



PREDICTION OF MATERNAL MORTALITY FOR PERU USING THE DOUBLE EXPONENTIAL SMOOTHING TECHNIQUE

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Abstract

This study uses annual time series data on MMR for Peru 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 0.7 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will continue on a downward trajectory to reach levels around 30 deaths per 100 000 live births by 2035. Therefore, we encourage authorities to direct resources towards implementation of quality improvement strategies.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

Introduction

Maternal mortality is a global public health problem. Nearly 800 women die each day from preventable causes related to pregnancy or childbirth (WHO, 2023). Hemorrhage, hypertensive disorders, and sepsis are responsible for over 50% of maternal deaths worldwide (Khan et al. 2006). In Sub-Saharan Africa, 65% of maternal deaths from hemorrhage occur following delivery (Campbell et al. 2006; Li et al, 1996). Maternal mortality affects low-middle countries more than the developed countries. 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). However, during the recent years, a significant decline of maternal mortality ratio at the global level was noted, with a reduction of 34.3% between 2000 and 2020,



an average rate of reduction of 2.9% per year (WHO, 2023; WBG, 2023; WHO, 2020). In Peru, women die from complications arising during pregnancy, childbirth and the postpartum period. The causes are direct - hemorrhage, pregnancy-induced hypertension, sepsis and abortion - with indirect causes being less common. In the years 2020 and 2021, during the COVID-19 outbreak, the number of indirect maternal deaths increased at national level (Peru, 2023). The objective of this paper is to project MMR for Peru using the double exponential smoothing technique. The findings of this paper will inform policy and allocation of resources that will facilitate the implementation of corrective public health interventions.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Marks & Castro (2026)	To examine how MWHs have been implemented across Latin America, analyzing their evolution, the specific needs they address in different countries, and their impact on maternal and neonatal health outcomes throughout the region	Scoping review	The evolution of MWHs suggests that they address a spectrum of needs beyond their original purposes, such as providing culturally responsive maternal support and psychosocial and early childhood support
Soto-Cabezas et al. (2025)	To analyze maternal mortality trends and epidemiological characteristics in Peru, explore its determinants during 2010–2021, and quantify its inequalities before and during the COVID-19 pandemic	-An ecological study that used administrative data from the 25 Peruvian regions (2010–2021) -applied mixed-effects negative binomial regression model	Researchers concluded maternal mortality in Peru declined significantly before 2020, but the COVID-19 pandemic reversed this progress, with MMR rising to pre-2010 levels. Eco-social inequalities persist, disproportionately affecting disadvantaged regions



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Ancaya & Pacheco-Romero (2024)	To determine the situation of maternal mortality (MM) in Peru between 2019 and 2023, visualizing the figures and interventions	Information was reviewed from the Maternal Mortality Epidemiological Surveillance System of the General Directorate of Epidemiology of the Ministry of Health, the HIS System for the registration and coding of information, and the Demographic and Family Health Survey for the years 2021 to 2023	A decrease in the number of maternal deaths (264 MM in 2023) and in the maternal mortality ratio (51.9 per 100,000 live births in 2023) in Peru was found. Direct causes of death are maintained, but in different percentages by natural regions, with hemorrhage being the leading cause of maternal mortality
García et al. (2024)	to explore the contextual factors and strategies that contributed to the successful implementation of key evidence-based interventions (EBIs) in Peru	This research utilized a hybrid implementation research framework and a mixed-methods approach to understand the factors associated with EBI implementation and the successful reduction of U5M between 2000–2015	Several EBIs contributed to the successful reduction of U5M in Peru between 2000–2015. Strategies such as the focus on equity throughout the study period contributed to an increase in coverage of EBIs like ANC visits, facility-based deliveries and infant vaccination which worked to reduce U5M
Zaman et al. (2024)	to better understand the experience of pregnant Venezuelan migrants/refugees in Brazil, Ecuador and Peru	Qualitative study	Pregnant Venezuelan migrants/refugees are a vulnerable population that encounter complex gender based and societal issues that are rarely sufficiently reported
Ramos Rosas et al. (2023)	to analyze the extent to which the introduction of SIS has increased equity in access and quality by comparing	Used secondary from 2021 round of the nationally-representative survey “ENDES”	findings indicated the persistence of inequities in access to maternal healthcare services that manifest themselves not



	the utilization of maternal healthcare services among women with different insurance coverages		only in the reduced utilization among the uninsured, but also in the lower quality of service coverage that uninsured women received compared with women insured under “Standard Insurance” or “SIS”
Avila-Jaquez (2019)	to learn the capacities provided by the public policy of Peru to women, as individuals, their households or their place where they live in order to prevent maternal mortality	Thirteen in-depth interviews were held with public servants, academics and activists, among others	The interviews suggested that the increase in infrastructure as well as in deliveries in which culture was respected have decreased maternal mortality
Weitzman (2017)	To examine the causal effect of women’s education on maternal health in Peru, a country where maternal mortality has declined by more than 70% in the last two and a half decades	To isolate the effects of education, the author employs an instrumented regression discontinuity that takes advantage of an exogenous source of variation—an amendment to compulsory schooling laws in 1993	he results indicate that extending women’s years of schooling reduced the probability of several maternal health complications at last pregnancy/birth, sometimes by as much as 29%

Methodology

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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

A_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 Peru 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	A
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.700
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	8.550757
Sum Square Error (SSE)	10553.287515
Mean Square Error (MSE)	270.597116
Mean Percentage Error (MPE)	-0.926168
Mean Absolute Percentage Error (MAPE)	8.680243

Residual Analysis for the Applied Model

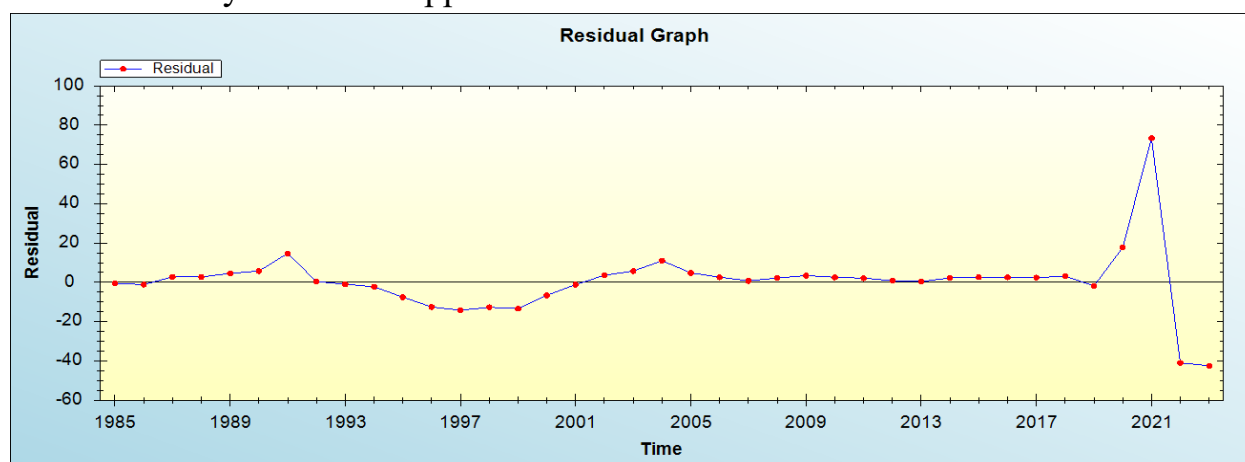


Figure 1: Residual analysis



In-sample Forecast for A

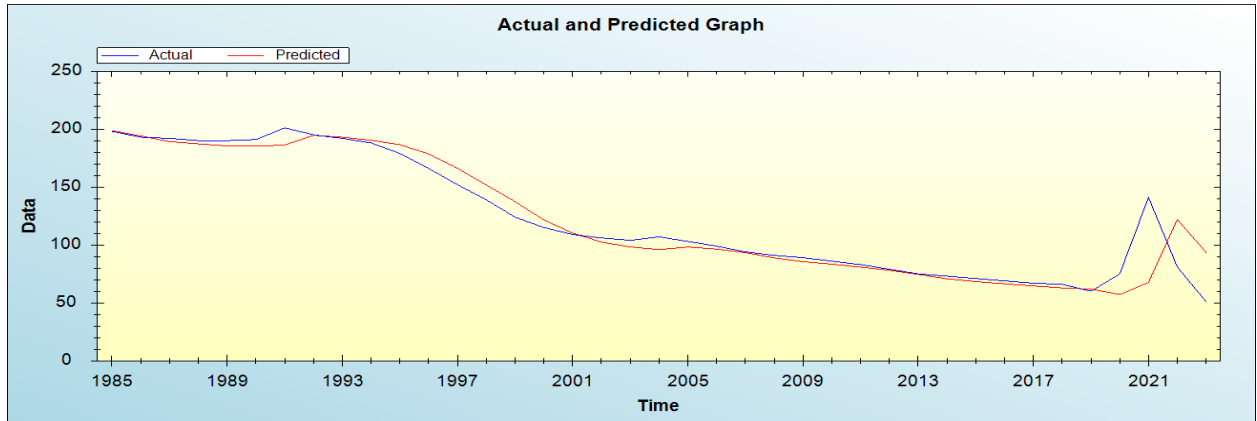


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

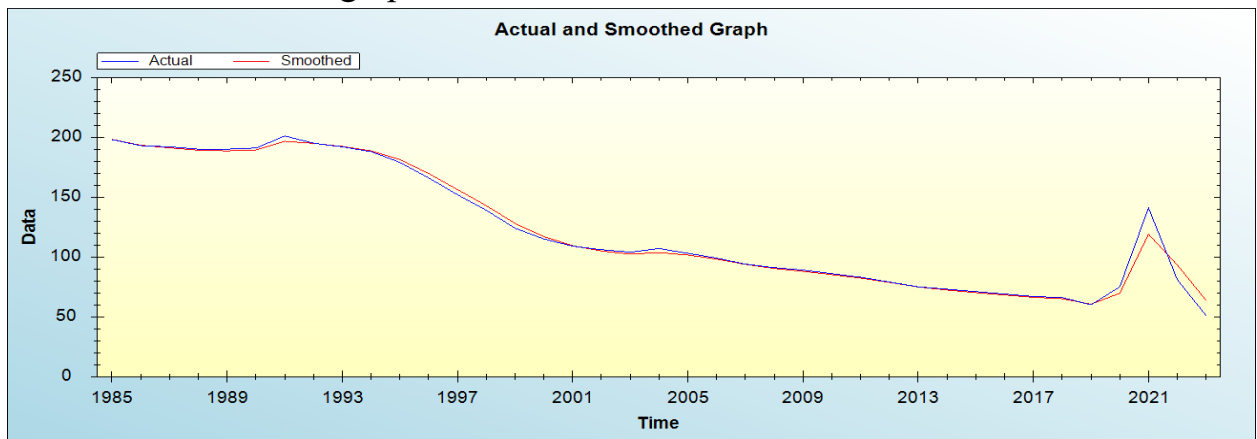


Figure 3: Actual and smoothed graph for A series

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

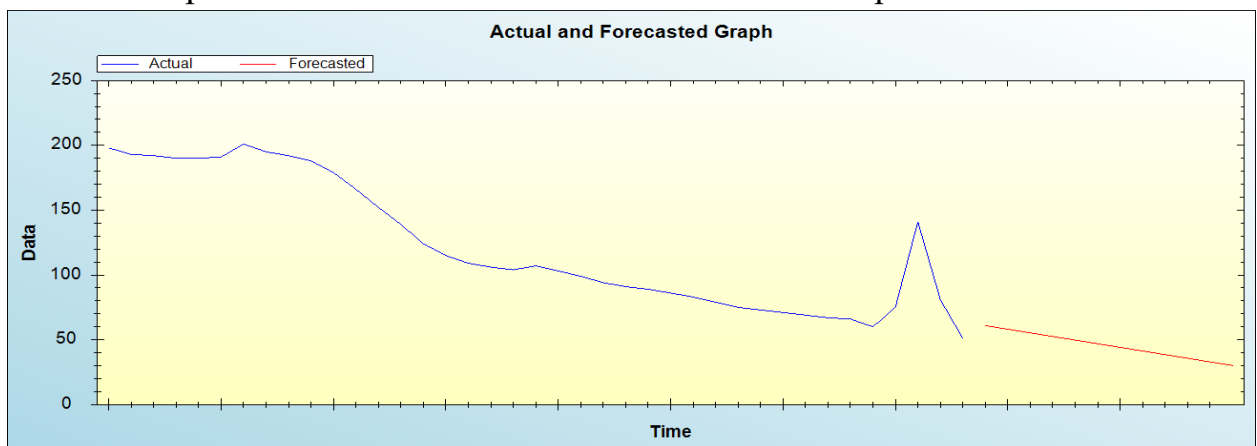


Figure 4: Out-of-sample forecast for A: actual and forecasted graph



Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	60.9403
2025	58.1383
2026	55.3362
2027	52.5342
2028	49.7322
2029	46.9301
2030	44.1281
2031	41.3260
2032	38.5240
2033	35.7219
2034	32.9199
2035	30.1179

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 continue on a downward trajectory to reach levels around 30 deaths per 100 000 live births by 2035.

Conclusion

This paper applied the double exponential smoothing method to forecast MMR for Peru and results indicate that MMR will continue on a downward trajectory to reach levels around 30 deaths per 100 000 live births by 2035. Therefore, we encourage health authorities to direct resources towards implementation of quality improvement strategies.

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