



PREDICTION OF ANNUAL MATERNAL MORTALITY RATE FOR THE GAMBIA USING THE DOUBLE EXPONENTIAL SMOOTHING MODEL

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Abstract

This study uses annual time series data on MMR for the Gambia 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 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will continue to fall but still remain high throughout 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

According to the World Bank, The Gambia is a West African country with an estimated population size of 2.4 million inhabitants. It has a high population density of around 176 people per square kilometer. The majority of the population (57%) resides in urban and peri-urban areas. The Gambia has five regions (Banjul, West Coast Region, Lower River Region, North Bank Region, Central River Region and Upper River Region) and eight Local Government Areas (LGA) namely: Banjul, Kanifing, Brikama, Mansakonko, Kerewan, Kuntaur, Janjanbureh and Basse. It has forty-three districts and a capital city. There are seven health regions in the Gambia, each headed by a health director (Sonko et al. 2024). With the highest maternal mortality rate of 597/100,000 as of 2017, The Gambia is rated 13th (CIA World Factbook (2019). The World Health Organization indicated that in 2017, there were approximately 430 maternal



deaths per 100,000 live births, which was a high rate in the country's history (WHO, 2019). According to the NDP of 2018 – 2021, the Gambian government set a goal in 2017 to reduce maternal and neonatal mortality from 433 to 315 per 100,000 people nationwide by 2021 (Gambia Government, 2017). Over the past decade, The Gambia has witnessed significant progress in maternal and child health due to programs aimed at enhancing maternal health through community-based interventions, as indicated in its Demographic Health Surveys (Michael et al. 2025). The purpose of this paper is to model and forecast MMR for The Gambia using the double exponential smoothing technique. The study findings are anticipated to highlight future trends of MMR in order to inform policy and allocation of resources to the maternal health program.

Literature Review

Author(s)	Objective(s)	Methodology	Key finding(s)
Michael et al. (2025)	To evaluate the effectiveness of community-based maternal health interventions implemented between 2010 and 2020	Employed a retrospective quasi-experimental design and secondary data analysis	the deployment of community health workers and traditional birth attendant training, have contributed to improved maternal health outcomes, although disparities still persist
Anyanwu et al. (2024)	to reveal the magnitude of preeclampsia in relation to maternal mortality in the Gambia	A retrospective study was conducted at the Edward Francis Small Teaching Hospital from January to December 2022. Maternal annual audit report was used to extract specific data which was entered into a computer database and analyzed with descriptive statistics	The menace of preeclampsia/Eclampsia is overwhelming and has maintained the leading cause of maternal mortality in Gambia
Harsono et al. (2024)	to identify structural barriers to maternal care during the early adaptation of the mobile Medical	conducted in-depth interviews and focus groups with 56 key stakeholders including previously	Dynamic inter-relations among structural level factors create barriers to maternity care in Cameroon



Modern American Journal of Medical and Health Sciences

ISSN (E): 3067-803X

Volume 2, Issue 9, September 2026

Website: usajournals.org

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	Information Service via Telephone (mMIST) program in Cameroon	and currently pregnant women, primary healthcare providers, administrators, and representatives of the Ministry of Health, recruited by purposive sampling. Thematic coding and analysis via modified grounded theory approach were conducted using NVivo12 software	
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	-retrospective study utilized routine data from all facilities in Kampala that provided childbirth services from 2016 to 2021. -conducted descriptive analysis and assessed time trends in IMMR	IMMR in Kampala increased from 2019-2021. Health infrastructure changes and maternal health initiatives potentially accounted for the observed trend by affecting data quality. Referral and facility readiness were underlying reasons for maternal deaths
Sonko et al. (2024)	To evaluate The Gambia's Maternal Mortality Surveillance System to determine its usefulness and to assess some of its system attributes	conducted a cross-sectional study and interviewed stakeholders in the maternal mortality surveillance system in The Gambia. Using a self-administered questionnaire prepared from the CDC updated guideline for surveillance system evaluation, means and standard deviations (SD), frequencies and proportions were calculated	The Gambia's maternal death surveillance system was found to be useful. The quality of data and completeness of reporting were poor, while the timeliness, flexibility, and representativeness of the surveillance system need to be improved



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Jasseh et al. (2023)	to estimate Gambia's burden and causes of pregnancy-related mortality (PRM) to guide reproductive health programming.	Using reported deaths and births in the 2013 Gambian census, national and regional pregnancy-related mortality ratios (PRM Ratios) were derived as the ratio of pregnancy-related deaths (PRDs) per 100 000 live births (lbs). Verbal autopsies were interpreted using InterVA- 5, and PRDs linked with extracted HDSS data to estimate annual PRM Ratios.	The census-based PRM Ratios for 2012 were consistent with the sociodemographic and reproductive health indicators that prevailed at that time and represented the burden of PRM. While HDSS-derived PRM Ratios were lower, the cause-of-death distribution produced was consistent with previous observations elsewhere
Touolak et al. (2023)	To analyze the factors associated with maternal mortality that occurred at the Gyneco-Obstetric and Pediatric Hospital of Yaounde (YGOPH) from the 1st January 2018 to the 31st December 2021.	conducted an analytical case control study with a retrospective data collection, using medical files of 210 participants (for 1 case, 2 survivors, totally 70 cases and 140 survivors). Data were collected using a questionnaire and analyzed with SPSS 25.0. A multivariate analysis was done to determine the independent factors associated with maternal mortality at YGOPH	Maternal mortality at YGOPH was explained by the following among other factors: Hypertensive disorders (AHR=3.304; P-value=0.019; 95%; CI=[1.401; 5.020]), Co-morbidities (AHR=3.01; P-value = 0.003; 95%; CI= [2.059; 3.900]), mode of delivery (AHR=2.900; P-value=0.002; 95%; CI=[4.652; 8.549]), Postpartum hemorrhage (AHR=3.700; P-value = 0.011; 95%; CI= [1.730; 4.002]), Infections (AHR=9.489; P-value=0.004; 95%; CI=[3.552; 12.519])
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 literature review	Obstetric hemorrhage, hypertensive disorders in pregnancy, non-obstetric complications, and pregnancy-related infections are the leading causes of maternal deaths in SSA



Meh et al. (2020)	To explore ratios and determinants of maternal mortality in women of childbearing age (15–49 years) and assessed differences between the North and South Cameroon	-used the Cameroon Demographic and Health Surveys (2004 and 2011) to extract a sample of 18,665 living or deceased women who had given birth -applied logistic regression	Maternal mortality ratios and determinants varied between women of childbearing age in the North and South of Cameroon
Wirsiy et al. (2019)	to assess the critical determinants of maternal mortality in Cameroon so as to facilitate inform decision making in regards to interventions on maternal health	Systematic review	Maternal age, parity, post-partum hemorrhage, unsafe abortion, domestic violence, hypertensive disorders of pregnancy, severe malaria, HIV/AIDS, inadequate antenatal care, pre-existing co-morbidities, place of delivery, education level, healthcare provider qualification, delays in arrival at health facilities, ectopic pregnancy, placenta previa, anemia, pneumonia, heart disease, number of prenatal visits

Methodology

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

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

Smoothing equation



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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

G_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 the Gambia 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	G
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	19.387220
Sum Square Error (SSE)	36310.010561
Mean Square Error (MSE)	931.025912
Mean Percentage Error (MPE)	0.276501
Mean Absolute Percentage Error (MAPE)	2.457364

Residual Analysis for the Applied Model

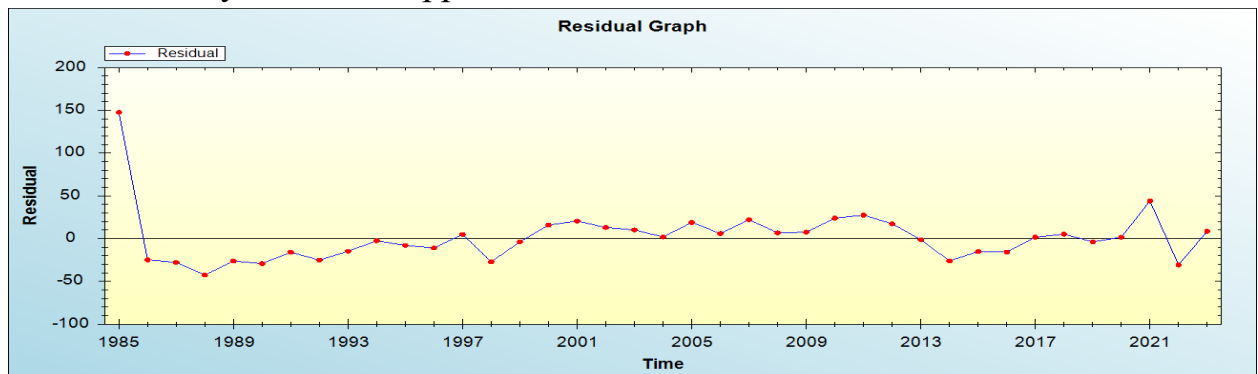


Figure 1: Residual analysis

In-sample Forecast for G

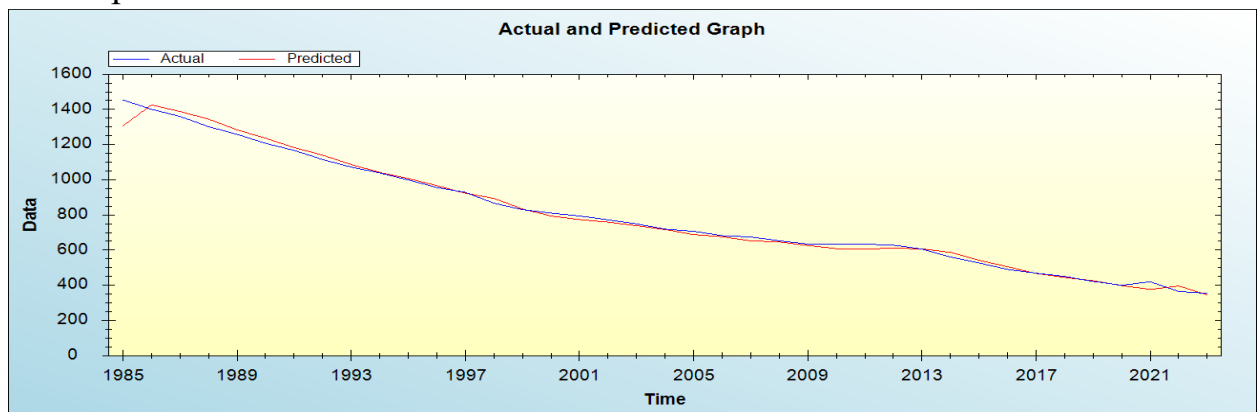


Figure 2: In-sample forecast for the G series



Actual and Smoothed graph for G series

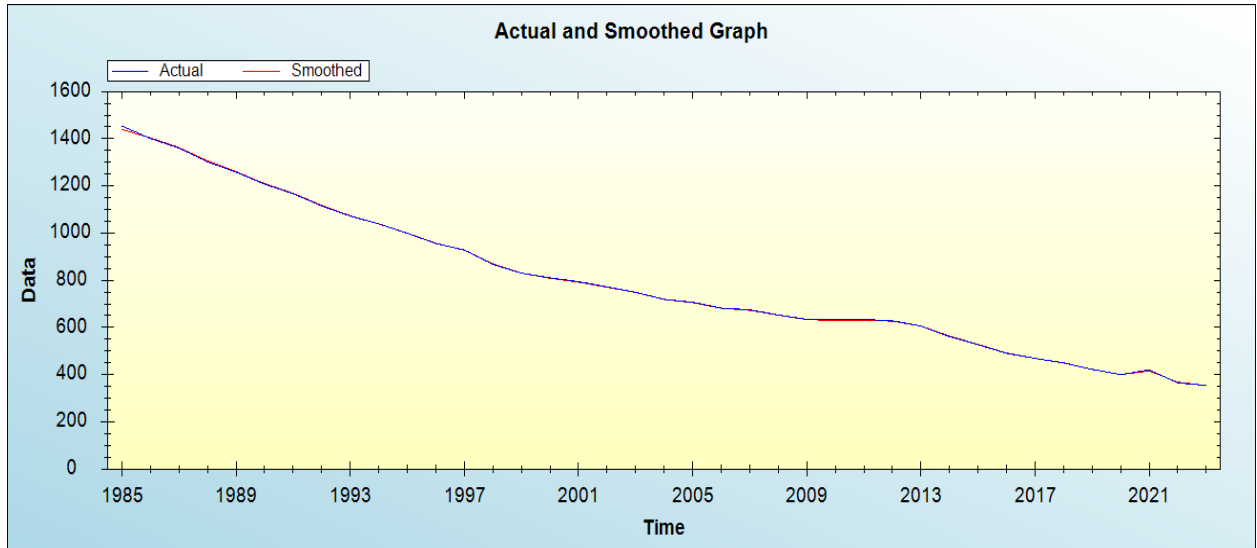


Figure 3: Actual and smoothed graph for G series

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

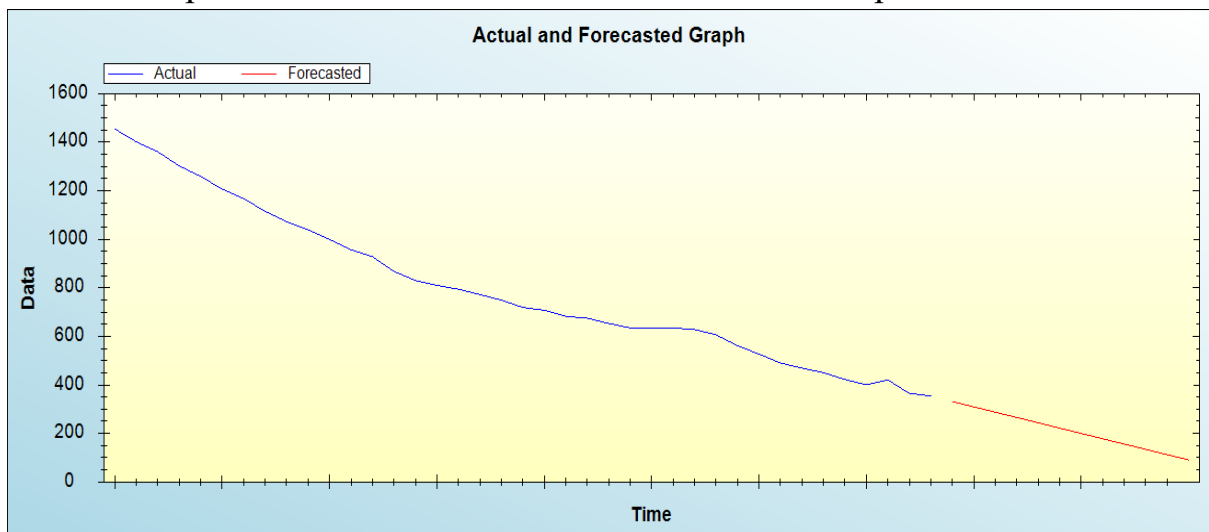


Figure 4: Out-of-sample forecast for G: actual and forecasted graph



Out-of-Sample Forecast for G: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	331.2751
2025	309.4068
2026	287.5385
2027	265.6702
2028	243.8019
2029	221.9336
2030	200.0653
2031	178.1970
2032	156.3288
2033	134.4605
2034	112.5922
2035	90.7239

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 remain high over the out of sample period.

Recommendations & Conclusion

The burden of maternal mortality is still very high in the Gambia. This indicates existence of challenges along the continuum of care which have remained unattended or partially resolved. In this study we applied the double exponential smoothing model to forecast MMR for the Gambia and findings indicate that MMR will continue to fall but still remain high over the out of sample period. Hence, we implore health authorities in this country 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) establish posts for obstetricians at government district hospitals particularly at high volume sites so that specialist services are provided 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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