



FORECASTING THE FUTURE PATH OF MATERNAL MORTALITY FOR CHINA USING THE DOUBLE EXPONENTIAL SMOOTHING MODEL

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Article history:		Abstract:
Received: 7 th May 2026	Accepted: 6 th June 2026	<i>This study uses annual time series data on MMR for China 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 remain very low over the out of sample period. Therefore, we encourage Chinese authorities to address local causes of maternal mortality and relentlessly carryout surveillance of severe maternal morbidity.</i>
Keywords: <i>Exponential smoothing, Forecasting, Maternal Mortality Ratio</i>		

INTRODUCTION

Maternal mortality continues to attract serious attention on the global stage. Reducing maternal mortality ratio (MMR) remains among the top priorities on the UN Agenda for sustainable development (Mgawadere et al. 2017). Maternal mortality ratio is an important health indicator that can be used in making comparisons across different time periods and geographic regions (Collier et al. 2019). In 2015, all UN member states set the Sustainable Development Goal which aims at reduce the MMR to 70.0 per 100,000 live births by 2030 (Callister et al. 2017). In 2016, the Chinese government proposed the Healthy China 2030 plan, which aimed to reduce the MMR to 18.0/100,000 births by 2020 and 12.0/100,000 births by 2030 (Tan et al. 2019). China has made significant progress towards achieving sustainable development goal 3.1 over the past decades (NHCC, 2022; Qiao et al. 2021). During the period 1949 to 2022, the maternal mortality ratio decreased from 1500 deaths to 15.7 deaths per 100 000 live births (NHCC, 2022). These positive developments are due to factors such as rapid socioeconomic development,

strong political will to improve maternal and child health, establishment of a maternal health system, advances in health technologies, reformation of social health insurance, implementation of national maternal health programs, and poverty alleviation (Qiao et al. 2021). More than 90% of Chinese households can reach the nearest health facility within 15 minutes (NHCC, 2021), and the majority of pregnant women can obtain affordable maternity services with about 95% of women covered by social health insurance (National Healthcare Security Administration, 2022). Coverage of maternity services has reached over 90% for antenatal care and postpartum visits and above 99% of deliveries are in medical facilities (NHCC, 2022).

The objective of this paper is to model and forecast MMR for China using the double exponential smoothing technique. The study findings are expected to detect any abnormal future trends of MMR. This will then stimulate an appropriate and timeous response to the problem of maternal mortality. The ultimate goal is to eliminate all preventable maternal deaths.

LITERATURE REVIEW

Author(s)	Objective(s)	Methodology	Main finding(s)
Wang et al. (2024)	to assess trends in MCH indicators nationally and separately in urban and rural areas and the impact of public policies over a 30-year period	An ecological study was conducted using data on neonatal mortality rate (NMR), infant mortality rate (IMR), under-five mortality rate (U5MR), and maternal mortality ratio (MMR) nationally and separately in urban and	MCH indicators have declined at the national level as well as separately in urban and rural areas but may have reached a plateau. Urban-rural disparities in MCH indicators have narrowed but still exist



		rural areas in China from 1991 to 2020	
Fang et al. (2024)	To examine the association between neonatal mortality and hospital delivery in China across urban and rural regions, regional disparities, and varying levels of economic development	Retrospective cohort study	An increase in hospital deliveries was associated with reduced neonatal mortality in rural and economically underdeveloped areas in China
Liu et al. (2022)	to analyze the changes in the proportion of pregnant women at high risk screened before and after the implementation of the risk management strategy and the association with maternal mortality during the two-child policy era in China.	conducted a nationwide longitudinal study using data obtained from the National Statistical Yearbook and the National Health Statistics Yearbook for all 31 provinces from 2008–2017 to assess and analyze the changes in the proportion of pregnant women at high risk screened before (2008–2013) and after (2014–2017) the implementation of the risk management strategy during the two-child policy era	The national risk management strategy contributed to the stable decline of MMR in China during the two-child policy era
Yu et al. (2021)	To determine the prevalence of MMR in Jinan, China from 1991 to 2020, analyzed the causes of trends and put forward some solutions to the difficulty existing in the process of reducing the MMR, hoping to serve as a model for some developing cities to reduce MMR.	-collected maternal mortality data from paper records, electronic files and network platforms. The time trend of MMR was tested by Cochran-Armitage Test (CAT) -the Chi-square test or Fisher's exact test was used to test the difference in MMR of different periods	Subsidy for hospitalized delivery of rural women, free prenatal check-ups for pregnant women and rapid referral system between hospitals have contributed to reducing MMR in Jinan
Chen et al. (2021)	to assess the trends in the maternal mortality ratio, the causes of maternal death, and the correlations between maternal mortality ratio and total health financing composition in	-Data in this longitudinal study were collected from the China Health Statistics Yearbooks (1991–2020) and China Statistical Yearbook 2020 -Linear regression analysis was used to	-China has made remarkable progress in improving maternal survival, especially in rural areas -The maternal mortality ratio in China showed a downward trend over time



	China from 1990 to 2019	assess the trends in the maternal mortality ratio in China -Pearson correlation analysis was used to assess the correlations between national maternal mortality ratio and total health financing composition	
Chen et al. (2020)	to determine whether the nationwide program 'Reducing maternal mortality and eliminating neonatal tetanus' contributed to the rapid decline in China's maternal mortality ratio (MMR) and neonatal tetanus elimination by enhancing hospital delivery	compared MMR and neonatal tetanus incidence rate (NTR) reductions by province from 2000 to 2013. The difference-in-difference method was used to analyze the program effect. Long-term effects were analyzed relative to MMR and NTR in 2000 and 2002, respectively, while short-term effects in a given year were analyzed relative to MMR and NTR in the preceding year	-The national program was associated with a faster decline in MMR in the long term. The rate of decline showed an inverse 'U' shape from 2000 to 2013, peaking in 2009 -The program had a short-term effect in MMR reduction in 2005, 2007, and 2009
Li et al. (2020)	-to adopt a quantitative evaluation model to analyze whether RP differences contribute to the different MMRs of the two cities	Based on collection of all publicly released policy documents regarding maternal health in the two cities, we assessed and compared the status of their maternal health care RPs from 2006 to 2017 through a series of quantitative indicators as regulatory elements coverage rate (RECR), departmental responsibility clarity rate (DRCR), and accountability mechanism clarity rate (AMCR), based on two characteristics of comprehensiveness and effectiveness of RPs	Compared with NYC, the more comprehensive and effective maternal health care RPs in SH had a stronger impact on MMR control, which contributed to the differences between the two cities' MMRs to some extent



Zhao et al. (2020)	To evaluate the longitudinal association between the utilization rate of the maternal health services of the BPHS project and such reduction	conducted a longitudinal study on the maternal health service utilization rates of the BPHS project and the maternal mortality ratios (MMR) in mainland China and its 31 provincial regions	The utilization of maternal health services increased continuously after the introduction of BPHS project in 2009 and MMR went downward from then on
Zhou et al. (2019)	To use data from the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2017 to help inform decision making and monitor progress on health at the province level	Used methods in GBD 2017 to analyze health patterns in the 34 province-level administrative units in China from 1990 to 2017.	-Stroke and ischemic heart disease were the leading causes of death and DALYs at the national level in China in 2017 -

METHODOLOGY

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

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

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**

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 China 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	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	2.060684
Sum Square Error (SSE)	588.383566
Mean Square Error (MSE)	15.086758
Mean Percentage Error (MPE)	1.281796
Mean Absolute Percentage Error (MAPE)	3.587333

Residual Analysis for the Applied Model

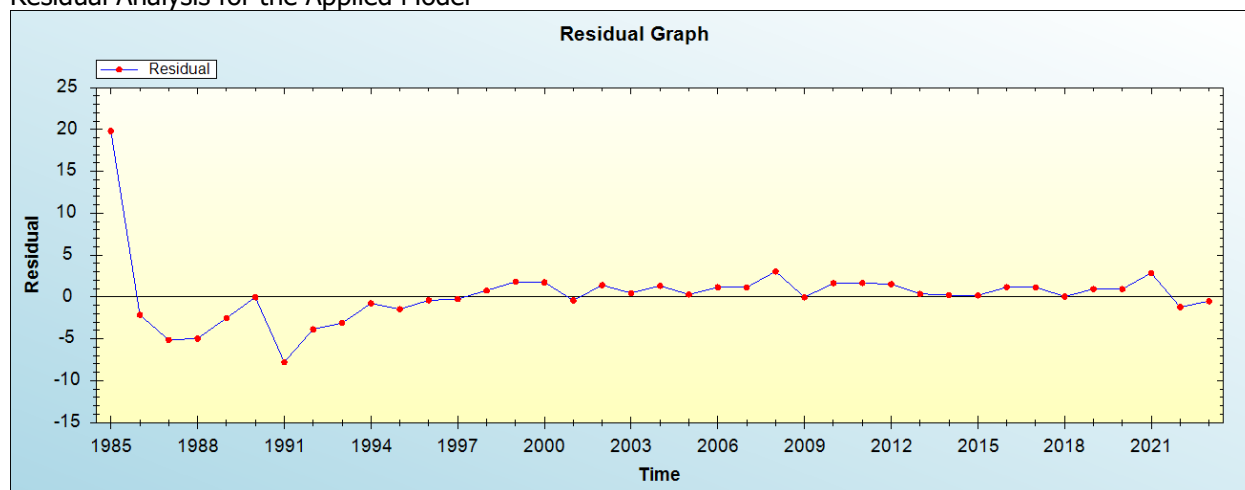


Figure 1: Residual analysis

In-sample Forecast for C

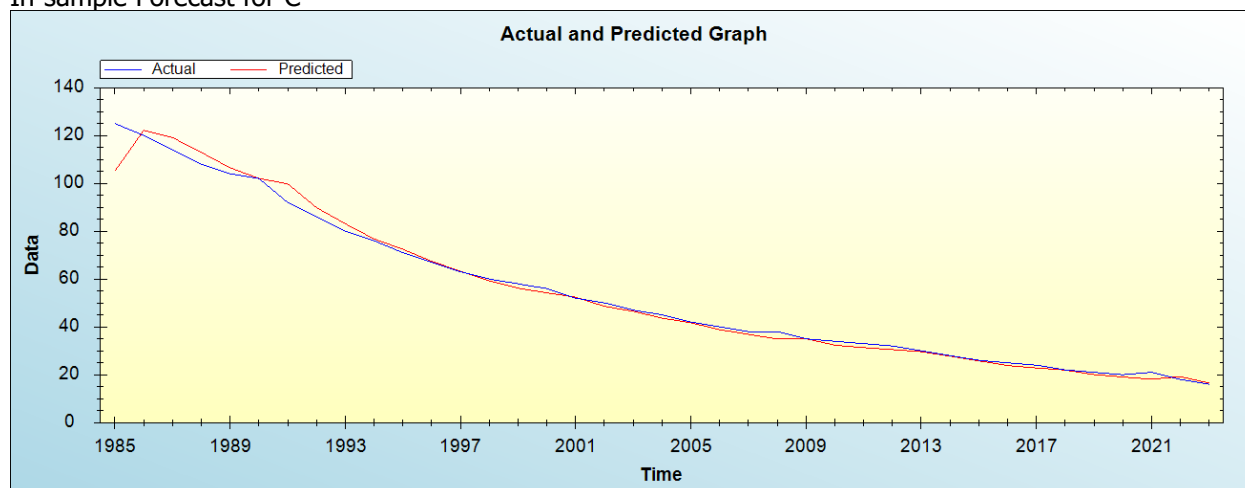


Figure 2: In-sample forecast for the C series

Actual and Smoothed graph for C series

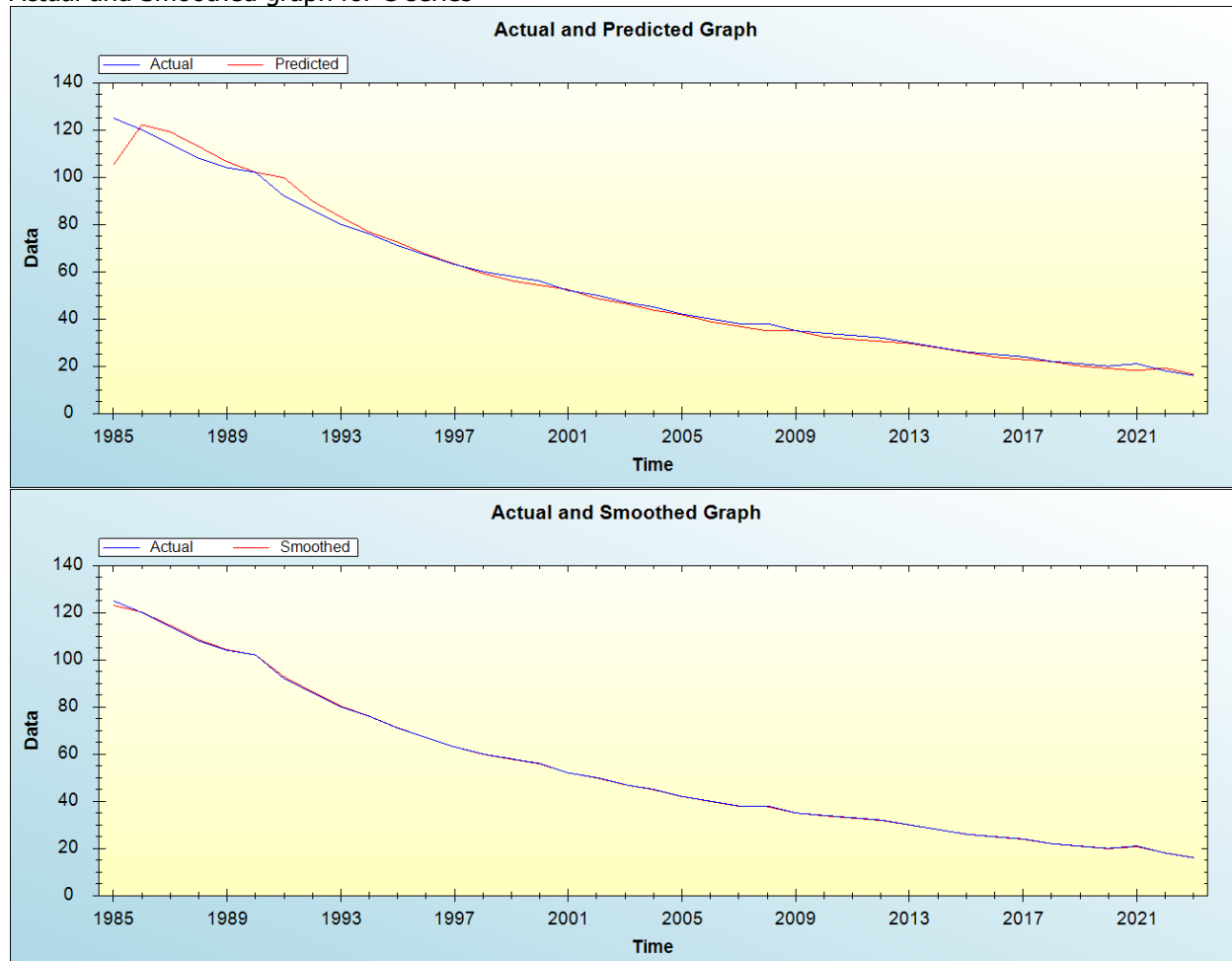


Figure 3: Actual and smoothed graph for C series

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

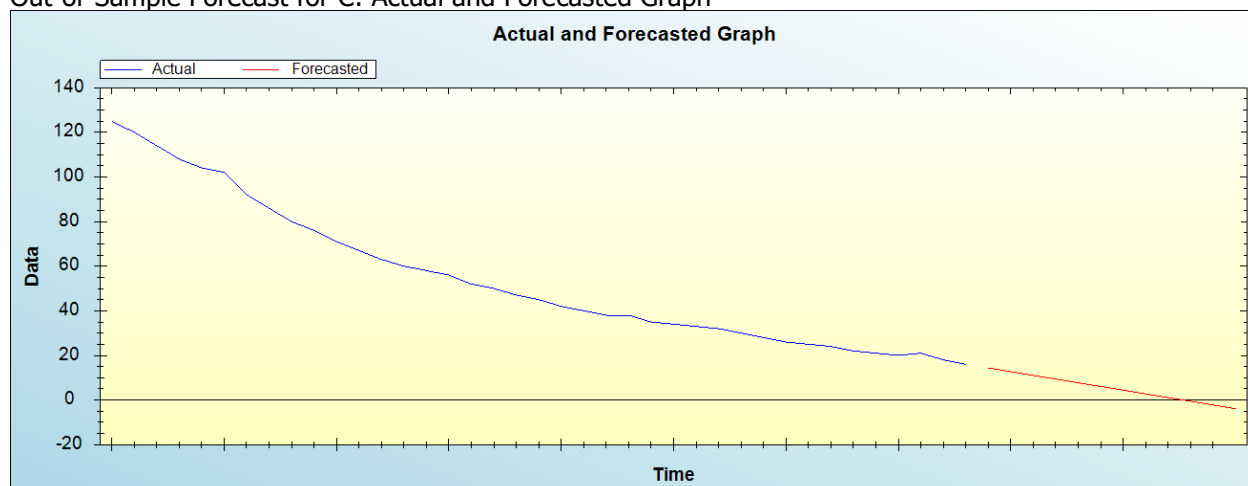


Figure 4: Out-of-sample forecast for C: actual and forecasted graph



Out-of-Sample Forecast for C: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted MMR
2024	14.3882
2025	12.7261
2026	11.0639
2027	9.4018
2028	7.7397
2029	6.0775
2030	4.4154
2031	2.7532
2032	1.0911
2033	-0.5711
2034	-2.2332
2035	-3.8954

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 remain very low over the out of sample period.

RECOMMENDATIONS & CONCLUSION

China has managed to lower its MMR to levels below 30 per 100 000 live births due to the rapid socioeconomic development, strong political will to improve maternal and child health, establishment of a maternal health system, advances in health technologies, reformation of social health insurance, implementation of national maternal health programs, and poverty alleviation. This study applies the double exponential smoothing method to forecast MMR for China and results indicate that MMR is expected to remain very low over the out of sample period. Therefore, we implore health authorities to address local causes of maternal deaths and improve surveillance of severe maternal morbidity (SMM) across the country and attend to its root causes.

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