



DETECTION OF FUTURE TRENDS OF MATERNAL MORTALITY FOR CHILE USING THE DOUBLE EXPONENTIAL SMOOTHING APPROACH

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Article history:	Abstract:
Received: 8 th May 2026 Accepted: 7 th June 2026	<i>This study uses annual time series data on MMR for Chile 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 remain very low throughout the out of sample period. Therefore, we encourage authorities to address local causes of maternal mortality and relentlessly implement routine quality improvement initiatives in order to keep maternal mortality under control.</i>
Keywords: <i>Exponential smoothing, Forecasting, Maternal Mortality Ratio</i>	

INTRODUCTION

Maternal mortality is defined by the World Health Organization (WHO) as the number of female deaths per 100,000 live births occurring during pregnancy or within 42 days of termination, irrespective of the cause (Alipour et al. 2023; WHO, 2012). Maternal death continues to be a major public health problem, especially in developing countries (Rodríguez-Robles et al. 2022; Ruas et al. 2020). According to WHO in 2017, a total of 295,000 maternal deaths were reported globally, with an overall maternal mortality ratio (MMR) of 211 per 100,000 live births, representing a 35% reduction compared to the year 2000. In addition, above 300,000 women die annually due to complications related to pregnancy and childbirth (Huang et al. 2025). Over the period 1990 and 2015, maternal mortality fell 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). However, maternal mortality in Latin America and the Caribbean (LAC) remains an unresolved problem, as huge disparities continue to exist as a result of unequal access to medical resource (Nigenda et al. 2024; Sáenz et al. 2024). Maternal mortality is mostly avoidable if targeted high impact and quality strategies are implemented during preconception, prenatal, intrapartum, and postpartum care periods (Souza et al. 2024; Lawrence et al. 2022; Kinney et al. 2021).

The objective of this study is to model and forecast MMR for Chile using the double exponential smoothing approach. The study results are expected to stimulate an appropriate National response that will help further reduce maternal mortality across 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 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, Pardo, and White women according to the region of the country, age, and cause. For	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



		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)
Contreras et al. (2020)	To compare maternal and perinatal outcomes between Chilean and Peruvian pregnant women in Santiago, Chile, between January and July 2017	Analytical cross-sectional study	The healthy immigrant effect was observed in pregnant Peruvian immigrants, mainly regarding the perinatal outcomes
Gonzalez et al. (2009)	To analyze trends in maternal, newborn, and child mortality in Chile between 1990 and 2004	Data were provided by the Chilean Ministry of Health on all pregnancies between 1990 and 2004 (approximately 4000000).	During the study period, the maternal mortality ratio decreased from 42.1 to 18.5 per 100000 live births. The mortality rate for neonates decreased from 9.0 to 5.7 per1000births, for infants from 7.8to3.1 per 1000 births, and for young children from 3.1 to 1.7 per 1000 live births

METHODOLOGY

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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation



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

$$0 < \beta < 1$$

Forecasting equation

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

C_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 Chile 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

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	C
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	1.314386
Sum Square Error (SSE)	181.764226
Mean Square Error (MSE)	4.660621
Mean Percentage Error (MPE)	1.442923
Mean Absolute Percentage Error (MAPE)	4.810647

Residual Analysis for the Applied Model

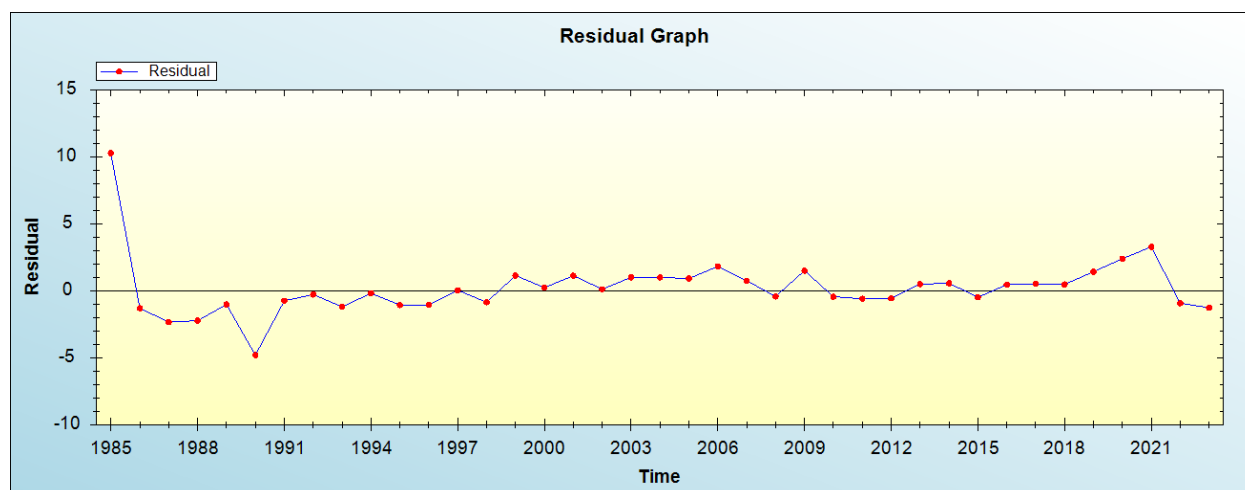


Figure 1: Residual analysis

In-sample Forecast for C

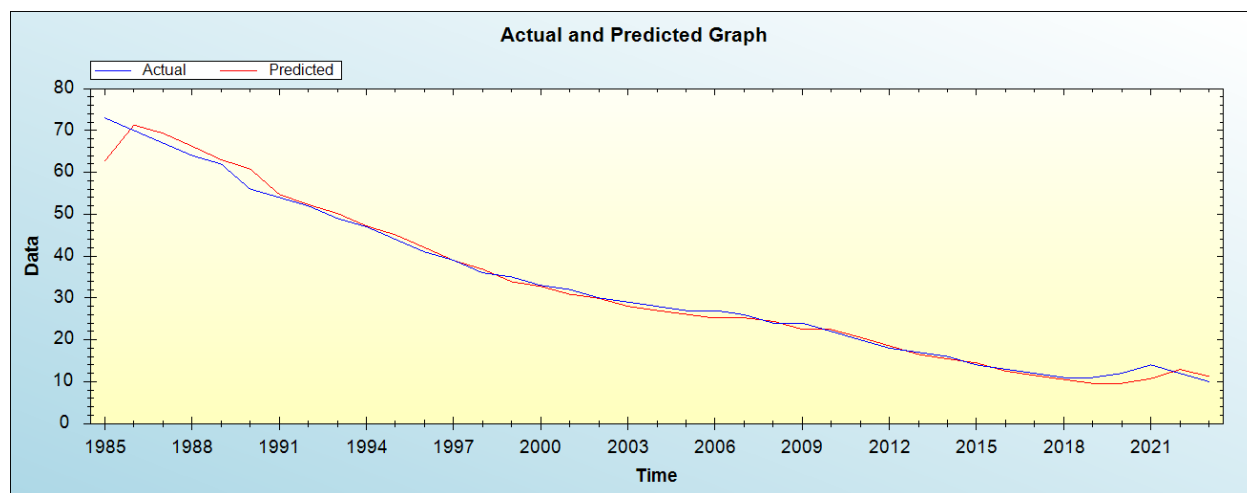


Figure 2: In-sample forecast for the C series

Actual and Smoothed graph for C series

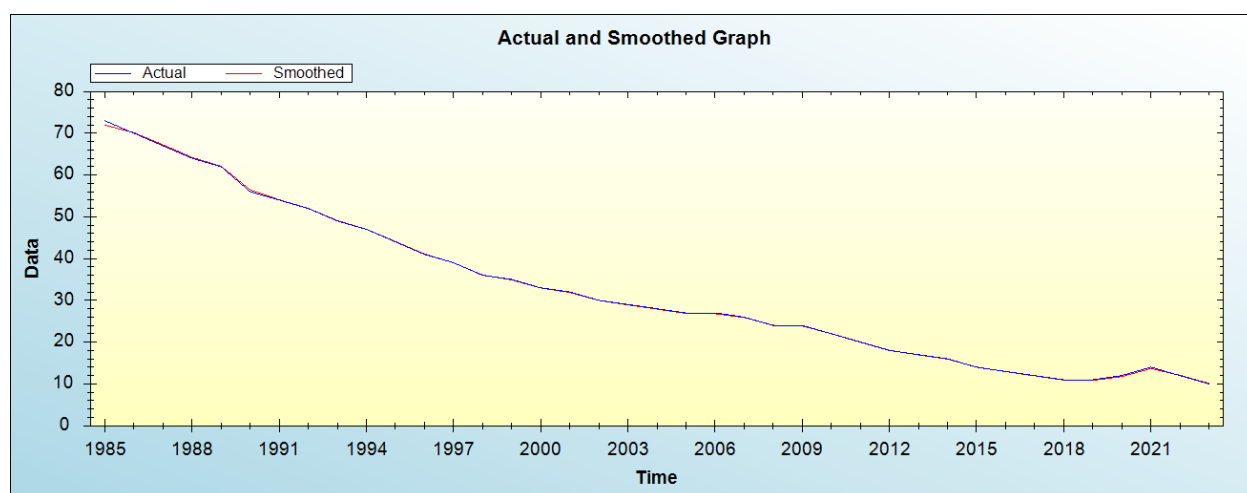


Figure 3: Actual and smoothed graph for C series

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

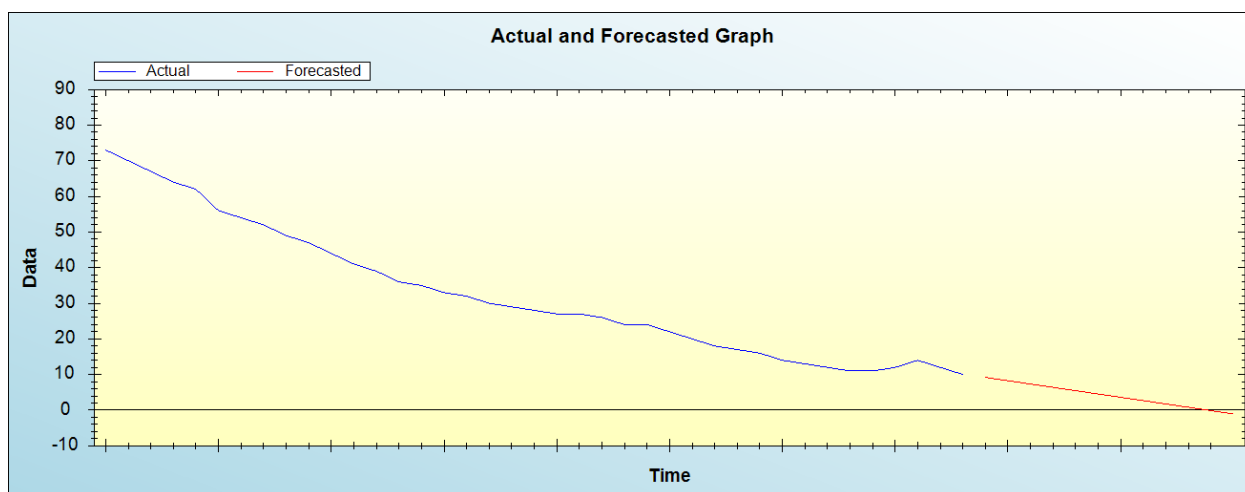


Figure 4: Out-of-sample forecast for C: actual and forecasted graph

Out-of-Sample Forecast for C: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	9.1952
2025	8.2628
2026	7.3304
2027	6.3980
2028	5.4655
2029	4.5331
2030	3.6007
2031	2.6683
2032	1.7358
2033	0.8034
2034	-0.1290
2035	-1.0614

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

This study applies the double exponential smoothing method to model and forecast MMR for Chile and findings indicate that MMR is anticipated to remain very low over the out of sample period. Therefore, health authorities are encouraged to address local causes of maternal deaths and conduct routine quality improvement activities across the country in order to keep maternal mortality under control.

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*. 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 Abenham 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. *Health Policy Plan*. 36(6):955–73
- [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*. 2022;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.Dj., 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.F.C., Rocha J.F.D., Rocha F.C., Andrade GRD., 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). Persistent 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*. 2024;12(2): e306–16.
- [12] WHO (2012). The WHO application of ICD-10 to deaths during pregnancy, childbirth and puerperium. ICD-MM: World Health Organization; 2012.
- [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.