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Forecasting Adolescent Fertility for Eritrea Using Holt's Double Exponential Smoothing Technique

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***Abstract* - This study uses annual time series data of adolescent fertility rate for Eritrea 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 0.2 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 Eritrea to address several factors that contribute to adolescent pregnancies that include socio-cultural, economic and geographic factors.**

Keywords: Exponential smoothing, Forecasting, adolescent fertility rate.

I. INTRODUCTION

Low-middle income countries continue to report high maternal and child mortality rates, hence there is urgent need for governments to concentrate their efforts on prevention strategies targeting teenage pregnancy reduction and ensuring access to sexual and reproductive health services among adolescents(WHO, 2019; UNICEF, 2019).WHO reported that in 2017, the global maternal mortality was 211 deaths per 100,000 live births and 86 percent of all deaths occurred in the sub-Saharan African region, where the ratio was 542 deaths per 100,000 live births. The objective of the agenda 2030 for sustainable development is to prevent adverse pregnancy outcomes including those linked to teenage pregnancy. The 3rd sustainable development goal aims at the substantial reduction of maternal mortality to less than 70 per 100 000 live births by 2030. In addition, target 3.2 focuses on the reduction of neonatal and under five mortality. The aim is to reduce neonatal mortality to as low as 12 deaths per 1000 live births and under five mortality to levels as low as 25 deaths per 1000 live births (UN, 2020; WHO, 2019; UNICEF, 2018; UN, 2016; UN, 2015). As indicated by SDG-3 target 3.7.2, sexual and reproductive health programs should be part of health interventions to address adverse sexual and reproductive health outcomes being experienced around the world, more so in low and middle income countries (WHO, 2011). Previous studies revealed that the reduction of high fertility rates in the developing world through comprehensive family planning programs will have a positive impact on maternal and child health (Edward *et al.* 2022; Monari *et al.* 2022; Mutea *et al.* 2022; Ahinkorah *et al.* 2021; Sarder *et al.* 2021; Harrington *et al.* 2021). High fertility rates are associated with high mortality rates among teenage pregnant mothers and under five children. Offering comprehensive sexuality education among adolescents will improve increase their knowledge and help prevent unintended pregnancies. Teenage conception is a health concern both in developing and developed countries and requires governments to establish teenage pregnancy prevention programs that are well resourced to meet adolescent needs. According to World Bank, Eritrea continues to face the challenge of teenage pregnancy. The country reported a gradual decline in adolescent fertility from around 119 births per 1000 women aged 15-19 to around 47 births per 1000 women aged 15-49 years in 2020. This shows that the government still needs to implement new strategies to curb teenage pregnancy to prevent adverse pregnancy outcomes.

The aim of this paper is to model and forecast future trends of adolescent fertility rate for Eritrea using the double exponential smoothing technique. The findings are expected to depict future trends of adolescent fertility in the out of sample period. This is anticipated to facilitate policymaking, planning and allocation of resources to teenage pregnancy prevention programs in the country.

II. METHODOLOGY

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

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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 double exponential smoothing method is specified as follows:

Model equation

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

Smoothing equation

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

$0<\alpha<1$

Trend estimation equation

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

$0<\beta<1$

Forecasting equation

$f_{t+h} = L_t + \mathrm{h} b_t$

E_t is the actual value of 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 slope of the trend at time t

Data Issues

This study is based on annual adolescent fertility rate in Eritrea 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

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Table 1: ES model summary

Variable	E
Included Observations	61
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.200
Forecast performance measures	
Mean Absolute Error (MAE)	1.102165
Sum Square Error (SSE)	278.633974
Mean Square Error (MSE)	4.567770
Mean Percentage Error (MPE)	-0.029958
Mean Absolute Percentage Error (MAPE)	1.129928

Residual Analysis for the Applied Model

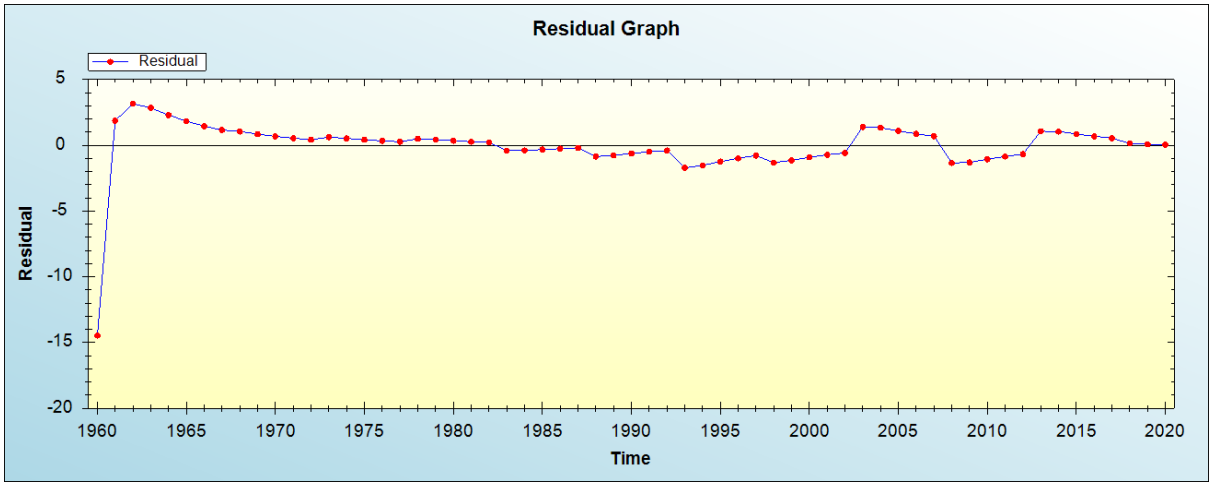

Figure 1: Residual analysis

In-sample Forecast for E

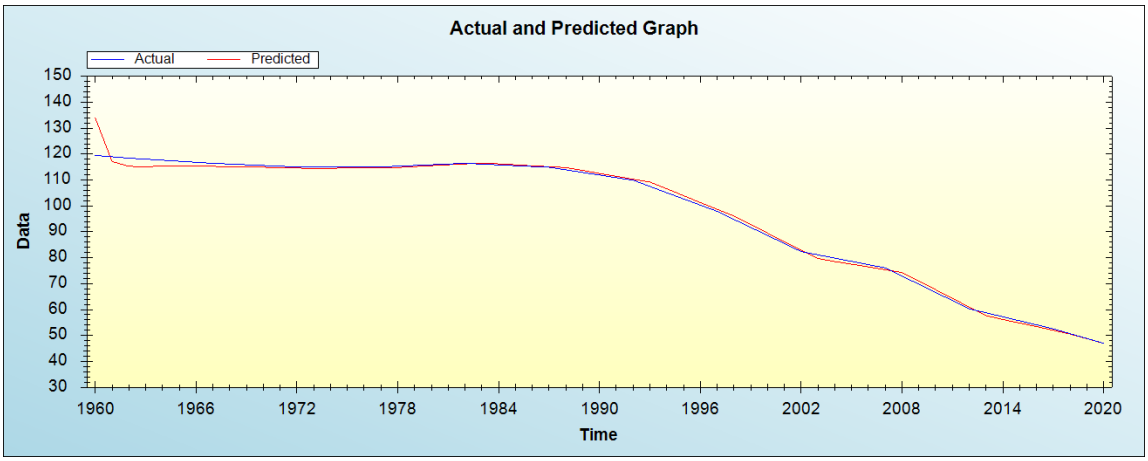

Figure 2: In-sample forecast for the E series

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Actual and Smoothed graph for E series

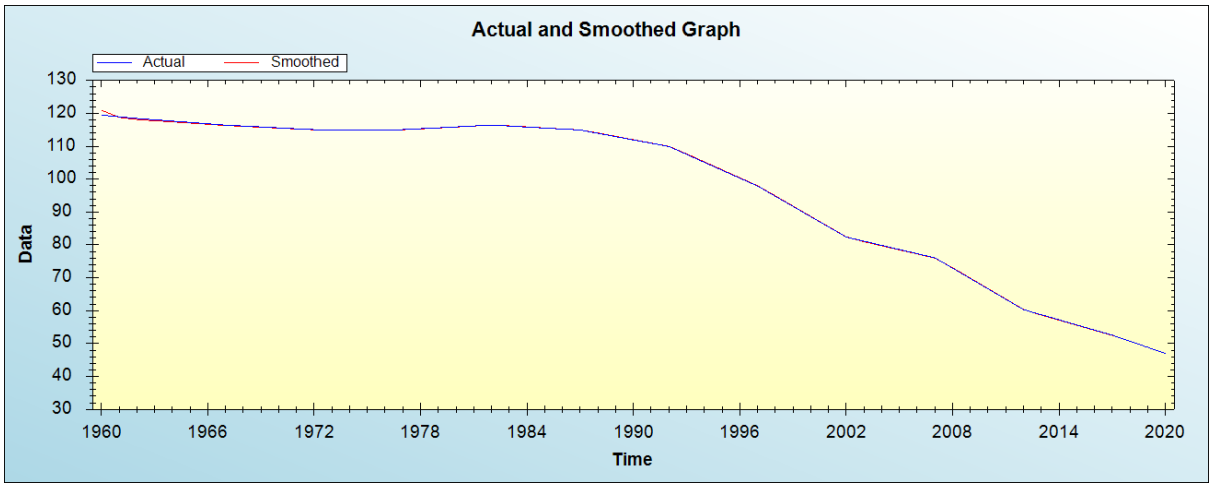

Figure 3: Actual and smoothed graph for E series

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

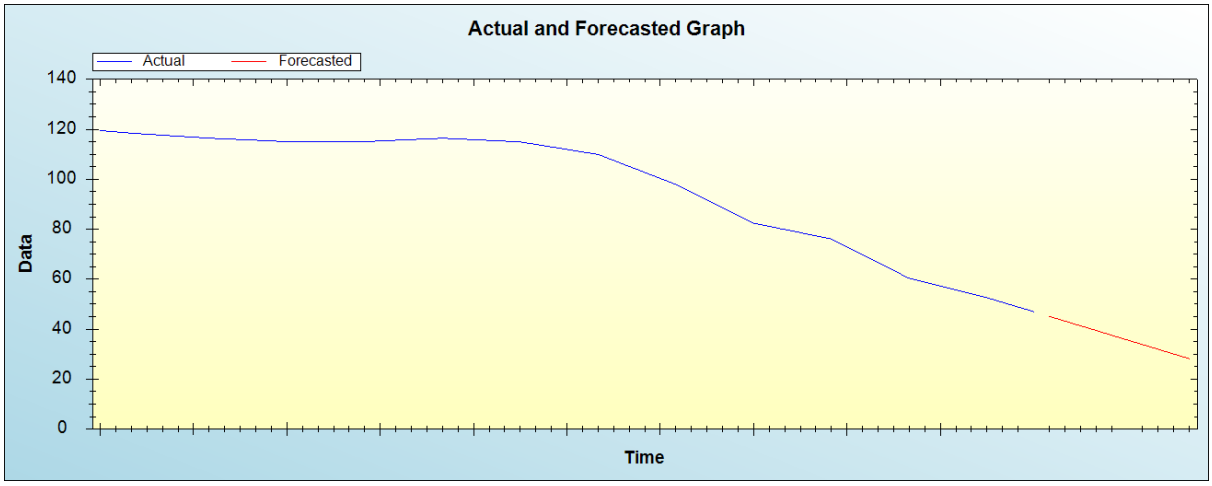

Figure 4: Out-of-sample forecast for E: actual and forecasted graph

Out-of-Sample Forecast for E: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Predicted adolescent fertility rate
2021	45.1135
2022	43.2295
2023	41.3455
2024	39.4615
2025	37.5775
2026	35.6935
2027	33.8095
2028	31.9255
2029	30.0415
2030	28.1575

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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 rate will continue to decline throughout the out of sample period.

IV. POLICY IMPLICATION & CONCLUSION

Eritrea continues to face the challenge of teenage pregnancy. The country reported a gradual decline in adolescent fertility from around 119 births per 1000 women aged 15-19 to around 47 births per 1000 women aged 15-49 years in 2020. This shows that the government still needs to implement new strategies to curb teenage pregnancy to prevent adverse pregnancy outcomes. This study applied Holt's double exponential smoothing technique to forecast adolescent fertility for Eritrea. Our results indicated that adolescent fertility will continue to decline throughout the out of sample period. Therefore, we encourage the government to address several factors that contribute to adolescent pregnancies that include socio-cultural, economic and geographic factors.

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