



DETECTION OF FUTURE TRENDS OF MATERNAL MORTALITY IN BURUNDI USING THE DOUBLE EXPONENTIAL SMOOTHING TECHNIQUE

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Abstract:

This study uses annual time series data on MMR for Burundi from 1985 to 2023 to predict future trends of MMR over the period 2024 to 2035. The study utilizes Holt's double exponential smoothing model. The optimal values of smoothing constants α and β are 0.6 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will continue on a downward path but still remain very high throughout the out of sample period. Hence, we implore health authorities to adopt the suggested 5-fold policy prescription.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio

INTRODUCTION

In developing countries women often encounter adverse health outcomes during pregnancy, childbirth, and the postpartum period (Jamieson et al. 2006). These outcomes include severe bleeding, infections, hypertensive disorders, delivery complications, unsafe abortion, and the aggravation of pre-existing health conditions (Alkema et al. 2016; Say et al. 2014). Obstetric hemorrhage accounts for 27.1% of all maternal deaths while hypertension and sepsis are account for 14 and 10.7% of deaths, respectively (Say et al. 2014). Approximately 830 women die every day across the globe from pregnancy- or childbirth-related complications with 99% of the mortality being reported in developing countries (Alkema et al. 2016). It is estimated that about two Burundian women out of 100 will die of pregnancy-related conditions including hemorrhage, infections, eclampsia and unsafe abortion during their reproductive life (Burundi, 2018). The government of Burundi made significant progress in

reducing adverse pregnancy outcomes, however a lot needs to be done. Burundi has one of the highest maternal mortality ratios in the world: 712 maternal deaths per 100,000 live births which is the eighth highest in the world (Alkema et al. 2016). It is worthy to mention that the majority of health conditions occurring during pregnancy, childbirth, and in the postpartum period are preventable and curable by timely and appropriate maternal health care (Pierre et al. 2018; WHO, 2018). Availing adequate resources and provision of quality antenatal, delivery and postnatal care is an effective method of reducing maternal and neonatal mortality (WHO, 2018; Gülmezoglu et al. 2016; Dowswell et al. 2015). The objective of this paper is to model and forecast MMR for Burundi using the double exponential smoothing technique. The study findings are envisioned to detect likely future trends of MMR thereby guiding policy and resource allocation to the health sector.

LITERATURE REVIEW

Author(s)	Objective(s)	Methodology	Main finding(s)
Ndayishimiye et al. (2025)	to assess neonatal survival and identify factors associated with neonatal mortality in one tertiary hospital of Bujumbura, Burundi	The study recruited 885 babies whose births occurred between October and December 2020 in Kamenge Teaching Hospital of the University of Burundi and followed them over four months - applied life table methods and	Neonatal mortality remains high, predominantly driven by preventable and curable complications



		implemented the Cox proportional hazard regression model to evaluate neonatal survival and determine factors associated with neonatal mortality	
Birabwa et al. (2024)	To describe the trends in IMMR between 2016 and 2021, and the causes and characteristics of maternal deaths in Kampala, Uganda	This retrospective study utilized routine data from all facilities in Kampala that provided childbirth services from 2016 to 2021.	Obstetric hemorrhage (44%) and hypertensive disorders in pregnancy (28%) were the most commonly recorded causes of death. Health system factors such as lack of blood and other supplies contributed to 65% of the deaths reviewed
Habonimana and Batura (2021)	To explore the socio-economic determinants that affect utilization of maternal health services in Burundi	-use data from the 2016–2017 Burundi Demographic and Health Survey (DHS) collected from 8941 women who reported a live birth in the five years that preceded the survey -applied multiple regression analysis	In Burundi, utilization of maternal health services is low and is mainly driven by legal union and wealth status
Bomela (2020)	To assess and analyses the causes of maternal mortality according to sociodemographic factors in South Africa	The causes of maternal deaths were assessed with respect to age, province, place of death, occupation, education and marital status. Data were obtained from the vital registration database of Statistics South Africa	The study shows evidence of variations in the causes of death among different socio-demographic subgroups
Adgoy (2018)	To explore the key social determinants and ways of coping mechanisms, for the reduction of maternal mortality, among African women living inside the African continent	Systematic review	The continental maternal death trend did not reduce as it was intended by Millennium Development Goals (Goal - 5) and still continues with Sustainable Development Goals (Goal-5), "Achieve gender equality and empower all women and girls"



Girum and Wasie (2017)	to identify correlates of maternal mortality in developing countries	Systematic review	Maternal mortality is correlated with multiples of socio-economic factors, health care system associated factors, disease burden and their complex interactions
Koneko et al. (2017)	To assess the effectiveness of the Maternal and Child Health (MCH) handbook for increasing notification of birth at health facilities and PNC uptake	Pre- and post-introduction measurement were applied including: (i) structured interviews with two different sets of randomly selected mothers having infants aged less than six weeks at the pre- or post-studies; and (ii) secondary data from the national health management information system	As previous studies showed, the MCH handbook appeared to help health personnel provide guidance on PNC, thereby it may have increased PNC. Furthermore, this study suggests the handbook contributed to every birth being counted
Taylor-Smith et al. (2012)	To estimate the reduction in maternal mortality associated with the emergency obstetric care provided by Medecins Sans Frontieres (MSF) and to compare this to the fifth Millennium Development Goal of reducing maternal mortality	The impact of MSF's intervention was approximated by estimating how many deaths were averted among women transferred to and treated at MSF's emergency obstetric care facility in Kabezi, Burundi, with a severe acute maternal morbidity. Using this estimate, the resulting theoretical maternal mortality ratio in Kabezi was calculated and compared to the Millennium Development Goal for Burundi	MSF intervention averted 74% (range 55–99%) of maternal deaths in Kabezi district, equating to a district maternal mortality rate of 208 (range 8–360) deaths/100 000 live births. This lies very near to the 2015 MDG 5 target for Burundi (285 deaths/100 000 live births)

METHODOLOGY

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Burundi. In exponential smoothing forecasts are generated from the smoothed original series with the most recent historical values having more influence than those in the more distant past as more recent values are allocated more weights than those in the distant past. This study uses the Holt's linear method (Double exponential smoothing) because it is an appropriate technique for modeling linear data.

Holt's linear method is specified as follows:



Model equation

$$Z_t = \mu_t + \rho_t \mathbf{t} + \varepsilon_t$$

Smoothing equation

$$S_t = \alpha Z_t + (1-\alpha) (S_{t-1} + b_{t-1})$$

$$0 < \alpha < 1$$

Trend estimation equation

$$b_t = \beta (S_t - S_{t-1}) + (1-\beta)b_{t-1}$$

$$0 < \beta < 1$$

Forecasting equation

$$f_{t+h} = S_t + hb_t$$

Z_t is the actual value of MMR at time t

ε_t is the time varying **error term**

μ_t is the time varying mean (**level**) term

ρ_t is the time varying **slope term**

$\mathbf{t}$ is the trend component of the time series

S_t is the exponentially smoothed value of MMR at time t

α is the exponential smoothing constant for the data

β is the smoothing constant for trend

f_{t+h} is the h step ahead forecast

b_t is the trend estimate (slope of the trend) at time t

b_{t-1} is the trend estimate at time $t-1$

DATA ISSUES

This study is based on annual MMR in Burundi for the period 1985– 2023. The out-of-sample forecast covers the period 2024 – 2035. All the data employed in this research paper was gathered from the World Bank online database.

Findings

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	Z
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.600
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	61.301447
Sum Square Error (SSE)	439880.030904
Mean Square Error (MSE)	11278.975151
Mean Percentage Error (MPE)	1.307730
Mean Absolute Percentage Error (MAPE)	6.146345

Residual Analysis for the Applied Model

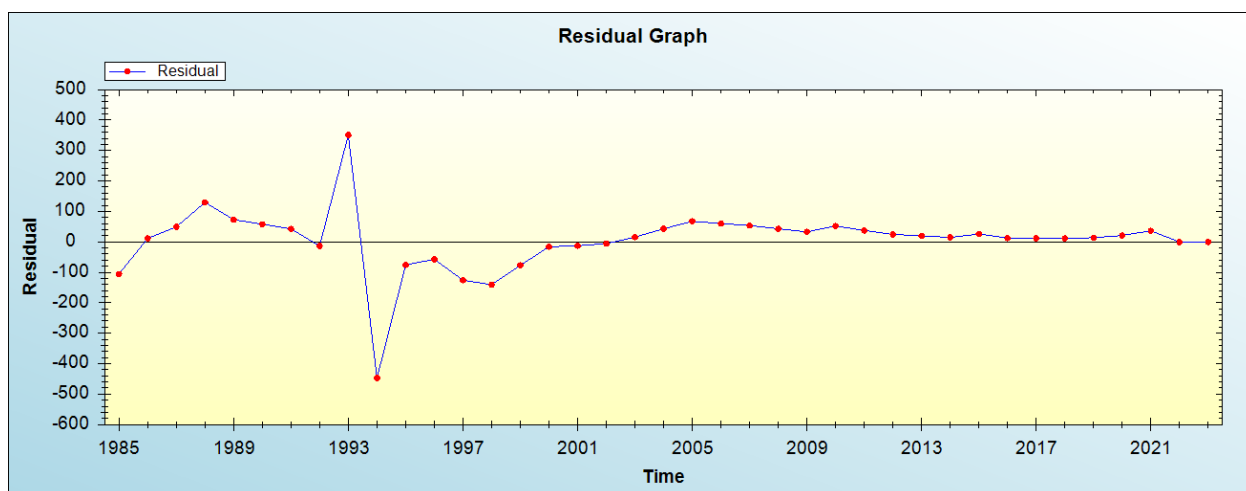


Figure 1: Residual analysis

In-sample Forecast for Z

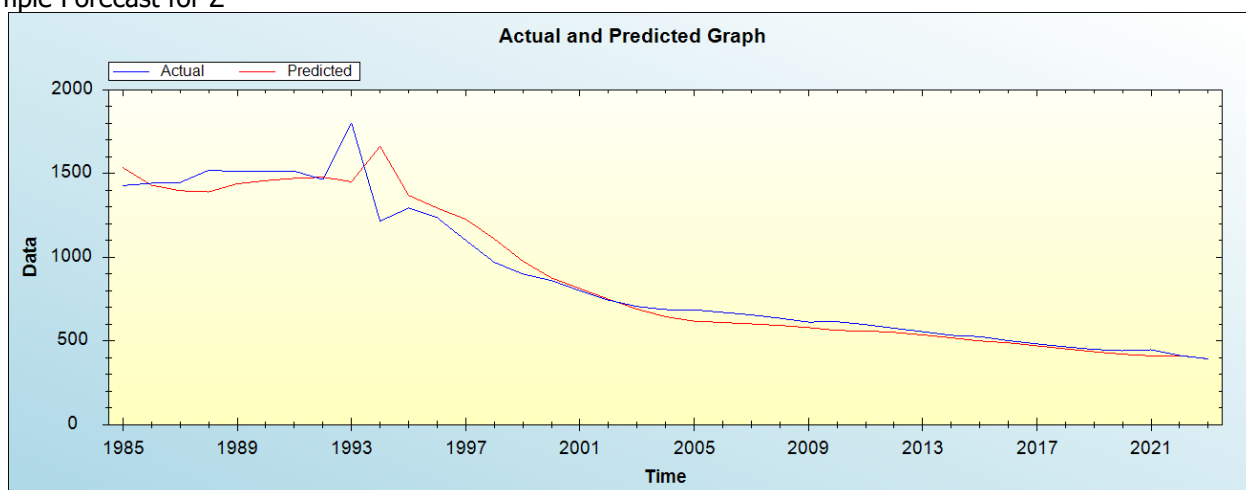


Figure 2: In-sample forecast for the Z series

Actual and Smoothed graph for Z series

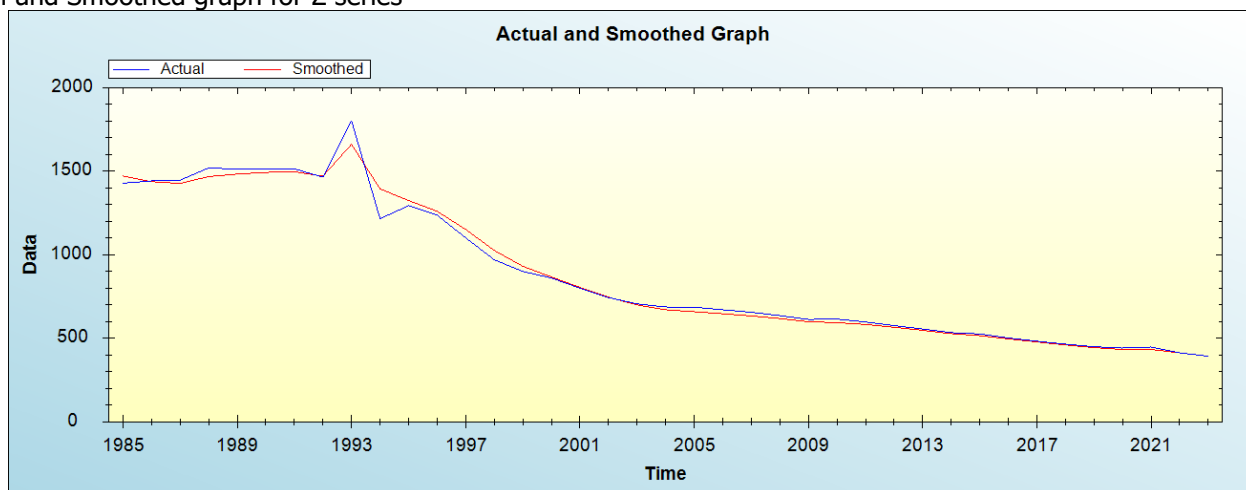


Figure 3: Actual and smoothed graph for Z series

Out-of-Sample Forecast for Z: Actual and Forecasted Graph

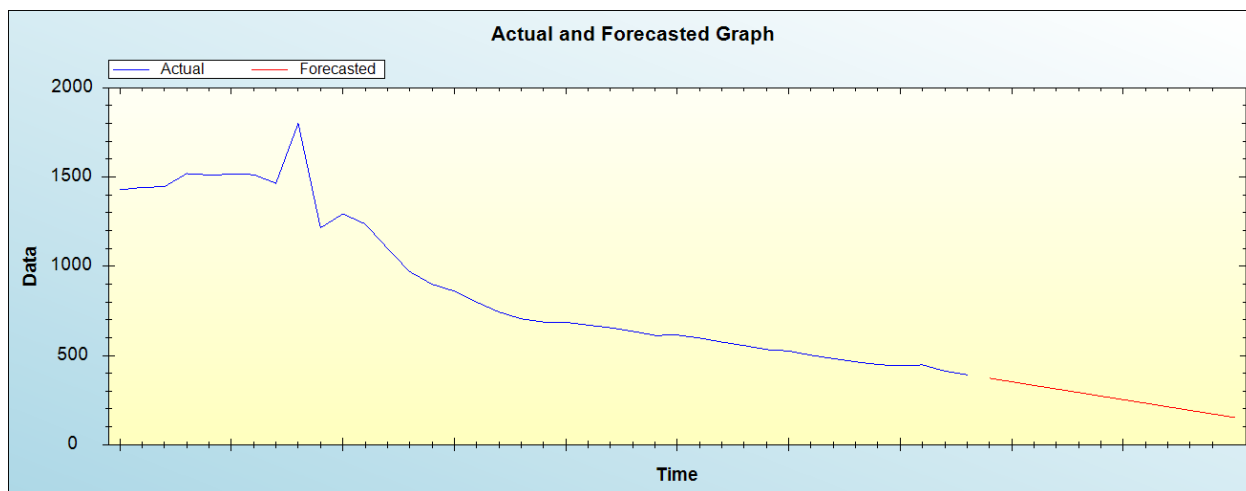


Figure 4: Out-of-sample forecast for Z: actual and forecasted graph

Out-of-Sample Forecast for Z: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	372.0887
2025	352.0987
2026	332.1086
2027	312.1186
2028	292.1285
2029	272.1385
2030	252.1484
2031	232.1584
2032	212.1683
2033	192.1783
2034	172.1882
2035	152.1982

The main results of the study are shown in table 1. It is clear that the model is stable as confirmed by evaluation criterion as well as the residual plot of the model shown in figure 1. It is projected that annual MMR will decline but remain very high over the out of sample period.

RECOMMENDATIONS & CONCLUSION

This paper uses the double exponential smoothing method to forecast MMR for Burundi and the results indicate that MMR will decline but still remain very high throughout the out of sample period. Therefore, health authorities are encourage to adopt the following policy prescription: (1) promote female education & enforce laws that curb child marriages, (2) ensure availability of adequate medical supplies and staff at all levels of the healthcare system particularly in the rural areas, (3) secondment of obstetricians at high volume district/general hospitals so that complicated maternity patients receive appropriate care in time (4) routine implementation of quality improvement initiatives and

(5) channeling more resources to the health sector so that coverage of maternity services is increased across the country

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