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## PREDICTING FUTURE VALUES OF ANNUAL MATERNAL MORTALITY RATE FOR PAKISTAN USING THE DOUBLE EXPONENTIAL SMOOTHING METHOD

Smartson. P. NYONI 1,

Thabani NYONI 2

1Independent Researcher & Medical Doctor, Harare, Zimbabwe

2Independent Researcher & Health Economist, Harare, Zimbabwe

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### Abstract

This study uses annual time series data on MMR for Pakistan 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  $\alpha$  and  $\beta$  are 0.9 and 0.3 respectively based on minimum MSE. The results of the study indicate that MMR will decline from around 147.6 in 2024 to about 65 deaths per 100 000 live births by 2035. Therefore, we encourage authorities to adopt the suggested 5-fold policy prescription.

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

### Introduction

According to WHO recent data around 295,000 women die annually during and following childbirth worldwide. South Asia alone accounts for almost 20% of all these deaths. It is critical to highlight that nearly 94% of maternal deaths are reported in underdeveloped countries (WHO, 2019). Pakistan Maternal Mortality Survey 2019 revealed demographic variations in maternal mortality rates of women residing in rural and urban areas of Pakistan. The maternal mortality ratio in Pakistan is 186 deaths per 100,000 live births. The ratio is about 26% higher in rural areas as compared to urban areas. High maternal mortality in Pakistan reflects neglect of women health as well as low quality obstetric services at the primary care level (NIPS & ICF, 2019). Data obtained from low-middle income



countries indicates that only 44% of deliveries in rural areas and 75% in urban areas were attended by skilled personnel (Pakistan DHS 2012-13). In order to prevent adverse maternal health outcomes, it is crucial to offer mothers with high quality and accessible maternity services during pregnancy, childbirth, and the postnatal period. Factors associated with maternal mortality in Pakistan include poverty, lack of education, gender-based inequalities, inadequate and poor quality of healthcare services, distant facilities, sociocultural values, malnutrition and violence against women, unfair distribution of resources, and political environment (Adnan et al. 2017). The objective of this study is to model and forecast future trends of MMR for Pakistan using double exponential smoothing technique. The study findings are expected to highlight likely future trends of MMR. This will then guide policy-making, planning and allocation of adequate 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)                                                                                                                                                                                                                                                                                                        |
|----------------------|----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Amhad et al. (2025)  | to identify socio-demographic and health system related factors associated with maternal mortality in Pakistan | Using the nested case-control design, researchers conducted an in-depth analysis of Pakistan Maternal Mortality Survey (PMMS) 2019                                               | secondary or higher maternal education, having had tetanus injection during the last pregnancy, ever-used contraception or being in the age group of 20–29 years were factors associated with lower risk of maternal mortality. Conversely, skilled birth attendance increases the risk of maternal death in Pakistan |
| Khan et al. (2025)   | to examine maternal mortality through the lens of the three delays model using data from Pakistan              | Researchers conducted a retrospective analysis of the Pakistan Maternal Mortality Survey 2018-2019, drawing on the Pakistan Demographic and Health Survey Verbal Autopsy dataset | Maternal mortality in Pakistan reflects a web of sociodemographic inequalities and systemic shortcomings                                                                                                                                                                                                              |
| Midhet et al. (2025) | To highlight the trends in maternal mortality levels and risk factors in Pakistan between 2007 and 2019        | This study compared the results of secondary data analysis of the Pakistan Maternal Mortality Survey 2019 with the Pakistan Demographic and Health Survey 2007. A nested case    | The modest reduction in MMR can be attributed to improved access to maternal health services in rural areas with increased antenatal care and institutional deliveries                                                                                                                                                |



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|                     |                                                                                                                                                                                             |                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                           |
|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                     |                                                                                                                                                                                             | control study was carved to compare maternal deaths with the women who survived a pregnancy, in the same sampling clusters during the same period                                                     |                                                                                                                                                                                                                                                                                                           |
| Wasim et al. (2025) | To assess the maternal mortality ratio (MMR), causes, trends and delays in care over a period of twelve years at institutional level                                                        | This cross-sectional study was conducted over a 12 years period (2011-2022) at Services Hospital, Lahore, Pakistan                                                                                    | Postpartum hemorrhage and cardiac disease in pregnancy were leading cause of death in 44(31.65%) and 31(22.3%) of patients in 2011-2016, while hypertensive disorders in 18(21.69%) patients and sepsis in 15(18.0%) patients were significantly responsible for maternal mortality in 2017-2022 (p=0.00) |
| Asif et al. (2023)  | to explore the community's perspectives of delays to use of health services in pregnancy and labor, using the 'three delays' model and the framework for determinants of maternal mortality | explorative-descriptive approach                                                                                                                                                                      | Women were unable to decide for themselves whether to attend a healthcare facility, there were issues reaching a facility in time and at the facility, either the resources or healthcare workers were lacking                                                                                            |
| Avais et al. (2023) | to find out the leading social factors causing maternal mortality in Hyderabad district, Pakistan                                                                                           | Qualitative study                                                                                                                                                                                     | Leading causes of maternal mortality were poverty 41.6%), negligence of family men (27.2%), illiteracy (12%), malnutrition (11.2%) and non-availability of medical facilities (8%) at the center of primary care                                                                                          |
| Akbar et al. (2021) | To determine the impact of antenatal care on maternal morbidity in three Military hospitals of Punjab in Pakistan                                                                           | Comparative cross-sectional study                                                                                                                                                                     | anemia, hypertension and diabetes were the most common comorbidities in expecting mothers. Un-booked mothers had more morbidities and complications of pregnancy than booked mothers. Furthermore, we found antenatal care to be beneficial in the prevention of these comorbidities and complications    |
| Anwar et al. (2018) | to determine accurate maternal and perinatal mortality through enhanced surveillance of births and deaths, compared with prior routinely collected data in Pakistan                         | An enhanced surveillance system was established that measured maternal, perinatal and neonatal mortality rates through more complete enumeration of births and deaths in a rural district of Pakistan | Higher maternal mortality, perinatal mortality and neonatal mortality rates were observed through enhanced surveillance compared to mortality rates in the previous 1.5 years from the routine monitoring system from increased completeness and coverage                                                 |



|                      |                                                                                                                                                                                                |                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                         |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Mazhar et al. (2018) | To assess the availability of essential obstetric and newborn care at referral level facilities of Pakistan that were selected for WHO MCS to correlate it with maternal and neonatal outcomes | This cross-sectional study assessed the infrastructure, equipment and services in 16 referral level government hospitals participating in WHO MCS from 1st March to 30th May, 2011 | Most components of Essential Maternal and Neonatal Obstetric Care were present in the studied facilities. Tertiary level facilities even with availability of adult and neonatal intensive care units had more adverse maternal and newborn outcomes perhaps due to more disease burden |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Methodology

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

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

$P_t$  is the actual value of MMR at time  $t$

$\varepsilon_t$  is the time varying **error term**

$\mu_t$  is the time varying mean (**level**) term

$\rho_t$  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  $t$

$\alpha$  is the exponential smoothing constant for the data



$\beta$  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 Pakistan 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           |
| <b>Smoothing constants</b>            |              |
| Alpha ( $\alpha$ ) for data           | 0.900        |
| Beta ( $\beta$ ) for trend            | 0.300        |
| <b>Forecast performance measures</b>  |              |
| Mean Absolute Error (MAE)             | 11.882249    |
| Sum Square Error (SSE)                | 13394.309589 |
| Mean Square Error (MSE)               | 343.443836   |
| Mean Percentage Error (MPE)           | 0.182350     |
| Mean Absolute Percentage Error (MAPE) | 3.677258     |

#### Residual Analysis for the Applied Model

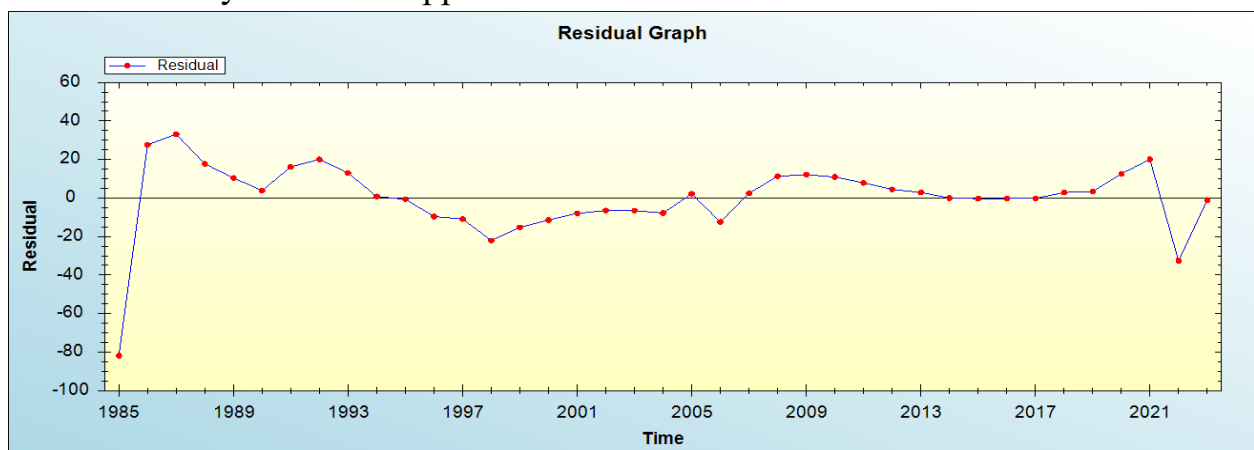


Figure 1: Residual analysis



### In-sample Forecast for P

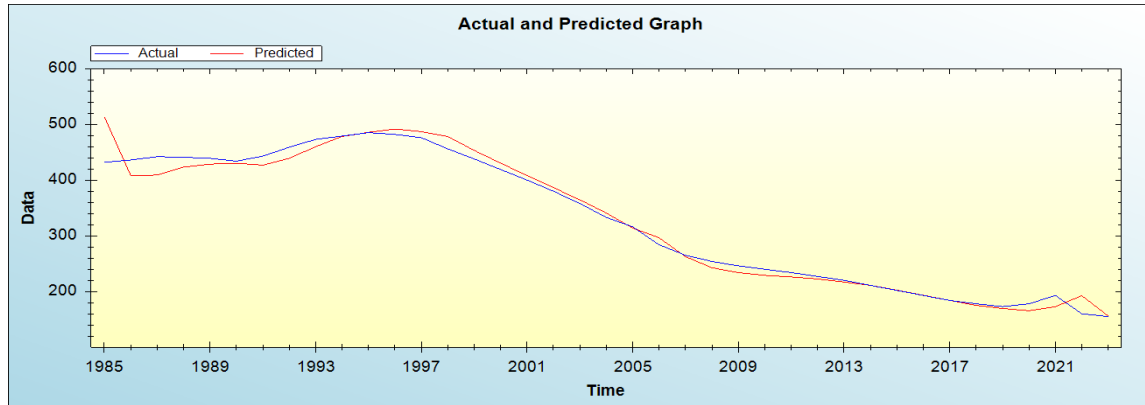


Figure 2: In-sample forecast for the P series

### Actual and Smoothed graph for P series

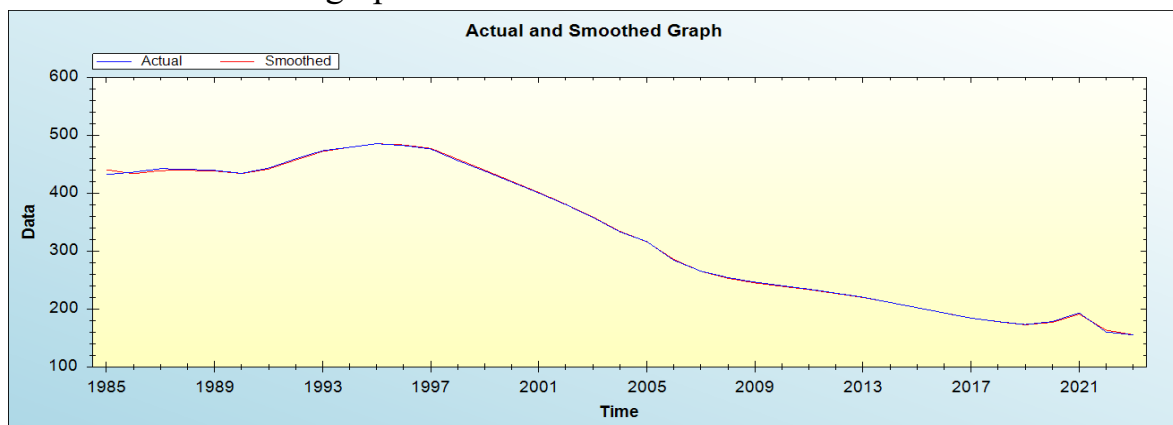


Figure 3: Actual and smoothed graph for P series

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

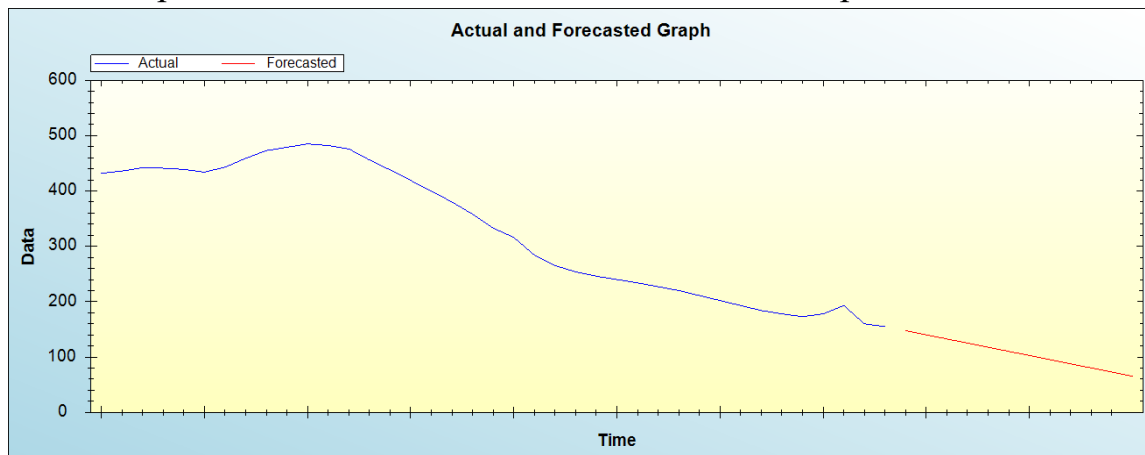


Figure 4: Out-of-sample forecast for A: actual and forecasted graph



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**Out-of-Sample Forecast for P: Forecasts only**

**Table 2: Tabulated out-of-sample forecasts**

| Year | Forecasted MMR |
|------|----------------|
| 2024 | 147.6234       |
| 2025 | 140.1403       |
| 2026 | 132.6572       |
| 2027 | 125.1742       |
| 2028 | 117.6911       |
| 2029 | 110.2080       |
| 2030 | 102.7250       |
| 2031 | 95.2419        |
| 2032 | 87.7588        |
| 2033 | 80.2758        |
| 2034 | 72.7927        |
| 2035 | 65.3096        |

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 147.6 in 2024 to about 65.3 deaths per 100 000 live births by 2035.

### **Recommendations & Conclusion**

High maternal mortality in Pakistan indicates neglect of women health as well as low-quality obstetric services at the primary care level. Factors associated with maternal mortality in Pakistan include poverty, lack of education, gender-based inequalities, inadequate and poor quality of healthcare services, distant facilities, sociocultural values, malnutrition and violence against women, unfair distribution of resources, and political environment. In this study we applied the technique to model and forecast MMR and findings suggest that MMR will decline from around 147.6 in 2024 to about 65.3 deaths per 100 000 live births by 2035. Hence, we encourage health authorities to adopt the following policy prescription:(1) end adolescent pregnancies 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) direct resources towards implementation of quality improvement initiatives (4) ensure availability of adequate medical supplies and offer staff retention schemes at all levels of care 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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