

Determination Of Future Trends Of Maternal Mortality For Ghana Using The Double Exponential Smoothing Technique

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Abstract

This study uses annual time series data on MMR for Ghana 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 very high throughout the out of sample period. Therefore, we encourage authorities to address local factors associated with maternal deaths and carryout routine quality improvement activities across the country.

Keyword(s): - Exponential smoothing, Forecasting, Maternal Mortality Ratio

Introduction

The maternal health program (MHP) is an essential component of the public health system as it was designed to identify and address challenges being faced by mothers and the newborns (Baatiema, 2025). MHP has six main pillars namely service delivery, logistics & supply, monitoring & evaluation, quality & training, management, and finance. A functional maternal and health program should be able to address all major causes of maternal deaths since most deaths are largely avoidable. Unfortunately, most developing countries are struggling to control maternal mortality due to various reasons which include lack of political will, poor accountability of government resources, incompetencies at various levels of the health care system, shortage of financial resources, beliefs and customs that affect health seeking behaviors of different populations. As a result, maternal mortality is still one of the top global public health issues, particularly in low and middle-income countries (WHO, 2024). Global Statistics also indicate that 287,000 maternal deaths occur every year, with Sub-Saharan Africa contributing 70% of the total maternal deaths (WHO, 2024). Many of these deaths are avoidable and are concentrated in the poorer regions of the world as timely access to high quality maternity care is unavailable (Agyei & Kumah, 2024; Bobo et al. 2023; Kyei-Nimakoh et al. 2017). Lowering maternal morbidity and mortality is a priority for Ghana's Ministry of Health, with ongoing efforts including provision of antenatal care and attendance at birth by skilled health personnel (Ministry of health, 2014). Available data indicates that over the period 2008-2014, 97% of women who gave birth in Ghana received antenatal care from a skilled provider at least once, 73% of births occurred in a health facility and 74% were attended by a skilled provider (GSS, 2015). However, disparities continue to exist throughout the country, and the maternal mortality rate per 100,000 live births remains high (WHO, 2014). The majority of these deaths result from inadequate EmOC and poorly equipped facilities (Essendi et al. 2015).

The objective of this paper is to model and forecast future trends of MMR for Ghana using the double exponential smoothing technique. The findings of this paper inform policy, planning and allocation of resources to the maternal and child health program with a view of further reducing maternal mortality across the country.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Amenah et al. (2025)	to map the multifaceted or related risk factors and causes of maternal mortality among women in Ghana	Systematic review	maternal mortality in Ghana is primarily driven by direct causes such as hemorrhage and sepsis, and indirect causes including anemia and sickle cell disease. Sociocultural determinants, such as place of delivery, geographical location, cultural beliefs, lack of support, and poverty, further shaped maternal outcomes
Asirifi et al. (2025)	To the influence of socioeconomic factors on maternal mortality rates, shedding light on the complex interplay between socioeconomic status and maternal health outcomes	retrospective descriptive study which involved all mothers who died from pregnancy-related conditions from 2020 to 2022	The leading causes of maternal mortality were hypertension in pregnancy (34%), hemorrhage (20%), comorbid medical conditions (10%), anemia (11%) and sepsis (9%), obstructed labor, abortion and infections recorded 3%, 7% and 4% respectively. A relationship between maternal mortality and demographics was also established, which showed that many of the deceased were between the ages of 26-45 years
Baatiema (2025)	To explore the Community-Based Health Planning and Services (CHPS) model and its impact on maternal healthcare delivery in	Systematic review	CHPS as a strategy has significant potential to improve maternal health outcomes, reduce mortality rates, and ensure equitable

	Ghana's primary healthcare system		access to care for women in rural and underserved areas. Key challenges such as inadequate funding, staff shortages, political interference, and cultural barriers persist, limiting the model's overall impact
Friedman & Keats (2024)	To evaluate a sequence of policies in Ghana that reduced the costs faced by mothers for maternal services	Used both an event-study and difference-in-differences framework, and combining 8 rounds of Demographic and Health Surveys to construct a 45-year retrospective panel of birth outcomes	access to antenatal care alone has no impact on mortality, that access to facility deliveries reduces the rural-urban mortality gap but does not close it, and that access to both high quality antenatal care, free institutional deliveries, and postnatal checkups eliminate the mortality gap entirely
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
Eghan (2019)	to assess the relationships between sociodemographic variables, service delivery factors, and maternal mortality among 8,171 women of reproductive age (15-45 years) living in the Greater Accra metropolitan area in Ghana	Case-control study	income ($p = .023$), primary ($p = .035$) and secondary ($p = .002$) education, and health insurance ($p = .008$) were significantly associated with maternal-related mortality

Adgoy (2018)	To explore the key social determinants and ways of coping mechanisms, for the reduction of maternal mortality, among African women living inside the African continent.	narrative literature review design	The continental maternal death trend did not reduce as it was intended by Millennium Development Goals (Goal - 5) and still continues with Sustainable Development Goals (Goal-5), “Achieve gender equality and empower all women and girls”
Apanga & Awoonor-Williams (2018)	To investigate a case of maternal death in rural Ghana that seeks to unravel the circumstances that lead to her death	Researchers conducted three in-depth interviews with healthcare staff as well as a focused group discussion comprising of six relatives of the deceased, including her husband	The investigation revealed that lack of logistics, medical, and laboratory equipment, inadequate knowledge about the benefits of antenatal care services as well as non-adherence of healthcare workers to treatment protocols and standard operating procedures were found as major setbacks to the provision of effective and quality maternal healthcare services in Ghana
Kyei-Onanjiri et al. (2018)	to examine the availability of emergency obstetric care interventions in the Upper East Region of Ghana	A cross-sectional survey of 120 health facilities was undertaken. Status of emergency obstetric care was assessed through an interviewer administered questionnaire to directors/in-charge officers of maternity care units in selected facilities. Data were analyzed using descriptive statistics	Eighty per cent of health facilities did not meet the criteria for provision of emergency obstetric care. Comparatively, private health facilities generally provided EmOC interventions less frequently than public health facilities
Lee et al. (2011)	To examine the leading causes of	Retrospective review	Hypertensive states of pregnancy were the

	maternal mortality in Ghana, classifies the main causes of maternal deaths and suggests how maternal care can be improved		leading cause of mortality (26.4%) and, together with hemorrhage, genital tract sepsis and early pregnancy deaths, accounted for 62.2% of all-cause maternal deaths and 87.3% of direct deaths. Infection and sickle cell disease accounted for 13.7% of all-cause maternal deaths and 61.1% of indirect deaths
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Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Ghana. 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 Ghana 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)	14.265493
Sum Square Error (SSE)	22159.277872
Mean Square Error (MSE)	568.186612
Mean Percentage Error (MPE)	0.744267
Mean Absolute Percentage Error (MAPE)	2.765018

Residual Analysis for the Applied Model

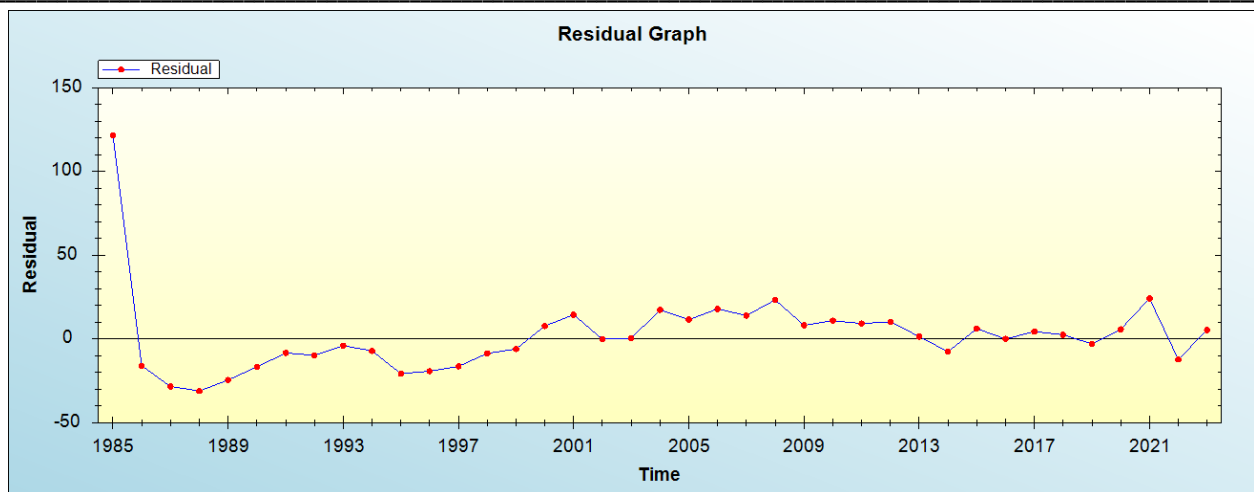


Figure 1: Residual analysis

In-sample Forecast for G

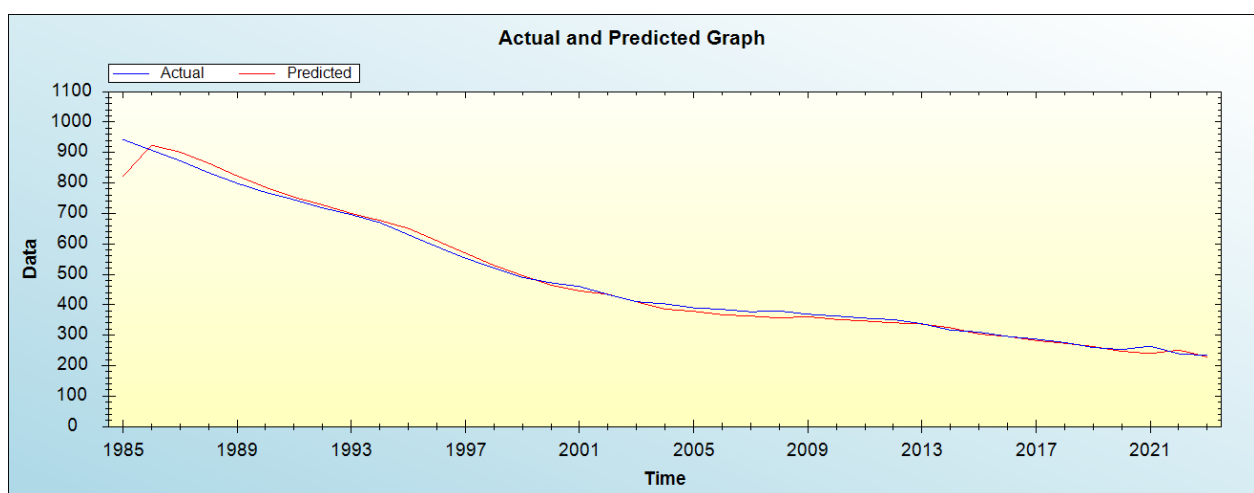


Figure 2: In-sample forecast for the G series

Actual and Smoothed graph for G series

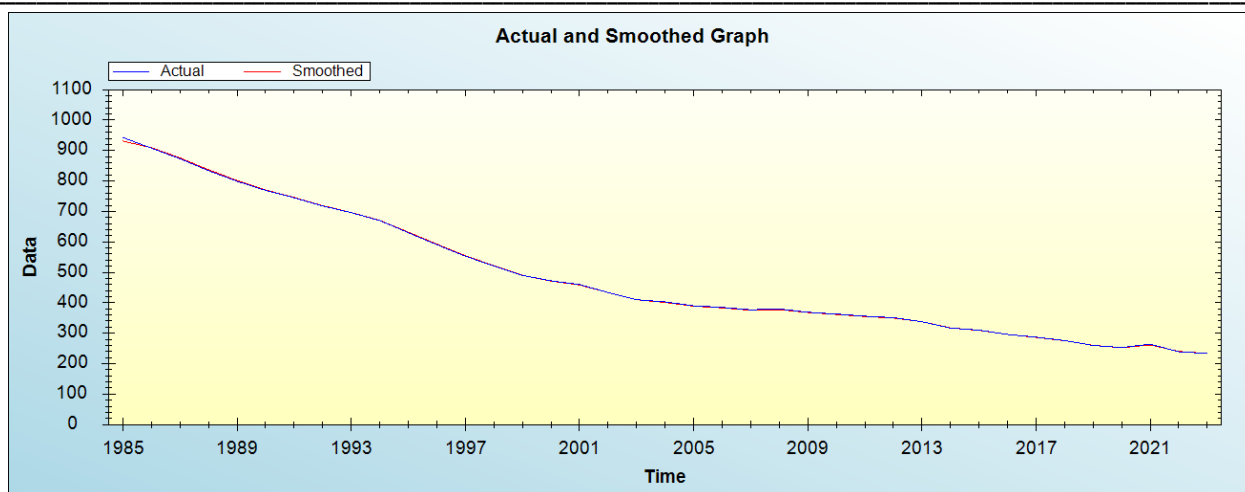


Figure 3: Actual and smoothed graph for G series

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

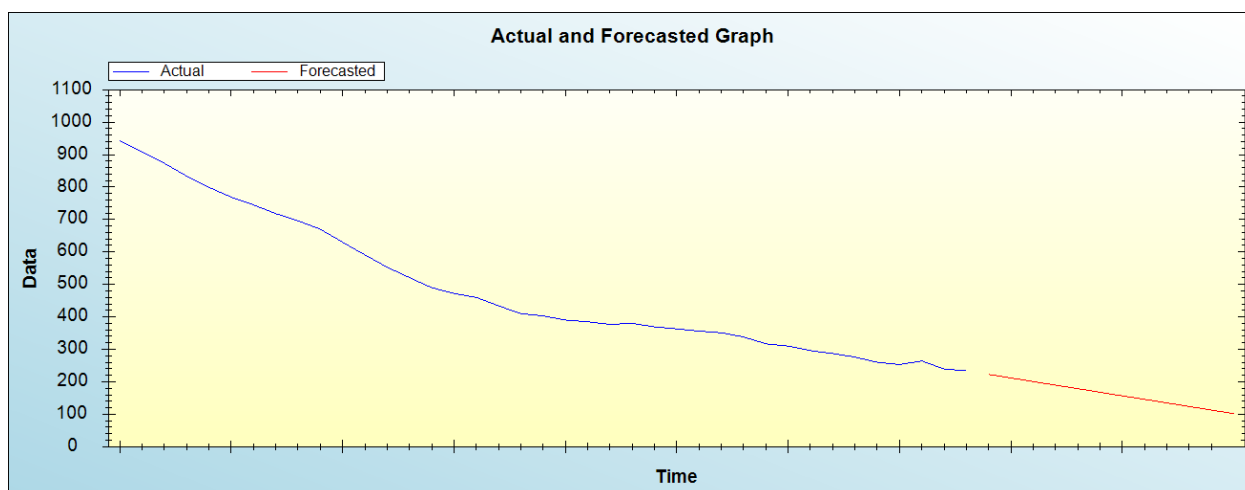


Figure 4: Out-of-sample forecast for G: actual and forecasted graph

Out-of-Sample Forecast for G: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	222.5114
2025	211.5438
2026	200.5762
2027	189.6087

2028	178.6411
2029	167.6735
2030	156.7059
2031	145.7384
2032	134.7708
2033	123.8032
2034	112.8357
2035	101.8681

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

This study utilized the double exponential smoothing model to forecast MMR for Ghana and results indicated that MMR will continue to fall but still remain very high in the out of sample period. Therefore, we encourage authorities in Ghana to address local factors associated with maternal deaths and focus should also be directed towards quality improvement at all levels of the healthcare system.

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