



ANNUAL MATERNAL MORTALITY RATE PROJECTION FOR NIGER USING THE DOUBLE EXPONENTIAL SMOOTHING TECHNIQUE

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Abstract

This study uses annual time series data on MMR for Niger 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 0.8 respectively based on minimum MSE. The results of the study indicate that MMR will continue to fall but still remain high throughout the out of sample period. Therefore, we encourage authorities to adopt the suggested 5-fold policy prescription.

Keywords: Exponential smoothing, Forecasting, Maternal Mortality Ratio.

Introduction

Niger is a landlocked West African country, lying on the southern edge of the Sahara Desert with 80% of its land occupied by the desert (PDES, 2022; INS, 2017). The population size in 2019 was estimated at 23.3 million inhabitants (UNFPA, 2022). 3 Niger is among the poorest countries in the world, being ranked as last on the Human Development Index (UNFPA, 2022). Approximately 50% of its population are living under the poverty line (World Bank, 2022). Despite these challenges, Niger has made significant progress in the reduction of under- 5 mortality (IGME, 2018; UNICEF, 2015). Data from United Nations Inter- Agency Group for Child Mortality Estimation (UN- IGME) indicates a slow neonatal mortality decline with only a 22% reduction between 2000 and 2010 and a stall at 34 per 1000 live births since 2010 (IGME,2020). In addition,



maternal mortality ratio (MMR) dropped from 867 to 441 per 100 000 live births between 2000 and 2020. The objective of this paper is to model and forecast MMR for Niger using the double exponential smoothing technique. The study findings will assist in policy making, planning and allocation of resources to the maternal and child health program so as to further reduce preventable maternal deaths across the country.

Literature Review

Author(s)	Objective(s)	Methodology	Key finding(s)
Ghosh et al. (2024)	To examine the sociodemographic risk factors and structural barriers associated with pregnancy care- seeking and institutional delivery, and (2) investigate the influence of residential distance to the nearest primary health facility in a rural population in Mali	population- based cross- sectional cohort design	education, occupation and distance are important determinants of pregnancy and delivery care in a rural Malian context
Idama et al. (2024)	to identify the key factors contributing to maternal mortality in Nigeria and proposed solutions to address this issue	Systematic review	he major causes of maternal mortality in Nigeria included hemorrhage, infection, unsafe abortion, hypertensive diseases of pregnancy, and obstructed labor. There were cases of socio-economic factors such as unavailability of electricity, transportation delay, the lack of skilled medical personal and cultural factors such as traditional beliefs
Kante et al. (2024)	To research on the drivers of progress and challenges in reducing maternal and neonatal mortality in Niger	Researchers reviewed two decades of health policies, analyzed mortality trends from	-Niger reduced maternal and neonatal mortality during 2000–2012, but progress has stalled



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		United Nations data and six national household surveys between 1998 and 2021 and assessed coverage and inequalities of maternal and newborn health indicators. Quality of care was evaluated from health facility surveys in 2015 and 2019 and emergency obstetric assessments in 2011 and 2017	- During the past decade, challenges included expansion of emergency care, continued high fertility, security issues, financing and health workforce
Traore et al. (2024)	To analyze trends and differences in several indicators of maternal and neonatal care coverage in Bamako	used secondary data from Mali's Demographic and Health Surveys from 2001 to 2018	results highlighted differential access to antenatal and childbirth care for non-poor and non-migrant women compared to their counterparts categorized as poor and migrant. The gaps were much larger depending on migration status (i.e., number of years since resettling in Bamako) and even tended to increase over time
Muriithi et al. (2022)	to identify these contributing factors and assess the frequency of their reporting in published literature	Scoping review	health facility— level factors were the most frequently reported contributing factors to maternal deaths in Africa
Toukara et al. (2022)	to examine disparities in education and geographic distance and how they affect utilization of maternal care within the Sélingué health district, a	cross sectional survey	disparities within the health district contribute to inadequate utilization among approximately 40% of the women in our sample. The concentration



	district with moderate geographic access to care, near Bamako, Mali		index demonstrated the impact of inequity in geographic access, comparing women residing near and far from the referral care facility
Traore et al. (2022)	to report the findings of the local maternal deaths surveillance and response (MDSR) committee in the health district of Municipality V of the district of Bamako	Conducted a retrospective study over a period from January 2009 to December 2017	The MMR remains high in Municipality V of the district of Bamako. These deaths were mostly from DOCs, with hemorrhage as the main cause
Bain et al. (2021)	To examine the national prevalence as well as the individual and contextual factors associated with maternal healthcare utilization in Mali.	The study analyzed data on 6335 women aged 15–49 years from Mali's 2018 Demographic and Health Survey	Prevalence of maternal healthcare utilization was 45.6% for ANC4+, 74.7% for SBA and 25.5% for PNC. At the individual level, ANC4+ and SBA utilization increased with increasing maternal age, level of formal education and wealth status
Camara et al. (2021)	to synthesize the characteristics and effectiveness of interventions to increase facility births or provision of postpartum care in sub-Saharan Africa.	Scoping review	Strategies identified in the literature as increasing facility births in the sub-Saharan African context include community awareness raising, health expenses reduction (transportation or user fee), non-monetary incentive programs (baby kits), or a combination of these with improvement of care quality (patient's privacy, waiting time, training of provider), and or follow-up of pregnant women to use health facility for birth



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Coulibaly et al. (2021)	To explore factors that contribute maternal mortality in Mali	Retrospective study	The main causes were hypertensive disorders/eclampsia and hemorrhage. 80% of these women's deaths were preventable
Olonade et al. (2019)	To focus on cogent issues affecting maternal mortality by unpacking its precipitating factors and examining the maternal health care system in Nigeria	Systematic review	It was noted that apart from the medical related causes (direct and indirect) of maternal mortality, certain socio-cultural and socioeconomic factors influence the outcome of pregnancy. Also, a poor health care system, which is a consequent of weak social structure, is a contributing factor
Tort et al. (2015)	to assess which factors contribute to maternal death occurring during PPH in Senegal and Mali	A cross-sectional survey nested in a cluster randomized trial (QUARITE trial) was carried out in 46 referral hospitals during the pre-intervention period from October 2007 to September 2008 in Senegal and Mali	The factors that were significantly associated with PPH maternal mortality were: age over 35 years (adjusted OR = 2.16 [1.26–3.72]), living in Mali (adjusted OR = 1.84 [1.13–3.00]), residing outside the region location of the hospital (adjusted OR = 2.43 [1.29–4.56]), pre-existing chronic disease before pregnancy (adjusted OR = 7.54 [2.54–22.44]) and prepartum severe anemia among others
Aa et al. (2011)	to estimate the maternal mortality ratio in Kita, rural Mali	Qualitative approach	The study found a very high maternal mortality in rural Mali



Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of MMR for Niger. 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 Niger 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	0.800
Forecast performance measures	
Mean Absolute Error (MAE)	8.343042
Sum Square Error (SSE)	4706.917738
Mean Square Error (MSE)	120.690198
Mean Percentage Error (MPE)	0.037674
Mean Absolute Percentage Error (MAPE)	1.275343

Residual Analysis for the Applied Model

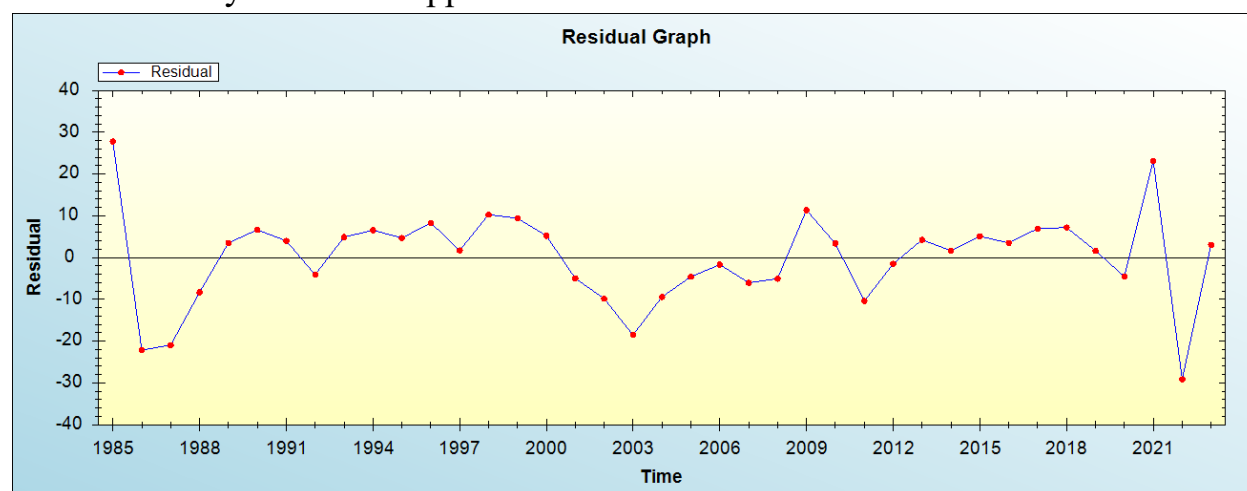


Figure 1: Residual analysis



In-sample Forecast for Z

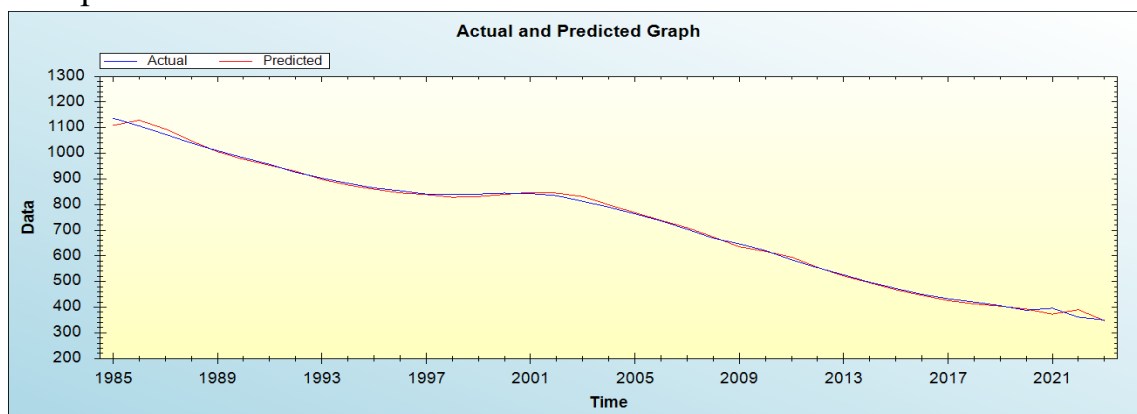


Figure 2: In-sample forecast for the Z series

Actual and Smoothed graph for Z series

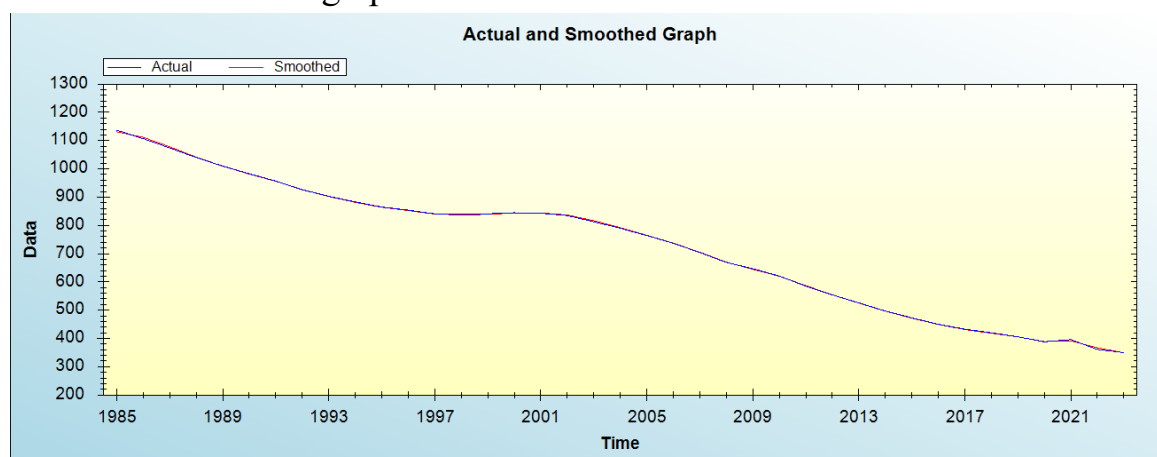


Figure 3: Actual and smoothed graph for Z series

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

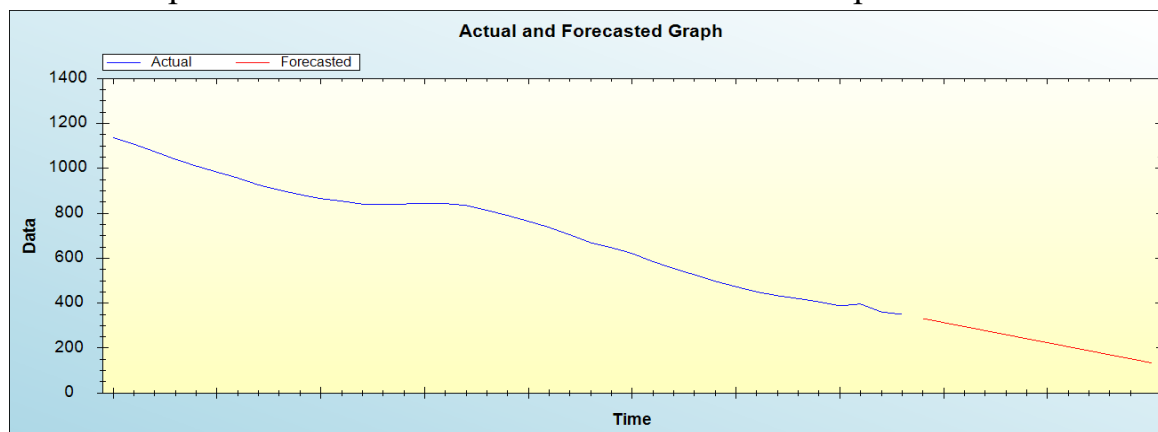


Figure 4: Out-of-sample forecast for Z: actual and forecasted graph



Out-of-Sample Forecast for Z: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	331.4617
2025	313.5344
2026	295.6072
2027	277.6799
2028	259.7527
2029	241.8254
2030	223.8982
2031	205.9709
2032	188.0437
2033	170.1164
2034	152.1891
2035	134.2619

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

Recommendations & Conclusion

The burden of maternal mortality in Niger is alarming and urgent measures must be taken to drastically reduce MMR. High teenage pregnancies, unsafe abortions, shortage of healthcare workers, inadequate medical supplies and long distances travelled to reach health facilities in rural areas are some of the major drivers of maternal deaths. In this paper, we applied the double exponential smoothing approach to project MMR and findings suggest that MMR will continue to fall but still remain high in the forecast period. Therefore, we encourage 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) implement quality improvement strategies (4) ensure availability of adequate



medical supplies and medical staff in all medical facilities and (5) create 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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