

MATERNAL MORTALITY PREDICTION FOR MEXICO USING THE DOUBLE EXPONENTIAL SMOOTHING TECHNIQUE

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ABSTRACT

This study uses annual time series data on MMR for Mexico 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 increase from around 54.8 in 2024 to about 57 deaths per 100 000 live births in 2035. Therefore, we encourage authorities to direct resources to quality improvement activities and continue routine surveillance of severe maternal morbidity.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

INTRODUCTION

Every day, approximately 830 women die from preventable causes associated with pregnancy or childbirth globally (WHO, 2018). The majority of maternal deaths are reported in developing countries (WHO, 2018), and 65% of these deaths are documented in sub-Saharan Africa (WHO, 2019). Achieving the third sustainable development goal (SDG-3.1) which focuses on reducing the global maternal mortality ratio to levels below 70 deaths per 100,000 live births by 2030 remains challenging in sub-Saharan Africa (WHO, 2019). Data indicates that maternal mortality ratios are highest where skilled birth attendance is the lowest (WHO, 2019). Most maternal deaths are reported during the intrapartum and peripartum periods (Ahmed et al. 2018; Merdad et al. 2018) highlighting the significance of early access to quality health services for birth and postpartum care. In addition, complications during childbirth and postpartum periods are best managed and treated in well-equipped and staffed health facilities. According to Mexico Policy Country Profile 2018, in 2020 maternal mortality stood at 59.1 deaths per 100 000 live births. The objective of this paper is to model and forecast MMR for Mexico using the double exponential smoothing technique. The findings of this paper will inform policy-making, planning and allocation resources to the maternal and child health program so as to further lower preventable maternal mortality across the country.

LITERATURE REVIEW

Author(s)	Objective(s)	Methodology	Main finding(s)
Doubova et al. (2025)	To assess the quality of childbirth care in Mexico	Data were collected from an observational IMSS-affiliated eCohort of pregnant women aged 18 to 49, focusing on their experiences, perceptions of healthcare quality, obstetric violence, and health outcomes. The analysis included Chi-square tests and multivariable linear regression	AMIIMSS improves women's childbirth experiences but reveals weaknesses due to poor hospital adherence to the program and poor perceived quality
Serván-Mori et al. (2025)	To analyze the temporal and territorial relationship between health system financing fragmentation and maternal mortality in the last two decades in Mexico	ecological-longitudinal study	Maternal deaths in the population without social security were more frequent among younger women, with less schooling, unmarried, and residing in rural areas, with higher Indigenous presence and greater social marginalization. From 2019 onwards, the MMR was higher in the population with social security.
Gutiérrez- Peláez et al. (2022)	To present a case that describes common challenges during an obstetric emergency in resource- poor settings	Case presentation	The analysis identifies the social determinants of health behind the slow and inadequate emergency response
Serván-Mori et al. (2021)	To describe the temporal and geographical patterns of the continuum of maternal health care in Mexico, as well as the sociodemographic characteristics that affect the likelihood of receiving this care	conducted a pooled cross-sectional analysis using the 1997, 2009, 2014 and 2018 waves of the National Survey of Demographic Dynamics, collating sociodemographic and obstetric characteristics of 93 745 women aged 12–54 years at last delivery	having social security and a higher level of education is positively associated with receiving the continuum of care. Researchers observed the largest relative increases in continuum of care coverage in Chiapas (181.5%) and Durango (160.6%), assigned human development index categories of low and medium, respectively
Servan-Mori et al. (2016)	To explore the relationship between public expenditure, coverage of adequate ANC (including timing, frequent and content), and the maternal mortality ratio-adjusted by cover age of adequate ANC-observed in Mexico in2012 at the State level	Performance analysis	Results suggest that in the 2003–2011 period, the public expenditure gap between women with and without Social Security decreased 74%, however, the distribution is less equitable among women without Social Security, across the States.

METHODOLOGY

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Mexico. 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 Mexico 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	0.400
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	6.280258
Sum Square Error (SSE)	5709.558470
Mean Square Error (MSE)	146.398935
Mean Percentage Error (MPE)	-0.182357
Mean Absolute Percentage Error (MAPE)	9.455803

Residual Analysis for the Applied Model

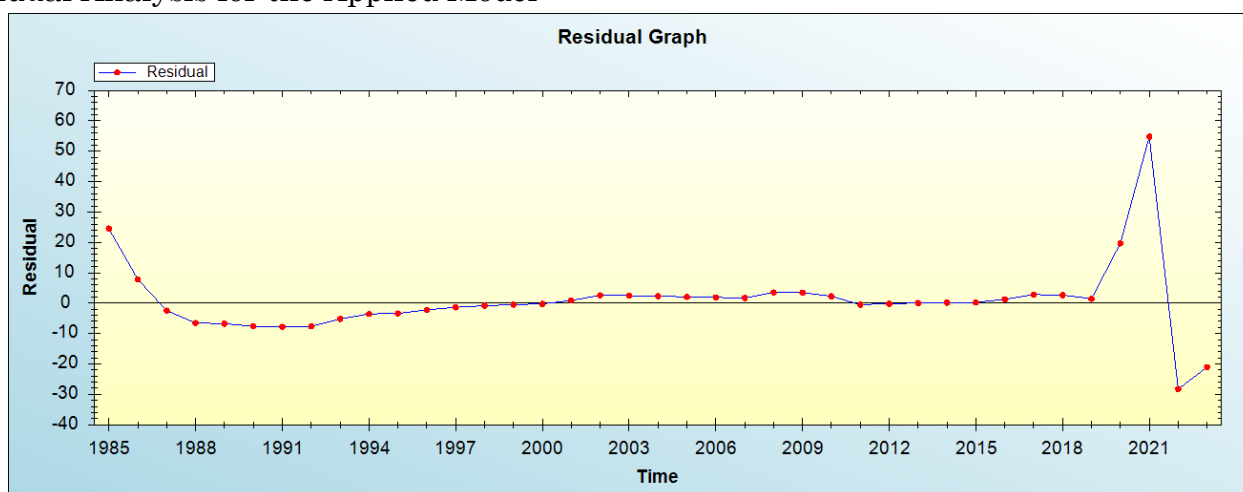


Figure 1: Residual analysis

In-sample Forecast for M

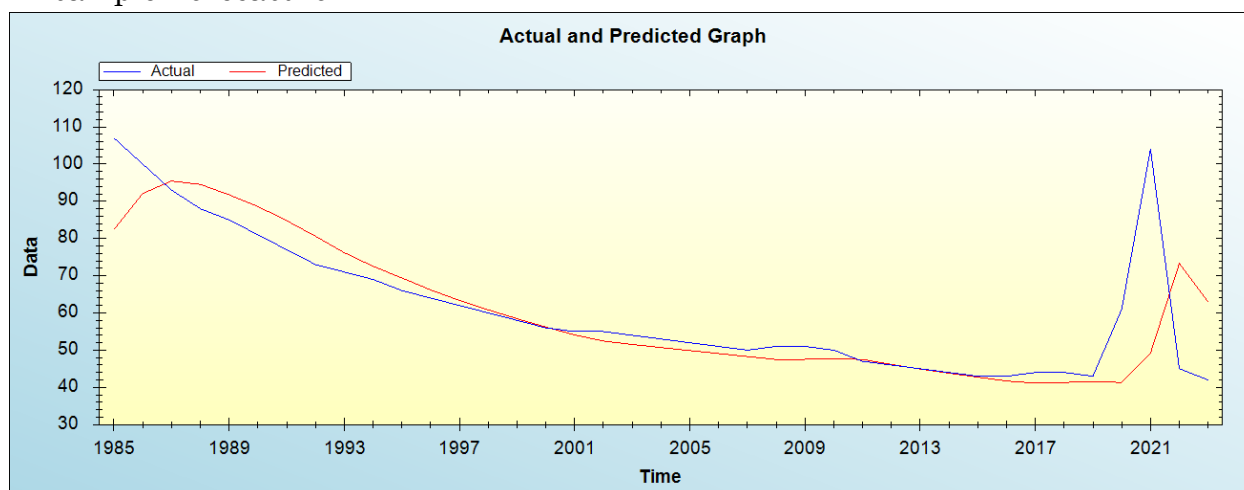


Figure 2: In-sample forecast for the M series

Actual and Smoothed graph for M series

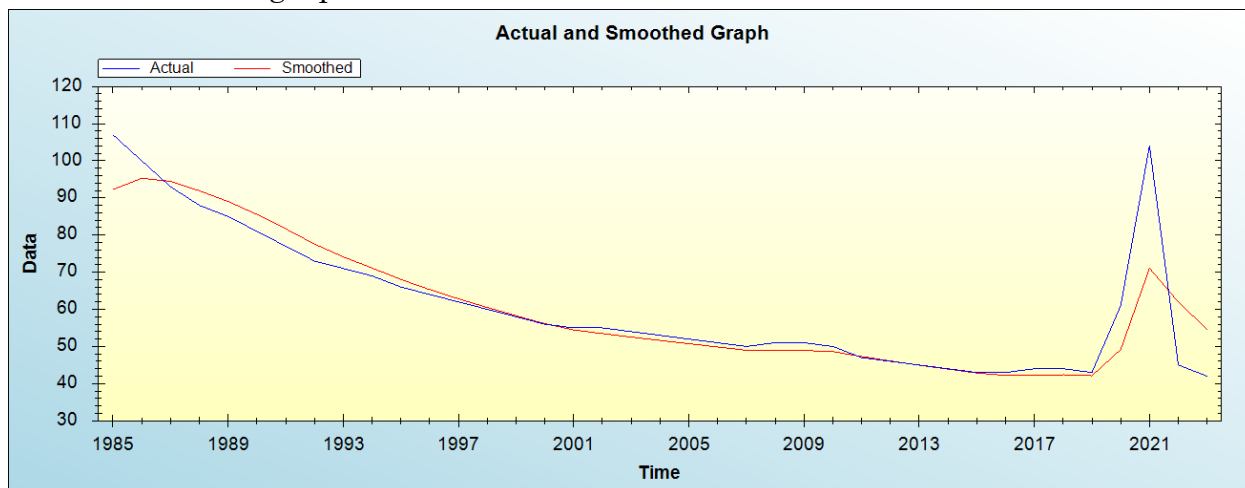


Figure 3: Actual and smoothed graph for M series

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

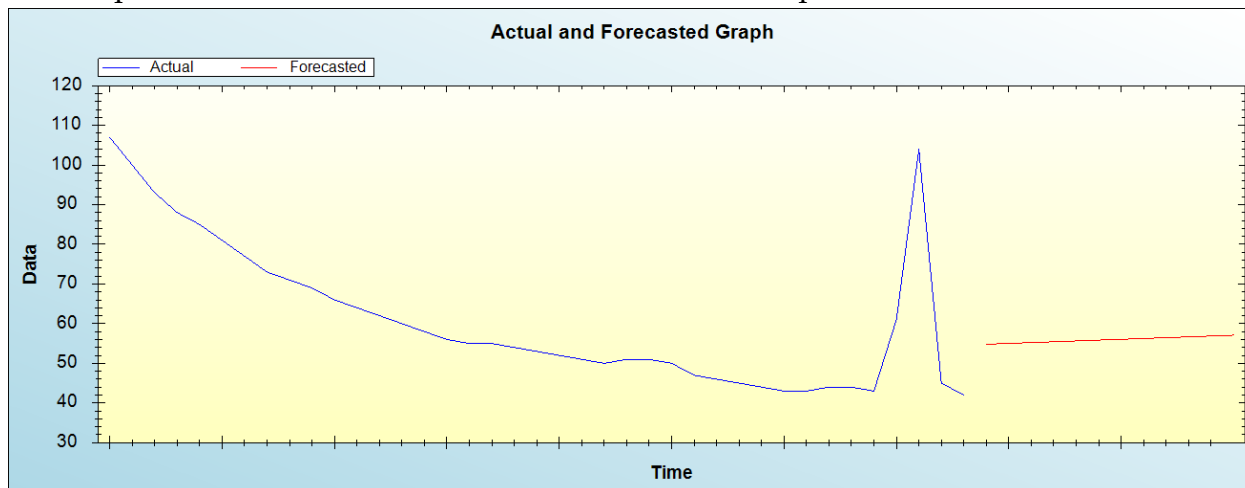


Figure 4: Out-of-sample forecast for M: actual and forecasted graph

Out-of-Sample Forecast for M: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	54.8183
2025	55.0252
2026	55.2321
2027	55.4390
2028	55.6459
2029	55.8528
2030	56.0597
2031	56.2667
2032	56.4736
2033	56.6805
2034	56.8874
2035	57.0943

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 slightly increase from around 54.8 in 2024 to about 57 deaths per 100 000 live births in 2035.

RECOMMENDATIONS & CONCLUSION

Maternal mortality ratio remains an important indicator for the quality of health services offered during antenatal, child birth and postnatal periods. Mexico has witnessed significant decline of MMR over the previous decades reflecting the government's commitment in reducing MMR to levels lower than 30 per 100 000 live births. In this study we applied the Holt's linear method to forecast MMR and findings indicate that MMR will slightly increase from around 54.8 in 2024 to about 57 deaths per 100 000 live births in 2035. Therefore, we implore the authorities to channel resources towards quality improvement initiatives and surveillance of severe maternal morbidities.

REFERENCES

1. Ahmed I., Ali S.M., Amenga-Etego S., Ariff S., Bahl R., and Baqui AH (2018). Population-based rates, timing, and causes of maternal deaths, stillbirths, and neonatal deaths in south Asia and sub-Saharan Africa: a multi-country prospective cohort study. *Lancet Glob Heal.* 6(12): e1297–308.
2. Merdad L and Ali M.M (2018). Timing of maternal death: Levels, trends, and ecological correlates using sibling data from 34 sub-Saharan African countries. *PLoS ONE.* 13(1):1–13.
3. Mexico Policy Country Profile 2018.
4. World Health Organization (2018). Maternal mortality: Levels and trends 2000 to 2017. 2017. World Health Organization. Maternal mortality. Key facts. WHO. 2018. <https://www.who.int/news-room/fact-sheets/detail/maternal-mortality>.
5. World Health Organization (2019). The World Health Statistics 2019. Monitoring health for the SDGs. 2019. <https://apps.who.int/iris/bitstream/handle/10665/324835/9789241565707-eng.pdf?ua=1>.
6. World Health Organization (WHO, 2019). SDG 3: Ensure healthy lives and promote wellbeing for all at all ages. WHO. 2019. <https://www.who.int/sdg/targets/en/>.