

CALCULATING EXPECTED FUTURE VALUES OF ANNUAL MATERNAL MORTALITY RATE FOR MALI USING HOLT'S LINEAR METHOD

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ABSTRACT

This study uses annual time series data on MMR for Mali 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 0.3 respectively based on minimum MSE. The results of the study indicate that MMR will continue to fall but still remain very high over the out of sample period. Therefore, we encourage health authorities to adopt the suggested 6-fold policy prescription.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

INTRODUCTION

Mali is one of the poorest nations in the world (Watkins, 2006), with most of its population residing in the rural areas where accessibility to emergency obstetric and neonatal care is a challenge (Aa et al. 2011). In Mali, the stillbirth rate in 2019 was 20 per 1000 total births and the MMR was 562 per 100 000 livebirths (WHO, 2023), which are among the highest globally. The health system in Mali has numerous challenges, top of the list being shortage of healthcare workers (Traore et al. 2014). According to Mali's national strategy, access to care including community-based obstetric care among rural populations depends on a system of community health workers (Dogba et al. 2012). Mali Demographic and Health Survey (DHS) data revealed that there is lack of qualified birth attendants, transportation facilities and distance as key barriers to seeking maternity services (Gage, 2007). The purpose of this study is to model and forecast MMR for Mali using the double exponential smoothing technique. The study findings will guide planning and allocation of resources to the maternal and child health program with a view to further reduce preventable maternal deaths across the country.

LITERATURE REVIEW

Author(s)	Objective(s)	Methodology	Key finding(s)
Ghosh et al. (2024)	To examine the sociodemographic risk factors and structural barriers associated with pregnancy care-seeking and institutional delivery, and (2) investigate the influence of residential distance to the nearest primary health facility in a rural population in Mali	population-based cross-sectional cohort design	education, occupation and distance are important determinants of pregnancy and delivery care in a rural Malian context

Traore et al. (2024)	To analyze trends and differences in several indicators of maternal and neonatal care coverage in Bamako	used secondary data from Mali's Demographic and Health Surveys from 2001 to 2018	results highlighted differential access to antenatal and childbirth care for non-poor and non-migrant women compared to their counterparts categorized as poor and migrant. The gaps were much larger depending on migration status (i.e., number of years since resettling in Bamako) and even tended to increase over time
Muriithi et al. (2022)	to identify these contributing factors and assess the frequency of their reporting in published literature	Scoping review	health facility— level factors were the most frequently reported contributing factors to maternal deaths in Africa
Kanté et al. (2020)	To analyze the maternal mortality in the two departments of CHU Point "G" in Bamako, because of high maternal mortality rate in our country	This was an analytical cross-sectional study on maternal deaths from February 19, 2005 to November 19, 2019 for patients admitted in both departments and who died during the pregnancy-puerperal period at CHU Point "G"	The study concluded that the frequency of maternal deaths is very high in Mali
Toukara et al. (2022)	to examine disparities in education and geographic distance and how they affect utilization of maternal care within the Sélingué health district, a district with moderate geographic access to care, near Bamako, Mali	cross sectional survey	disparities within the health district contribute to inadequate utilization among approximately 40% of the women in our sample. The concentration index demonstrated the impact of inequity in geographic access, comparing women residing near and far from the referral care facility
Traore et al. (2022)	to report the findings of the local maternal deaths surveillance and response (MDSR) committee in the health district of Municipality V of the district of Bamako	Conducted a retrospective study over a period from January 2009 to December 2017	The MMR remains high in Municipality V of the district of Bamako. These deaths were mostly from DOCs, with hemorrhage as the main cause
Bain et al. (2021)	To examine the national prevalence as well as the individual and contextual factors associated with maternal healthcare utilization in Mali.	The study analyzed data on 6335 women aged 15–49 years from Mali's 2018 Demographic and Health Survey	Prevalence of maternal healthcare utilization was 45.6% for ANC4+, 74.7% for SBA and 25.5% for PNC. At the individual level, ANC4+ and SBA utilization increased with increasing maternal age, level of formal education and wealth status

Camara et al. (2021)	to synthesize the characteristics and effectiveness of interventions to increase facility births or provision of postpartum care in sub-Saharan Africa.	Scoping review	Strategies identified in the literature as increasing facility births in the sub-Saharan African context include community awareness raising, health expenses reduction (transportation or user fee), non-monetary incentive programs (baby kits), or a combination of these with improvement of care quality (patient's privacy, waiting time, training of provider), and or follow-up of pregnant women to use health facility for birth
Coulibaly et al. (2021)	To explore factors that contribute maternal mortality in Mali	Retrospective study	The main causes were hypertensive disorders/eclampsia and hemorrhage. 80% of these women's deaths were preventable
Tort et al. (2015)	to assess which factors contribute to maternal death occurring during PPH in Senegal and Mali	A cross-sectional survey nested in a cluster randomized trial (QUARITE trial) was carried out in 46 referral hospitals during the pre-intervention period from October 2007 to September 2008 in Senegal and Mali	The factors that were significantly associated with PPH maternal mortality were: age over 35 years (adjusted OR = 2.16 [1.26–3.72]), living in Mali (adjusted OR = 1.84 [1.13–3.00]), residing outside the region location of the hospital (adjusted OR = 2.43 [1.29–4.56]), pre-existing chronic disease before pregnancy (adjusted OR = 7.54 [2.54–22.44]) and prepartum severe anemia among others
Aa et al. (2011)	to estimate the maternal mortality ratio in Kita, rural Mali	Qualitative approach	The study found a very high maternal mortality in rural Mali

METHODOLOGY

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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

M_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 Mali 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	M
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.300
Forecast performance measures	
Mean Absolute Error (MAE)	13.977308
Sum Square Error (SSE)	16712.308715
Mean Square Error (MSE)	428.520736
Mean Percentage Error (MPE)	0.162223
Mean Absolute Percentage Error (MAPE)	1.971727

Residual Analysis for the Applied Model

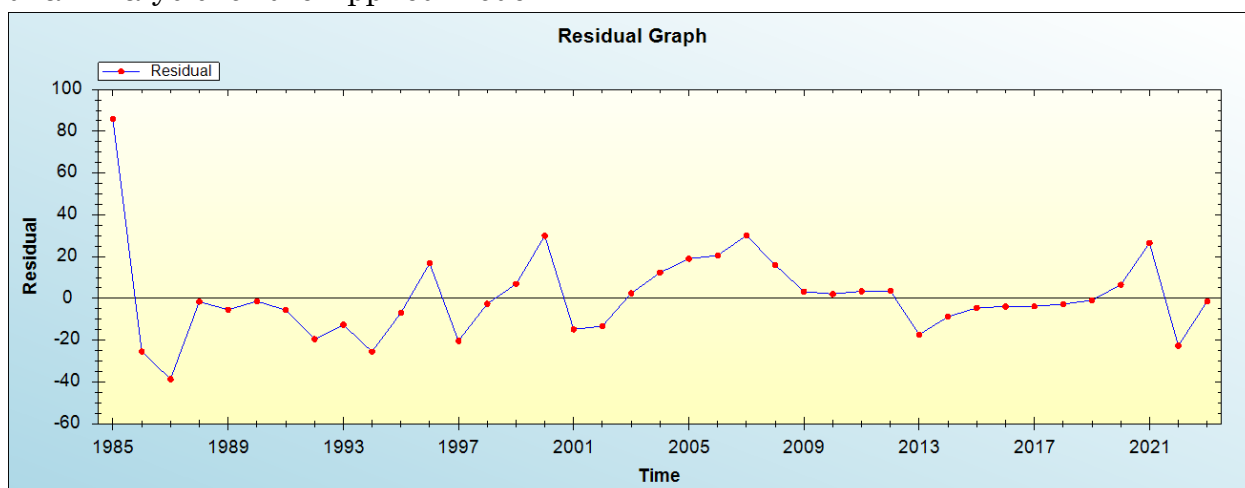


Figure 1: Residual analysis

In-sample Forecast for M

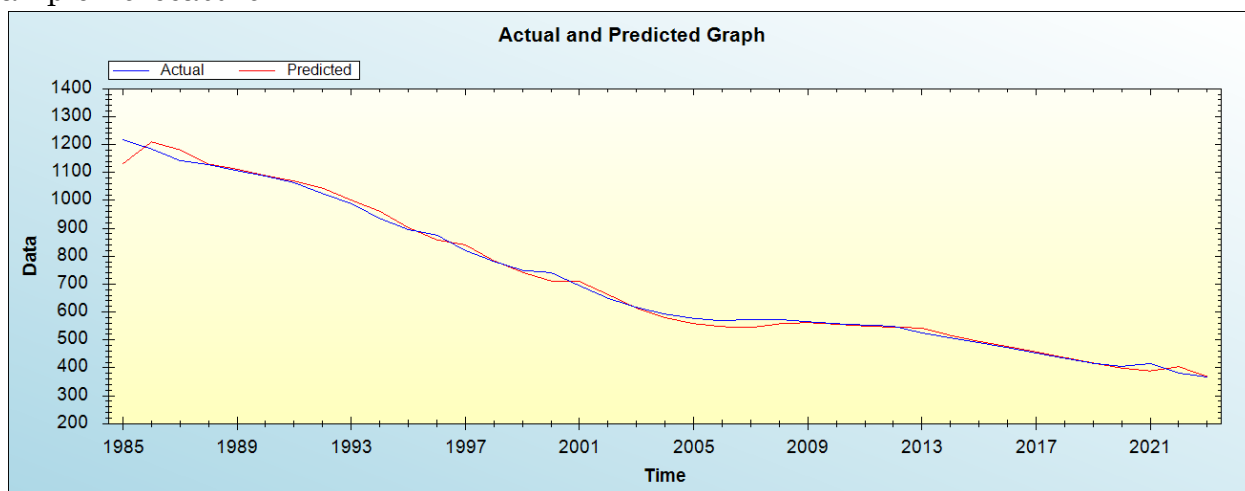


Figure 2: In-sample forecast for the M series

Actual and Smoothed graph for M series

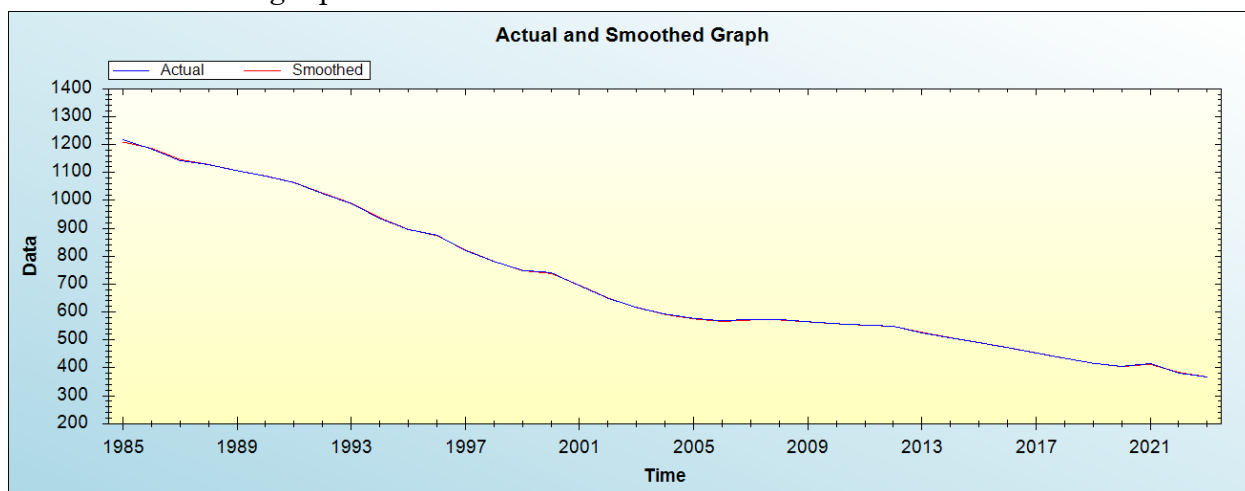


Figure 3: Actual and smoothed graph for M series

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

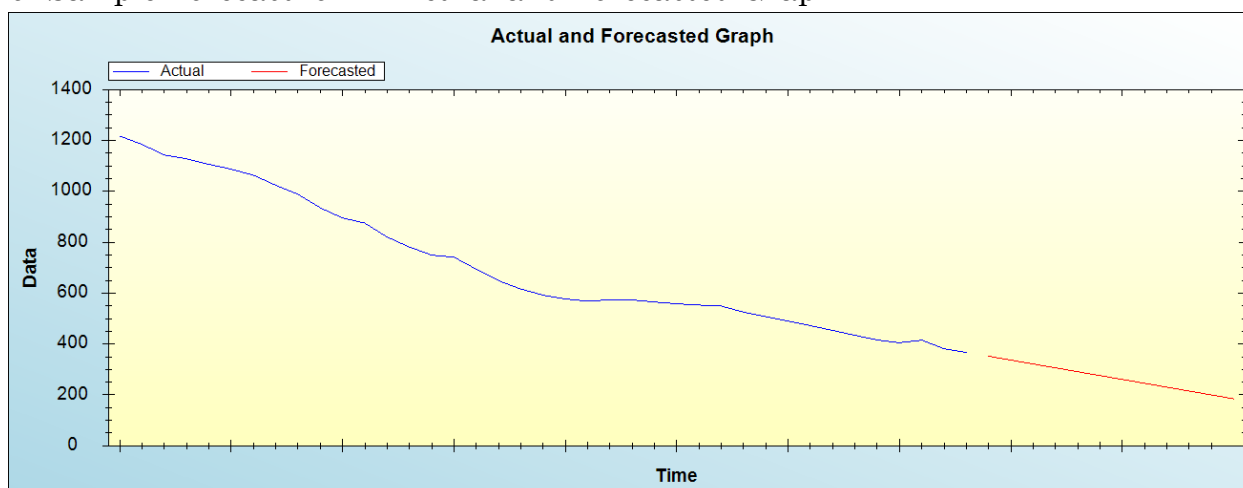


Figure 4: Out-of-sample forecast for M: actual and forecasted graph

Out-of-Sample Forecast for M: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	351.9392
2025	336.7334
2026	321.5275
2027	306.3216
2028	291.1158
2029	275.9099
2030	260.7041
2031	245.4982
2032	230.2923
2033	215.0865
2034	199.8806
2035	184.6747

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

Mali's maternal mortality rates are alarming and this is a cause for concern. The main challenges affecting maternal health include lack of qualified birth attendants, shortage of transportation facilities and long distances travelled to the nearest healthcare facility. In this study we applied the double exponential smoothing method to forecast MMR for Mali and findings indicate that MMR will continue to fall but still remain very high in the out of sample period. Therefore, we implore 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) improve quality of maternity services (4) ensure availability of adequate medical supplies and medical staff in all medical facilities (5) create 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 & Gynecology training can be attached at high volume district hospitals under the supervision of provincial consultants and (6) improvement of road infrastructure.

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