARIMA (0, 2, 2) Model for Maternal Deaths

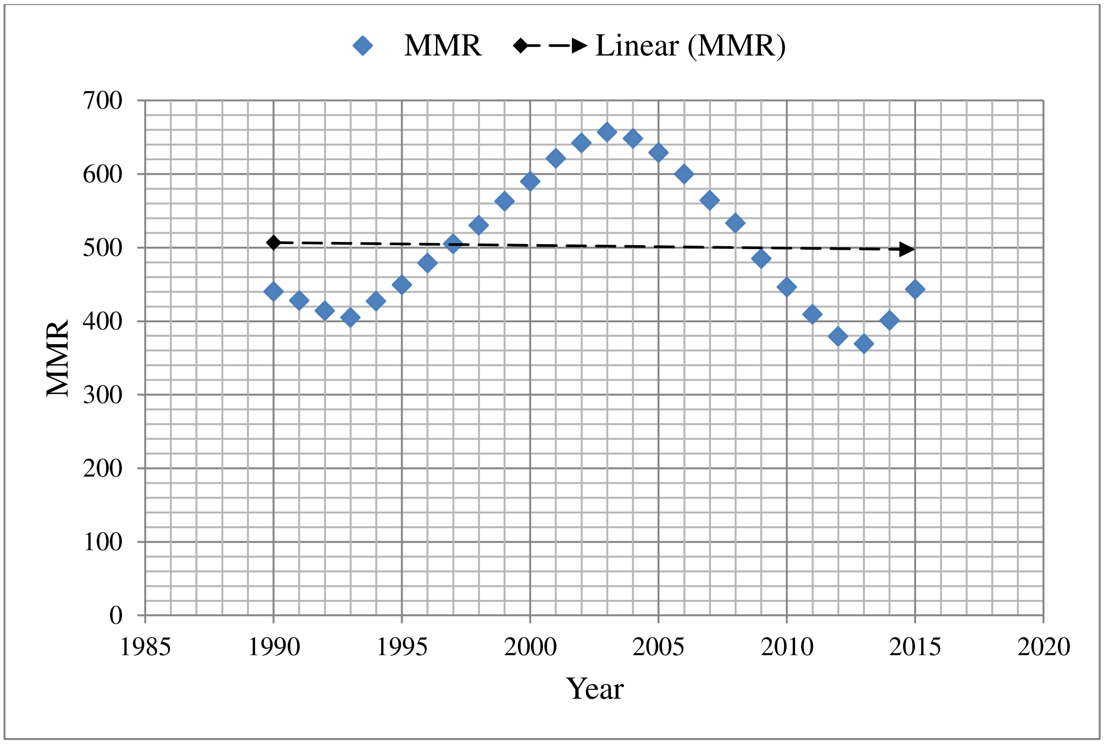


Since the corresponding inverse roots of the characteristic polynomial lie in the unit circle, then we can conclude that the chosen ARIMA (0, 2, 2) model is stable and indeed suitable for forecasting maternal deaths in Zimbabwe.

<u>Diagnostic Tests and Model Evaluation (for Maternal Mortality Ratio [MMR])</u>

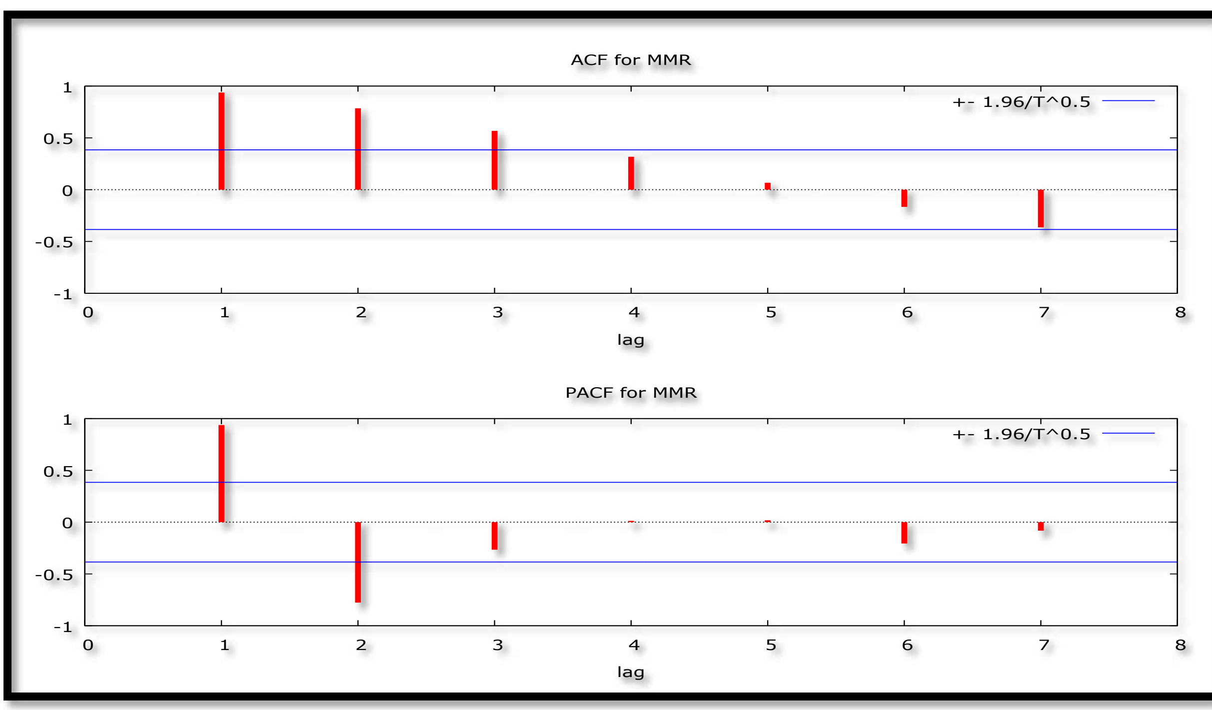
Stationarity Tests: Graphical Analysis

Figure 8: Graphical Analysis



The Correlogram in Levels

Figure 9: Correlogram in Levels



The ADF Test

Table 14: Levels-intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
MMR	-4.835689	0.0008	-3.737853	@1%	Stationary
			-2.991878	@5%	Stationary
			-2.635542	@10%	Stationary

Table 15: Levels-trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
MMR	-4.574080	0.0072	-4.416345	@1%	Stationary
			-3.622033	@5%	Stationary
			-3.248592	@10%	Stationary

Table 16: Levels-without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
MMR	0.278862	0.7576	-2.674290	@1%	Not stationary
			-1.957204	@5%	Not stationary
			-1.608175	@10%	Not stationary

The Correlogram at 1st Differences

Figure 10: Correlogram at 1st Differences

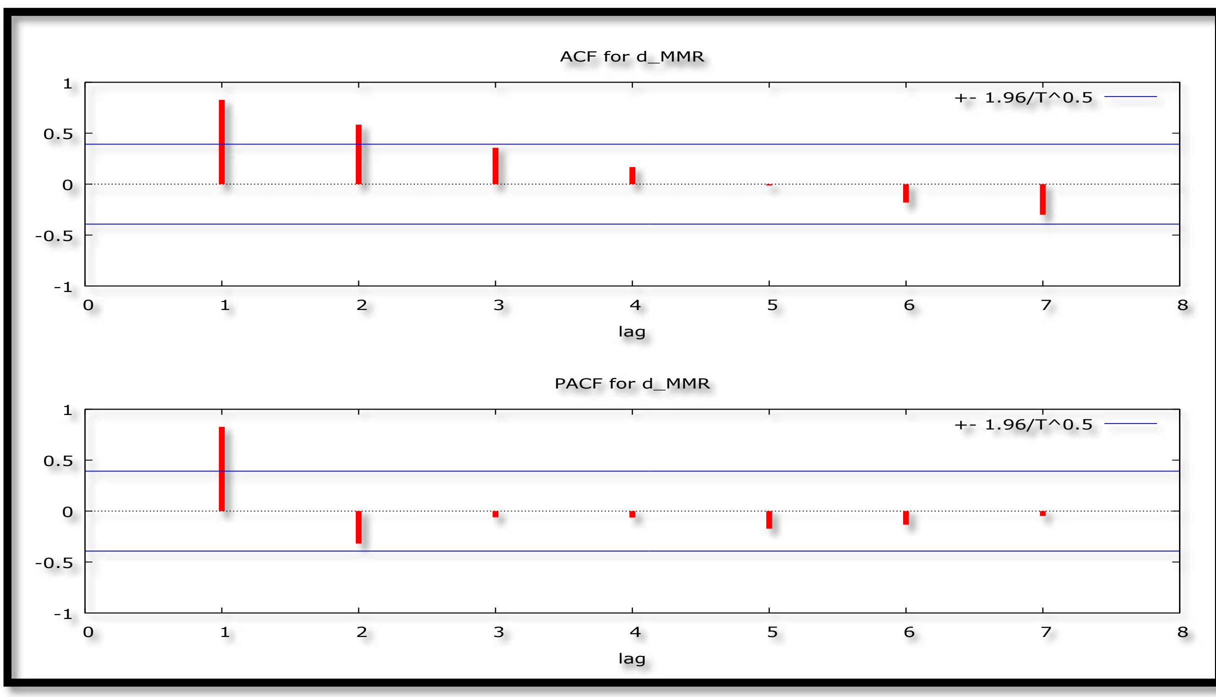


Table 17: 1st Difference-intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
MMR	-2.201644	0.2112	-3.769597	@1%	Not stationary
			-3.004861	@5%	Not stationary

		-2.642242	@10%	Not stationary

Table 18: 1st Difference-trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
MMR	-0.490672	0.9767	-4.394309	@1%	Not stationary
			-3.612199	@5%	Not stationary
			-3.243079	@10%	Not stationary

Table 19: 1st Difference-without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
MMR	-2.278961	0.0249	-2.674290	@1%	Not stationary
			-1.957204	@5%	Stationary
			-1.608175	@10%	Stationary

Correlogram at 2nd Differences

Figure 11: Correlogram at 2nd Differences

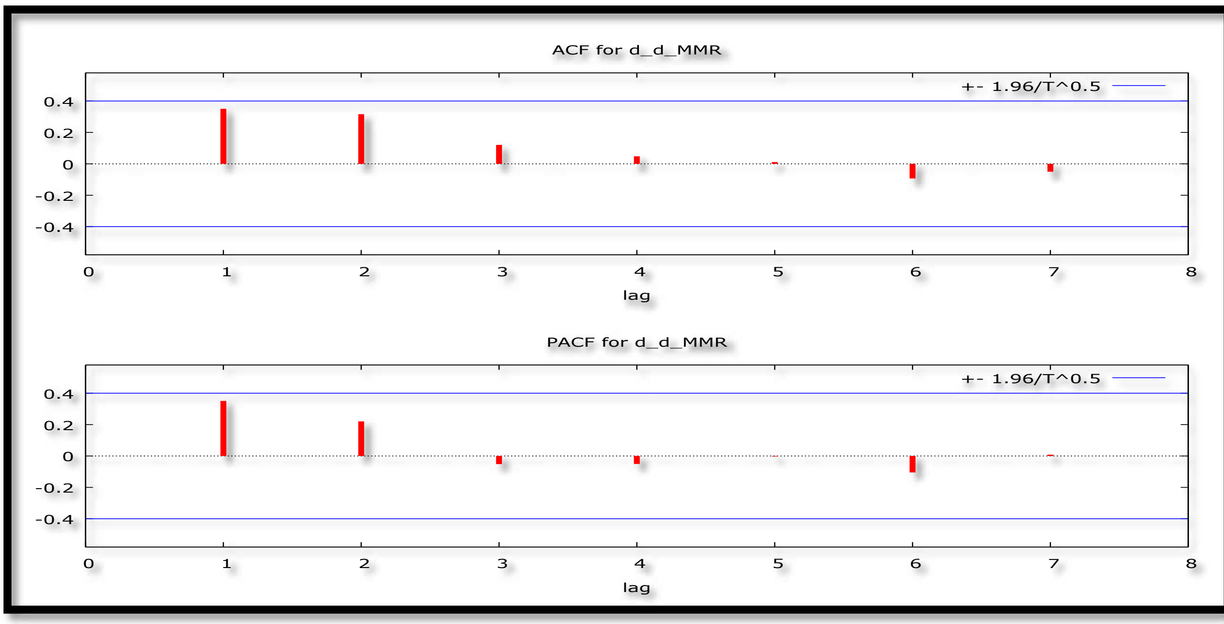


Table 20: 2nd Difference-intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
MMR	-3.142596	0.0373	-3.752946	@1%	Not stationary
			-2.998064	@5%	Stationary
			-2.638752	@10%	Stationary

Table 21: 2nd Difference-trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
MMR	-1.249531	0.8738	-4.440739	@1%	Not stationary
			-3.632896	@5%	Not stationary
			-3.254671	@10%	Not stationary

Table 22: 2nd Difference-without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
MMR	-3.137377	0.0032	-2.669359	@1%	Stationary
			-1.956406	@5%	Stationary
			-1.608495	@10%	Stationary

In figure 8 above, it is clear that the MMR trend generally follows a "W-shaped-like" curve and it is indeed reasonable to suspect that it is non-stationary. Figures 9 – 11 and tables 14 – 22 are formal tests for stationarity and as illustrated, variable MMR is an I (2) variable.

Evaluation of ARIMA Models (without a constant)

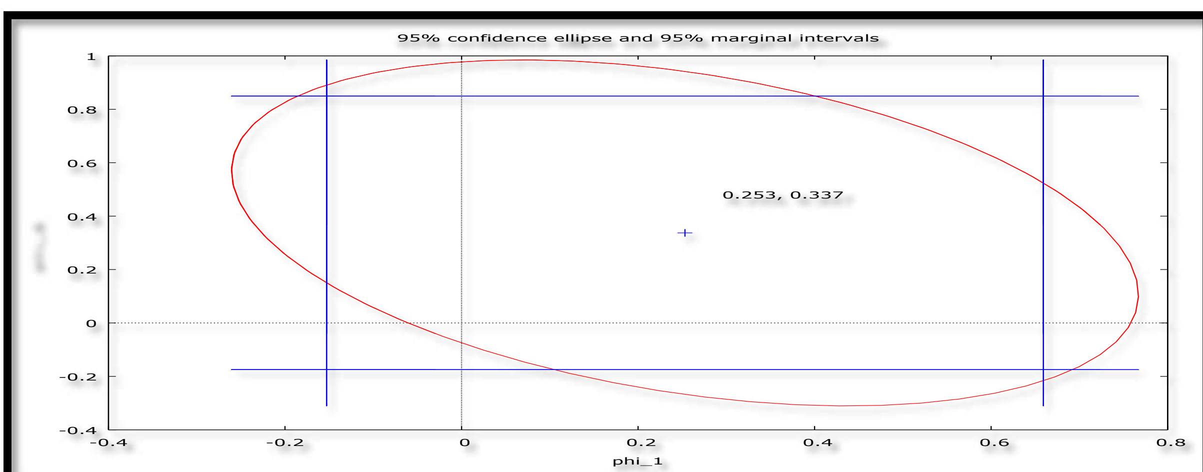
Table 23: Evaluation of ARIMA Models (without a constant)

Model	AIC	U	ME	MAE	RMSE	MAPE
ARIMA (1, 2, 1)	197.1814	0.51634	1.7223	9.5899	12.933	2.0479
ARIMA (6, 2, 0)	203.4144	0.50514	1.4241	8.7188	12.463	1.8786
ARIMA (7, 2, 0)	205.2325	0.50265	1.4095	8.7289	12.41	1.8656
ARIMA (0, 2, 1)	197.3836	0.54016	1.8181	10.088	13.581	2.1296
ARIMA (0, 2, 2)	196.3058	0.52087	1.6471	8.8329	12.721	1.9015
ARIMA (1, 2, 0)	196.2138	0.52416	1.5953	9.9939	13.233	2.1205
ARIMA (2, 2, 0)	**196.1987**	0.51063	1.7685	9.2336	12.627	1.9828
ARIMA (3, 2, 0)	198.1778	0.51067	1.711	9.2358	12.627	1.9821
ARIMA (4, 2, 0)	199.594	0.50864	1.523	8.881	12.509	1.9165
ARIMA (5, 2, 0)	201.5186	0.504	1.4977	9.0218	12.492	1.9362
ARIMA (1, 2, 2)	197.6382	0.50483	1.6651	9.1456	12.485	1.9679
ARIMA (2, 2, 1)	198.1898	0.51063	1.745	9.2384	12.627	1.9833

The optimal model, in this regard, is the ARIMA (2, 2, 0) and is thus chosen.

Confidence Ellipse of the ARIMA (2, 2, 0) Model for MMR

Figure 12: Confidence Ellipse of the ARIMA (2, 2, 0) Model for MMR

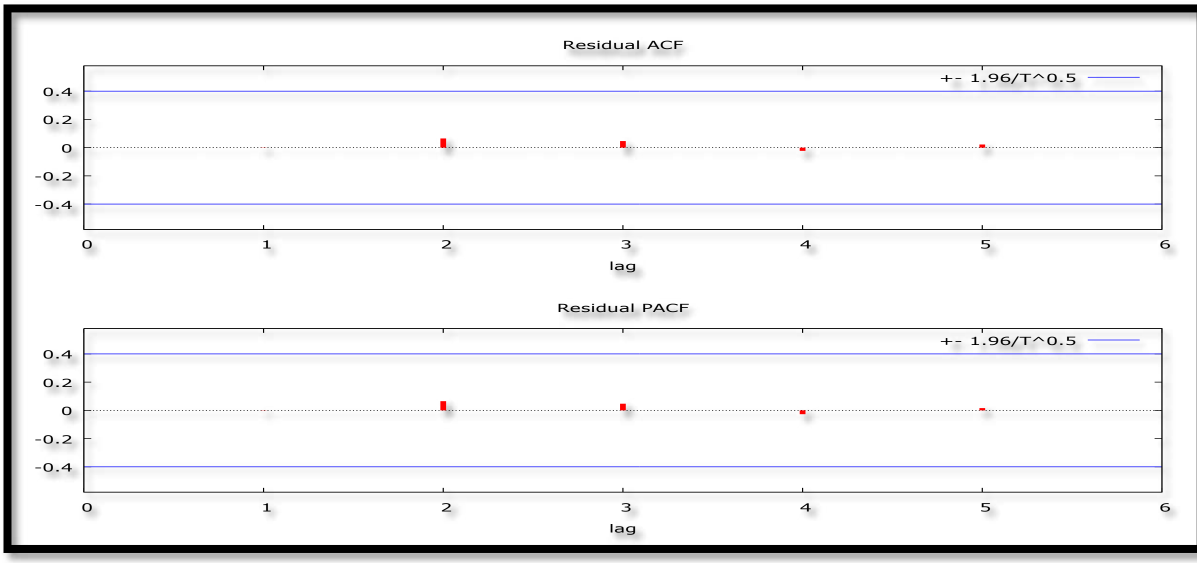


The figure above shows the region in which the realization of the two test statistics must lie for the researcher not to reject the null hypothesis. Figure 12 absolutely confirms the accuracy of the ARIMA (2, 2, 0) model in forecasting MMR in Zimbabwe.

Residual & Stability Tests

Residual Correlogram of the ARIMA (2, 2, 0) Model for MMR

Figure 13: Residual Correlogram of the ARIMA (2, 2, 0) Model for MMR



ADF Tests of the Residuals of the ARIMA (2, 2, 0) Model for MMR

Table 24: Levels-intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
R_t	-5.117254	0.0005	-3.788030	@1%	Stationary
			-3.012363	@5%	Stationary
			-2.646119	@10%	Stationary

Table 25: Levels-trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
R_t	-6.154814	0.0003	-4.467895	@1%	Stationary
			-3.644963	@5%	Stationary
			-3.261452	@10%	Stationary

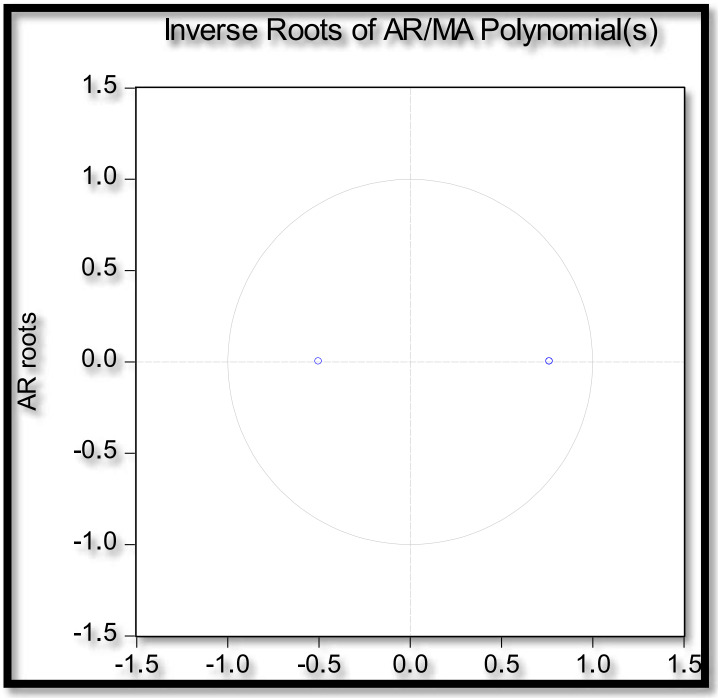
Table 26: without intercept and trend & intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
R_t	-5.292257	0.0000	-2.679735	@1%	Stationary
			-1.958088	@5%	Stationary
			-1.607830	@10%	Stationary

Figure 13 and tables 24 to 26 show that the residuals of the ARIMA (2, 2, 0) model are stationary.

Stability Test of the ARIMA (2, 2, 0) Model for MMR

Figure 14: Inverse Roots of the ARIMA (2, 2, 0) Model for MMR



Since the corresponding inverse roots of the characteristic polynomial lie in the unit circle, then we can conclude that the chosen ARIMA (2, 2, 0) model is stable and indeed suitable for forecasting MMR in Zimbabwe.

4. Findings of the Study

Table 14: Descriptive Statistics

Description	Statistic (Number of Maternal Deaths)	Statistic (MMR)
Mean	2234.6	502.15
Median	2250	482
Minimum	1600	369
Maximum	2900	657
Standard deviation	417.56	92.932
Skewness	0.0096778	0.30999
Excess kurtosis	-1.2734	-1.3096

As shown in table 14 above, the means for maternal deaths and MMR are positive, i.e 2234.6 and 502.15 respectively. The medians for maternal deaths and MMR are 2250 and 482 respectively. The maximum for maternal deaths and MMR are 2900 and 657 respectively. The minimum for maternal deaths and MMR are 1600 and 369 respectively. Since skewness statistics for maternal deaths and MMR are 0.0096778 and 0.30999 respectively, it basically implies that variables M_t and MMR_t are positively skewed and non-symmetric. Excess kurtosis for maternal deaths and MMR is -1.2734 and -1.3096 respectively and this shows that both M_t *and* MMR_t are not normally distributed.

Results Presentation[1] (Maternal Deaths ARIMA model)

Table 15: Results Presentation (Maternal Deaths ARIMA model)

ARIMA (0, 2, 2) Model: $\Delta^2 M_{t-1} = -0.278554Z_{t-1} + 0.452172Z_{t-2}$ … … … … …. … … … … [13] P: 0.1349 0.0.0503 S. E: 0.186332 0.231007				
Variable	Coefficient	Standard Error	z	p-value
θ_1	-0.278554	0.186332	-1.495	0.1349
θ_2	0.452172	0.231007	1.957	0.0503*

Figure 15: Forecast Graph (Maternal Deaths)

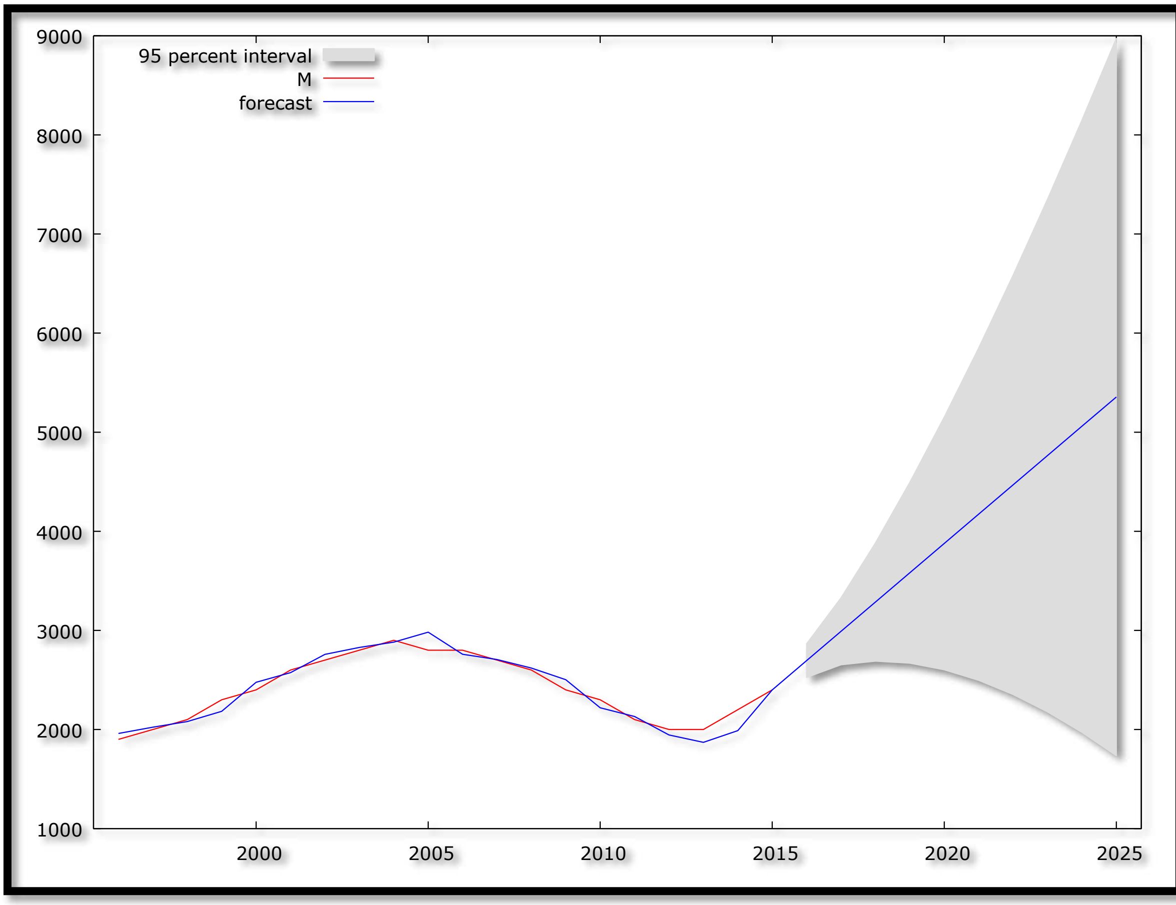


Table 16: Predicted Maternal Deaths

Year	Predicted Maternal	Standard Error	95% interval

[1] * means significant at 10% level of significance

	Deaths		
2016	2695.40	86.6581	(2525.55, 2865.25)
2017	2990.95	172.521	(2652.82, 3329.09)
2018	3286.51	304.474	(2689.75, 3883.27)
2019	3582.06	465.854	(2669.00, 4495.12)
2020	3877.61	650.690	(2602.28, 5152.94)
2021	4173.17	855.876	(2495.68, 5850.65)
2022	4468.72	1079.39	(2353.15, 6584.29)
2023	4764.27	1319.76	(2177.59, 7350.96)
2024	5059.82	1575.84	(1971.24, 8148.41)
2025	5355.38	1846.69	(1735.94, 8974.82)

Figure 16: Predicted Maternal Deaths

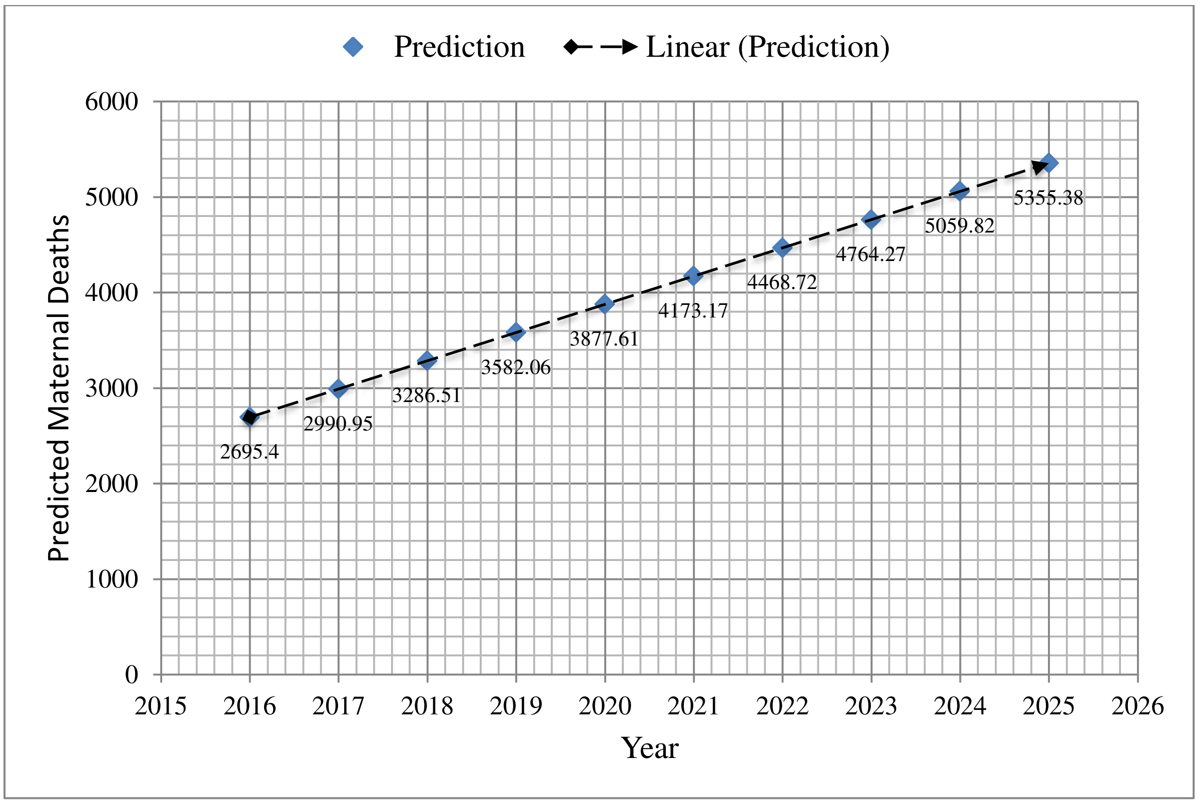


Table 15 shows the main results of the ARIMA (0, 2, 2) model depicting annual maternal deaths in Zimbabwe. Figure 15 & 16 and table 16 show the predicted maternal deaths over the period 2016 – 2025. The study regrets to note that maternal deaths are likely to increase over the out-of-sample forecast as shown in figures 15 & 16 and table 16.

<u>Results Presentation (MMR ARIMA model)</u>

Table 17: Results Presentation (MMR ARIMA model)

ARIMA (2, 2, 0) Model:

$$\Delta^2 MMR_{t-1} = -0.729771\Delta^2 MMR_{t-1} + 0.914701\Delta^2 MMR_{t-2} \ldots . [14]$$

P: 0.1960 0.1720

S. E: 0.195795 0.246872

Variable	Coefficient	Standard Error	z	p-value
$\emptyset_1$	0.253144	0.195795	1.293	0.1960
$\emptyset_2$	0.337213	0.246872	1.366	0.1720

Figure 17: Forecast Graph (MMR)

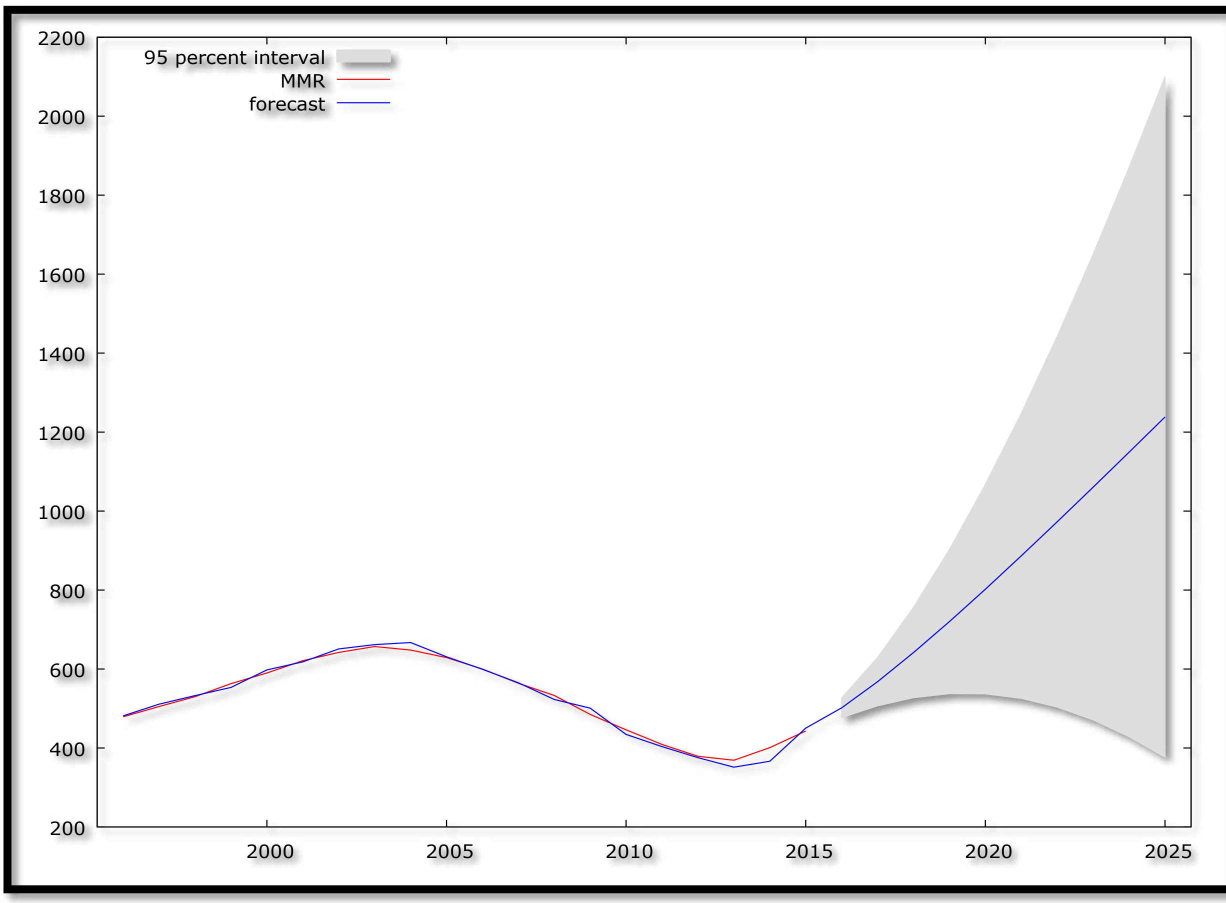


Table 18: Predicted MMR

Year	Predicted MMR	Standard Error	95% interval
2016	501.694	12.6192	(476.961, 526.428)
2017	567.987	31.1074	(507.018, 628.956)
2018	641.833	58.3027	(527.561, 756.104)
2019	720.152	93.0716	(537.735, 902.569)
2020	802.152	135.218	(537.130, 1067.17)
2021	886.592	184.150	(525.664, 1247.52)
2022	972.890	239.453	(503.571, 1442.21)
2023	1060.48	300.680	(471.160, 1649.80)

2024	1149.03	367.454	(428.830, 1869.22)
2025	1238.25	439.427	(376.989, 2099.51)

Figure 18: Predicted MMR

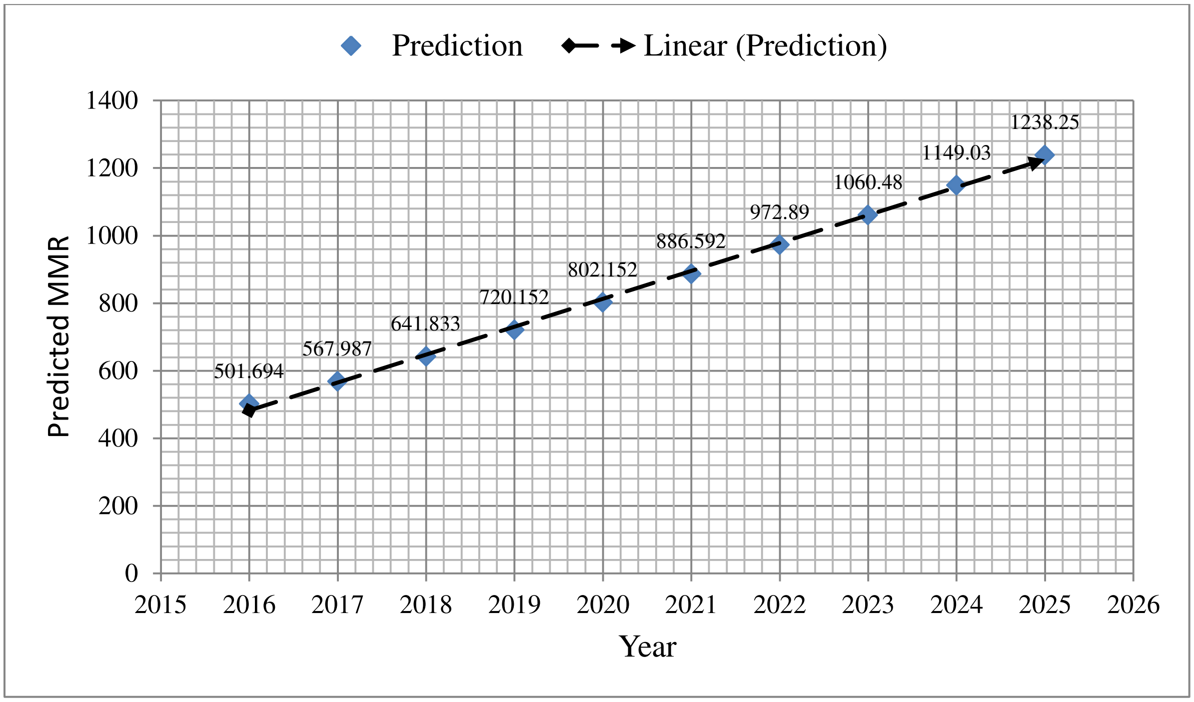


Table 17 shows the main results of the ARIMA (2, 2, 0) model depicting annual MMR in Zimbabwe. Figure 17 & 18 and table 18 show the predicted MMR over the period 2016 – 2025. The study projects a likely increase in maternal mortality ratios in Zimbabwe over the out-of-sample forecast as illustrated in figures 17 & 18 and table 18.

5. Policy Prescriptions

i. There is need for increased health sector spending in Zimbabwe, especially investment in health education, particularly, in midwifery skills. In this regard, the government of Zimbabwe should also ensure that maternal health care institutions are capacitated with skilled professionals to deliver emergency obstetrical and gynaecological care services.
ii. There is need for health sector reform in Zimbabwe.
iii. There is need for extensive capacity building, for example, through up-scaling of maternal health service facilities in Zimbabwe.

6. Conclusion

Most countries with high maternal (and newborn) mortality have very limited resources, overstretched health workers, and relatively weak systems and governance (Koblinsky, 2017). The economy of Zimbabwe is riddled with poverty, inequality, informality, chronic and recurrent phases of economic stagnation, poor institutional climate, cash crisis, rampant corruption, political volatility, low savings and investment, high interest rates, high costs of production, lack of competitiveness, low aggregate demand, poor infrastructure as well as high rates of unemployment (Nyoni & Bonga, 2017). These are some of the main issues that militate against the revival of the health sector in Zimbabwe. This study analyzed maternal deaths as well as maternal mortality ratios over the period 1990 – 2015 using the Box – Jenkins ARIMA framework. Based on the minimum AIC statistics, the ARIMA (0, 2, 2) model and the ARIMA (2, 2, 0) model were found to be optimal for forecasting maternal deaths and MMR respectively. Further research could be done in terms of empirically analyzing the determinants of maternal mortality as well as impact of maternal mortality on economic growth in Zimbabwe.

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