

Applying The Double Exponential Smoothing Model To Forecast Maternal Mortality For The Democratic Republic Of Congo

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Abstract

This study uses annual time series data on MMR for the DRC 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 continue on a downward trajectory but still remain very high throughout the out of sample period. Therefore, we encourage health authorities to adopt the 5-fold policy prescription.

Keyword(s): - *Exponential smoothing, Forecasting, Maternal Mortality Ratio*

Introduction

The Democratic Republic of Congo (DRC) is among the countries in the world that usually report very high maternal, neonatal and infant mortality rates (Kabra et al. 2023). Although statistics indicate a gradual decline in maternal mortality rate since 2000, data revealed that in 2017, 16 000 maternal deaths were documented (WHO, 2019). In 2020, the maternal mortality rate in DRC rose to 547 deaths per 100 000 live births, a 16% increase from 2017 (IAHO & WHO, 2023). In addition, neonatal, infant and child mortality rates were also high, at 28, 58 and 104 deaths per 1000 live births, respectively (WHO, 2019). The etiology of maternal deaths includes insufficient follow-up during pregnancy or after delivery and poor quality of care (Mukuna et al. 2018). The Multiple Indicator Cluster Survey (MICS) 2016–2018 revealed that only 17.6% of women of reproductive age in the DRC use modern contraceptives, while 28.7% have an unmet need for FP. Among currently married women, there is a 57% demand for FP, especially postpartum, when 37% of women wish to delay and space births, while 20% want to limit births. The DRC adopted the performance-based financing (PBF) approach to promote quality maternal health care without financial barriers (Paul et al. 2018). The government provides Universal Health Coverage (Ministry of Health, 2016) through the provision of the quality and quantity of care in health facilities (Gergen et al. 2018; Ngom, 2016).

The objective of this study is to model and forecast MMR for the DRC using the double exponential smoothing model. The study findings are expected to guide policy formulation, planning and allocation of resources to the maternal and child health program. The ultimate goal is to further reduce avoidable maternal deaths to levels below 70 deaths per 100 000 live births.

Literature Review

Author (s)	Objective(s)	Methodology	Main finding(s)
Hotchkiss et al. (2025)	To assess the impact of a large, complex health systems strengthening program on maternal health care utilization in the DRC.	A difference-in-differences approach was applied using population-based household survey data at base line (2014) and endline (2017) from treatment and matched comparison	The health systems strengthening program significantly increased the probability of facility-based delivery, but had no significant impact on receiving at least four ANC visits. Qualitative findings

		areas in three provinces	suggest that uptake of ANC was constrained by travel distance, time burdens, limited community outreach, and cultural norms discouraging early ANC initiation
Ngavele et al. (2025)	to determine the frequency, causes, and associated factors of maternal mortality in the health zone of Bunia in Ituri province	retrospective descriptive	The results show that the frequency of maternal deaths in the health zone was 0.11%. Hemorrhage was the leading cause of maternal death in the Bunia health zone, accounting for 45.95%. Delays in seeking medical care were the most significant factor associated with maternal deaths, representing 22.95%. Insufficient technical facilities were the most significant structural factor, representing 50.82%. Delays in care were the primary factor linked to midwives, at 67.21%
Matongo et al. (2024)	to determine the frequency of serious maternal morbidity at the Ruashi military hospital (DRC) with a view to ensuring good care and monitoring of pregnant women	descriptive study	The incidence of maternal morbidity was 24.2%, of which 32.4% had anemia followed by hemorrhage with 27% and finally sepsis and uterine subinvolution with 5.4% each
Mwene-Batu et al. (2024)	to describe the trends as well as the epidemiological profile and causes of reported institutional maternal deaths between 2013 and 2022 in Eastern DRC	retrospective descriptive study	Overall, 62,6% of the deaths were reported from secondary hospital. Most deaths were of married women in their thirties (93.5%). Almost half (47.8%) had not completed four antenatal

			consultations. The main direct causes of death were, in decreasing order of frequency: post-partum hemorrhage (55.2%), uterine rupture (14.0), hypertensive disorders (8.4%), abortion (7.7%) puerperal infections (2.8%) and placental abruption (0.7%)
Ramazani et al. (2021)	To measure the mortality rate in health facilities in eastern DRC and identifies the associated risk factors	analytical epidemiological study based on retrospective data maternal deaths recorded in 59 health facilities, in three health zones in the southern part of Maniema province in east DRC	The maternal mortality rate was estimated at 620 deaths per 100,000 live births, of which 46% of maternal deaths were related to a parturients' delayed decision in seeking healthcare in time (first delay)
Zhang et al. (2021)	To explore the relationship between self-reported insecurity of mothers and maternal health-seeking behaviors and diseases in children in the DRC	Applied logistic regression	Conflicts increase mothers' insecurities and negatively affect children's development
Shon et al. (2018)	to evaluate the costs and benefits of the MCH project	conducted a cost-benefit analysis (CBA) using a benefit-cost ratio (BCR)	The benefits of reduced maternal mortality and the mortality of infants and children aged under 5 years were estimated as USD 681,416, USD 4,332,376, and USD 1,710,184, respectively, in monetary terms
Odette et al. (2017)	to analyze the etiologies of maternal deaths occurring in a tertiary hospital in DRC	This is a descriptive cross-sectional study with retrospective data collection of maternal deaths that occurred in the reference provincial	Bleeding with 61.04% was the leading cause of maternal death followed by eclampsia (31.58%). Indirect causes were

		hospital Jason Sendwe from 2013 to 2015. All cases of maternal deaths in line with the definition of World Health Organization have been included.	dominated by heart disease (30.0%)
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Methodology

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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

D_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 the DRC 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	D
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	18.192700
Sum Square Error (SSE)	31539.095861
Mean Square Error (MSE)	808.694766
Mean Percentage Error (MPE)	-0.236994
Mean Absolute Percentage Error (MAPE)	2.730287

Residual Analysis for the Applied Model

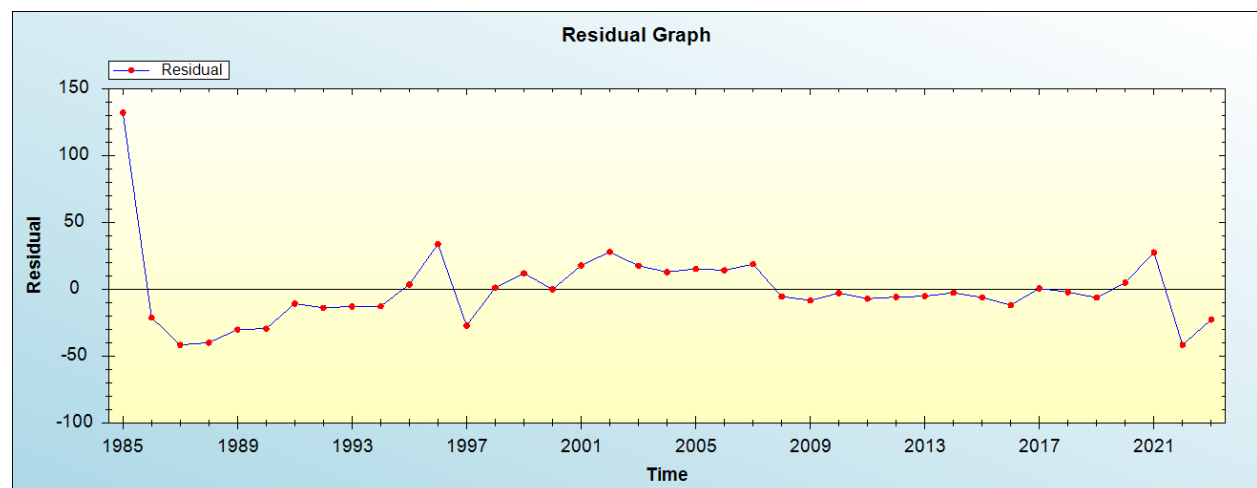


Figure 1: Residual analysis

In-sample Forecast for D

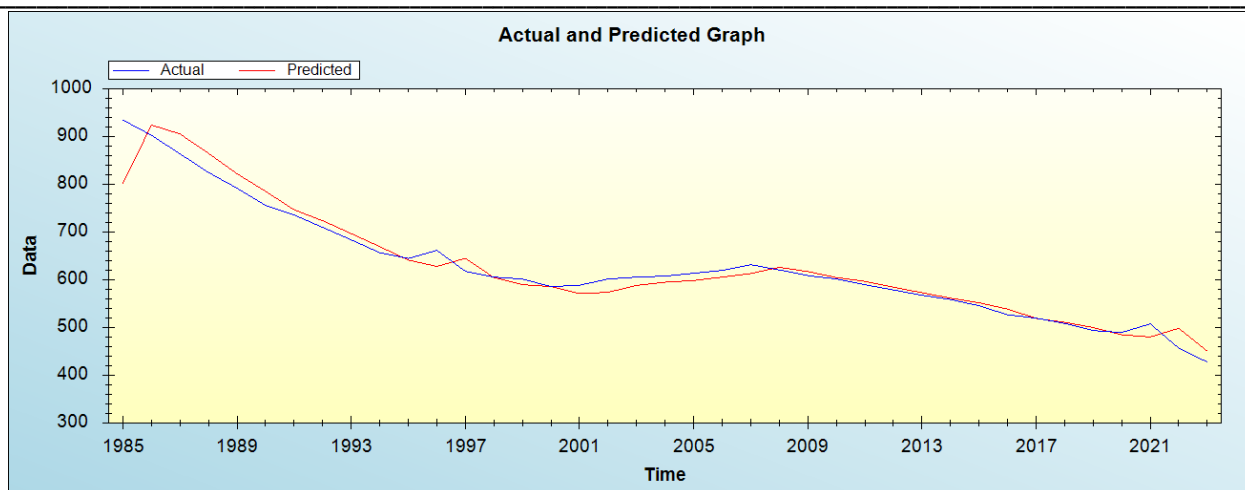


Figure 2: In-sample forecast for the D series

Actual and Smoothed graph for D series

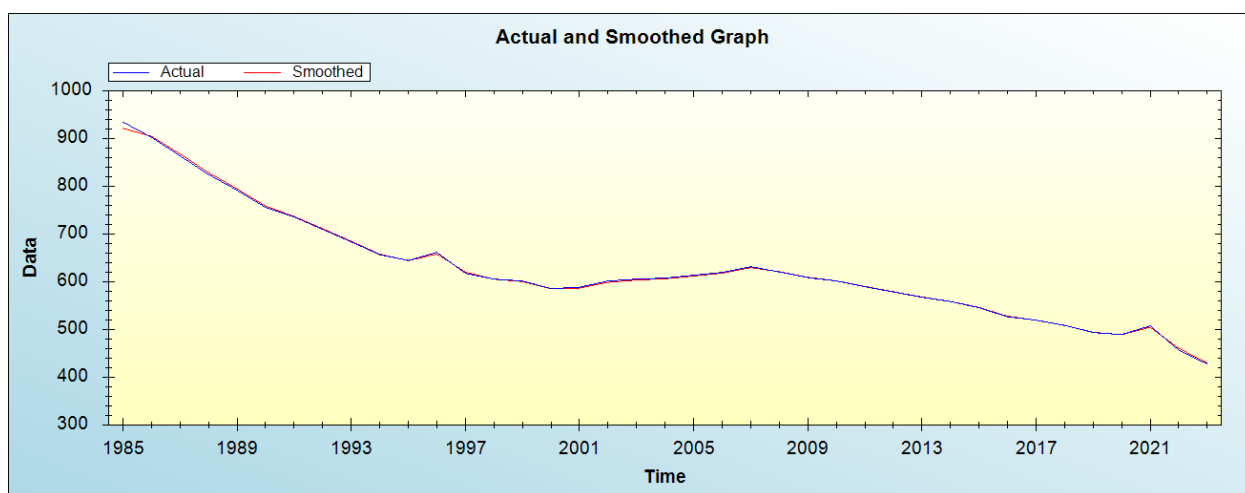


Figure 3: Actual and smoothed graph for D series

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

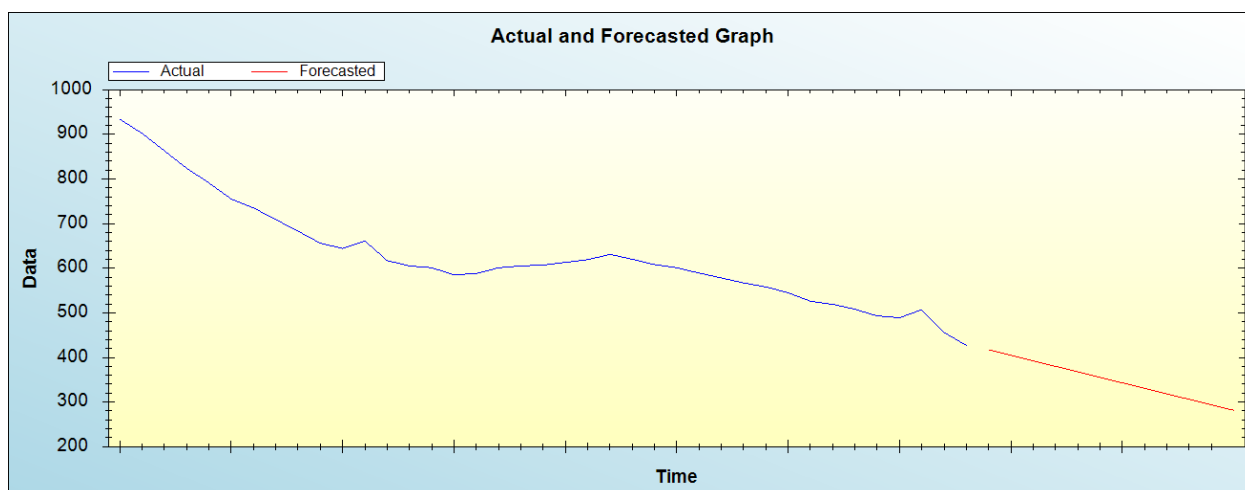


Figure 4: Out-of-sample forecast for D: actual and forecasted graph

Out-of-Sample Forecast for D: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	416.9680
2025	404.6446
2026	392.3212
2027	379.9978
2028	367.6744
2029	355.3510
2030	343.0276
2031	330.7042
2032	318.3808
2033	306.0574
2034	293.7340
2035	281.4106

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 but still remain very high over the out of sample period.

Recommendations & conclusion

High maternal and neonatal mortality rates in the DRC are a cause for concern. The leading causes of maternal deaths are excessive bleeding, eclampsia, sepsis and lastly indirect causes such as cardiovascular disorders. This study projects MMR for the DRC and results indicate that MMR is expected to continue on a downward trajectory but still remain very high throughout the out of sample period. Hence, we implore health authorities to adopt the following policy prescription: (1) end teenage pregnancy by enforcing laws that prohibit early child marriage, promote female education and comprehensive sexual and reproductive health education in schools (2) Improve coverage of maternal and child health services across the country (3) improve quality of maternity services (4) ensure availability of adequate medical supplies and medical staff in all medical facilities and (5) creating posts for obstetricians at government general or district hospitals particularly at high volume sites so that specialist services are accessed at the first referral level. Alternatively, Registrars undergoing Obstetrics & Gynecology training can be attached at high volume district hospitals under the supervision of provincial consultants.

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