Estimating The Future Burden of Adolescent Fertility for China Using Holt's Double Exponential Smoothing Technique

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Abstract - **This study uses annual time series data of adolescent fertility rate for China 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 are0.9 and0.3 respectively based on minimum MSE. The results of the study indicate that annual adolescent fertility will remain below 10 births per 1000 women aged 15-19 years throughout the out of sample period. Therefore, we implore Chinese authorities to prioritize adolescent health in marginalized communities where there are challenges in accessing sexual and reproductive health services.**

Keywords: Exponential smoothing, Forecasting, adolescent fertility rate.

I. INTRODUCTION

Falling pregnant during the adolescent stage is an embarrassing thing in many African societies, therefore many pregnant adolescents encounter mental trauma, get expelled from school, and experience social rejection (Croft *et al*.2018; UNIFPA, 2016;Chalasani*et al*.2013; Muula, 2008). The magnitude of mental trauma experienced by pregnant teenagers is sometimes unbearable leading to major depression. The resultant adverse pregnancy outcomes can be long term (Nguyen *et al*.2019; Woog & Kagesten, 2017; Kaphagawani & Kalipeni 2017;Neal *et al.* 2016;Patton *et al*.2016; de Onis & Branca, 2016;Azevedo*et al*.2015; Margret, 2015;Okigbo CC., & Speizer, 2015;Tebeu*et al*.2012; WHO, 2007;Larsson*et al*. 2002). Several previous studies revealed that being sexually active at an early age, early marriage, older teenage, married women, educational attainment, age at 1st sex, household wealth, family structure, exposure to media, community poverty level, and contraceptive use are significantly associated with adolescent pregnancy (Birhanu *et al*.2019;Wado*et al*.2019; Brahmbhatt *et al*.2014). Studies conducted in China revealed that risk factors such as the marriage market, common-law marriage, and unprotected sex greatly influence adolescent pregnancy (Luo *et al.* 2020; Yu *et al*.2019; Li *et al*.2013). According to the World Bank, adolescent fertility in China gradually declined from 68 births per 1000 women aged 15-19 in 1960 to 7.66 births per 1000 women in 2020. This indicates that there has been significant progress made in the reduction of teenage pregnancy in the country, however there is need to end all child marriages and teen pregnancy to avert adverse maternal and child health outcomes.

The aim of this paper is to model and forecast adolescent fertility for China using Holt's double exponential smoothing technique. Findings of this paper will depict the future burden of adolescent fertility in the out of sample period. This will inform family planning policy, planning and allocation of adequate resources to teenage pregnancy prevention.

II. METHODOLOGY

This study utilizes an exponential smoothing technique to model and forecast future trends of adolescent fertility rate in 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 represented as follows:

Model equation

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

Smoothing equation

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

$0 < \alpha < 1$

Trend estimation equation

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

$0 < \beta < 1$

Forecasting equation

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

A_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 trend estimate at time period t-1

Data Issues

This study is based on annual adolescent fertility rate in China 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	A
Included Observations	61
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.300

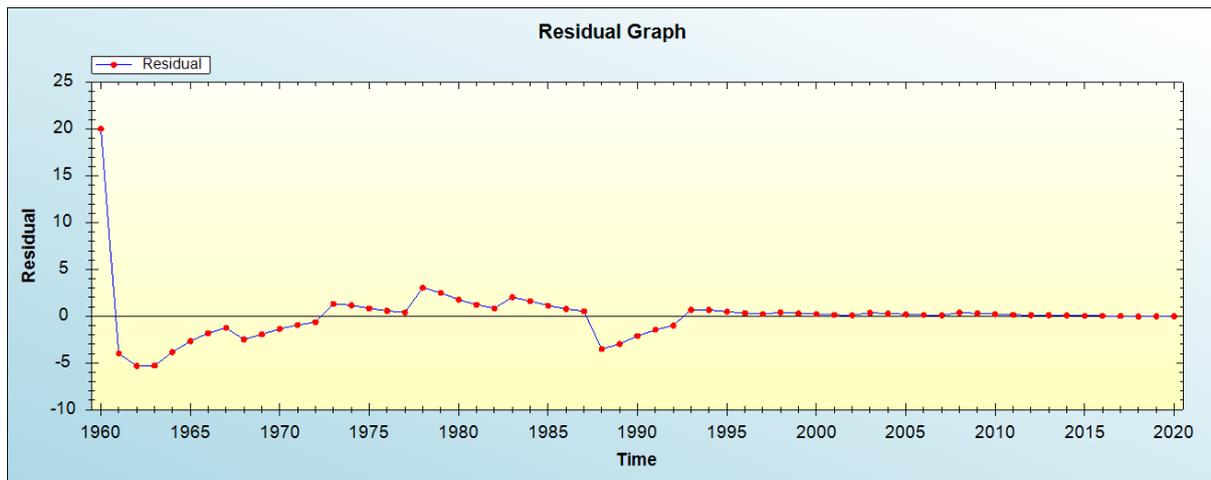| Forecast performance measures	
Mean Absolute Error (MAE)	1.451756
Sum Square Error (SSE)	579.022175
Mean Square Error (MSE)	9.492167
Mean Percentage Error (MPE)	1.301629
Mean Absolute Percentage Error (MAPE)	4.942949

Residual Analysis for the Applied Model

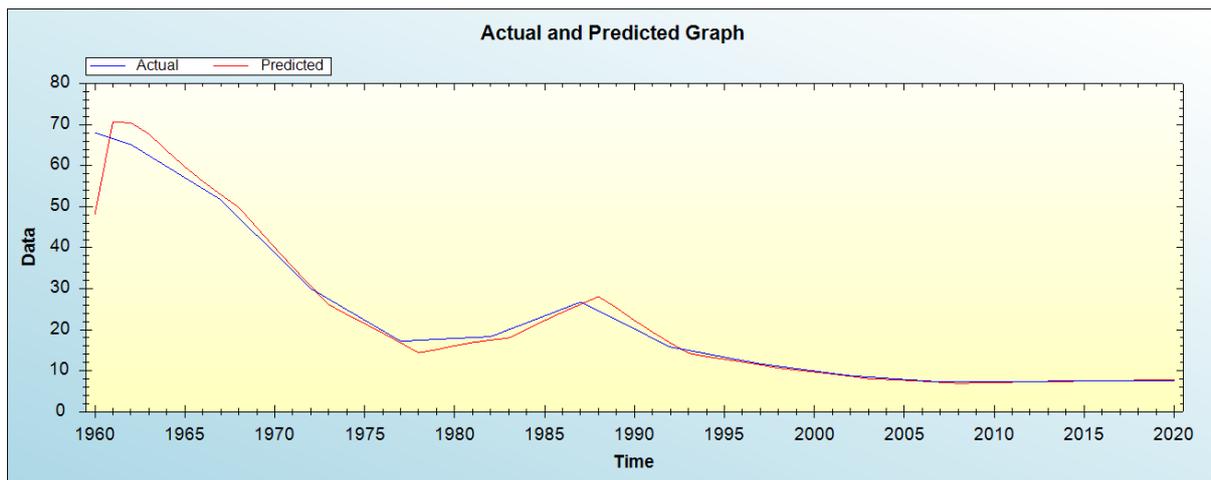Figure 1: Residual analysis

In-sample Forecast for A

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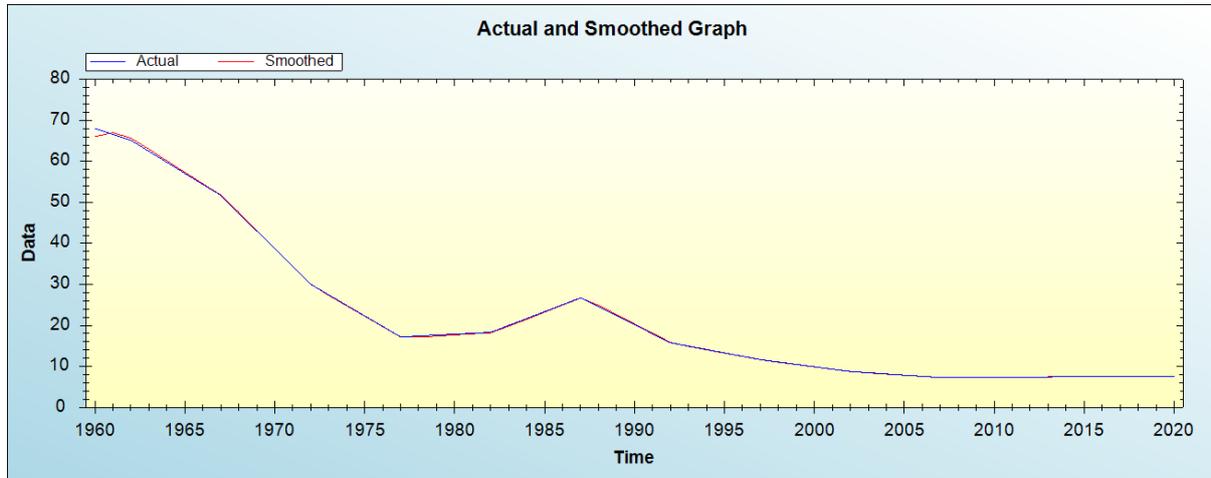
Actual and Smoothed graph for A series

Figure 3: Actual and smoothed graph for A series

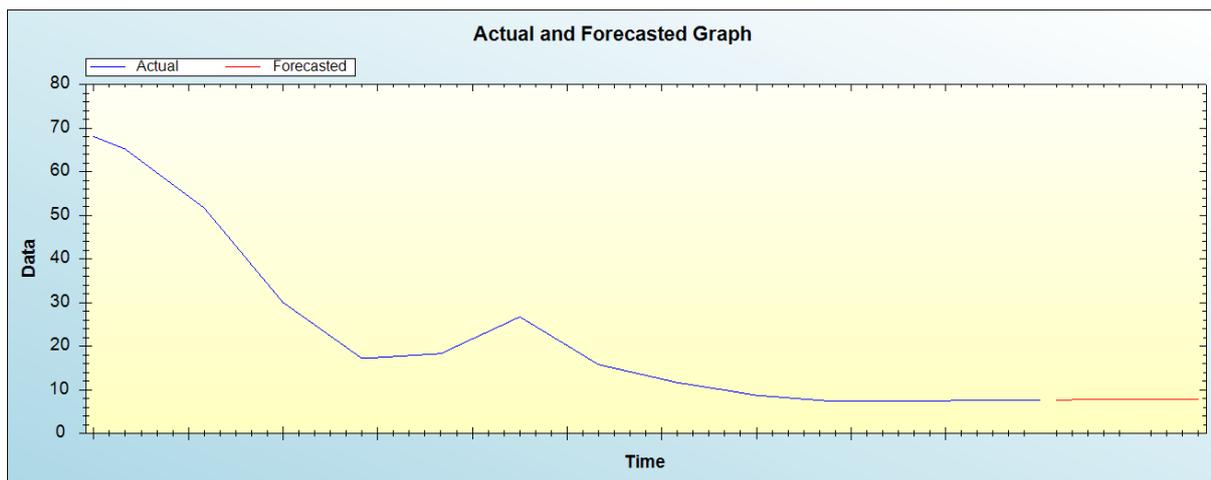Out-of-Sample Forecast for A: Actual and Forecasted Graph

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

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted adolescent fertility rate
2021	7.6793
2022	7.6979
2023	7.7164
2024	7.7350
2025	7.7536
2026	7.7721
2027	7.7907
2028	7.8092
2029	7.8278
2030	7.8463

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 remain below 10 births per 1000 women aged 15-19 years throughout the out of sample period.

IV. POLICY IMPLICATION & CONCLUSION

In China risk factors such as the marriage market, common-law marriage, and unprotected sex greatly influence adolescent pregnancy. As revealed by the World Bank, adolescent fertility in China gradually declined from 68 births per 1000 women aged 15-19 in 1960 to 7.66 births per 1000 women in 2020. This shows that there has been significant progress made in the reduction of teenage pregnancy in the country, however there is need to end all child marriages and teen pregnancy to avert adverse maternal and child health outcomes. This study applied Holt's double exponential smoothing technique to predict future trends of adolescent fertility for China. Our study findings revealed that adolescent fertility will remain below 10 births per 1000 women aged 15-19 years throughout the out of sample period. Therefore, we encourage the Chinese government to prioritize adolescent health in marginalized communities where there are challenges in accessing sexual and reproductive health services.

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