



HOLT'S LINEAR METHOD APPLICATION IN FORECASTING MATERNAL MORTALITY FOR TOGO

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Abstract

This study uses annual time series data on MMR for Togo 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 0.9 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 health authorities to adopt the suggested 5-fold policy prescription

Keywords:Exponential smoothing, Forecasting, Maternal Mortality Ratio

Introduction

Maternal mortality is a global public health problem particularly for low-middle income countries, 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 than 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). Many 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). In Togo, according to estimates from the United Nations system in 2017, the maternal mortality ratio was 396/100,000 live births (WHO, 2019). The main causes of maternal death are known and more than 80% of these deaths could be prevented or avoided by actions which have already proven their effectiveness, and which are affordable even in the poorest countries in the world (Dumont, 2017). The objective of this paper is to model and forecast MMR for Togo using the double exponential smoothing technique. The study findings are expected to inform policy making, planning and allocation of resources to the health sector so that preventable maternal deaths are further reduced.

Literature Review

Author(s)	Objective(s)	Methodology	Key finding(s)
Hilim et al. (2025)	to determine the factors associated with low PNC coverage among women aged 15 to 49 in Togo central region	case-control study	The study confirmed the low uptake of postnatal care, and associated factors are sociodemographic and clinical
Kota et al. (2025)	To explore the impact of food insecurity on the use of maternal health services among Togolese women in the Savanes region, aged between 18 and 49 years	Qualitative approach	Women experiencing food insecurity are less likely to seek maternal health services, as their limited financial resources are prioritized for food rather than healthcare
Edem et al. (2024)	To analyze maternal deaths, identify causes and dysfunctions leading to these deaths in order to contribute to the implementation of strategies to reduce maternal mortality at CHU Kara	Cross-sectional descriptive study involving 65 cases of maternal deaths recorded at CHU-Kara from January 1, 2018 to June 30, 2021	The causes were mainly direct obstetric causes (81.54%), with preeclampsia and its complications (28.30%) and immediate postpartum hemorrhage (20.75%) being the most common. However, uterine rupture



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			(20.5%) and post-abortion sepsis (16.4%) were the most lethal etiologies
Fagan et al. (2024)	to describe the implementation of this service and assess its effectiveness on access to emergency obstetric care by estimating its coverage of women with obstetric complications	retrospective cross-sectional study using routinely collected data from ambulance logbooks	Estimated coverage of obstetric complications increased over time and as the programme expanded, from 18% in 2020 to 35.7% in 2021, and 66.5% in 2022
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
Douaguibe et al. (2023)	to determine the frequency of reviews of maternal deaths, the epidemiological, sociodemographic aspects and the causes of these reviewed maternal deaths in Togo	This was a descriptive and cross-sectional, multicenter study lasting four and a half years, from the 1st of January 2018 to the 30th of June 2022, relating to the review of maternal deaths in three reference hospitals of two health regions of south Togo	The causes of maternal deaths were dominated by direct obstetric causes (89.7%). The main cause was hemorrhage (72.5%), the main cause being immediate postpartum hemorrhage (50.7%)
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



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			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
Kota et al. (2023)	to analyze factors associated with use of maternal health services among Togolese women aged 15–49 years	used data from third round of nationally representative Demographic and Health Survey conducted in Togo in 2013	this study showed that socio-economic inequality and socio-cultural barriers influenced the use of maternal healthcare services in Togo
Ajavon et al. (2022)	To determine the maternal mortality rate, the epidemiological profile, the causes of death and the dysfunctions noted in Togo	cross-sectional and descriptive study from January 1 to December 31, 2020	Hemorrhage, preeclampsia, and complications of abortion were the main direct obstetric causes, while anemia was the main indirect obstetric cause. Factors related to deaths were inadequate quality of health care and lack of universal health insurance
Nnadi et al. (2022)	to estimate the effect of maternal mortality on economic development in	Cross-sectional data analysis of selected member	The explanatory variables in the model were statistically significant at



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	Sub-Sahara African region. Cross-sectional data analysis of selected member countries in the region under focus was employed using double-log econometric model	countries in the region under focus was employed using double-log econometric model	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
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 Togo. 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 Togo 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	0.900
Forecast performance measures	
Mean Absolute Error (MAE)	12.088538
Sum Square Error (SSE)	10412.378318
Mean Square Error (MSE)	266.984059
Mean Percentage Error (MPE)	-0.014649
Mean Absolute Percentage Error (MAPE)	2.339377

Residual Analysis for the Applied Model

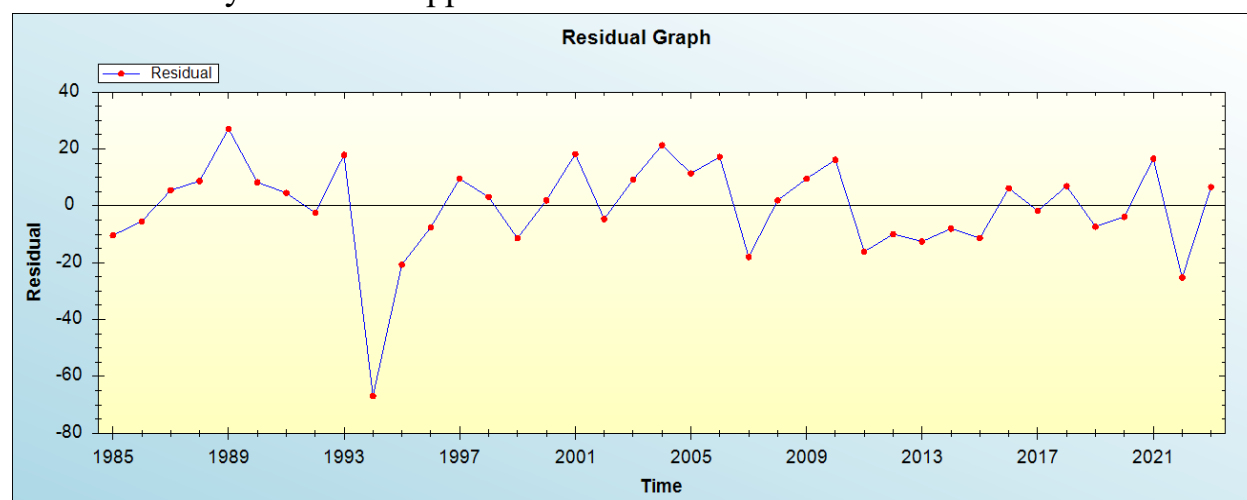


Figure 1: Residual analysis



In-sample Forecast for A

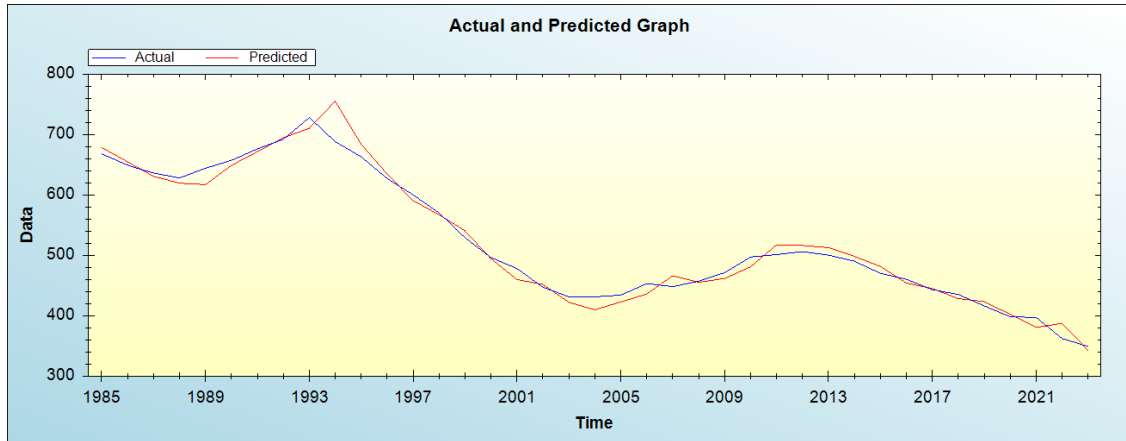


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

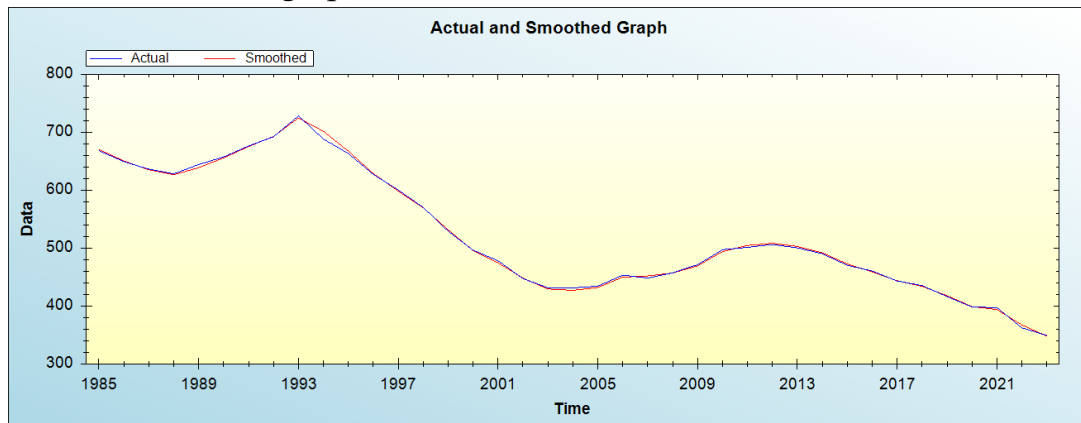


Figure 3: Actual and smoothed graph for A series

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

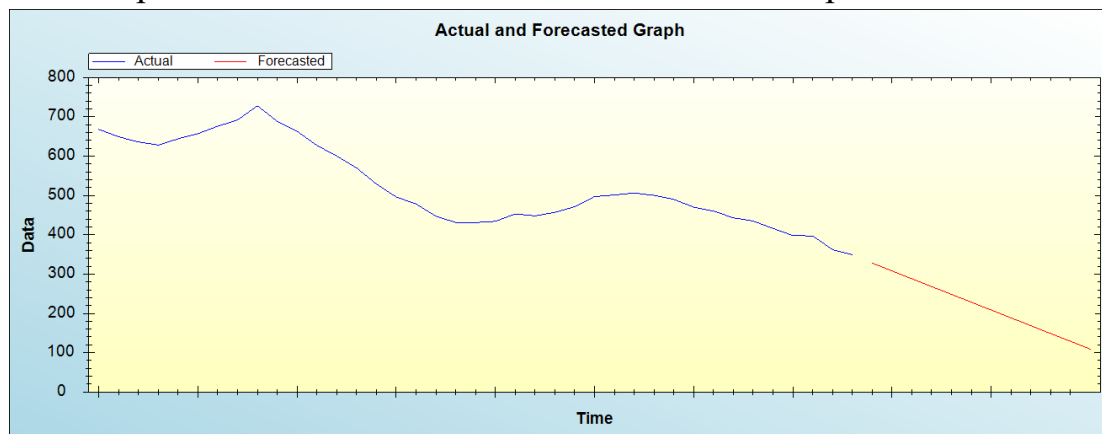


Figure 4: Out-of-sample forecast for A: actual and forecasted graph



Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	327.8007
2025	307.9132
2026	288.0257
2027	268.1382
2028	248.2506
2029	228.3631
2030	208.4756
2031	188.5881
2032	168.7006
2033	148.8130
2034	128.9255
2035	109.0380

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 drop but still remain very high over the out of sample period.

Recommendations & Conclusion

The scourge of maternal mortality remains high in Togo and this reflects several challenges across the country that need to be addressed. In this study we applied the double exponential smoothing technique to model and forecast MMR for Togo and results indicate that MMR will continue to fall but still remain very high throughout the out of sample period. Hence, we implore health authorities in Togo to adopt the following policy prescription: (1) end 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 country (3) improve quality of maternity services (4) ensure availability of adequate medical supplies and medical staff in all medical facilities and (5) create posts for obstetricians at government district hospitals especially high volume sites so that specialist



services are accessed 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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