Adolescent Fertility Forecasting for South Africa Using Holt's Linear Method

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Abstract - **This study uses annual time series data of adolescent fertility rate for the Republic of South Africa 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 rate will continue to decline throughout the out of sample period. Therefore, we encourage authorities in South Africa to scale up educational campaigns, protect sexual and reproductive rights for women and girls, promote girl child education and provide accessible affordable adolescent healthcare services.**

Keywords: Exponential smoothing, Forecasting, adolescent fertility rate.

I. INTRODUCTION

The average global birth rate among adolescents is 49 per 1,000 girls, with Sub-Saharan Africa on the forefront with an adolescent birth rate around 120 per 1,000 girls (UN, 2011). Worldwide, approximately 16 million adolescent girls aged 15 to 19 give birth every year and about 2.5 million of these births occur to girls below 16 years of age in LMICs each year (WHO, 2016; Neal*et al.* 2012). Teenage pregnancy and child birth carry bigger risks of mortality and morbidity among adolescents. The significant risks associated with adolescent pregnancy include preterm births, hypertensive disorders, anemia, poor nutritional status, repeat pregnancy and psychosocial issues such as stress, depression and anxiety (Michaels-Igbokwe *et al*. 2015; Ickovics *et al.* 2011; WHO, 2007). Studies conducted in South Africa revealed that teenage pregnancy is driven by factors such as poverty, gender inequalities, gender-based violence, substance abuse, poor access to contraceptives and issues with termination of pregnancy; low, inconsistent and incorrect use of contraceptives, limited number of healthcare practitioners and healthcare facilities, poor healthcare workers' attitudes and behavior, and inadequate sexual and reproductive health (SRH) information (Bhana *et al.* 2010; Mkhwananzi, 2010; Jewkes*et al.* 2009; Bearinger *et al.* 2007; Chigona & Chetty, 2007; Pettifor *et al.* 2005; Eaton*et al.* 2003; Vundule*et al.* 2001). Other than, healthcare systems related factors, adolescents in general tend to engage in risky behaviors including sexual activities that expose them to risks such as unwanted pregnancies, sexually transmitted infections (STI's), and HIV (Atuyamb e*et al.* 2015). Several previous studies on teenage pregnancy conducted in South Africa have highlighted the increase risk of occurrence of adverse maternal and child health outcomes among teenagers (Du Preez*et al.* 2019; Maxwell*et al.* 2016; Thobejane, 2015).

This paper applied Holt's double exponential smoothing technique to forecast future trends of adolescent fertility for South Africa. The findings of this piece of work are expected to depict the future burden of adolescent fertility in the out of sample period and assist authorities in this country to review the current legal and policy framework with an objective of identifying and addressing gaps which lead to teenage pregnancies. This will provide guidance for planning and resource allocation towards programs that are designed to end child marriages and protect sexual and reproductive health rights of women.

II. METHODOLOGY

This study utilizes an exponential smoothing technique to model and forecast future trends of adolescent fertility rate in South Africa. 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 double exponential smoothing method is specified as follows:

Model equation

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

Smoothing equation

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

$0 < \alpha < 1$

Trend estimation equation

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

$0 < \beta < 1$

Forecasting equation

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

K_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

Data Issues

This study is based on annual adolescent fertility rate in South Africa 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	K
Included Observations	61
Smoothing constants	

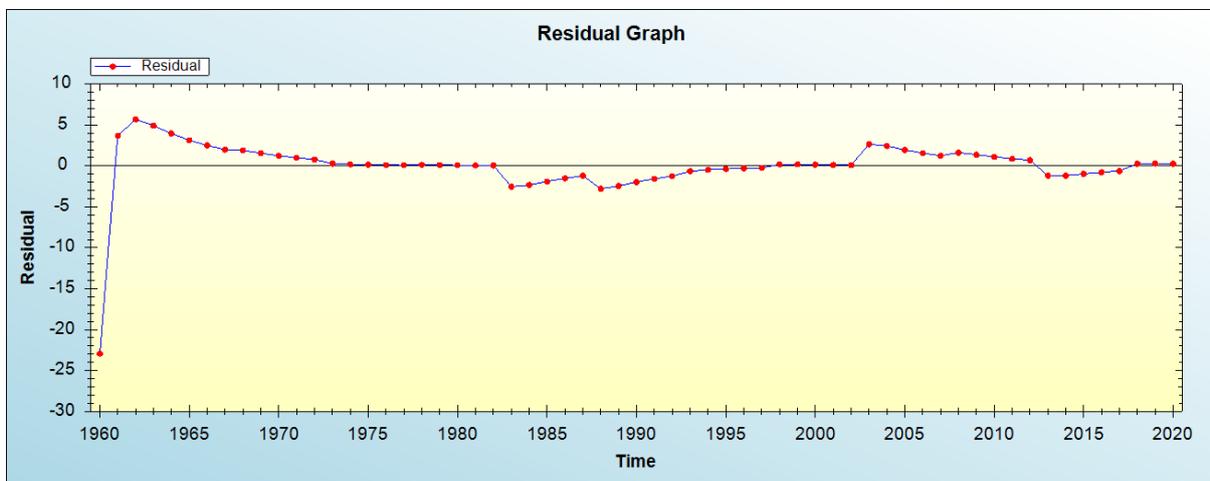| Alpha (α) for data	0.900
Beta (β) for trend	0.200
Forecast performance measures	
Mean Absolute Error (MAE)	1.641034
Sum Square Error (SSE)	716.463381
Mean Square Error (MSE)	11.745301
Mean Percentage Error (MPE)	0.121513
Mean Absolute Percentage Error (MAPE)	1.995717

Residual Analysis for the Applied Model

Figure 1: Residual analysis

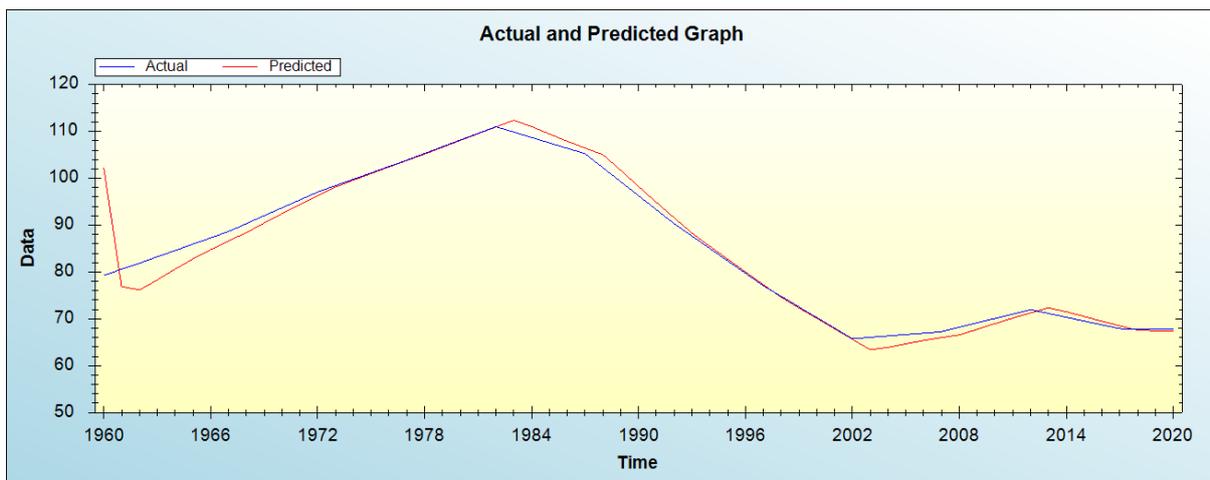In-sample Forecast for K

Figure 2: In-sample forecast for the K series
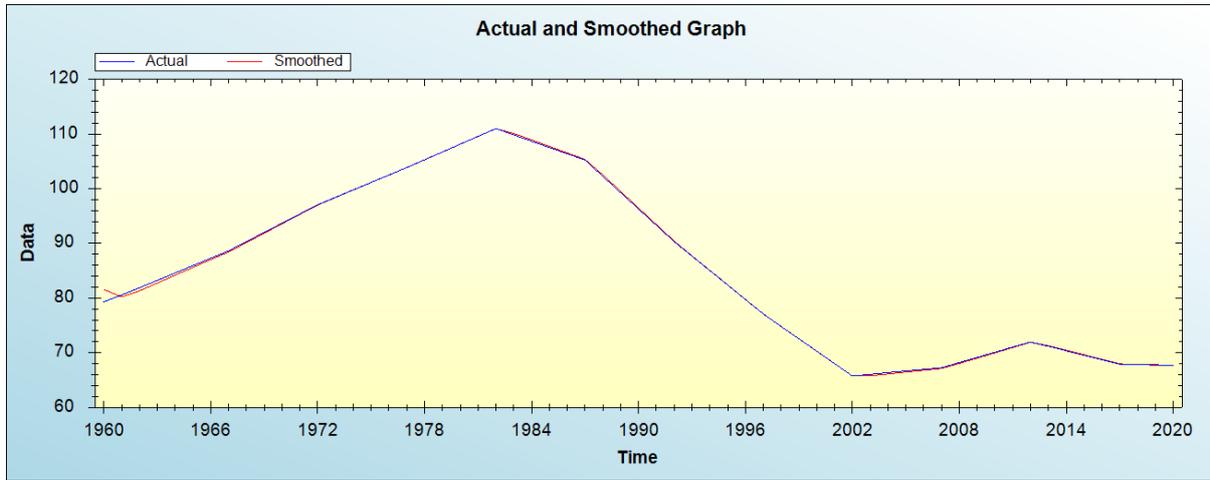
Actual and Smoothed graph for K series

Figure 3: Actual and smoothed graph for K series

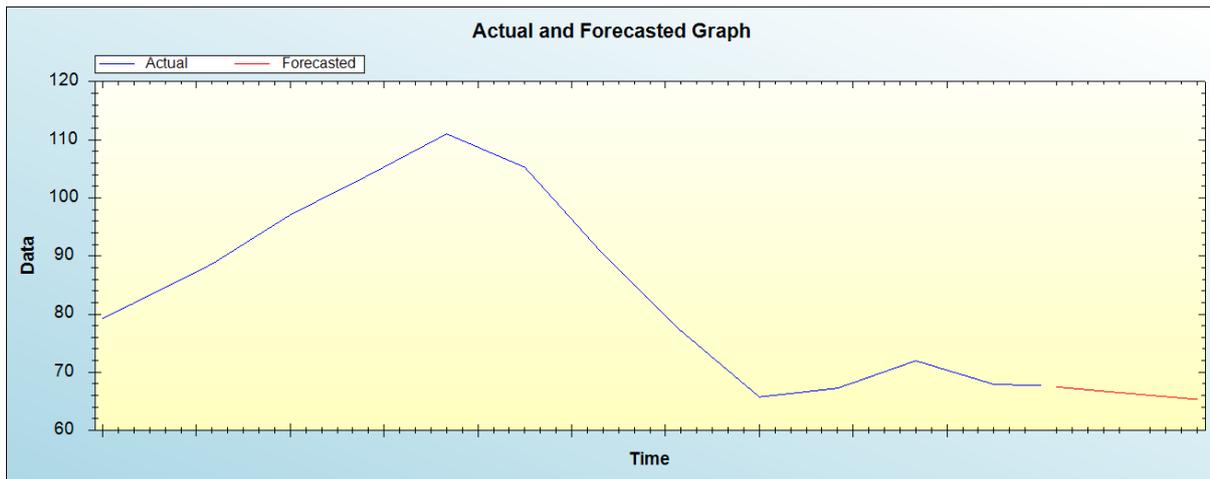Out-of-Sample Forecast for K: Actual and Forecasted Graph

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

Out-of-Sample Forecast for K: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted adolescent fertility rate
2021	67.4652
2022	67.2257
2023	66.9863
2024	66.7468
2025	66.5073
2026	66.2679
2027	66.0284
2028	65.7889
2029	65.5495
2030	65.3100

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 drop throughout the out of sample period.

IV. POLICY IMPLICATION & CONCLUSION

As revealed by the World Bank, adolescent fertility has been steadily declining in South Africa from 111 births per 1000 women aged 15-19 years in 1982 to 67 births per 1000 women aged 15-19 in 2020. Risk factors for teenage pregnancy in South Africa are poverty, gender inequalities, gender-based violence, substance abuse, poor access to contraceptives and issues with termination of pregnancy; low, inconsistent and incorrect use of contraceptives, limited number of healthcare practitioners and healthcare facilities, poor healthcare workers' attitudes and behavior, and inadequate sexual and reproductive health (SRH) information. This study proposed Holt's double exponential smoothing technique to forecast future trends of adolescent fertility for South Africa. Our study findings suggested that adolescent fertility will continue to decline throughout the out of sample period. Hence, we encourage the South African government to scale up educational campaigns, protect sexual and reproductive rights for women and girls, promote girl child education and provide accessible affordable adolescent healthcare services.

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Citation of this Article:

Smartson. P. NYONI, Thabani NYONI, "Adolescent Fertility Forecasting for South Africa Using Holt's Linear Method" Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 7, Issue 2, pp 361-366, February 2023. Article DOI https://doi.org/10.47001/IRJIET/2022.702060

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