

Applying Holt's Double Exponential Smoothing Method in Forecasting Adolescent Fertility for Sierra Leone

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Abstract - This study uses annual time series data of adolescent fertility rate for Sierra Leone from 1960 to 2020 to predict future trends of adolescent fertility rate over the period 2021 to 2030. The study utilizes Holt's linear 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 annual adolescent fertility will continue to decline throughout the out of sample period. Therefore, we encourage authorities in Sierra Leone to relentlessly enforce laws that protect sexual and reproductive health rights of women and girls, promote girl child education, fund empowerment programs for youths and provide accessible and affordable adolescent health services across the whole country.

Keywords: Exponential smoothing, Forecasting, adolescent fertility rate.

I. INTRODUCTION

Sierra Leone is a West African country bordering Guinea and Liberia. It has a total population of seven million, 22 percent of which are adolescents' aged 10–19 (SSL, 2015). Its main economic activity is agriculture with approximately fifty eight percent of all households in the country being agricultural households (SSL, 2015). Above fifty percent of the population are living in poverty (SSL, 2019). The country continues to face the problem of maternal and under five mortality as a result of a variety of reasons which include adolescent pregnancy (Stark *et al.* 2015; SSL, 2010). Sierra Leone has one of the highest rates of maternal mortality in the world reporting 1360 deaths per 100,000 live births in 2015 (Hariri, 2019). National statistics revealed that 34 percent of all pregnancies in the country are associated with teenage pregnancy and 40 percent of maternal deaths are due to adolescent pregnancy (Espíndola & Bautista, 2017). According to WHO, Infants born to young mothers under the age of 20 have a 50% higher risk of neonatal mortality. Evidence shows that the level of maternal and newborn mortality increased by 30 and 24 percent between 2014 and 2015 (Jones *et al.* 2017). Literature indicates that among female adolescents aged 15–19 who are not in a union, 53.7 percent reported using a modern method of contraception (SSL, 2018). In addition, modern contraceptive use has increased by 13 percent among married adolescents, from 1.2% in 2008 to 14.3% in 2019 (SSL & ICF, 2019; SSL & ICF macro, 2009).

This paper applies the double exponential smoothing technique to model and forecast future trends of adolescent fertility in Sierra Leone. The findings of this study are expected to depict the future burden of adolescent births in the out of sample period. This will inform policies, planning and allocation of resources to teenage pregnancy prevention programs.

II. METHODOLOGY

This study utilizes an exponential smoothing technique to model and forecast future trends of adolescent fertility rate in Sierra Leone. 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

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

Smoothing equation

$$L_t = \alpha V_t + (1-\alpha)(L_{t-1} + b_{t-1})$$

$$0 < \alpha < 1$$

Trend estimation equation

$$b_t = \beta (L_t - L_{t-1}) + (1-\beta)b_{t-1}$$

$$0 < \beta < 1$$

Forecasting equation

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

V_t is the actual adolescent fertility rate 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

L_t is the exponentially smoothed value of adolescent fertility rate 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 at time t

b_{t-1} is the trend estimate at time t-1

Data Issues

This study is based on annual adolescent fertility rate in Sierra Leone for the period 1960 – 2020. The out-of-sample forecast covers the period 2021 – 2030. All the data employed in this research paper was gathered from the World Bank online database.

III. FINDINGS OF THE STUDY

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	V
Included Observations	61
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100

Forecast performance measures	
Mean Absolute Error (MAE)	1.986902
Sum Square Error (SSE)	1275.436085
Mean Square Error (MSE)	20.908788
Mean Percentage Error (MPE)	-0.137410
Mean Absolute Percentage Error (MAPE)	1.050930

Residual Analysis for the Applied Model

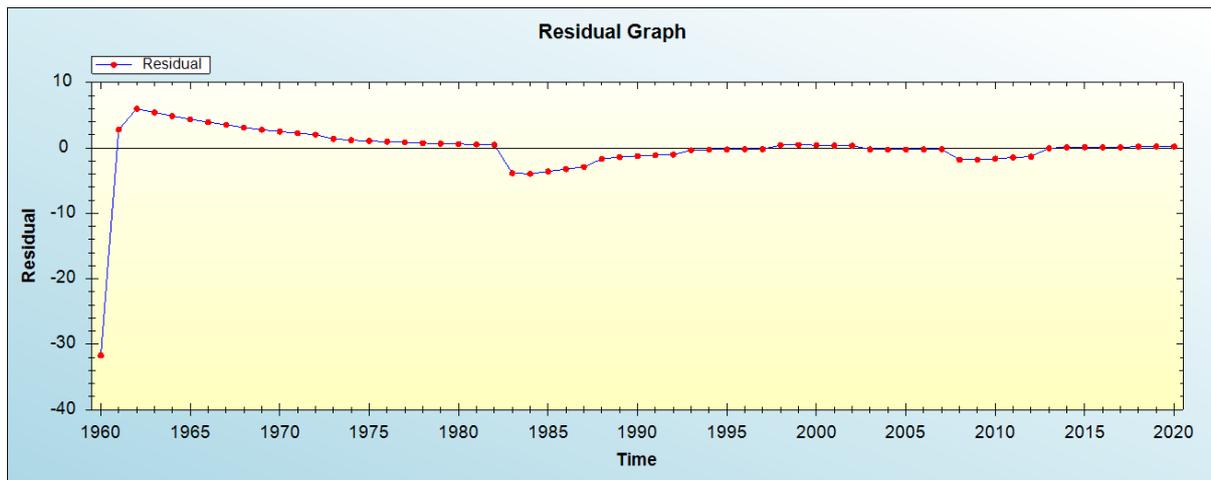


Figure 1: Residual analysis

In-sample Forecast for V

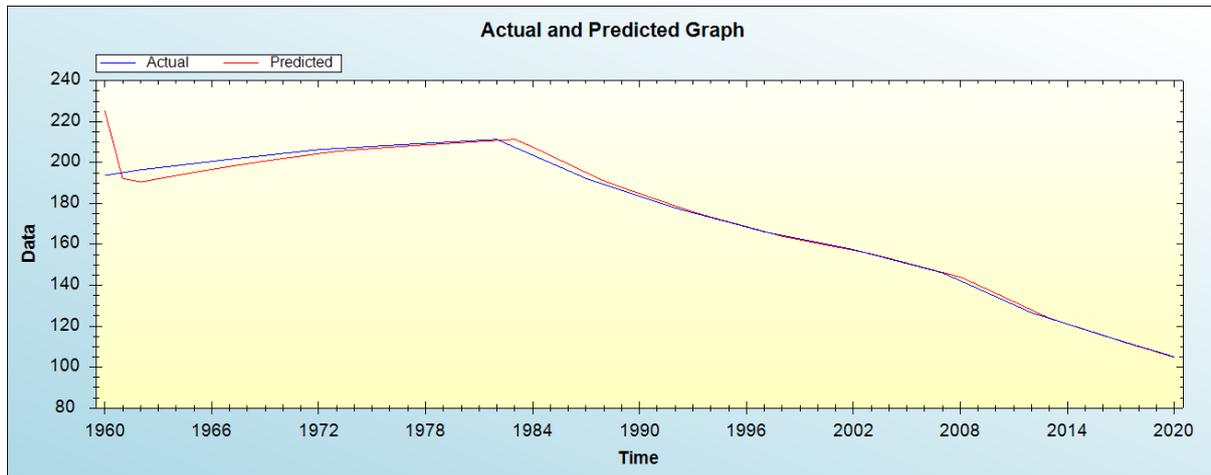


Figure 2: In-sample forecast for the V series

Actual and Smoothed graph for V series

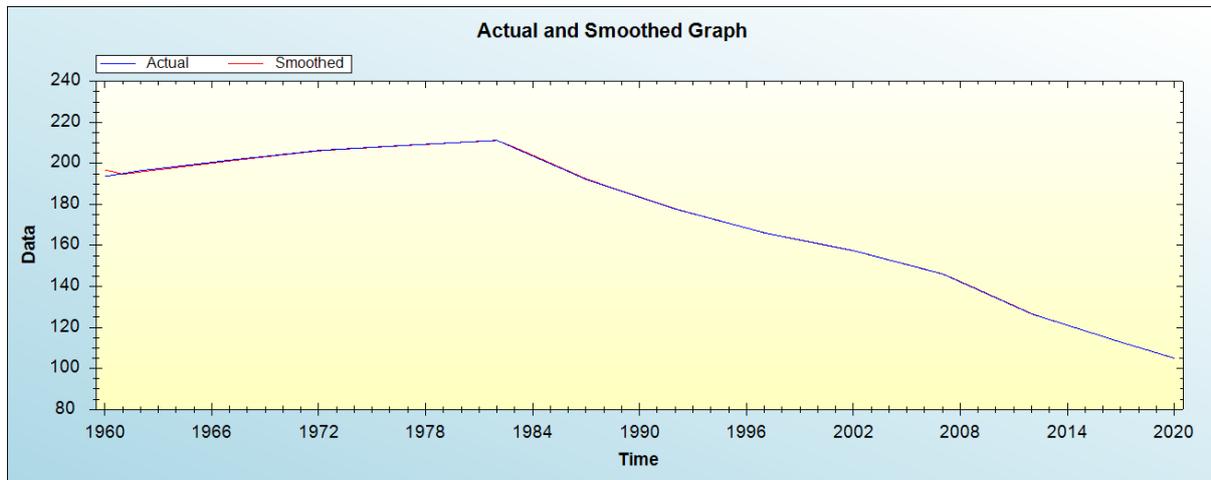


Figure 3: Actual and smoothed graph for V series

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

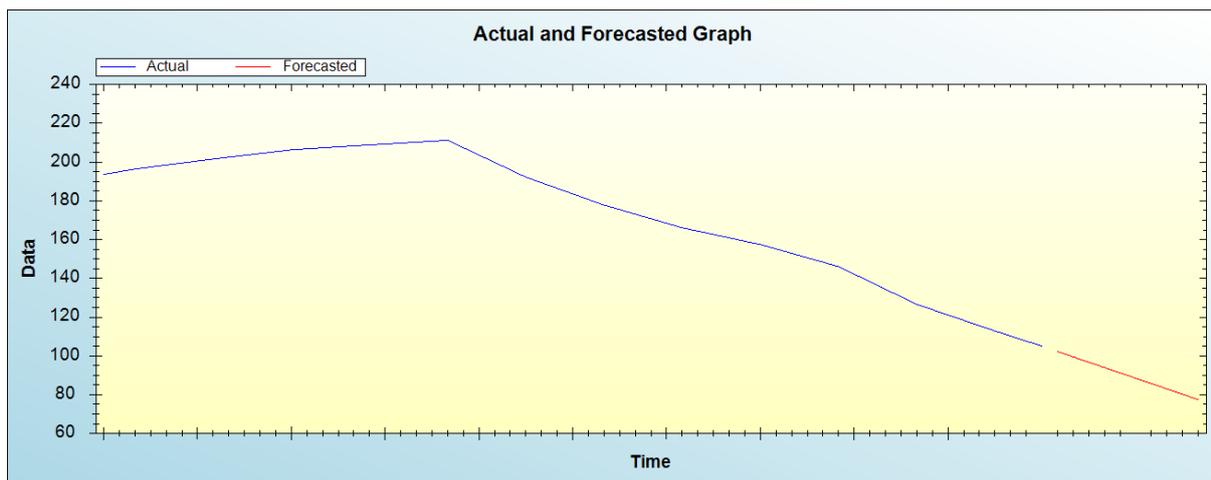


Figure 4: Out-of-sample forecast for V: actual and forecasted graph

Out-of-Sample Forecast for V: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted adolescent fertility rate
2021	102.2542
2022	99.4991
2023	96.7441
2024	93.9891
2025	91.2340
2026	88.4790
2027	85.7239
2028	82.9689
2029	80.2139
2030	77.4588

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 adolescent fertility will continue to decline throughout the out of sample period.

IV. POLICY IMPLICATION & CONCLUSION

Sierra Leone has one of the highest rates of maternal mortality in the world reporting 1360 deaths per 100,000 live births in 2015. According to the National statistics, 34 percent of all pregnancies in the country are associated with teenage pregnancy and 40 percent of maternal deaths are due to adolescent pregnancy. Risk factors for teenage pregnancy include poverty, non-use of modern methods of contraception, low educational level and inadequate SRH information among adolescents. Sierra Leone's adolescent fertility steadily declined from 211 births per 1000 women aged 15-19 years in 1982 to 105 births per 1000 women aged 15-19 years in 2020. These figures indicate that adolescent fertility is still very high in this country. This study applied Holt's double exponential smoothing technique to forecast future trends of adolescent fertility for Sierra Leone. Our study findings suggested that adolescent fertility will continue to decline but remain very high throughout the out of sample period. Therefore, authorities in this country are encouraged to relentlessly enforce laws that protect sexual and reproductive health rights of women and girls, promote girl child education, fund empowerment programs for youths and increase awareness campaigns among communities.

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