



DETECTING FUTURE TRENDS OF MATERNAL MORTALITY FOR URUGUAY USING THE DOUBLE EXPONENTIAL SMOOTHING MODEL

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Abstract

This study uses annual time series data on MMR for Uruguay 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 0.3 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will remain below 30 deaths per 100 000 live births throughout the out of sample period. Therefore, we encourage authorities to continue addressing causes of maternal mortality across the country.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

Introduction

Maternal mortality is defined as the death of a woman whilst pregnant or within 42 days of the termination of her pregnancy, regardless of the duration and site of the pregnancy, due to any cause related to or worsened by the pregnancy itself or related care, but not due to accidental or incidental causes (WHO, 2021). Over the period 1990-2015, maternal mortality ratio in the Americas dropped by 49% (PAHO, 2017). According to WHO data MMR dropped to 58 maternal deaths per 100,000 live births in 2017 (WHO, 2000). However, disparities continue to exist in maternal mortality across countries in the Americas, ranging from 10 maternal deaths per 100,000 live births in Canada to as high as 480 per 100,000 in Haiti in 2017 (WHO, 2000). These disparities are as a result of socio-economic factors both between geographic areas and population groups. Across and within



countries alike, maternal deaths are disproportionately concentrated in women and territories that are poorer, less educated, or that have less access to sanitation and, more proximally, less access to timely and quality health care services (Enríquez-Nava et al. 2020; Tullo et al. 2020; Casalino-Rojo et al. 2018; PAHO, 2017; Sanhueza et al. 2017). The objective of this paper is to model and forecast MMR for Uruguay using the double exponential smoothing model. The findings of this study will inform policy making, planning and allocation of resources to the maternal and child health program in the region in order to eliminate all avoidable maternal deaths.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
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 BMI increase was independently associated with new-onset dysglycemia. No independent predictor of T2DM progression was identified. Dyslipidemia was independently associated with higher pre-pregnancy BMI and multiparity, whereas postpartum BMI change was not independently associated after multivariable adjustment
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. 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
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 fetoneonatal 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



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			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
Schildberger et al. (2017)	-To investigate the personal meanings and experiences of women with disabilities in regard to pregnancy, childbirth and the puerperium	Conducted semi-structured interviews	Participants reported limited acceptance of their life decisions and experienced an environment of discriminatory attitudes. They experienced a lack of support and lack of confidence in their parenting abilities, which negatively influenced their self-efficacy and self-awareness. Violations of personal borders and a feeling of being watched and controlled were reported



Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Uruguay. 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 Uruguay 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	0.300
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	2.948802
Sum Square Error (SSE)	1428.278065
Mean Square Error (MSE)	36.622514
Mean Percentage Error (MPE)	1.095942
Mean Absolute Percentage Error (MAPE)	10.996761

Residual Analysis for the Applied Model

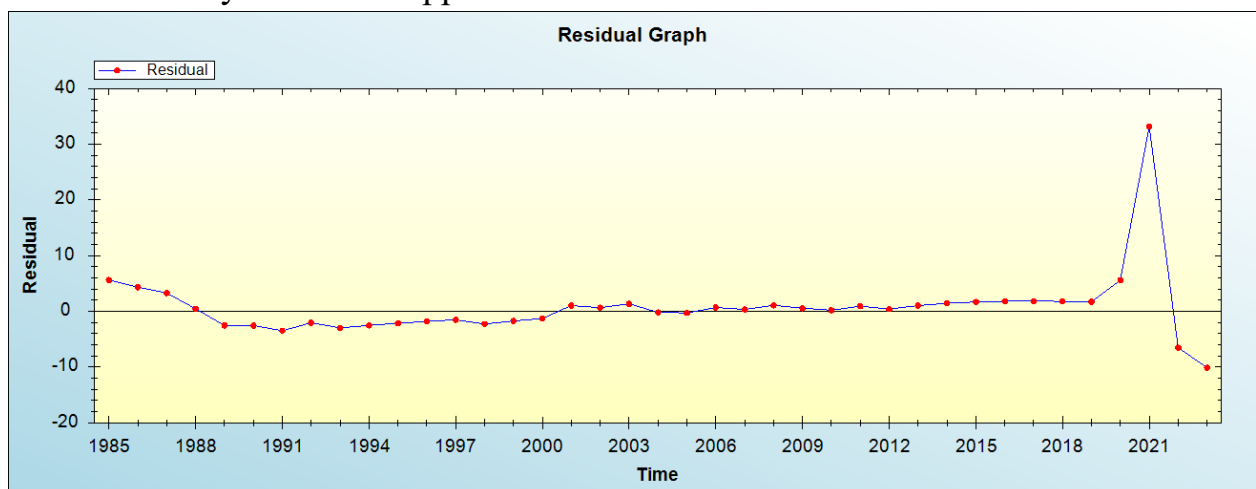


Figure 1: Residual analysis



In-sample Forecast for A

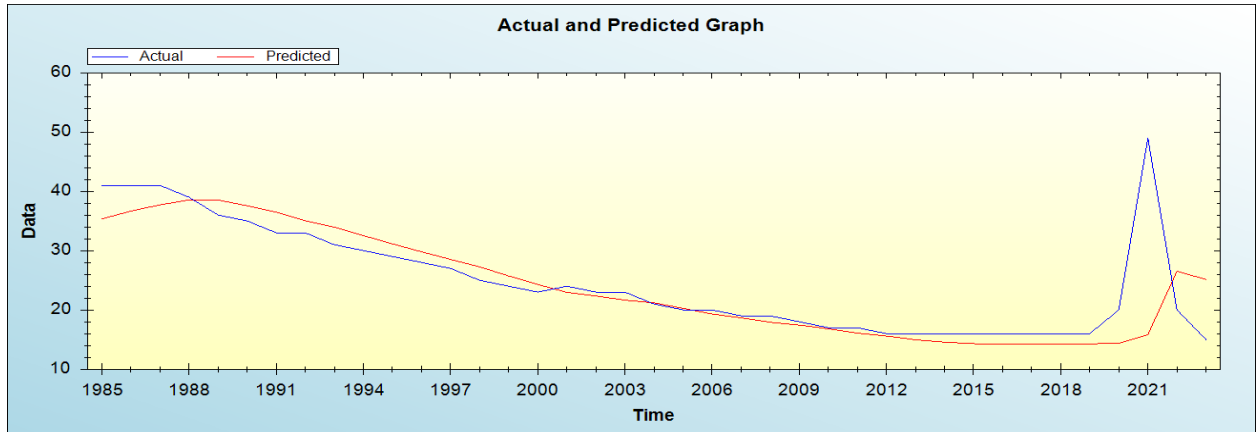


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

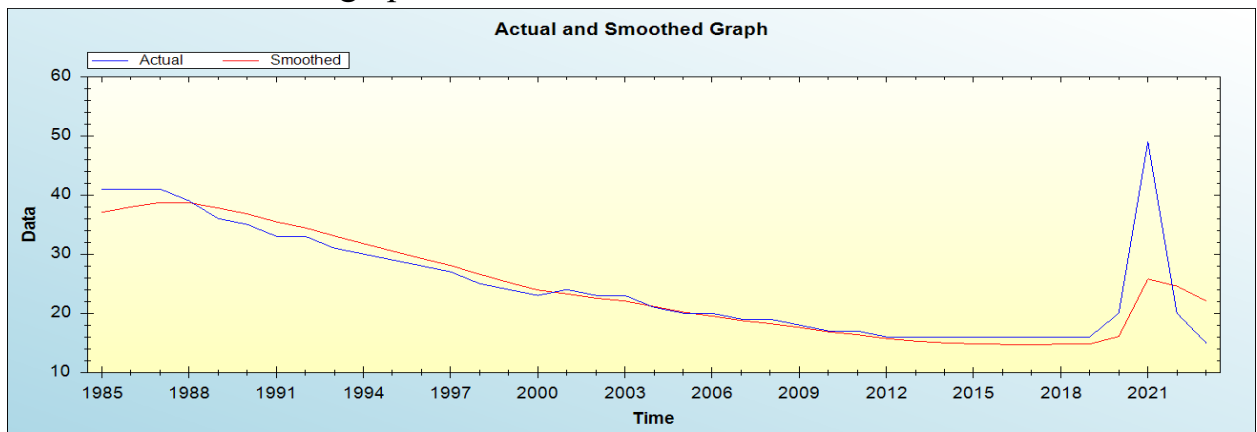


Figure 3: Actual and smoothed graph for A series

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

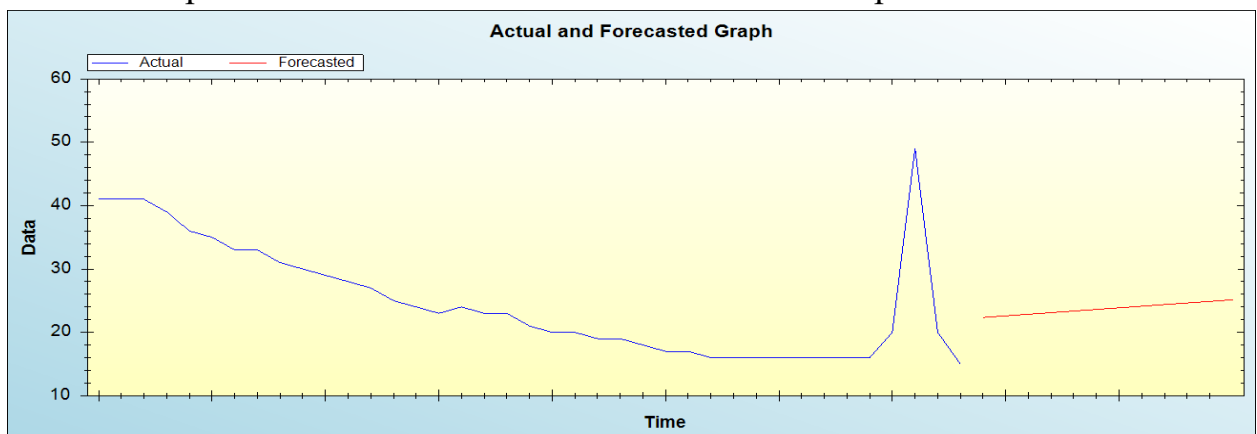


Figure 4: Out-of-sample forecast for A: actual and forecasted graph



Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	22.3470
2025	22.6010
2026	22.8550
2027	23.1091
2028	23.3631
2029	23.6171
2030	23.8711
2031	24.1251
2032	24.3792
2033	24.6332
2034	24.8872
2035	25.1412

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 over the out of sample period.

Conclusion

In this study the double exponential smoothing technique was used to model and forecast MMR for Uruguay and findings indicate that MMR will remain below 30 deaths per 100 000 live births over the out of sample period. Hence, we implore health authorities to relentlessly address local causes of maternal mortality.



References

1. Casalino-Rojo E., Ochoa-Almenabar E., Mujica O.J., and Munayco C.V (2018). Desigual dades sociogeogràfiques en la mortalitat materna en Perú: 2001–2015 [Sociogeographic inequalities in maternal mortality in Peru: 2001–2015]. *Rev Peru Med Exp Salud Publica*. 35(2):351–3.
2. Enríquez-Nava M.F., Esquivel-Velásquez A.D., PatónSanjines M., Pooley Ayarza B.C., Alarcón R., Hernández Muñoz R (2020). Comportamiento y desigualdades sociales en indicadores priorizados del Objetivo de Desarrollo Sostenible 3 en Bolivia [Behavior and social inequalities in prioritized indicators of Sustainable Development Goal 3 in Bolivia]. *Pan Am J Public Health*. 2020;44: e1018.
3. PAHO (2017). Regional progress towards achieving the health-related Millennium Development Goals. Washington DC.
4. Pan American Health Organization (2017). Health in the Americas +, 2017 Edition. Summary: Regional outlook and country profiles.
5. Sanhueza A., Roldán J.C, Ríos P., Acuña M.C., and Espinosa I (2017). Social inequalities in maternal mortality among the provinces of Ecuador. *Pan Am J Public Health*. 2017;41: e97.
6. Tullo E., Lerea M.J., González R., Galeano J., Insfrán M.D., and Muñoz M (2020). Desigualdades sanitarias y sociales en la salud materna y del niño en Paraguay [Health and social inequalities in maternal and child health in Paraguay]. *Pan Am J Public Health*. 2020;44: e107.
7. WHO (2000). Trends in Maternal Mortality. to 2017: estimates by WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division. Geneva, p. 2019.
8. WHO (2021). International Classification of Diseases, Eleventh Revision (ICD-11), World Health Organization (WHO) 2019/2021. [https:// icd. who. int/ brows e11](https://icd.who.int/brows e11).