



PROJECTION OF EXPECTED FUTURE VALUES OF ANNUAL MATERNAL MORTALITY RATE FOR PANAMA USING HOLT'S LINEAR METHOD

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Abstract

This study uses annual time series data on MMR for Panama 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 0.4 and 0.1 respectively based on minimum MSE. The results of the study indicate that MMR will decline from around 43.4 in 2024 to about 33 deaths per 100 000 live births by 2035. Therefore, we encourage authorities to address local causes of maternal deaths and continue quality improvement initiatives.

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). During the period 1990-2015, maternal mortality ratio in the Americas dropped by 49% (PAHO, 2017). According to WHO statistics 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 due to 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). Panama has adopted numerous strategies in order to reduce maternal mortality. In 2000, Panama adopted the United Nations' (UN) Millennium Development Goals (MDGs) that encouraged governments to lower maternal mortality by 75% from 1990 to 2015 (UN, 2015). The Ministry of Health managed to lower the maternal mortality ratio (MMR) from 53 in 1990 to a target of fewer than 13 deaths per 100 000 live births by 2015 (Panama, 2015). In 2015, the agenda 2030 for sustainable development came into existence and SDG-3.1 encourages countries around the world to reduce the MMR to levels below 70 deaths per 100 000 live births by 2030. In 2015 the Government of Panama enacted Executive Decree No. 393 to align its national goals with the 2030 SDGs. This decree mandated the ongoing monitoring, policy formulation, planning, program development, and issuance of recommendations to fulfill these goals (Ministry of foreign affairs Panama, 2015).

The objective of this study is to model and forecast MMR for Panama using Holt's linear method. The study results are anticipated to inform policy making, planning and allocation of resources to the maternal and child health program with a view to further reduce preventable maternal mortality across the country.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Doubova et al. (2025)	To assess the quality of childbirth care in Mexico	Data were collected from an observational IMSS-affiliated eCohort of pregnant women aged 18 to 49, focusing on their experiences, perceptions of healthcare quality, obstetric violence, and health outcomes. The analysis included Chi-square tests and multivariable linear regression	AMIIMSS improves women's childbirth experiences but reveals weaknesses due to poor hospital adherence to the program and poor perceived quality



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Serván-Mori et al. (2025)	To analyze the temporal and territorial relationship between health system financing fragmentation and maternal mortality in the last two decades in Mexico	ecological-longitudinal study	Maternal deaths in the population without social security were more frequent among younger women, with less schooling, unmarried, and residing in rural areas, with higher Indigenous presence and greater social marginalization. From 2019 onwards, the MMR was higher in the population with social security.
Chavez et al. (2024)	To examine maternal mortality in Panama, analyzing its direct obstetric deaths, indirect obstetric deaths, and contributory conditions	This cohort study used publicly available data from the National Institute of Statistics and Census to present a 25-year retrospective analysis of maternal deaths in the Republic of Panama from 1998 to 2022	there were substantially more direct obstetric causes (61.2%) than indirect obstetric causes (23.9%), contributory causes (13.6%), or unknown/undetermined causes (1.4%) of maternal mortality, despite being highly preventable
Gutiérrez- Peláez et al. (2022)	To present a case that describes common challenges during an obstetric emergency in resource- poor settings	Case presentation	The analysis identifies the social determinants of health behind the slow and inadequate emergency response
Serván-Mori et al. (2021)	To describe the temporal and geographical patterns of the continuum of maternal health care in Mexico, as well as the sociodemographic characteristics that affect the likelihood of receiving this care	conducted a pooled cross-sectional analysis using the 1997, 2009, 2014 and 2018 waves of the National Survey of Demographic Dynamics, collating sociodemographic and obstetric characteristics of 93 745 women aged 12–54 years at last delivery	having social security and a higher level of education is positively associated with receiving the continuum of care. Researchers observed the largest relative increases in continuum of care coverage in Chiapas (181.5%) and Durango (160.6%), assigned human development index categories of low and medium, respectively
Acevedo et al. (2020)	assess the relationship between distance to a woman's assigned health clinic and obstetric care utilization in Panama	cross- sectional study	Distance is an important barrier to obstetric care utilization, with women in more distant locations suffering significantly lower use of prenatal, childbirth and postpartum care compared with



			women in closer vicinity to a health establishment
Servan-Mori et al. (2016)	To explore the relationship between public expenditure, coverage of adequate ANC (including timing, frequent and content), and the maternal mortality ratio-adjusted by cover age of adequate ANC-observed in Mexico in2012 at the State level	Performance analysis	Results suggest that in the 2003–2011 period, the public expenditure gap between women with and without Social Security decreased 74%, however, the distribution is less equitable among women without Social Security, across the States.

Methodology

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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

P_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 Panama 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	P
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.400
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	3.862805
Sum Square Error (SSE)	1799.380496
Mean Square Error (MSE)	46.137961
Mean Percentage Error (MPE)	-0.447131
Mean Absolute Percentage Error (MAPE)	6.490505



Residual Analysis for the Applied Model

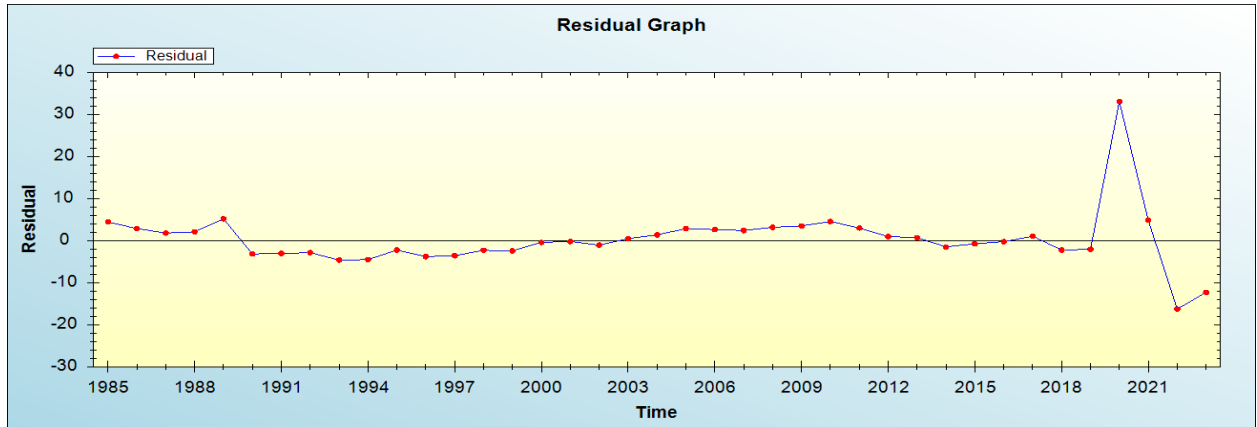


Figure 1: Residual analysis

In-sample Forecast for P

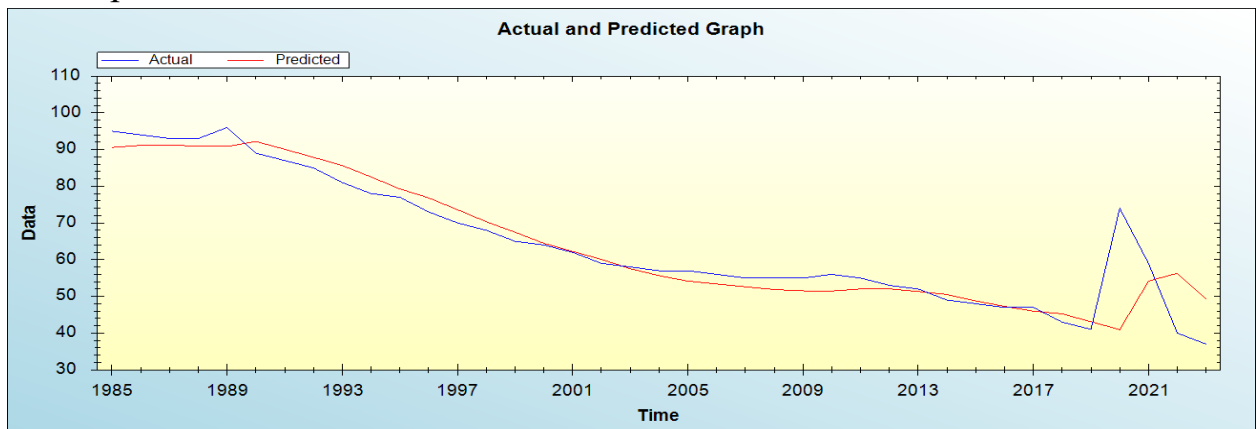


Figure 2: In-sample forecast for the P series

Actual and Smoothed graph for P series

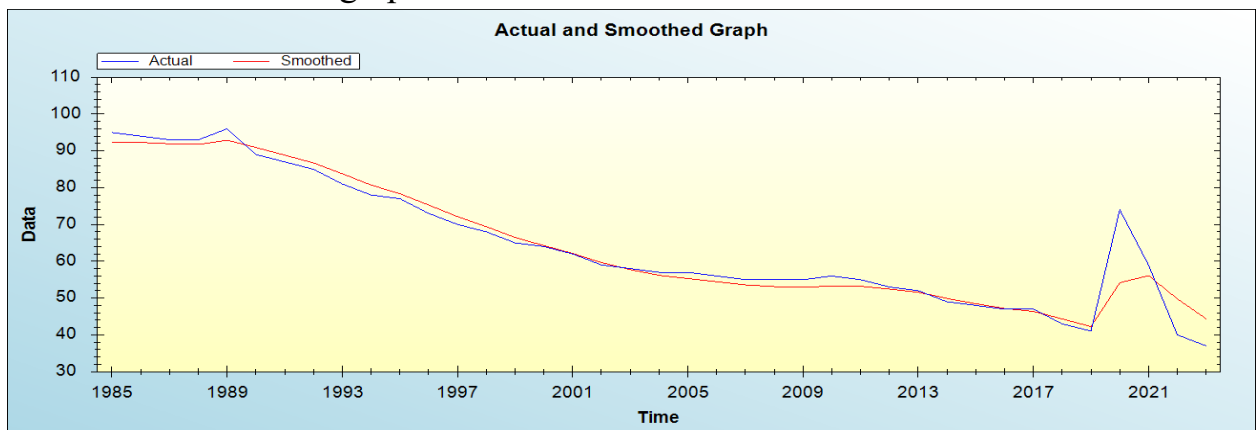


Figure 3: Actual and smoothed graph for P series



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

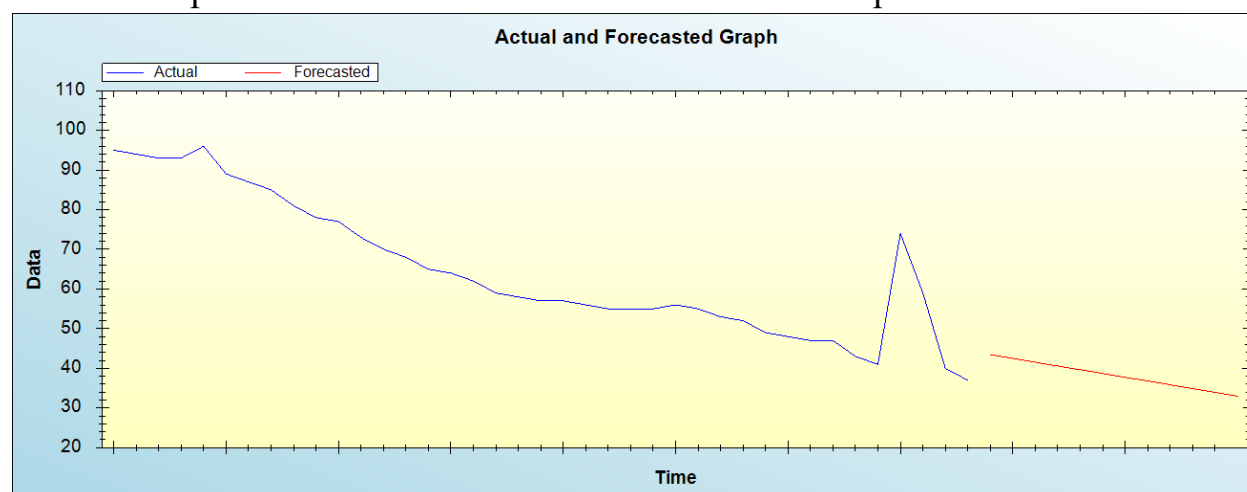


Figure 4: Out-of-sample forecast for P: actual and forecasted graph

Out-of-Sample Forecast for P: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	43.4450
2025	42.4961
2026	41.5471
2027	40.5981
2028	39.6491
2029	38.7001
2030	37.7511
2031	36.8021
2032	35.8531
2033	34.9042
2034	33.9552
2035	33.0062

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 decline from around 43. 4 in 2024 to about 33 deaths per 100 000 live births in 2035.



Recommendations & Conclusion

Panama has made significant strides in the reduction of maternal mortality ratio which is currently below the regional target of 30 maternal deaths per 100 000 live births. This reflects the government's commitment to improve the quality of maternal health care services during the antenatal, child birth and puerperium periods. In this paper we applied the double exponential smoothing technique to model and forecast MMR for Panama and results indicate that MMR is expected to decline from around 43.4 in 2024 to about 33 deaths per 100 000 live births in 2035. Hence, we encourage authorities to tirelessly address local factors associated with maternal deaths and continue routine quality improvement activities.

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