



MATERNAL MORTALITY PROJECTION FOR THE UNITED STATES OF AMERICA USING THE DOUBLE EXPONENTIAL SMOOTHING APPROACH

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Abstract

This study uses annual time series data on MMR for the United States of America (USA) 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 0.3 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will increase but still remain below 30 deaths per 100 000 live births over the out of sample period. Therefore, we encourage authorities to relentlessly address major drivers of maternal mortality across the country.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

Introduction

Maternal mortality is a critical indicator of the quality of health care in a particular population at a specified time period (Amnesty international, 2010; Hunt & Bueno de Mesquita, 2010; WHO, 2010). The demise of a mother during pregnancy, childbirth or post-partum has negative consequences for the index child, other children, spouses, other family members, and community as a whole. (Lawson & Keirse, 2013; Amnesty international, 2010; Hogan et al. 2010; Hunt & Bueno de Mesquita, 2010; WHO, 2010). Close to 800 women die every day from avoidable causes related to pregnancy or childbirth (WHO, 2023). Hemorrhage, hypertensive disorders, and sepsis are responsible for over 50% of maternal deaths worldwide (Khan et al. 2006). In Sub-Saharan Africa, 65% of



maternal deaths from obstetric bleeding that takes place after delivery (Campbell et al. 2006; Li et al, 1996). Maternal mortality affects low-middle countries more than the developed countries. The burden remains high in low-and middle-income countries (LMICs), with 95% of the burden of maternal mortality and the majority of deaths occurring in sub-Saharan Africa (SSA) (WHO, 2023). According to the WHO, at the global level, the maternal mortality ratio in 2020 was estimated at 233 per 100,000 live births (WHO, 2020). However, during the recent years, a significant decline of maternal mortality ratio at the global level was noted, with a reduction of 34.3% between 2000 and 2020, an average rate of reduction of 2.9% per year (WHO, 2023; WBG, 2023; WHO, 2020). The purpose of this paper is to model and forecast MMR for the USA using double exponential smoothing technique. The findings of this piece of work are envisioned to highlight likely future trends of MMR in this country. This will inform health policies, planning and allocation of resources to the maternal and child health program with a view of eradicating preventable maternal deaths.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Tsushima et al. (2026)	To determine the long-term incidence of dysglycemia and dyslipidemia after GDM and evaluated whether postpartum changes in body mass index (BMI) independently predicted these outcomes.	Prospective cohort study	Postpartum BMI increase was independently associated with new-onset dysglycemia. No independent predictor of T2DM progression was identified. Dyslipidemia was independently associated with higher pre-pregnancy BMI and multiparity, whereas postpartum BMI change was not independently associated after multivariable adjustment
Yue et al. (2026)	to perform an umbrella review to summarize the current evidence to provide a reference for clinicians and future research	Systematic review	Positive aPLs significantly increased the risk of miscarriage rate in assisted reproductive technology (ART) and were also associated with total fetal loss, PE, intrauterine growth retardation and placental abruption



Chen et al. (2025)	To examine the age-standardized national rates of pregnancy-related death from 2018 to 2022 in the US, stratified by cause, and to compare the rates across states and race and ethnicity.	Cross-sectional study	pregnancy-related deaths in the US, rates increased during 2018 to 2022, with large variations by state and race and ethnicity
Nunn et al. (2025)	To explore whether changes in key characteristics among Victorian Aboriginal and/or Torres Strait Islander women contributed to reduced perinatal death rates	Retrospective population-based cohort study of all births in Victoria from 2000–2019	Changes in key maternal characteristics may have contributed to improved perinatal death rates among babies of Victorian Aboriginal and/or Torres Strait Islander women
Haninger-Vacariu et al. (2024)	To describe pregnancy and delivery outcomes in women with Fabry disease	Retrospective cohort-study of women with Fabry disease in Austria using a specific questionnaire and the Austrian Mother–Child Health Passport	The cohort-study in women with Fabry disease showed an increase of pain burden during pregnancies and clearly points to an increased risk for preeclampsia, prematurity, and neonates small for gestational age. With a substantial number of high-risk pregnancies, neonatal outcomes are somewhat worse in Fabry disease than in the general public
Kornyicki & Fedor (2024)	to publish findings on the lifestyle factors of pregnant women in Hungary and their impact on early childhood health status by examining changes over time and regional/geographical disparities	Secondary analysis of raw indicators reported by health visitors as per mandatory annual report data for the period of 1997–2019 in Hungary	Interventions to improve early childhood health in some counties of Hungary are urgently needed to reduce regional disparities
Wilhelm et al. (2024)	To describe the contribution of CA to NMR in Malta, investigating possible associations with known maternal risk factors of	-Anonymous data for births and neonatal deaths were obtained for 2006 2020 from the National	Between 2006 and 2020, Malta's NMR remained stable. Maternal Nationality, from non- EU low- income countries, was associated with higher neonatal mortality



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	maternal age, nationality, and education	Obstetrics Information System (NOIS) in Malta -applied regression analysis	
Diguisto et al. (2022)	To compare maternal mortality in eight countries with enhanced surveillance systems	Descriptive multi-country population-based study	Variations in maternal mortality ratios exist between high income European countries with enhanced surveillance systems
Wami et al. (2022)	To explore both real maternal and foeto-neonatal characteristics associated with Hungarian homebirths	Retrospective cohort study	Aggregated maternal complications (primary uterine inertia, prolonged second stage labor, and third stage hemorrhage) were prevalent among homebirth cases (1.29% vs. 0.72%, $p < 0.05$) and were associated with an average of 11.77% rate of transfer to a health care institution. On the other hand, the rate of operative (vaginal or caesarean) delivery was 26.31% among institutionalized births
Lameijer et al. (2019)	to present an extensive overview concerning the specific cardiovascular causes of maternal death and to identify avoidable contributing care factors related to these deaths	Researchers assessed all cases of maternal death due to cardiovascular disorders collected by a systematic national confidential enquiry of maternal deaths published by the Dutch Maternal Mortality and Morbidity Committee on behalf of the Netherlands Society of Obstetrics and	The maternal cardiovascular mortality ratio is low in the Netherlands and the main causes of maternal cardiovascular mortality are in line with other European reports



		Gynecology over a 21-year period (1993–2013) in the Netherlands	
Schildberger et al. (2017)	-To investigate the personal meanings and experiences of women with disabilities in regard to pregnancy, childbirth and the puerperium	Conducted semi-structured interviews	Participants reported limited acceptance of their life decisions and experienced an environment of discriminatory attitudes. They experienced a lack of support and lack of confidence in their parenting abilities, which negatively influenced their self-efficacy and self-awareness. Violations of personal borders and a feeling of being watched and controlled were reported

Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for the USA. 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 the USA 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	0.300
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	1.244992
Sum Square Error (SSE)	215.251804
Mean Square Error (MSE)	5.519277
Mean Percentage Error (MPE)	-0.243272
Mean Absolute Percentage Error (MAPE)	7.613883



Residual Analysis for the Applied Model

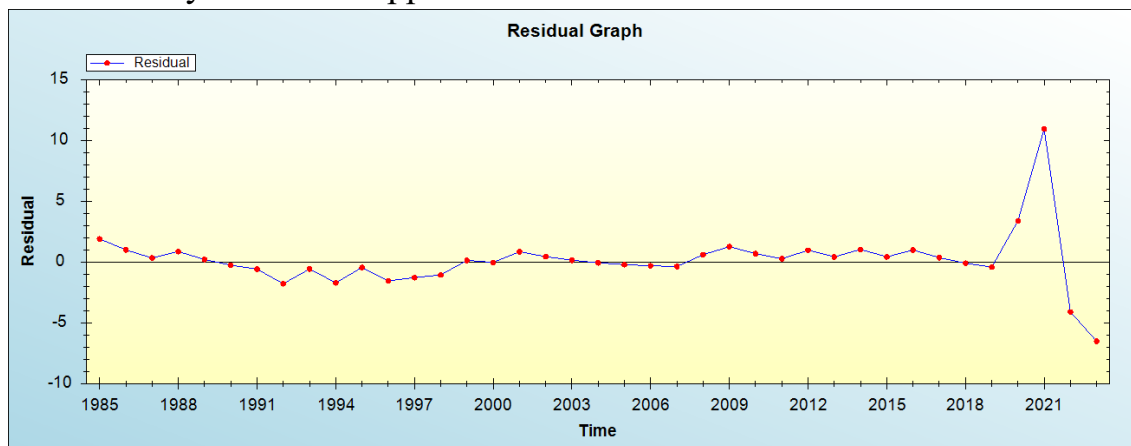


Figure 1: Residual analysis

In-sample Forecast for A

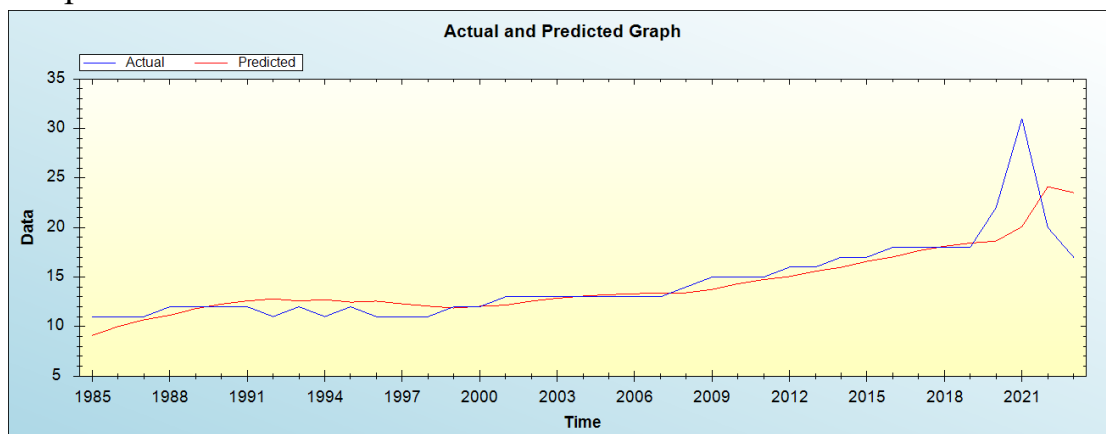


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

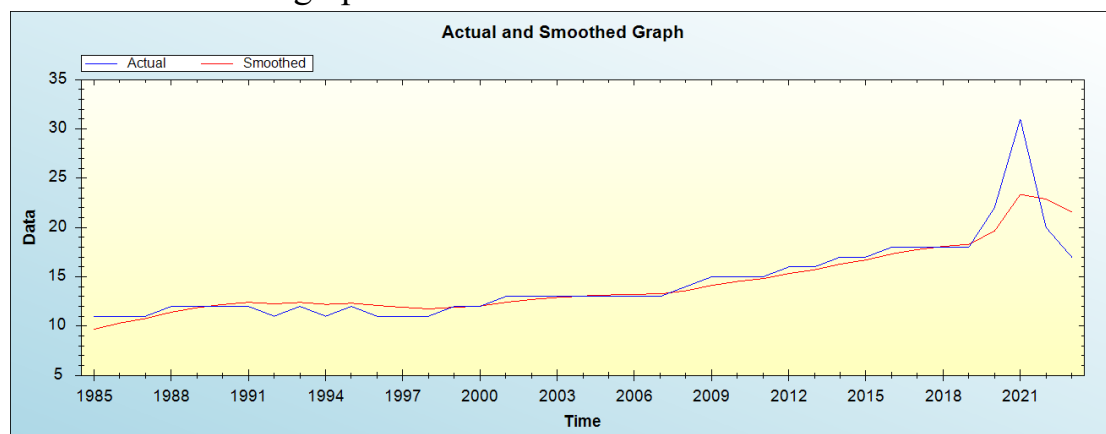


Figure 3: Actual and smoothed graph for A series



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

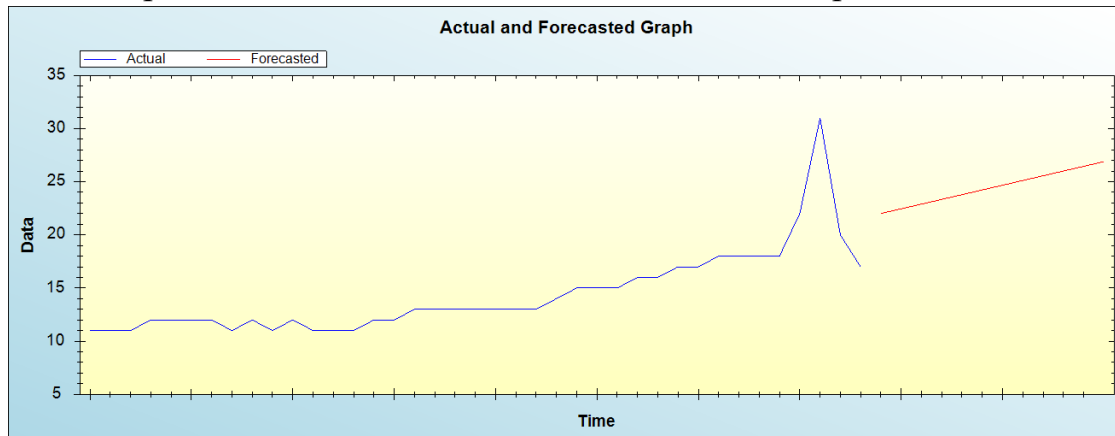


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	22.0086
2025	22.4526
2026	22.8966
2027	23.3406
2028	23.7846
2029	24.2286
2030	24.6726
2031	25.1166
2032	25.5606
2033	26.0046
2034	26.4486
2035	26.8926

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 increase but still remain below 30 deaths per 100 000 live births over the out of sample period.



Recommendations & Conclusion

The burden of maternal mortality is huge in low-middle income countries as a result of several challenges that include shortage of skilled birth attendants, lack of medical supplies, dilapidated infrastructure, lack of political will and poor accountability of state resources. Most maternal deaths in developing countries are as result of direct causes such as eclampsia, excessive bleeding, obstructed labor and sepsis. On the hand, in the developed world maternal deaths usually emanate from indirect causes namely non communicable diseases such as diabetes mellitus and cardiovascular disorders. In this paper we applied the double exponential smoothing technique to model and forecast MMR for the USA and findings indicate that MMR will increase but still remain below 30 deaths per 100 000 live births in the out of sample period. Hence, we implore USA authorities to relentlessly address local causes of maternal mortality.

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