

Prediction Of Maternal Mortality For Denmark Using The Double Exponential Smoothing Approach

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Abstract

This study uses annual time series data on MMR for Denmark 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 0.4 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will remain very low over the out of sample period. Therefore, we encourage authorities to address local causes of avoidable maternal deaths.

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

Introduction

Maternal mortality ratio is the number of female deaths per 100,000 live births happening during pregnancy or within 42 days of termination, irrespective of the cause (Alipour et al; 2023; WHO, 2012). Developing countries bear the biggest burden of maternal mortality globally (Rodríguez-Robles et al. 2023; Ruas et al. 2020). WHO statistics indicated that, in 2017, around 295,000 maternal deaths were reported worldwide, with an overall maternal mortality ratio (MMR) of 211 per 100,000 live births (WHO, 2019). Moreover, above 300,000 women die yearly as a result of complications linked to pregnancy and childbirth (Huang et al. 2025). During the period 1990-2015, maternal deaths declined by 43%, from 532,000 to 303,000, with the MMR decreasing from 385 to 216 per 100,000 live births (Kurjak et al. 2023; Alkema et al. 2016). Maternal mortality continues to be a huge burden in developing countries as significant health disparities persist due to unequal access to medical resource (Nigenda & Serván-Mori, 2024; Sáenz et al. 2024). It is important to highlight that maternal mortality is largely avoidable through strategic interventions, including high-quality preconception, prenatal, intrapartum, and postpartum care (Souza et al. 2024; Lawrence et al. 2022; Kinney et al. 2021). The aim of this paper is to model and forecast MMR for Denmark using the double exponential smoothing model. The findings of this paper will assist in policy formulation, planning and allocation of resources to the health sector.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Mackin et al. (2026)	to understand how levels of MNH care are organized in different country contexts	Scoping review	Three or four levels of MNH facility care were most commonly reported. Linking maternal and newborn facility care to community connections is an important consideration to ensure equitable access to routine and emergency care.
Tsushima et al. (2026)	To determine the long-term incidence of dysglycemia and dyslipidemia after GDM and evaluated	Prospective cohort study	Postpartum BMI increase was independently associated with new-onset dysglycemia.

	whether postpartum changes in body mass index (BMI) independently predicted these outcomes.		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
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
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
Bødker et al. (2021)	To present validated Danish register data for two periods between 1985 and 2017	Maternal deaths were identified from 1985 to 1994 and from 2002 to 2017 by linking four national health registers, death certificates and notifications from	Overall maternal mortality decreased in the course of the two periods (n = 33 years), with a significant decrease during the last period

		maternity wards. A group of obstetricians categorized and assessed all medical records, classifying each case by cause of death.	
Bødker et al. (2021)	To keep track of the maternal mortality rate and causes of death to identify learning points for future management of critical illness among obstetric patients and in pinpointing risk factors	identified maternal deaths between 2002 and 2017 by linking four Danish national health registers, using death certificates and reports from hospitals. An audit group then categorized each case by cause of death before identifying any suboptimal care and learning points, which may serve as a foundation for national guidelines and educational strategies	Seventy women died during pregnancy or within six weeks of a pregnancy in the study period. The most frequent causes of death were cardiovascular disease (n = 14), hypertensive disorder (n = 10), suicide (n = 10) and thromboembolism (n = 7). Suboptimal care was identified in 30 of the 70 cases
Morong et al. (2017)	This study was a retrospective cohort study of cases of in-hospital maternal deaths in the Ochsner Health System (Louisiana, United States) and the Queensland Health System (Australia) from 1995 to 2013	-to determine if American and Australian women have a similar rate of preventable maternal death and if the deaths were attributable to the same factors	Women from Louisiana, United States and Queensland, Australia have similar rates of preventable maternal death. No statistically significant factors explained trends in Australian maternal death; American maternal mortality was significantly associated with point of entry into prenatal care, likely influenced by insurance status
Nahidi & Hajifoghaha (2017)	To provide the current situation and trend of MMR in the Eastern Mediterranean region between 1990 and 2015	Systematic review	Based on the collected data, 36 out of 66 studies met the required criteria and were chosen for analysis. All countries of this region showed a downward trend

			between 1990 and 2015, and this change varied from 16.30% in Yemen to 76.56% in Lebanon. The maternal mortality reduction was 69.88% in Iran in the same time
Bouvier-Colle et al. (2012)	To assess capacity to develop routine monitoring of maternal health in the European Union using indicators of maternal mortality and severe morbidity	Analysis of aggregate data from routine statistical systems compiled by the EURO-PERISTAT project and comparison with data from national enquiries	Currently available data on maternal mortality and morbidity are insufficient for monitoring trends over time in Europe and for comparison between countries

Methodology

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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

D_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 Denmark 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	D
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.400
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.583623
Sum Square Error (SSE)	33.139944
Mean Square Error (MSE)	0.849742
Mean Percentage Error (MPE)	0.475665
Mean Absolute Percentage Error (MAPE)	7.779194

Residual Analysis for the Applied Model

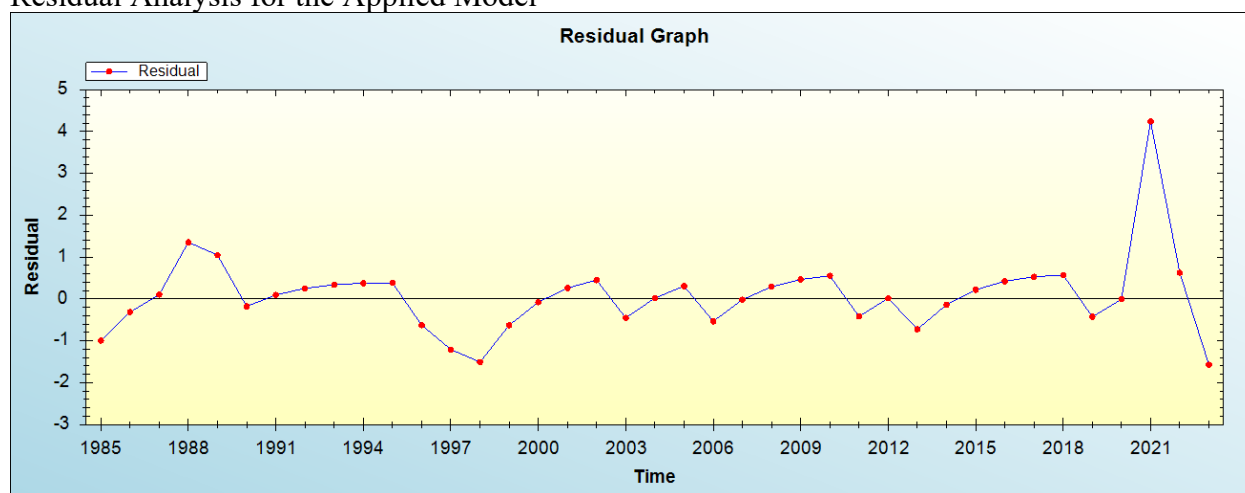


Figure 1: Residual analysis

In-sample Forecast for D

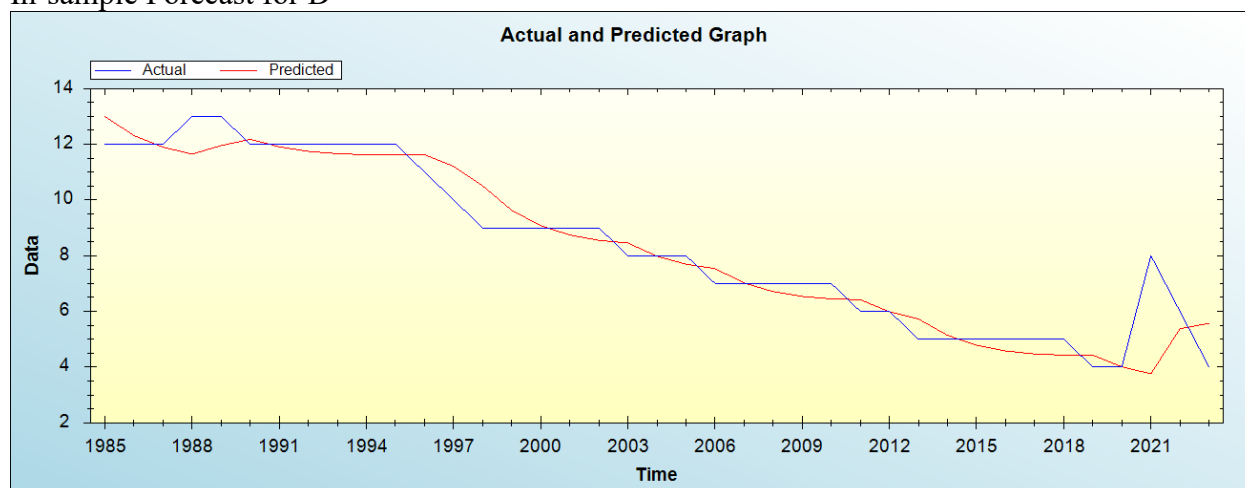


Figure 2: In-sample forecast for the D series

Actual and Smoothed graph for D series

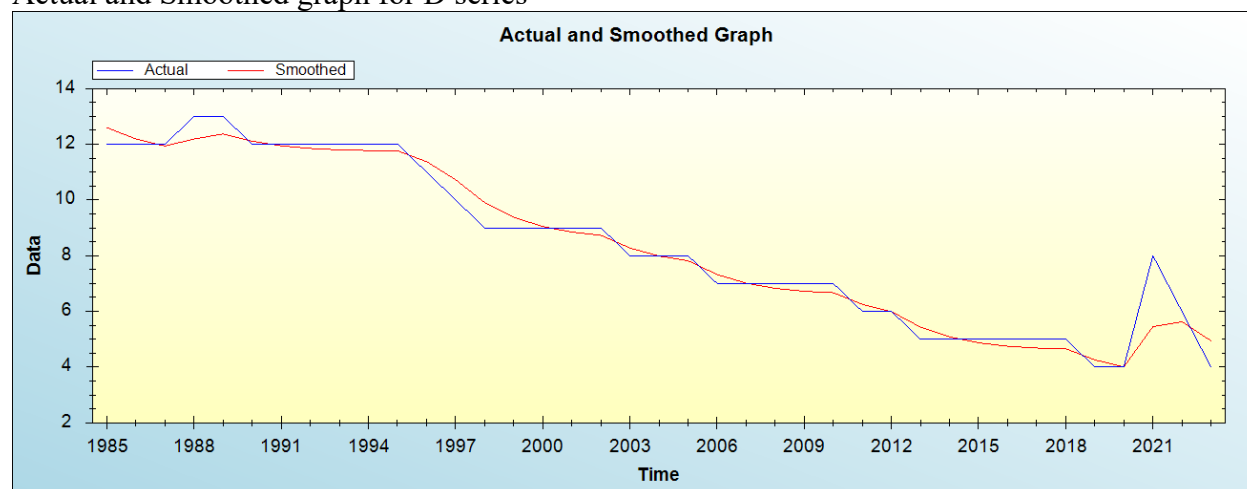


Figure 3: Actual and smoothed graph for D series

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

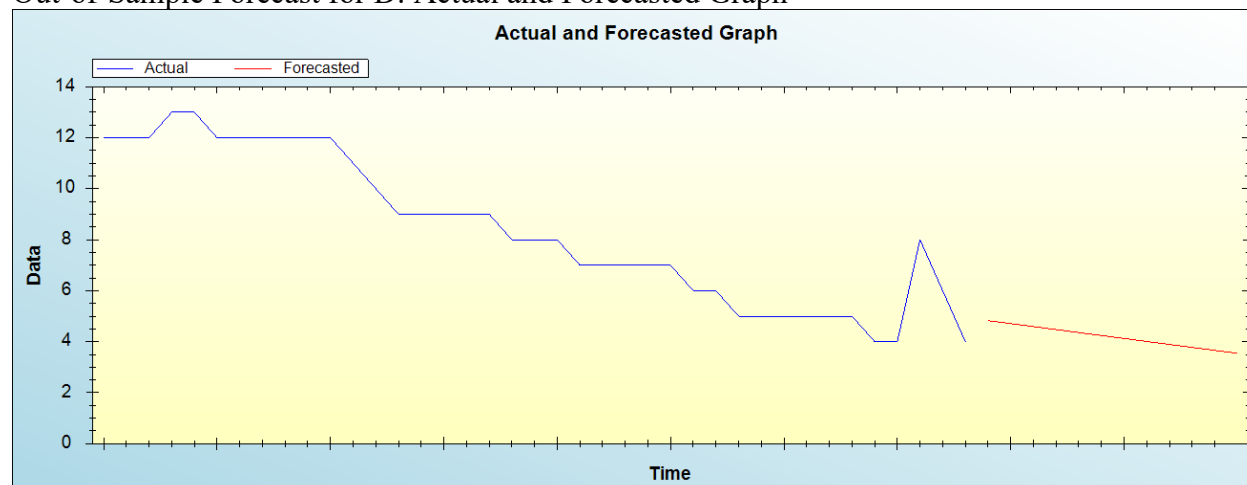


Figure 4: Out-of-sample forecast for D: actual and forecasted graph

Out-of-Sample Forecast for D: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	4.8255
2025	4.7087
2026	4.5919
2027	4.4751
2028	4.3584
2029	4.2416
2030	4.1248
2031	4.0080
2032	3.8912
2033	3.7744
2034	3.6577
2035	3.5409

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 remain very low over the out of sample period.

Recommendations & Conclusion

In this paper we applied the double exponential smoothing method to forecast MMR for Denmark and the results indicated that MMR will remain very low in the forecast period. Therefore, we encourage health authorities to address local drivers of maternal deaths.

References

1. Alipour J., Payandeh A., and Karimi A (2023). Prevalence of maternal mortality causes based on ICD-MM: a systematic review and meta-analysis. *BMC Pregnancy Childbirth*. 2023;23(1):821
2. Alkema L., Chou D., Hogan D., Zhang S., Moller A-B., and Gemmill A (2016). Global, regional, and National levels and trends in maternal mortality between 1990 and 2015, with scenario-based projections to 2030: a systematic analysis by the UN maternal mortality Estimation Inter-Agency group. *Lancet*. 387(10017):462–74.
3. Huang R.S., Spence A.R., and Abenhaim H.A (2025). Age-related disparities in National maternal mortality trends: A population-based study. *PLoS ONE*. 20(1): e0316578.
4. Kinney M.V., Walugembe D.R., Wanduru P., Waiswa P., and George A (2021). Maternal and perinatal death surveillance and response in low-and middle-income countries: a scoping review of implementation factors.
5. Kurjak A., Stanojević M., and Dudenhausen J (2023). Why maternal mortality in the world remains tragedy in low-income countries and shame for high-income ones: will sustainable development goals (SDG) help? *J Perinat Med*. 51(2):170–81.
6. Lawrence E.R., Klein T.J., and Beyuo T.K (2022). Maternal mortality in low- and middle-income countries. *Obstet Gynecol Clin North Am*. 49(4):713–33.
7. Nigenda G., and Serván-Mori E (2024). Human resources for health and maternal mortality in Latin America and the Caribbean over the last three decades: a systemic-perspective reflections. *Int J Equity Health*. 2024;23(1):67.
8. Rodríguez-Robles A.L., Avila-Sánchez M.D.J., and Picazzo-Palencia E (2022). Análisis de La muerte materna mediante categorías sociales En Nuevo león, 2014–2019. *Horizonte Sanitario*. 2022;21(3):411–21.
9. Ruas C.A.M., Quadros J..FC., Rocha J.F.D., Rocha F.C., Andrade G.R.D., and Piris ÁP (2020). Profile and Spatial distribution on maternal mortality. *Revista Brasileira De Saúde Materno Infantil*. 2020;20(2):385–96.
10. Sáenz R., Nigenda G., Gómez-Duarte I., Rojas K., Castro A., and Serván-Mori E (2024). Per sistent inequities in maternal mortality in Latin America and the caribbean, 1990–2019. *Int J Equity Health*. 2024;23(1):96.
11. Souza J.P., Day L.T., Rezende-Gomes A.C., Zhang J., Mori R., and Baguiya A (2024). A global analysis of the determinants of maternal health and transitions in maternal mortality. *Lancet Global Health*. 12(2): e306–16. 13.
12. WHO (2012). The WHO application of ICD-10 to deaths during preg nancy, childbirth and puerperium. ICD-MM.
13. WHO (2019). Trends in maternal mortality 2000 to 2017: estimates by WHO, UNICEF, UNFPA. World Bank Group and the United Nations Population Division; 2019.