

PREDICTION OF ANNUAL MATERNAL MORTALITY RATE FOR JAPAN USING THE DOUBLE EXPONENTIAL SMOOTHING TECHNIQUE

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ABSTRACT

This study uses annual time series data on MMR for Japan 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 0.8 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.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio

INTRODUCTION

Maternal mortality is a worldwide public health problem. Close to 800 women die every day from avoidable causes related to pregnancy or childbirth (WHO, 2023). This scourge affects low-middle countries more. 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). During these recent years, a significant decline of maternal mortality ratio at the global level was observed, with a decline of 34.3% between 2000 and 2020, an average rate of reduction of 2.9% per year (WHO, 2023; WBG, 2023; WHO, 2020). According the World Bank, maternal mortality in Japan declined significant over the previous decades due to improvements in the quality and accessibility of maternal health care services. The aim of this paper is to model and forecast MMR for Japan using the double exponential smoothing technique. The study findings will inform policy and resource allocation so as to eliminate all preventable maternal mortality.

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 postpartum changes in body mass index (BMI) independently predicted these outcomes	Prospective cohort study	postpartum weight change may help identify women at higher risk of subsequent metabolic 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 2022–2024 management period at Tartagal Hospital (HT)	Participatory Action Research (PAR) with a qualitative-quantitative analysis. Twelve 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	intercultural, comprehensive, and territory-based management of 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 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

		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	
Critto et al. (2022)	To examine the effects of a pandemic influenza virus on cause-specific maternal mortality time series, using Argentinian vital statistics	-conducted a population-based natural experiment from national vital records of maternal deaths between 1980 and 2017 -applied Join-point regression models	Over this 38-year study, the MMR decreased by 58.6% (69.5 to 28.8 deaths/100,000 live 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)
Kajihara (2018)	To review the history of MCH handbook and clarify the purpose of establishing MCH handbook in Japan	The researcher examined prior documents and papers and then looked up at the documents and original articles	In 1926, infant mortality was 289,275 and neonatal mortality was 119,624 in Japan And furthermore, f low number to be prematurely delivered of a child was almost 300,000 and maternal death by deliver was 5,000 per year. In 1940, maternal mortality rate was 239.6 per child birth 100,000. The origin of the maternal and child health book was “Mutterpass” from Germany.
Hasegawa et al. (2016)	To clarify the problems related to maternal deaths in Japan, including the diseases themselves, causes, treatments and the hospital or regional systems	Descriptive study	Maternal deaths were frequently caused by obstetric hemorrhage (23%), brain disease (16%), amniotic fluid embolism (12%), cardiovascular disease (8%) and pulmonary disease (8%)

METHODOLOGY

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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

J_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 Japan 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	J
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.800
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.612703
Sum Square Error (SSE)	27.109063
Mean Square Error (MSE)	0.695104
Mean Percentage Error (MPE)	-0.033389
Mean Absolute Percentage Error (MAPE)	8.127269

Residual Analysis for the Applied Model

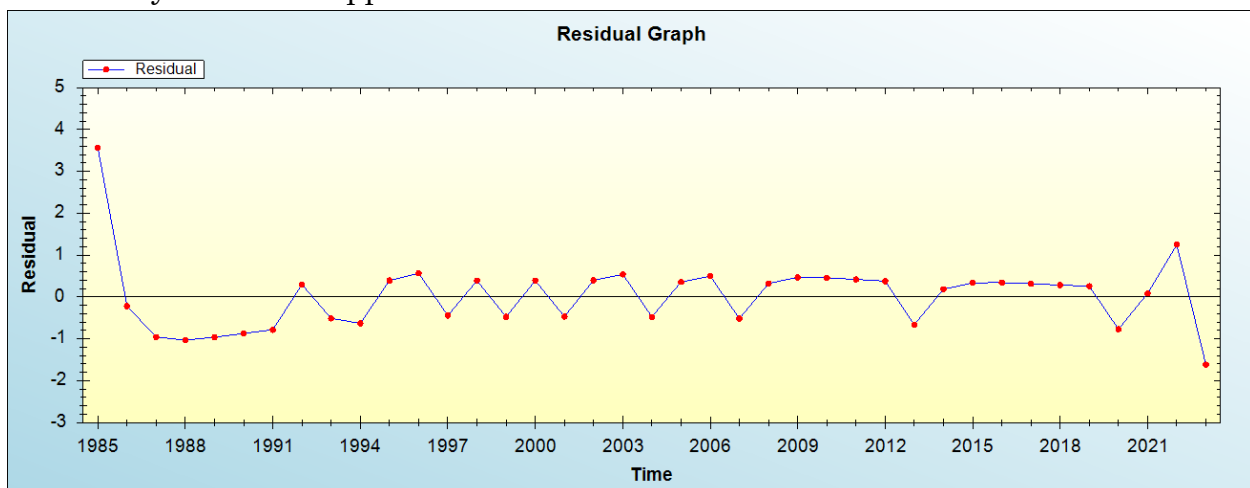


Figure 1: Residual analysis

In-sample Forecast for J

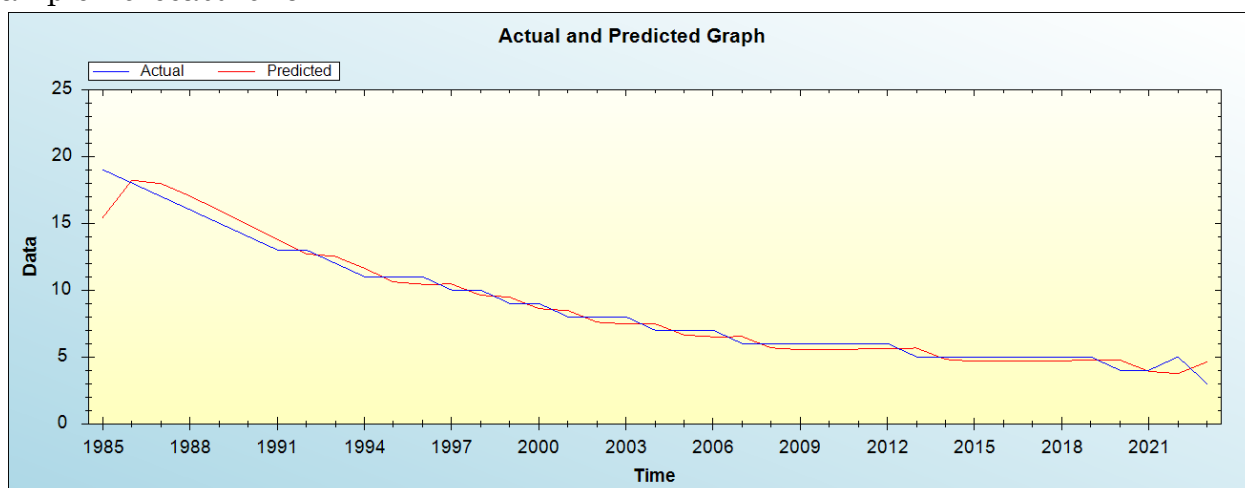


Figure 2: In-sample forecast for the J series

Actual and Smoothed graph for J series

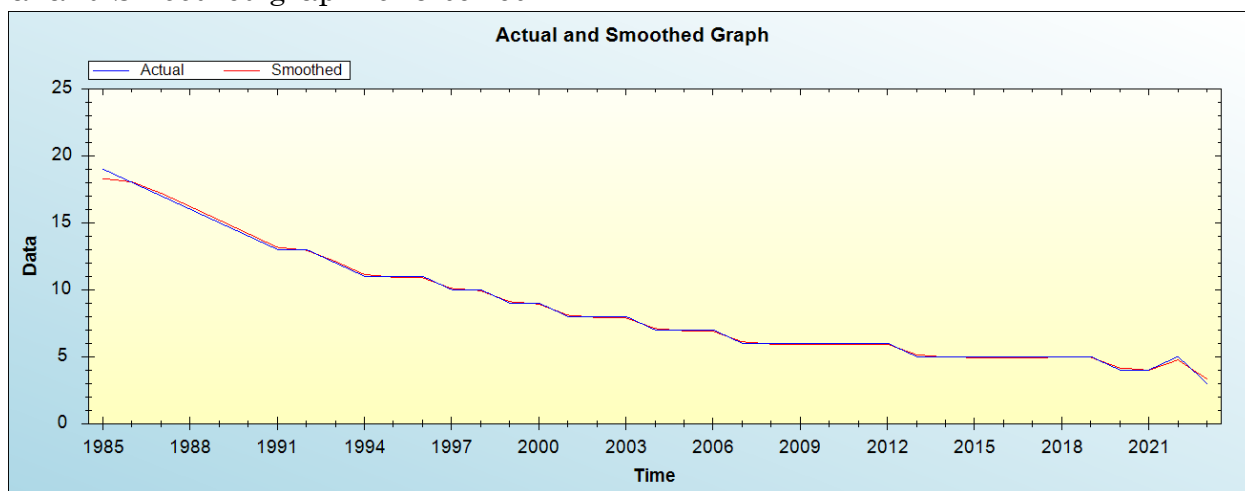


Figure 3: Actual and smoothed graph for J series

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

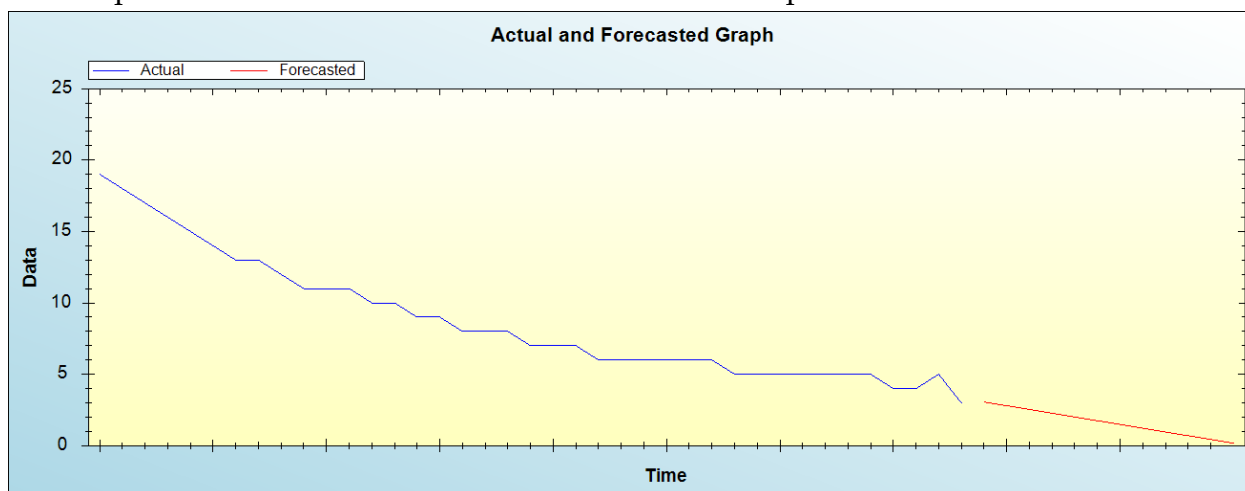


Figure 4: Out-of-sample forecast for J: actual and forecasted graph

Out-of-Sample Forecast for J: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	3.0605
2025	2.7978
2026	2.5351
2027	2.2723
2028	2.0096
2029	1.7468
2030	1.4841
2031	1.2214
2032	0.9586
2033	0.6959
2034	0.4331
2035	0.1704

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 the out of sample period.

RECOMMENDATIONS & CONCLUSION

In this study we applied the double exponential smoothing method to forecast MMR for Japan and the results indicate that MMR will remain very low over the out of sample period. Hence, Japanese authorities are encouraged to continue addressing local causes of maternal mortality across the country.

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