



MATERNAL MORTALITY PROJECTION FOR SUB SAHARAN AFRICA USING THE DOUBLE EXPONENTIAL SMOOTHING TECHNIQUE

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Abstract

This study uses annual time series data on MMR for Sub-Saharan Africa 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 0.8 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will continue to fall but still remain very high throughout the out of sample period. Therefore, we encourage regional health authorities to adopt the suggested 6-fold policy prescription.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

Introduction

Maternal mortality is a global public health problem particularly for Sub-Saharan Africa (SSA), where the burden of maternal mortality and morbidity is disproportionately high (Musarandega et al. 2021). Sub-Saharan Africa accounts for the largest percentage of global maternal deaths, as it contributes nearly two-thirds of all maternal deaths (WHO, 2024). SSA is still committed to the sustainable development goals including SDG 3.1 which focuses on the reduction of maternal mortality to less 70 per 100 000 live births by 2030. However, numerous challenges still persist hindering the achievement of this goal (Vallely et al. 2023; UN, 2015). Several factors contribute to the persistently high maternal mortality rates in Sub-Saharan Africa. These include inadequate access to quality maternal healthcare services, limited availability of skilled birth attendants, poor infrastructure, socioeconomic disparities, cultural beliefs and practices, and weak



health systems (Esther et al. 2023; Flake et al. 2023; Onambele et al. 2023; Dahab et al. 2020; Prata et al. 2010; Graham et al. 2001). Direct causes of maternal deaths such as hemorrhage, hypertensive disorders, sepsis, and obstructed labor, further contribute to maternal morbidity and mortality in the sub-Saharan region (Ngonzi et al. 2016). The objective of this paper is to model and forecast MMR for SSA using the double exponential smoothing technique. The results of the study are expected to assist in designing policies and effective strategies that will substantially reduce maternal deaths to levels below 70 per 100 000 live births or even better than that.

Literature Review

Author(s)	Objective(s)	Methodology	Key finding(s)
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 -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;



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			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
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	-Used Demographic and Health Survey data -descriptive and multilevel regression analyses were conducted on four key elements of the	—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



	vital elements of the continuum of care	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	on to have a skilled delivery or receive postnatal care
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Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Sub-Saharan Africa. 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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

A_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 Sub-Saharan Africa 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	A
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.800
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	16.655509
Sum Square Error (SSE)	19383.450084
Mean Square Error (MSE)	497.011541
Mean Percentage Error (MPE)	0.067797
Mean Absolute Percentage Error (MAPE)	2.207141



Residual Analysis for the Applied Model

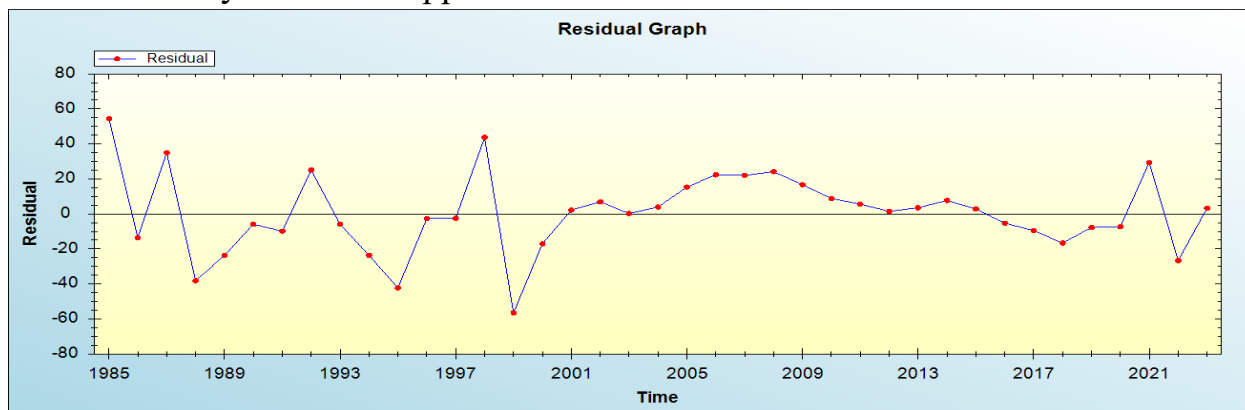


Figure 1: Residual analysis

In-sample Forecast for A

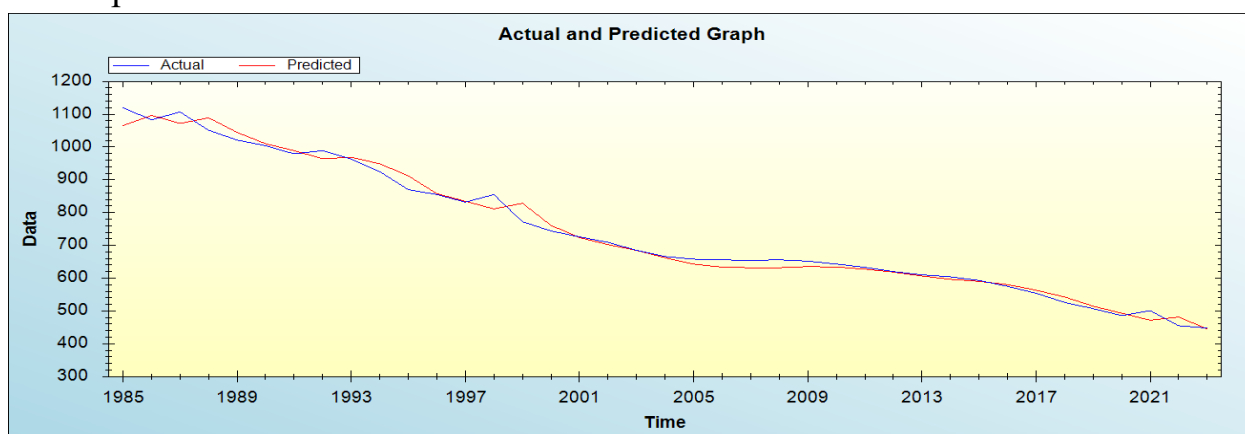


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

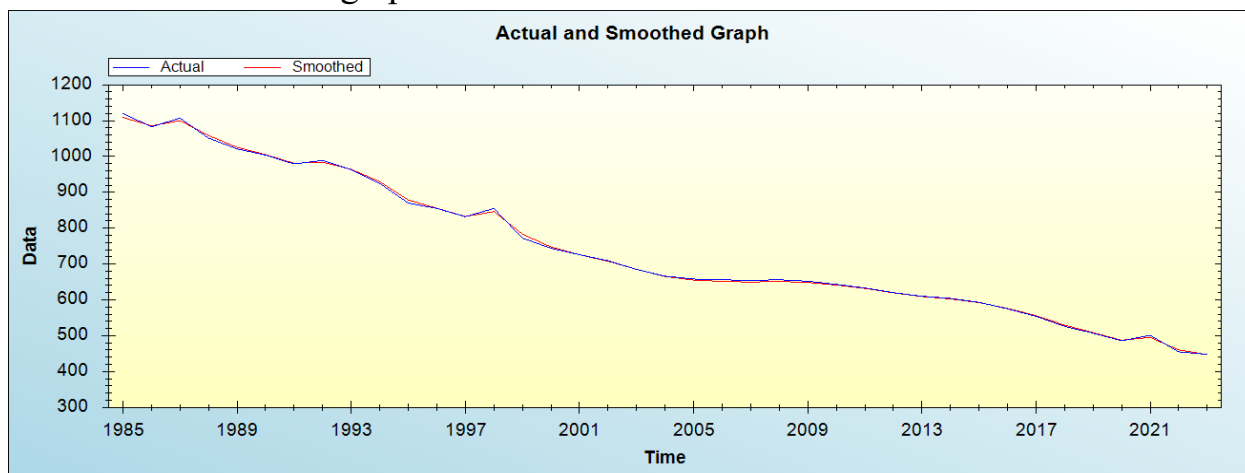


Figure 3: Actual and smoothed graph for A series



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

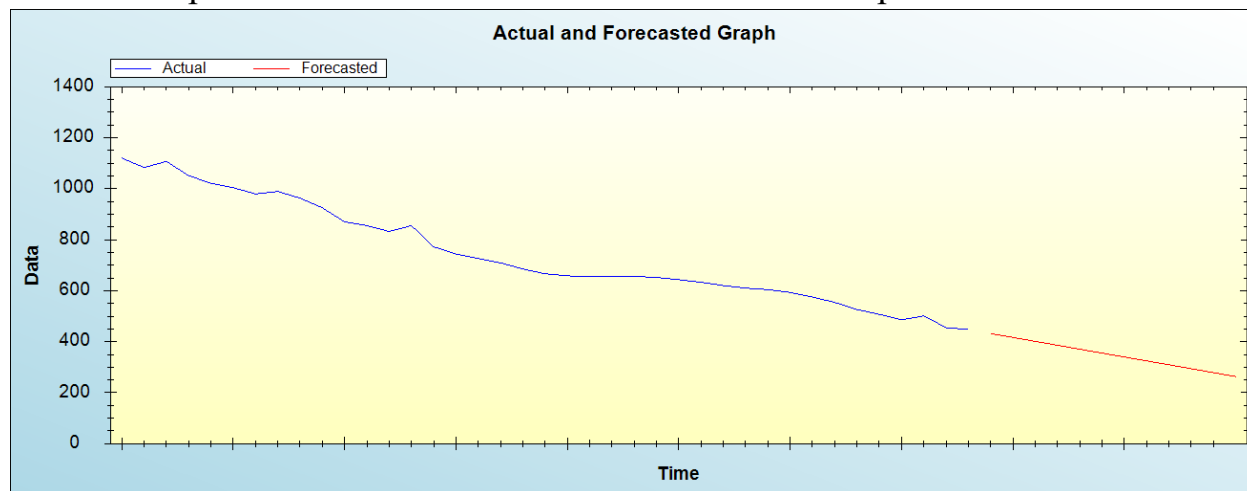


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	431.9972
2025	416.6503
2026	401.3034
2027	385.9565
2028	370.6096
2029	355.2627
2030	339.9158
2031	324.5689
2032	309.2220
2033	293.8751
2034	278.5282
2035	263.1813

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 continue to fall but still remain very high over the out of sample period.



Recommendations & Conclusion

Developing countries are still struggling to control maternal mortality. Regional collaboration is one of the tools that can be utilized to address this problem. Mobilization of resources at regional level can be a panacea to the limited resources in some countries. A regional task force on maternal and child health can facilitate resource mobilization and implementation of various initiatives that seek to lower maternal mortality. The task force oversees maternal and child health programs in different countries and ensures adherence to WHO quality standards. In addition, regional collaboration allows sharing and cross pollination of ideas. Currently the state of maternal health is not satisfactory in SSA due to the persistent high maternal mortality rates being reported by different countries. There is generally a consensus among healthcare professionals and policy makers that current strategies must be reviewed and reconfigured so that MMR is lowered to levels below 70 per 100 000 live births or even better. This paper applies the double exponential smoothing method to forecast MMR for SSA region and the study findings indicate that MMR will continue to fall but still remain very high throughout the out of sample period. Therefore, this paper calls for regional policy makers to make bold decisions that will positively impact maternal and child health in the region. We implore authorities in the region to adopt the following policy prescription: (1) curb teenage 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 region (3) direct some of the resources towards routine quality improvement activities (4) ensuring availability of adequate commodities and medical staff in all medical facilities, (5) creating posts for obstetricians at government general or district hospitals particularly at high volume sites so that specialist services are accessed at the first referral level. Alternatively, Registrars undergoing Obstetrics and Gynecology training can be attached at high volume district & general hospitals under the supervision of a consultant based at a provincial hospital and (6) Regional bodies such as the African Union should work tirelessly to end wars in conflict affected areas of the



African continent so that a conducive environment for maternal and child health is established.

References

1. Dahab R and Sakellariou D (2020). Barriers to accessing maternal care in low-income countries in Africa: A systematic review. *Int. J. Environ. Res. Public Health* 2020, 17, 4292.
2. Esther A.Q., Yahaya H., Esther A.O., Aboagye-Mensah P., Blessing A.J., and Ikome T.E (2023). A Scoping Review on Influence of Socioeconomic Status on Antenatal Care Utilization and Pregnancy Outcomes in Sub-Saharan Africa. *MedRxiv* 2023, 28, 514–519.
3. Flake S (2022). Lack of Access to Maternal Healthcare in Sub-Saharan Africa. *Ballard Brief* 2022, 2022, 4.
4. Graham W.J., Bell J.S., and Bullough C.H.W (2001). Can skilled attendance at delivery reduce maternal mortality in developing countries? In *Safe Motherhood Strategies: A Review of the Evidence 2001*; Elsevier: Amsterdam, The Netherlands.
5. Musarandega R., Nyakura M., Machekano R., Pattinson R., and Munjanja S.P (2021). Causes of maternal mortality in Sub-Saharan Africa: A systematic review of studies published from 2015 to 2020. *J. Glob. Health* 2021, 11, 04048.
6. Ngonzi J., Tornes Y.F., Mukasa P.K., Salongo W., Kabakyenga J., Sezalio M., Wouters K., Jacquem Y., and Van Geertruyden J.-P (2016). Puerperal sepsis, the leading cause of maternal deaths at a Tertiary University Teaching Hospital in Uganda. *BMC Pregnancy Childbirth* 2016, 16, 207.
7. Onambele L., Guillen-Aguinaga S., Guillen-Aguinaga L., Ortega-Leon W., Montejo R., Alas-Brun R., Aguinaga-Ontoso E., Aguinaga-Ontoso I., and Guillen-Grima F (2023). Trends, Projections, and Regional Disparities of Maternal Mortality in Africa (1990–2030): An ARIMA Forecasting Approach. *Epidemiologia* 2023, 4, 322–351.



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8. Prata N., Passano P., Sreenivas A and Gerdt C.E (2010). Maternal Mortality in Developing Countries: Challenges in Scaling-Up Priority Interventions. *Womens Health* 2010, 6, 311–327.
 9. United Nations (2015). Goal 3: Ensure Healthy Lives and Promote Well-Being for All at All Ages. Available online: <https://tinyurl.com/29nvv5f5>
 10. Vallely L.M., Calvert B., De Silva M., Panisi L., Babona D., Bolnga J., Duro-Aina T., Noovao-Hill A., Naidu S., and Leisher S (2023). Improving maternal and newborn health and reducing stillbirths in the Western Pacific Region—Current situation and the way forward. *Lancet Reg. Health West. Pac.* 2023, 32, 100653.
 11. World Health Organization (2024). Maternal Mortality.