



PREDICTION OF ANNUAL MATERNAL MORTALITY RATE FOR PORTUGAL USING THE HOLT'S LINEAR TECHNIQUE

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Abstract

This study uses annual time series data on MMR for Portugal 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 slightly increase but still remain below 20 deaths per 100 000 live births over the out of sample period. Therefore, we encourage authorities to address local causes of maternal mortality.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

Introduction

Maternal mortality ratio (MMR) is being used globally as a key indicator to monitor maternal health (WHO, 2025; WHO, 2023). According to the World Health Organization (WHO), the maternal mortality ratio in Portugal was estimated at 15 deaths per 100,000 live births between 2000 and 2023, with the lifetime risk of maternal death remaining stable (WHO, 2025). The country has witnessed a low sustained overall fertility rate of 1.40 births per woman in 2024 (INS Portugal, 2024), and a persistent trend towards delayed childbearing, with the mean age at first birth reaching 30.7 years in 2024 (INS Portugal, 2024). As a result of improvements in the quality of maternal health care and the resultant low maternal mortality rates in high-income countries (WHO, 2025), severe maternal morbidity surveillance has been used to monitor maternal health and



quality of maternal care (Kilpatrick & Ecker, 2016). This paper, however models and projects MMR for Portugal using Holt's linear method. The findings are expected to stimulate an appropriate national response in order to further reduce avoidable maternal deaths in the country.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Camarinha et al. (2026)	to estimate Severe Maternal Morbidity (SMM) rates and trends among public hospital deliveries in Portugal, 2010-2018, and identify associated factors	A register-based observational cross-sectional study was conducted using public hospital admission delivery episodes	Trends in SMM between 2010 and 2018 in Portugal show an increase, particularly for blood transfusion. Risk factors included age, hospitalization length, intensity of diagnoses and procedures, and ICD-10-CM/PCS coding
Yue et al. (2026)	to perform an umbrella review to summarize the current evidence to provide a reference for clinicians and future research	Systematic review	Positive aPLs significantly increased the risk of miscarriage rate in assisted reproductive technology (ART) and were also associated with total fetal loss, PE, intrauterine growth retardation and placental abruption
Nunn et al. (2025)	To explore whether changes in key characteristics among Victorian Aboriginal and/or Torres Strait Islander women contributed to reduced perinatal death rates	Retrospective population-based cohort study of all births in Victoria from 2000–2019	Changes in key maternal characteristics may have contributed to improved perinatal death rates among babies of Victorian Aboriginal and/or Torres Strait Islander women
Haninger-Vacariu et al. (2024)	To describe pregnancy and delivery outcomes in women with Fabry disease	Retrospective cohort-study of women with Fabry disease in Austria using a specific questionnaire and the Austrian Mother–Child Health Passport	The cohort-study in women with Fabry disease showed an increase of pain burden during pregnancies and clearly points to an increased risk for preeclampsia, prematurity, and neonates small for gestational age.



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			With a substantial number of high-risk pregnancies, neonatal outcomes are somewhat worse in Fabry disease than in the general public
Kornyicki & Fedor (2024)	to publish findings on the lifestyle factors of pregnant women in Hungary and their impact on early childhood health status by examining changes over time and regional/geographical disparities	Secondary analysis of raw indicators reported by health visitors as per mandatory annual report data for the period of 1997–2019 in Hungary	Interventions to improve early childhood health in some counties of Hungary are urgently needed to reduce regional disparities
Wilhelm et al. (2024)	To describe the contribution of CA to NMR in Malta, investigating possible associations with known maternal risk factors of maternal age, nationality, and education	-Anonymous data for births and neonatal deaths were obtained for 2006 2020 from the National Obstetrics Information System (NOIS) in Malta -applied regression analysis	Between 2006 and 2020, Malta's NMR remained stable. Maternal Nationality, from non- EU low- income countries, was associated with higher neonatal mortality
Pintassilgo et al. (2023)	(1) to describe the characteristics of childbirth in Portugal according to the place of birth, and (2) to analyze the association between homebirth assistance and perinatal, neonatal, and infant mortality rates	Researchers performed a descriptive, correlational analysis of the official datasets of live births in Portugal (census-based) produced by the National Institute of Statistics.	In 2020, home births had more similarities with hospital births than to births occurring in any “other place”. Furthermore, considering the 1995–2020 timeframe, home births with specialized assistance were negatively correlated with perinatal, neonatal, and infant mortality, and home births with non-specialized professional assistance or those that were unassisted showed a positive correlation with these mortality rates
Diguisto et al. (2022)	To compare maternal mortality in eight countries with enhanced surveillance systems	Descriptive multi-country population-based study	Variations in maternal mortality ratios exist between high income European countries with



			enhanced surveillance systems
Wami et al. (2022)	To explore both real maternal and foeto-neonatal characteristics associated with Hungarian homebirths	Retrospective cohort study	Aggregated maternal complications (primary uterine inertia, prolonged second stage labor, and third stage hemorrhage) were prevalent among homebirth cases (1.29% vs. 0.72%, $p < 0.05$) and were associated with an average of 11.77% rate of transfer to a health care institution. On the other hand, the rate of operative (vaginal or caesarean) delivery was 26.31% among institutionalized births
Lameijer et al. (2019)	to present an extensive overview concerning the specific cardiovascular causes of maternal death and to identify avoidable contributing care factors related to these deaths	Researchers assessed all cases of maternal death due to cardiovascular disorders collected by a systematic national confidential enquiry of maternal deaths published by the Dutch Maternal Mortality and Morbidity Committee on behalf of the Netherlands Society of Obstetrics and Gynecology over a 21-year period (1993–2013) in the Netherlands	The maternal cardiovascular mortality ratio is low in the Netherlands and the main causes of maternal cardiovascular mortality are in line with other European reports

Methodology

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

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

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

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

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**

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 Portugal 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	0.800
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	1.013663
Sum Square Error (SSE)	84.549301
Mean Square Error (MSE)	2.167931
Mean Percentage Error (MPE)	1.136313
Mean Absolute Percentage Error (MAPE)	7.524306

Residual Analysis for the Applied Model

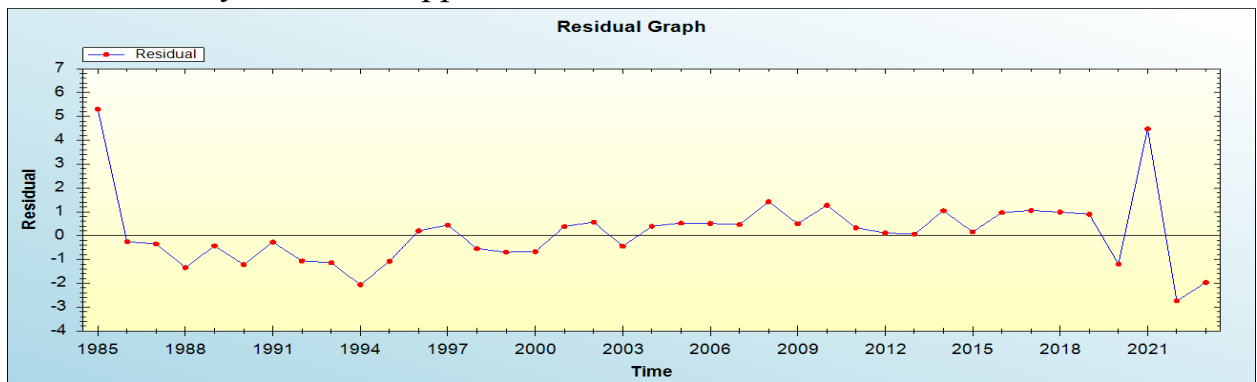


Figure 1: Residual analysis

In-sample Forecast for Z

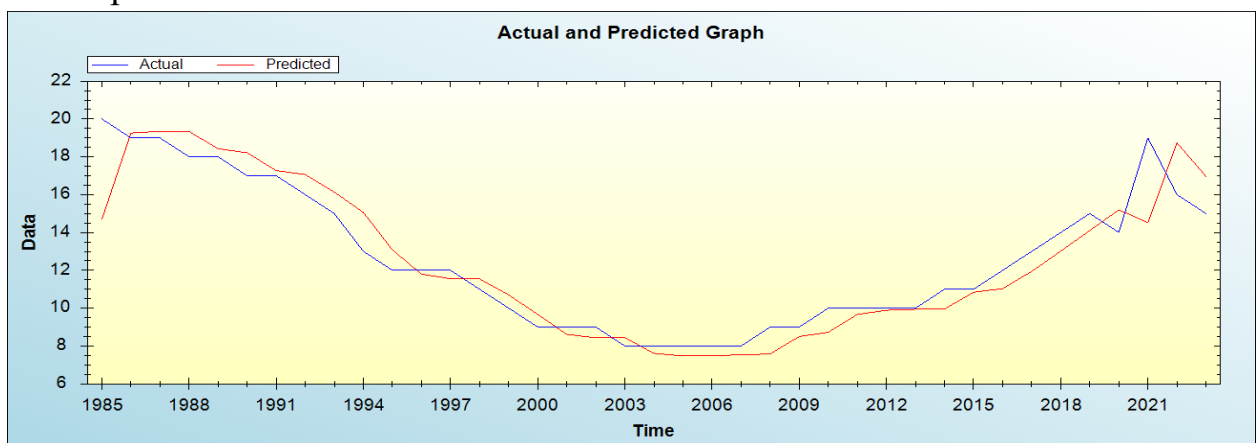


Figure 2: In-sample forecast for the Z series



Actual and Smoothed graph for Z series

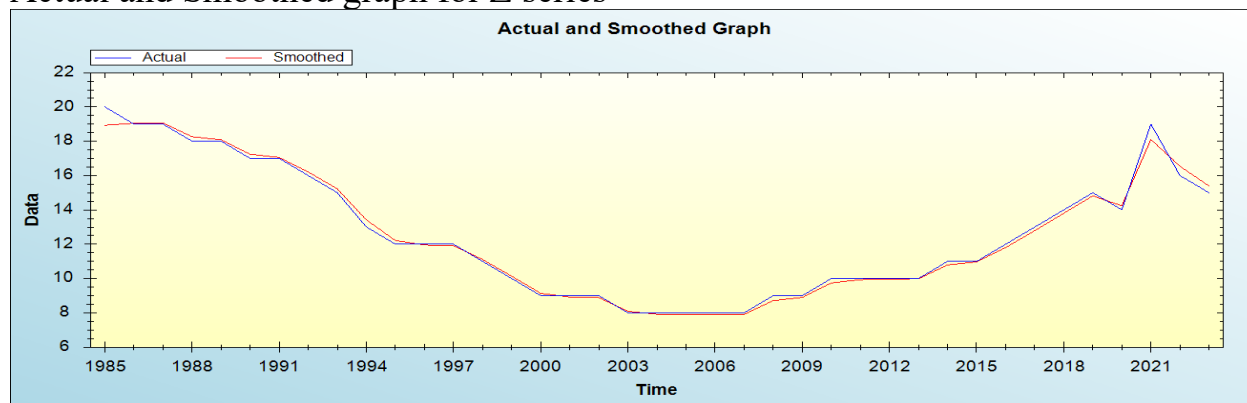


Figure 3: Actual and smoothed graph for Z series

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

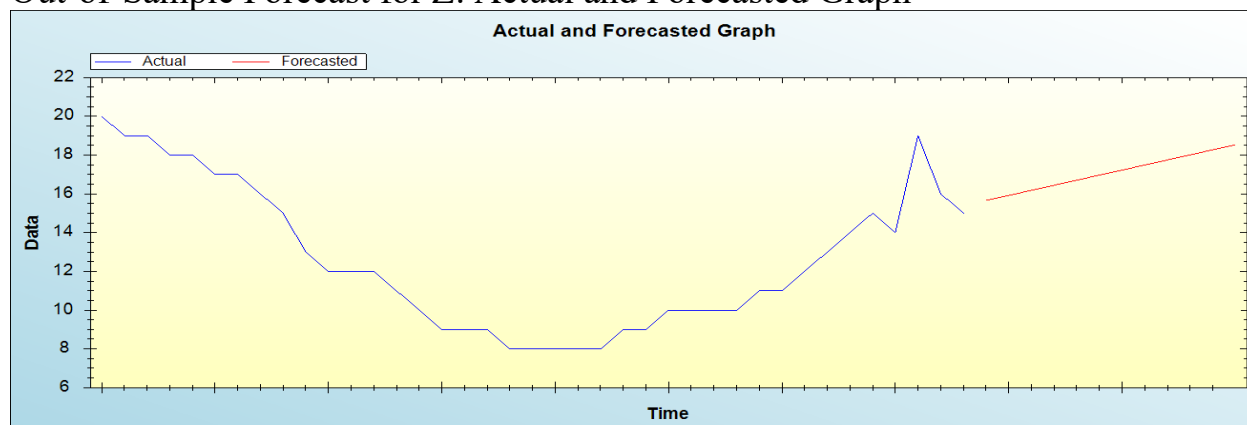


Figure 4: Out-of-sample forecast for Z: actual and forecasted graph

Out-of-Sample Forecast for Z: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	15.6550
2025	15.9165
2026	16.1780
2027	16.4396
2028	16.7011
2029	16.9626
2030	17.2242
2031	17.4857
2032	17.7472
2033	18.0087
2034	18.2703
2035	18.5318



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 is expected to increase slightly but will remain below 20 deaths per 100 000 live births over the out of sample period.

Conclusion

Maternal mortality in Portugal is very low and the causes are indirect such as cardiovascular diseases. This study applies the double exponential smoothing method to model and forecast MMR for Portugal and results indicate that MMR will increase slightly but remain below 20 deaths per 100 000 live births over the out of sample period. Hence, authorities should relentlessly attend to local drivers of indirect maternal deaths.

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