



APPLICATION OF THE DOUBLE EXPONENTIAL SMOOTHING TECHNIQUE TO PREDICT MATERNAL MORTALITY FOR CHAD

Smartson. P. NYONI¹, Thabani NYONI²

¹*Independent Researcher & Medical Doctor, Harare, Zimbabwe*

²*Independent Researcher & Health Economist, Harare, Zimbabwe*

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Abstract:

This study uses annual time series data on MMR for Chad 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 0.3 respectively based on minimum MSE. The results of the study indicate that MMR will continue to fall but still remain very high throughout the out of sample period. Therefore, we encourage authorities.

Keywords: *Exponential smoothing, Forecasting, Maternal Mortality Ratio*

INTRODUCTION

Chad ranks 187 out of 189 countries regarding the Human Development Index and ranks 160 out of 162 countries in terms of gender inequalities (UNDP, 2019). The level of literacy is much lower among women (22%) compared with men (54%) and only 14% of women receive a secondary- level education compared with 33% of men (INSD, 2016). Approximately 300 000 maternal deaths were reported across the globe in 2017 and the majority of these were avoidable (kim & Kim, 2019; WHO, 2019). Maternal mortality continues to be a relevant public health issue despite reductions in global maternal mortality by 38% in the period from 2000 to 2017 (Kim & kim, 2019; WHO, 2019).1–3. The World Health Organization (WHO) highlighted that the major barriers to access to maternal healthcare and contributing factors of maternal mortality are poverty, physical distance to healthcare service, lack of information on service availability and health risks, inadequate services and cultural beliefs and practice (WHO, 2019). Chad has the second highest maternal mortality ratio worldwide (World Bank, 2020). In 2018

WHO revealed that the maternal mortality ratio stood at 856 deaths per 100 000 live births for Chad (WHO, 2019). The Chad Demographic and Health Survey 2014–15 indicated that maternal deaths account for 45% of all deaths among women of reproductive age (15–49 years) (Kim and Kim, 2019), coverage of maternal health service (MHS) at national level is low, with 64% of women reporting use of antenatal care (ANC), 24% reporting use of delivery care in a healthcare facility (DC) and only 22% reporting use of postnatal care (PNC) in 2014–2015 (INSD, 2016). Furthermore, gender- related inequalities are linked to maternal mortality (Chirowa et al. 2013).

The objective of this study is to model and project future trends of MMR for Chad using the double exponential smoothing technique. The results of this study are envisioned to detect early abnormal trends of MMR so as to inform policy and allocation of resources to the health sector. Adequate resources allocation and timeous action will help reduce maternal mortality to levels below 70 deaths per 100 000 live births.

LITERATURE REVIEW

Author(s)	Objective(s)	Methodology	Main finding(s)
Compaoré et al. (2025)	to determine the frequencies and causes of severe maternal outcomes (SMO: MNM + MD) in regional and district hospitals in Benin, Burkina Faso and Niger	Between 1st February 2008 and 31st October 2010, we conducted an SMO incidence study in 36 hospitals in the three countries	-the burden of severe maternal outcomes was high in Benin, Burkina Faso and Niger -most women had a near miss complication on admission to a participating hospital, indicating the need to facilitate access to obstetric care for



			women with high-risk pregnancies and complications
Ilboudo et al. (2023)	To examine the effects of this policy on the use of services, health outcomes, and removal of costs.	Interrupted time-series regressions were used to investigate the effects of the policy on the use of health services and health outcomes. In addition, an analysis of household expenditures was conducted to assess the effects of spending on delivery, care for children, and other exempted (antenatal, postnatal, etc.) services on household expenditures	the user fee removal policy significantly increased the use of healthcare facilities for child consultations and reduced mortality from severe malaria in children under the age of five years. It also has increased the use of health facilities for assisted deliveries, complicated deliveries, and second antenatal visits, and reduced cesarean deliveries and intrahospital infant mortality, although not significantly
Krause et al. (2025)	to develop a tool to support maternal health (MH) planning and prioritization decisions and identify priority regions/provinces for intervention in Chad based on aggregate MH coverage gap scores (Target-Coverage=Coverage Gap)	- A rapid review was conducted to identify key indicators and relevant national targets. The 2019 Multiple Indicator Cluster Survey and other national surveys were the data sources for selected indicators at the provincial level. Aggregate MH coverage gaps were calculated and displayed using geographic information system software to visualize variations by province -Eleven key informant interviews (KIIs) and six focus group discussions (FGDs) were conducted with clinicians and administrators to understand existing MH planning, prioritization, and maternal mortality risks in Chad	-Indicators contributing the most to coverage gaps include emergency obstetric care, adolescent births, tetanus vaccination, and delivery by skilled health personnel -KIIs and FGDs revealed that existing MH planning in Chad differs provincially and by health system level, with no clear prioritization processes identified



Rahman et al. (2022)	To analyze ANC visits among adolescent and adult mothers.	Using all available Demographic and Health Survey and Multiple Indicator Cluster Surveys between 2000 and 2019 in 54 LMICs, we estimated proportion of ANC visits among women. Bayesian hierarchical regression models were used to estimate trend, projection, and determinants of single and four ANC visits (ANC1 and ANC4) independently	Determinant analysis found increased odds of receiving ANC visits during pregnancy for adolescent mothers with higher educational levels, frequency of listening/watching mass media, and various household socio-economic status factors
Erismann et al. (2021)	to assess the use of antenatal (ANC) and postnatal care (PNC) services, health facility delivery and infant health services after 4 years of a health systems intervention for improving the infrastructure, supplies, training and sensitization for maternal and infant health in two districts of rural Chad	Data from a repeated cross-sectional household survey conducted in Yao and Danamadji in 2015 and in 2018 were analyzed	A combination of health systems strengthening interventions was associated with an increased use of certain maternal and infant health services
Musarandega et al. (2021)	to identify the leading causes of maternal deaths using the international classification of disease – 10th revision, for maternal mortality (ICD-MM)	Systematic review	Obstetric hemorrhage, hypertensive disorders in pregnancy, non-obstetric complications, and pregnancy-related infections are the leading causes of maternal deaths in SSA
Zamane et al. (2018)	to study the cases of maternal deaths in the Dori Regional Hospital, Burkina Faso in the Sahel region, by analyzing the epidemiological aspects of these deaths in order to guide decision-making	descriptive cross-sectional study which spanned the period from January 1, 2014 to December 31, 2016. Cases of maternal death and live births that occurred in the hospital during this period were collected by documentary review	A total of 141 maternal deaths and 2,626 live births were recorded with a maternal mortality ratio of 5,369 for 100,000 live births. In 99 (72.20%) cases, death occurred in the postpartum. A home delivery had been reported in 33.70% of



			cases. Direct obstetric causes were found in 72.10% of cases. They were mainly represented by infections (32.40%) and hemorrhages (23%). Anemia was the indirect cause of death in 25 women (17.80%). The delay in health care access and the lack of blood products contributed to maternal deaths in 64.50% and 26.20% of cases
Marquis et al. (2019)	to estimate the use of maternal health services (MHS) and to identify barriers to access MHS in Sila region in southeast Chad	Retrospective cross-sectional, population-based survey using two-stage cluster sampling methodology	In Sila region, use of MHS is low and does not meet WHO- defined standards regarding maternal health. Among all services, use of ANC was better than for other MHS. ANC usage is positively associated with the use of further life- saving MHS including DC and could be used as an entry point to the community
Girum and Wasie (2017)	to identify correlates of maternal mortality in developing countries	Systematic review	Maternal mortality is correlated with multiples of socio-economic factors, health care system associated factors, disease burden and their complex interactions
Storeng et al. (2012)	To investigate mortality in women in Burkina Faso in the 4 years following a life-threatening near-miss obstetric complication and to identify the medical, social and health-care-related causes of death	In total, 1014 women were recruited after hospital discharge and followed for up to 4 years: 337 had near-miss complications and 677 had uncomplicated pregnancies. Significant differences in mortality between the groups were assessed using Fisher's exact test	Women in Burkina Faso who initially survived a near-miss obstetric complication had an increased risk of all-cause and pregnancy-related death in the ensuing 4 years



METHODOLOGY

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

$$C_t = \mu_t + \rho_t \mathbf{t} + \varepsilon_t$$

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

C_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**

$\mathbf{t}$ is the trend component of the time series

S_t is the exponentially smoothed value of MMR at time t

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 Chad 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

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	C
Included Observations	39
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.300
Forecast performance measures	
Mean Absolute Error (MAE)	26.814852
Sum Square Error (SSE)	40891.757339
Mean Square Error (MSE)	1048.506598
Mean Percentage Error (MPE)	-0.414292
Mean Absolute Percentage Error (MAPE)	2.479318

Residual Analysis for the Applied Model

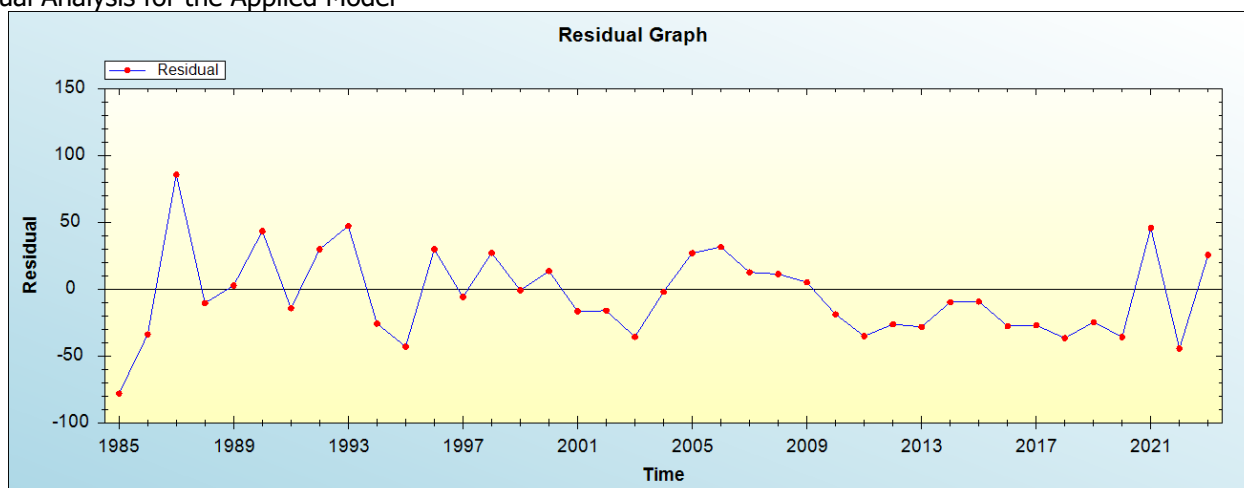


Figure 1: Residual analysis

In-sample Forecast for C

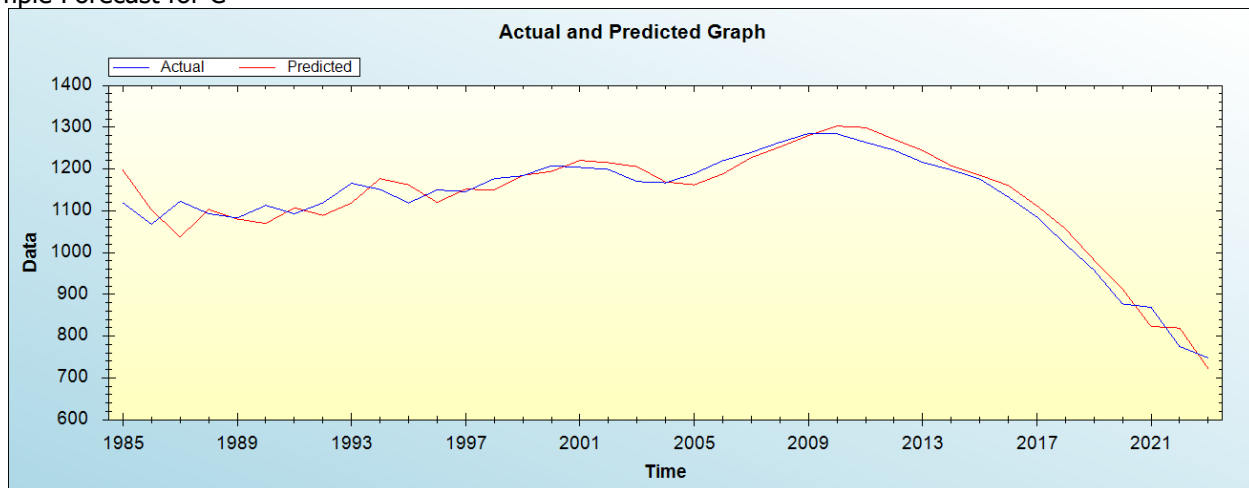


Figure 2: In-sample forecast for the C series

Actual and Smoothed graph for C series

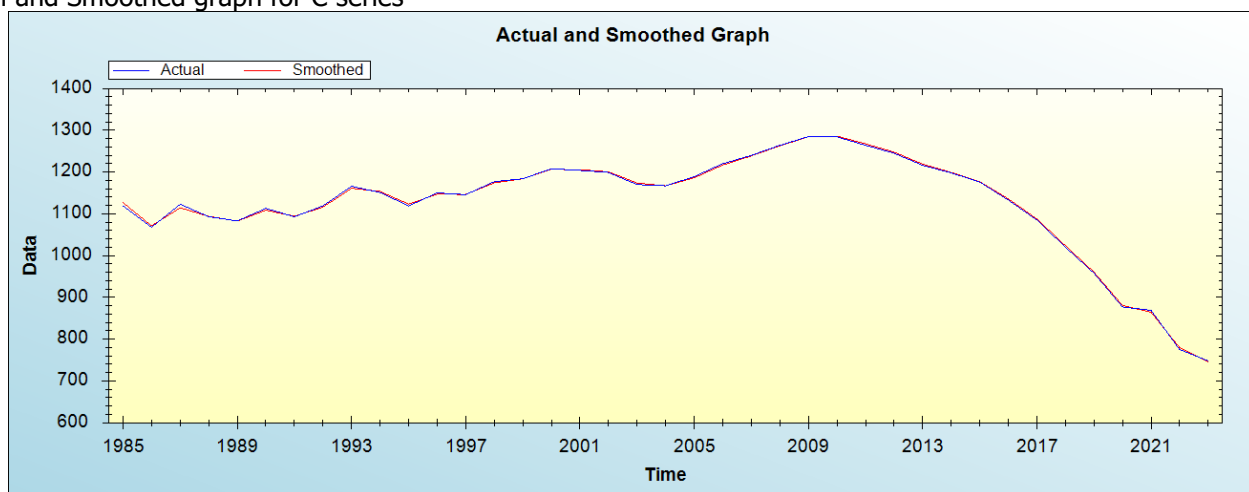


Figure 3: Actual and smoothed graph for C series

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

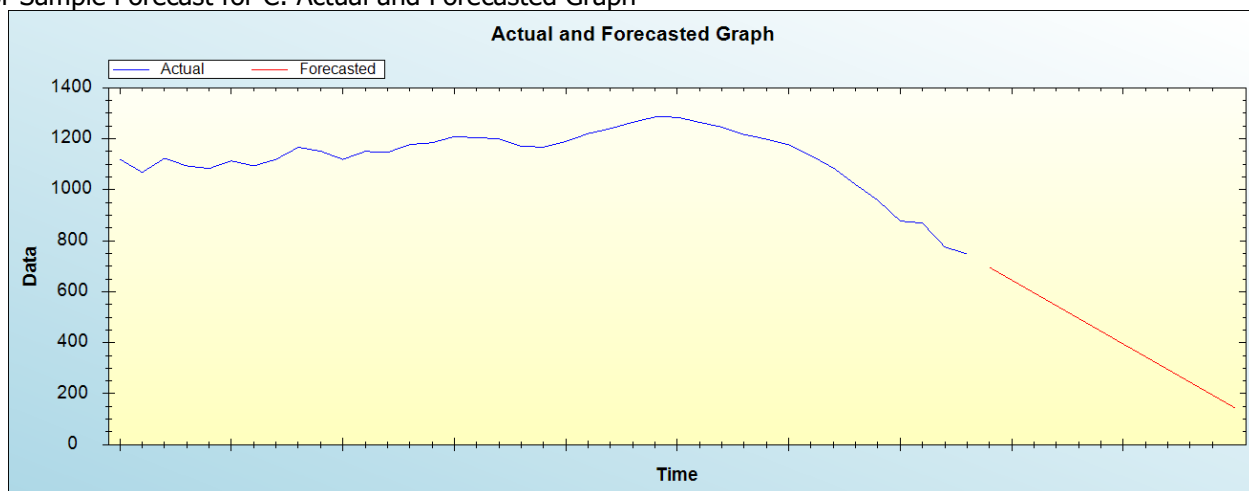




Figure 4: Out-of-sample forecast for C: actual and forecasted graph

Out-of-Sample Forecast for C: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	695.3826
2025	645.3157
2026	595.2487
2027	545.1818
2028	495.1148
2029	445.0479
2030	394.9809
2031	344.9139
2032	294.8470
2033	244.7800
2034	194.7131
2035	144.6461

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

RECOMMENDATIONS & CONCLUSION

High maternal mortality rates in Chad reflect low ANC coverage, challenges in accessing maternal and child care services and deficiencies in quality of healthcare services offered across the country. This paper applies the double exponential smoothing model to project MMR for Chad and the findings indicate that MMR is expected to fall but still remain very high throughout the forecast period. Therefore, we implore health authorities to adopt the following policy prescription: (1) reduce 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 for maternal and child health services across the country (3) carryout routine quality improvement initiatives (4) ensure availability of adequate commodities 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.

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