



PREDICTION OF MATERNAL MORTALITY FOR BRAZIL USING THE DOUBLE EXPONENTIAL SMOOTHING APPROACH

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Abstract:

This study uses annual time series data on MMR for Brazil 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 decline from around 70 in 2024 to about 60 deaths per 100 000 live births by 2035. Therefore, we encourage authorities to address local factors associated with maternal mortality.

Keywords: *Exponential smoothing, Forecasting, Maternal Mortality Ratio*

INTRODUCTION

Reducing maternal mortality is a global public health issue included in the United Nations Sustainable Development Goals (SDG) (Dantas-Silva et al. 2024). The third SDG promotes health and well-being for all, SDG5 promotes gender equity, and SDG10 focuses on reduction of inequities (UN, 2015). Reducing maternal mortality, increasing the quality of maternal care, and ensuring universal access to sexual and reproductive health services are among the goals. Thus, improving health measures, promoting gender equity, and reducing inequities are vital to the reduction of maternal mortality (WHO, 2023). Maternal mortality in Brazil has significantly declined since 1990, from 1990 to 2010, the maternal mortality rate (MMR) showed a sharper drop, followed by a stabilization trend until 2019. In Brazil, a 39% reduction in MMR from 1990 to 2019 was observed, decreasing from 111.4 to 62.1 deaths per 100,000 live births (Leal et al. 2022). Nevertheless, Brazil will remain far from reaching the target agreed by the Brazilian government with the SDG, to reach an MMR of 30 per 100,000 live births by 2030 (Brazil, 2021). The aim of this paper is to model and forecast MMR for Brazil using the double exponential smoothing technique. The study findings will stimulate an appropriate national response in order to further reduce maternal mortality in the country.

LITERATURE REVIEW

Author(s)	Objective(s)	Methodology	Key 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 whether	Prospective cohort study	postpartum weight change may help identify women at higher risk of subsequent metabolic



	postpartum changes in body mass index (BMI) independently predicted these outcomes		abnormalities, particularly dysglycemia, in this high-risk population, although causal relationships cannot be inferred from this observational study
Yue et al. (2026)	to perform an umbrella review to summarize the current evidence to provide a reference for clinicians and future research	Systematic literature review	This review offers a thorough overview of the current evidence linking SLE, SS and APS to pregnancy and assisted reproductive outcomes. It identifies existing gaps and proposes future research directions
Cresswell et al. (2025)	To obtain updated evidence on causes of maternal death is needed to accelerate progress	Systematic review	Globally, the most common cause of maternal death was hemorrhage (27%; 80% uncertainty interval 22–32), followed by indirect obstetric deaths (23%, 18–30), and hypertensive disorders (16%, 14–19). The proportion of hemorrhage deaths varied substantially by region and was highest in sub-Saharan Africa and Western Asia and Northern Africa.
Quiroz-Acuña et al. (2025)	To assess maternal mortality trends in LAC women from 1997 to 2019, providing key insights to address this issue.	ecological observational time-series study	Despite overall progress, regional differences in maternal mortality persist across Latin America and the Caribbean. These variations highlight the importance of strengthening maternal health systems, improving access to skilled birth attendance, and ensuring quality prenatal and postnatal care
Silvana et al. (2025)	To describe the factors influencing the reduction of maternal mortality during the	Participatory Action Research (PAR) with a qualitative-quantitative analysis. Twelve	intercultural, comprehensive, and territory-based management of



	2022–2024 management period at Tartagal Hospital (HT)	meetings and interviews were conducted with the healthcare team, along with 10 validated surveys administered to obstetric inpatients (10/12/24), and an analysis of hospital databases	pregnancy and childbirth led to a reduction in maternal mortality beginning in 2022. Teamwork and intersectoral collaboration optimized available resources, consolidating a sustainable and effective model for maternal health. However, the greatest challenge lies in maintaining and increasing funding to ensure the continuity of this policy
Nigenda and Serván-Mori (2024)	To discuss the relationship between the availability of human resources for health and the maternal mortality ratio for the period 1990–2021 in Latin America	used secondary data from a global source to show patterns in the relationship between these two aspects and identify gaps in the Latin American and Caribbean regions	Although variations in maternal mortality rate cannot be explained solely through the provision of health personnel, it is important to consider that it is critical to find new modalities on how human resources for health could integrate and create synergies with other resources to increase systems capacity to deliver care according to conditions in each country
Silva et al. (2024)	To assess maternal mortality (MM) in Brazilian Black, Pardo, and White women	evaluated the maternal mortality rate (MMR) using data from the Brazilian Ministry of Health public databases from 2017 to 2022. We compared MMR among Black, Pardo, and White women according to the region of the country, age, and cause. For statistical analysis, the Q2 test prevalence ratio (PR) and confidence interval (CI) were calculated	Black women presented higher MMR in all years, in all geographic regions, age groups, and causes. In Brazil, Black skin color is a key MM determinant
Critto et al. (2022)	To examine the effects of a pandemic influenza virus on cause-specific maternal mortality time	-conducted a population-based natural experiment from national vital records of	Over this 38-year study, the MMR decreased by 58.6% (69.5 to 28.8 deaths/100,000 live



	series, Argentinian statistics	using vital	maternal deaths between 1980 and 2017 -applied Join-point regression models	births), transitioning from direct obstetric causes (67.0 to 21.1/100,000 live births; 68.4% decrease) to indirect causes (2.6 to 7.7/ 100,000 live births; 196.2% increase)
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Methodology

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

$$Z_t = \mu_t + \rho_t \mathbf{t} + \varepsilon_t$$

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

Z_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**

$\mathbf{t}$ 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 Brazil 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	Z
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	8.329140
Sum Square Error (SSE)	8266.313271
Mean Square Error (MSE)	211.956751
Mean Percentage Error (MPE)	0.224773
Mean Absolute Percentage Error (MAPE)	8.385791

Residual Analysis for the Applied Model

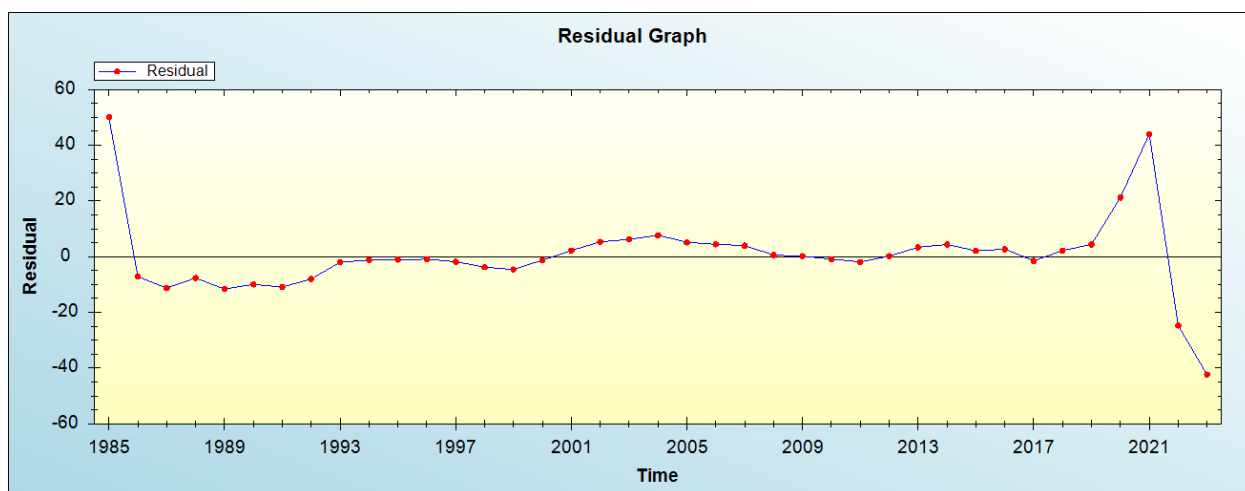


Figure 1: Residual analysis

In-sample Forecast for Z

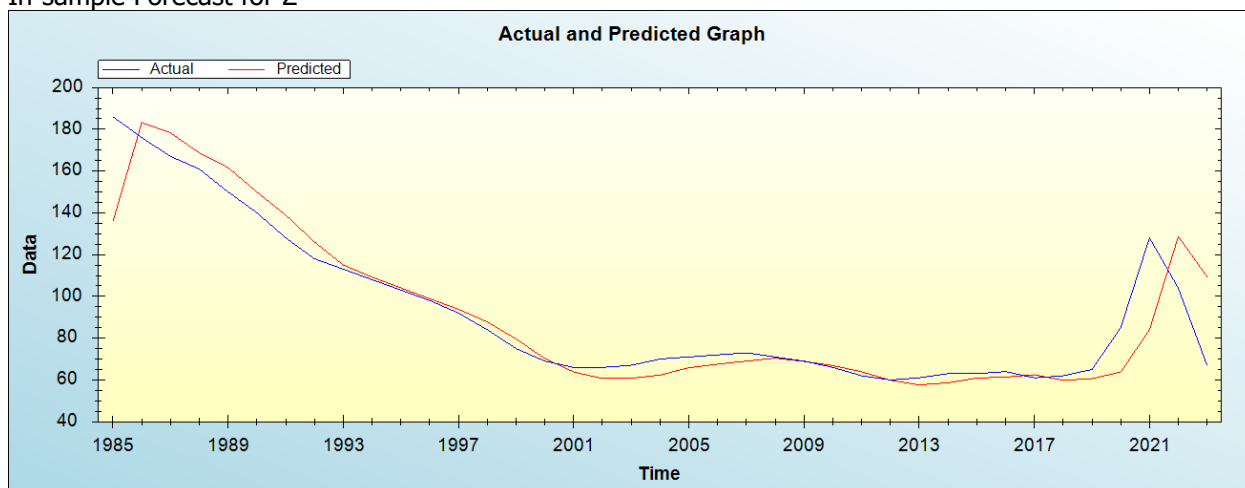


Figure 2: In-sample forecast for the Z series

Actual and Smoothed graph for Z series

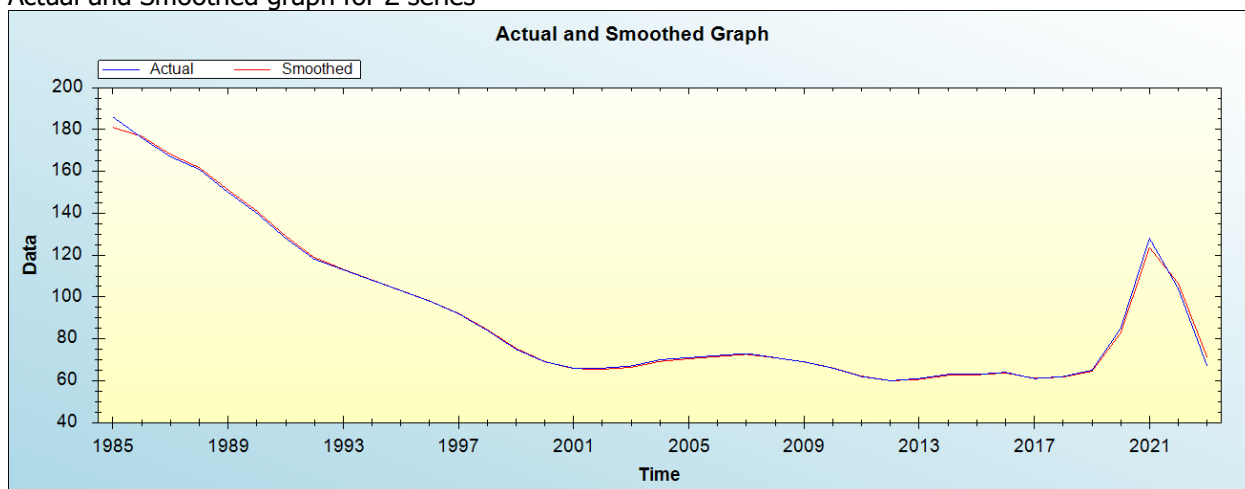


Figure 3: Actual and smoothed graph for Z series

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

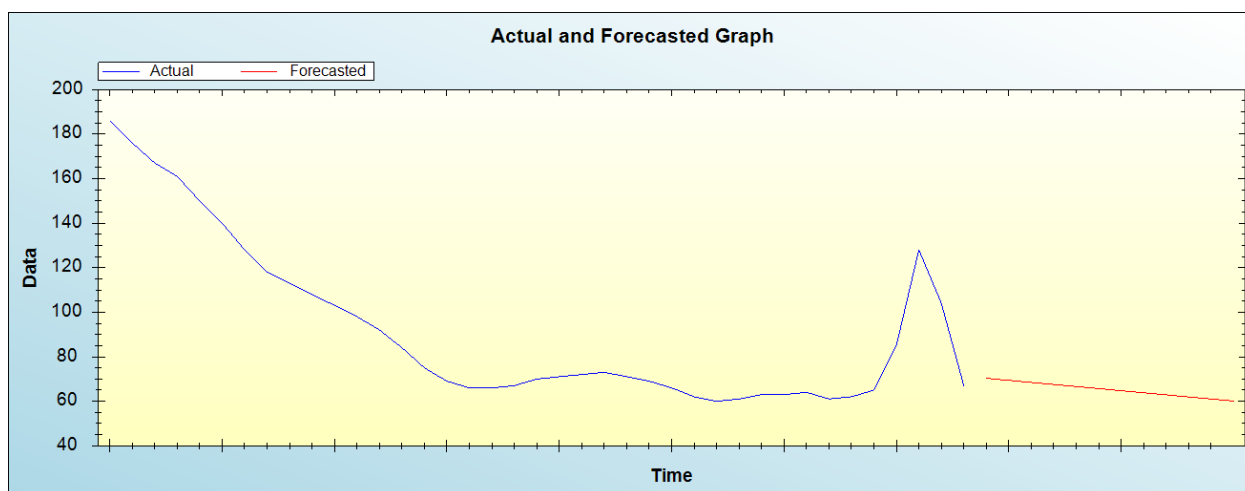


Figure 4: Out-of-sample forecast for Z: actual and forecasted graph

Out-of-Sample Forecast for Z: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	70.3068
2025	69.3782
2026	68.4496
2027	67.5210
2028	66.5924
2029	65.6638
2030	64.7352
2031	63.8066
2032	62.8780
2033	61.9494
2034	61.0208
2035	60.0922

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 from around 70 in 2024 to about 60 deaths per 100 000 live births by 2035.

Recommendations & Conclusion

Maternal mortality is still a public health problem in the Americas including Brazil. Although Brazil has managed to significantly reduce MMR over the past decades, it is still far away from achieving the regional target of 30 maternal deaths per 100 000 live births. This paper applies the double exponential smoothing method to forecast MMR for Brazil and the results indicate that MMR will decline from around 70 in 2024 to about 60 deaths per 100 000 live births in 2035. Therefore, we encourage health authorities to address local factors associated with maternal mortality.

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