



DETECTION OF FUTURE TRENDS OF ANNUAL MATERNAL MORTALITY RATE FOR TANZANIA USING HOLT'S LINEAR METHOD

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Abstract

This study uses annual time series data on MMR for Tanzania 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 0.9 and 0.9 respectively based on minimum MSE. The results of the study indicate that MMR is expected to increase and also remain very high over the out of sample period. Therefore, we encourage authorities to adopt the suggested 5-fold policy prescription.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

Introduction

The maternal mortality ratio in Sub-Saharan Africa is around 546 per 100,000 live births, representing roughly two thirds of the global maternal deaths (Alkema et al. 2016; WHO, 2015). Tanzania is among the countries in Sub-Saharan Africa with the highest maternal mortality ratio (MMR). The most recent population-based surveys highlighted that the average MMR in Tanzania is 556 per 100,000 live births (Tanzania DHS 2016 & Malaria Indicator survey) while the United Nations reported 950 per 100,000 live births (WHO, 2015). Over the period 1990–2016 MMRs in Tanzania were persistently high despite several initiatives that were implemented by the government (Shoo et al. 2017; Mboera et al. 2015; Shija et al. 2011). Maternal deaths are associated with both direct and indirect obstetric causes. The direct causes, which include hemorrhage, hypertensive disorders, obstructed labor, and sepsis are account for nearly 75% of maternal



deaths globally (Say et al. 2014; Lozano et al, 2012; Khan et al. 2006; Boerma,1987). On the other hand, indirect causes of maternal death include the effects of pre-existing disorders, such as HIV, malaria, tuberculosis, mental diseases, epilepsy, and diabetes (WHO, 2012; Khan et al. 2006). Well documented predictors of maternal deaths include antenatal care, maternal education, age and gravidity (Yego et al. 2014; Chandra-Mouli et al. 2013; Ujah et al. 2005). The objective of this paper is to model and forecast MMR for Tanzania using Holt's linear method. The study results will assist in policy making, planning and allocation of adequate resources to the health sector.

Literature Review

Author(s)	Objective(s)	Methodology	Key finding(s)
Kidayi et al. (2026)	To explore perceptions and experiences of nurse educators (lecturers) and midwives on simulation-based education in Tanzania	qualitative descriptive study	Students were indeed experienced, but not trained in how to use simulation-based education, and nurse educators had inadequate skills. A high number of students with inadequate infrastructure and resources is the major challenge experienced by participants
Jena et al. (2025)	To estimate the pooled magnitude of neonatal mortality and its association with maternal and child health care in SSA	Systematic review	Neonatal mortality in SSA remains high. Maternal health services such as exposure to antenatal care and institutional delivery and child health services such as early initiation of breastfeeding were related to reducing the burden of neonatal mortality
Lukwa et al. (2024)	To evaluate the effectiveness and value of value-based healthcare interventions in improving maternal health outcomes in Sub-Saharan Africa	Systematic review	The results suggest that VBHC can significantly improve maternal health, evidenced by successful implementations like obstetric units in Sierra Leone and integrated care in South Africa, which improved outcomes and cost-effectiveness
Baig et al. (2023)	To Investigate maternal mortality in Southeast Asia, Europe and Africa	Literature review	-Inadequate care is one of the major causes of maternal mortality in majority of regions across the globe



Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, Issue 8, August 2026

Website: usajournals.org

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			-The three delays model plays a significant role in the higher maternal mortality rate
Konlan et al. (2023)	To identify factors that influence women's decision for a CS are synthesized to clarify policy initiatives that improve care	Systematic review	The prevalence of CS was 2.1% to 18.5% of all live births as the socioeconomic status (SES) and demographic factors that influence the rate of CS were higher SES, education, and age; place of birth; urban residence; and women headed household
Mlambo et al. (2023)	to investigate the macro determinants of maternal mortality in Southern African Development Community (SADC) states	A panel data estimation (Generalized Method of Moments) covering the period from 2005–2019 was used to examine how various factors affect maternal mortality	The econometric analysis reveals a significant positive impact of fertility, GDP per capita and HIV on maternal mortality
Okonji et al. (2023)	To assess maternal mortality patterns by age and country in Sub-Saharan Africa	The demographic and health survey data were used for the study	The study found that the patterns of death vary across different countries
Nnadi et al. (2022)	to estimate the effect of maternal mortality on economic development in Sub-Sahara African region. Cross-sectional data analysis of selected member countries in the region under focus was employed using double-log econometric model	Cross-sectional data analysis of selected member countries in the region under focus was employed using double-log econometric model	The explanatory variables in the model were statistically significant at 5% level while other coefficients like maternal mortality, exports and imports conform to the apriori expectations and impacted negatively on the overall GDP
Musarandega et al. (2021)	to identify the leading causes of maternal deaths using the international classification of disease – 10th revision, for maternal mortality (ICD-MM)	Systematic review	Obstetric hemorrhage, hypertensive disorders in pregnancy, non-obstetric complications, and pregnancy-related infections are the leading causes of maternal deaths in SSA
Said et al. (2021)	To identify gaps in documenting information and developing recommendations,	-A total of 76 facility maternal deaths that occurred in two regions in Southern Tanzania in 2018	-Abstraction of information to prepare narrative summaries used in the MDSR system is inadequately done



	comprehensiveness of written narrative summaries and action plans in Tanzania	were included for analysis - Using a prepared checklist from Tanzania 2015 MDSR guideline, researchers assessed comprehensiveness by presence or absence of items in four domains, each with several attributes	-Most recommendations were unspecific with a focus on improving quality of care in health facilities
Lilungulu et al. (2020)	to identify the magnitude and predictors of maternal and perinatal mortality among women with severe maternal outcomes admitted to Dodoma Regional Referral Hospital, Tanzania	A retrospective cross-sectional study was conducted from October 2015 to January 2016 at Dodoma Regional Referral Hospital in Dodoma City	Most of the maternal morbidity and mortality were due to direct causes in which postpartum hemorrhage and hypertensive disorders were the leading causes
Nassoro et al. (2020)	to analyze causes and associated factors for maternal deaths in Dodoma Regional Referral Hospital (DRRH)	- A retrospective review of all files of the women who died in 2018 and were classified as maternal deaths	Maternal mortality is still high in Dodoma Regional Referral Hospital. Eclampsia was the leading cause of maternal deaths in 2018 followed by sepsis and obstetric hemorrhage. Delays associated with health system factors (third-phase delay) contributed much more to maternal mortality than the first-phase delay
Bwana et al. (2019)	to determine the causes and maternal mortality trends in public hospitals of Tanzania from 2006–2015	Retrospective study	During the ten year period (2006–2015) there was an increase in the number of hospital maternal deaths in public hospitals in Tanzania. Maternal deaths accounted for 5% of all women of child-bearing age in-hospital mortalities. Most maternal deaths were due to direct causes including eclampsia, hemorrhage and sepsis



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
Singh et al. (2016)	To assess how countries in regions of the world where maternal mortality is highest - South Asia and Sub-Saharan Africa - are performing with regards to providing women with vital elements of the continuum of care	-Used Demographic and Health Survey data -descriptive and multilevel regression analyses were conducted on four key elements of the continuum of care - at least one antenatal care visit, four or more antenatal care visits, delivery with a skilled birth attendant and postnatal checks for the mother within the first 24 hours since birth	—Results indicated that a major drop-out (more than 50%) occurs early on in the continuum of care between the first antenatal care visit and four or more antenatal care visits. Few women (less than 5%) who do not receive any antenatal care go on to have a skilled delivery or receive postnatal care

Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Tanzania. 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 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

$$Z_t = \mu_t + \rho_t t + \varepsilon_t$$

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**

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 Tanzania 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 of the study

Exponential smoothing Model Summary



Table 1: ES model summary

Variable	Z
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.900
Forecast performance measures	
Mean Absolute Error (MAE)	28.807802
Sum Square Error (SSE)	71921.941619
Mean Square Error (MSE)	1844.152349
Mean Percentage Error (MPE)	1.904514
Mean Absolute Percentage Error (MAPE)	8.910605

Residual Analysis for the Applied Model

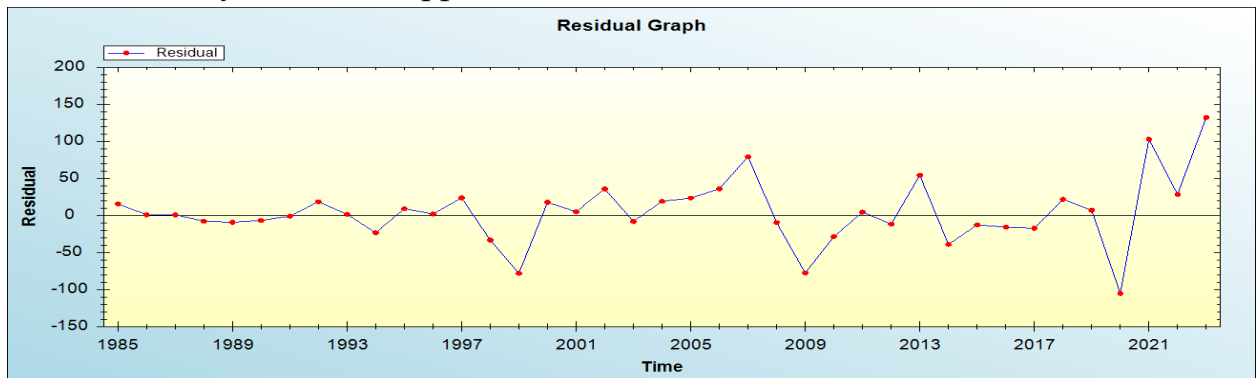


Figure 1: Residual analysis

In-sample Forecast for A

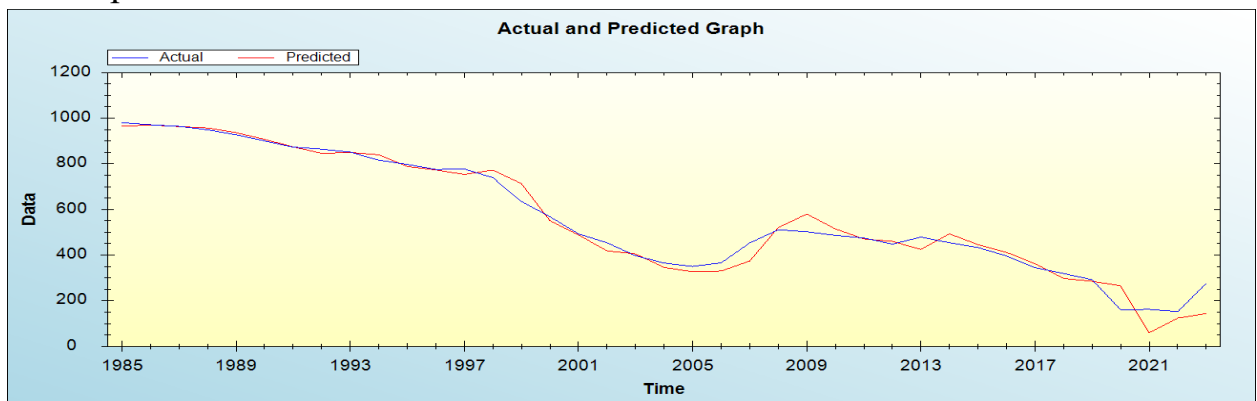


Figure 2: In-sample forecast for the A series



Actual and Smoothed graph for A series

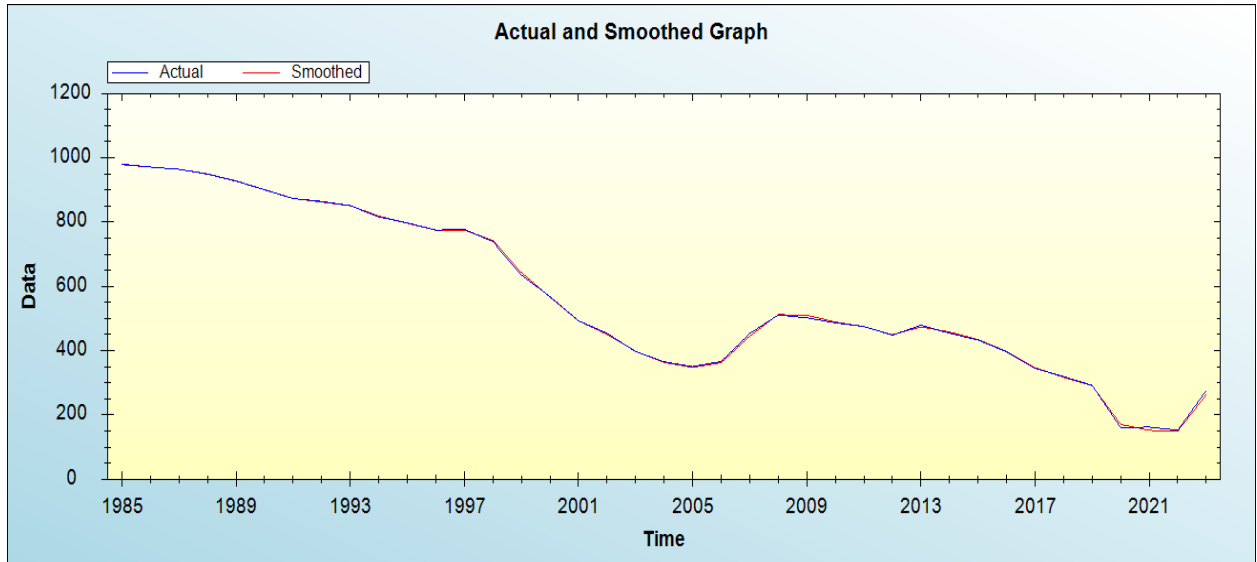


Figure 3: Actual and smoothed graph for A series

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

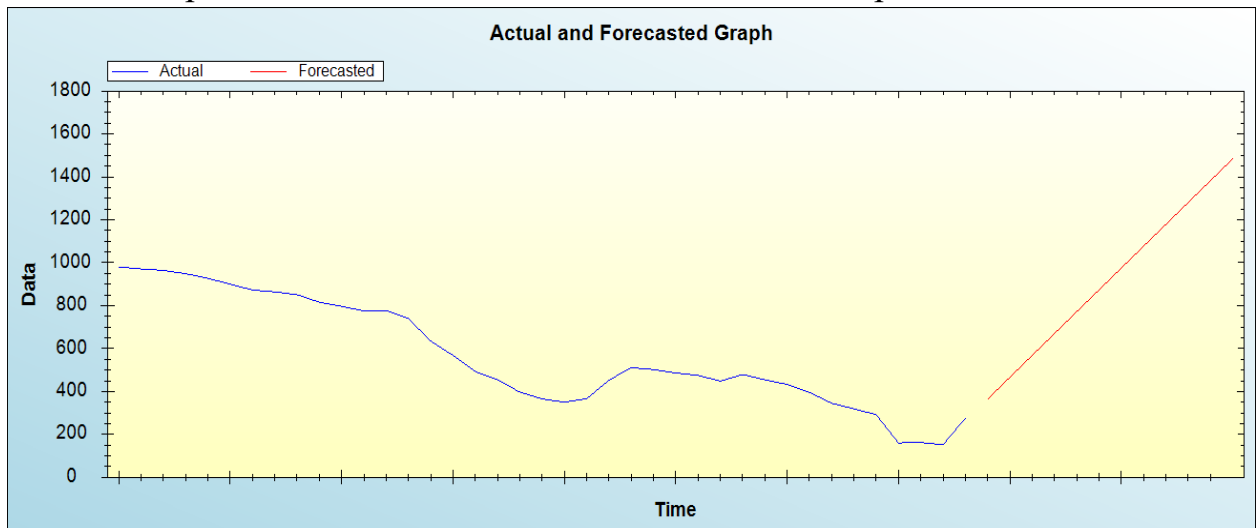


Figure 4: Out-of-sample forecast for A: actual and forecasted graph



Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	364.5720
2025	466.3375
2026	568.1029
2027	669.8683
2028	771.6338
2029	873.3992
2030	975.1646
2031	1076.9301
2032	1178.6955
2033	1280.4610
2034	1382.2264
2035	1483.9918

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 is expected to increase and remain very high over the out of sample period.

Recommendations & Conclusion

High maternal mortality rates in Tanzania reflect the presence of serious issues along the continuum of care that need to be addressed. In addition, these very high MMRs across the country indicate that a lot of challenges have remained partially resolved or unattended for decades now. In this study we applied the double exponential smoothing technique to model and forecast MMR for Tanzania and results indicate that MMR is anticipated to increase and also remain very high over the out of sample period. Hence, we encourage health authorities to adopt the following policy prescription: (1) end adolescent pregnancy by enforcing laws that prohibit early child marriage, promote female education and comprehensive sexual and reproductive health education in schools (2) Improve coverage of maternal and child health services across the country (3) allocate resources towards quality improvement initiatives (4) ensure availability of



adequate medical supplies and medical staff in all medical facilities and (5) create posts for obstetricians at government district hospitals particularly at high volume sites so that specialist services are offered at the first referral level. Alternatively, Registrars undergoing Obstetrics & Gynecology training can be attached at high volume district hospitals under the supervision of provincial consultants.

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