

Using Holt's Linear Method to Calculate Anticipated Future Values of Annual Adolescent Fertility Rate to Inform Adolescent Health Initiatives in Zimbabwe

¹Dr. Smartson. P. NYONI, ²Thabani NYONI

¹ZICHIRE Project, University of Zimbabwe, Harare, Zimbabwe

²Independent Researcher & Health Economist, Harare, Zimbabwe

Abstract - Teenage conception remains a huge public health problem in Sub-Saharan Africa of which Zimbabwe is no exception. Child marriages, poverty, lack of education, peer pressure, poor parenting and social media influence are among the top drivers of adolescent pregnancy. This empirical research uses annual time series data of adolescent fertility rate for Zimbabwe from 1960 to 2020 to predict future trends of adolescent fertility over the period 2021 to 2030. Holt's linear method (HLM) was employed with optimal values of smoothing constants α and β being 0.9 and 0.8 respectively based on minimum MSE. The results of the study indicate that adolescent fertility will decline from approximately 75 births per 1000 women aged 15-19 years in 2021 down to around 50 births per 1000 women aged 15-19 years by the end of 2030. Therefore, there is need for authorities in Zimbabwe to continuously support girl child education, enforce laws that protect women's rights, address factors that significantly contribute to high teenage pregnancies, ensure availability of adolescent friendly facilities, increase financial support to youth empowerment programs and scale up campaigns against gender-based violence and early child marriages among communities.

Keywords: Exponential smoothing, Forecasting, adolescent fertility rate, ASRH.

I. INTRODUCTION

The agenda 2030 for sustainable development is an outcome document that was written and signed by all UN member states in September 2015 at the UN Head Quarters. It contains 17 objectives (SDGs) which are attached to 169 targets. The purpose of this document was to address most of the challenges that affect our planet earth (UN, 2020; WHO, 2019; UNICEF, 2018; UN, 2016; UN, 2015). Ensuring health for all at every stage of life was among the major highlights of sustainable development goals. All UN member countries acknowledged that maternal and child mortality are important public health issues which require a unified global response. As stated by the document, all member states must strive to achieve set health and health-related targets by the end of 2030. The 3rd sustainable development goal is specifically designed to push member countries to achieve substantial reduction of maternal and child mortality by the end of 2030. Global maternal mortality ratio should decline to levels below 70 per 100 000 live births, under five mortality must be at least 25 deaths per 1000 live births and neonatal mortality should be at least 12 deaths per 1000 live births (UN, 2016; UN, 2015).

Sexual and reproductive health issues are recognized as an important pillar in the reduction of maternal and under-five mortality especially adolescent sexual and reproductive health (ASRH). Adolescent pregnancy and child birth is a huge public health problem both in developing and developed regions of the world (Grønvik & Fossgard, 2018; Pradhan *et al.* 2018; Sama *et al.* 2017). An estimated ninety five percent of teenage pregnancies occur in low-middle income countries with 36.4 million women becoming mothers before age 18 and 5.6 million having a live birth before age 15 in 2010 (Edilberto, 2013). It is well documented that pregnancy during the adolescent stage is associated with medical problems such as obstructed labour, obstetric hemorrhage, hypertensive disorders, anemia, psychological disorders and malnutrition in children born to teenage mothers (Merdad & Ali, 2018; Munakampe *et al.* 2018; Neal *et al.* 2018). In developing countries major drivers of adolescent pregnancy include poverty, lack of education, peer pressure, poor parental guidance, substance and drug abuse, and inadequate SRH information (Gunawardena *et al.* 2019; Magnusson *et al.* 2019; Kassa *et al.* 2018; Yakubu & Salisu, 2018).

In the case of Zimbabwe, the National Adolescent fertility study (2015) revealed that 58.4 percent of adolescent pregnancies are associated with cultural practices such as forced / early teenage marriage, traditional cleansing, wife pledging and Human Immunodeficiency Virus (HIV) cleansing (Naomi, 2016). In Zimbabwe there has been a combined effort in trying to improve adolescent sexual and reproductive health (Agency ZNS, 2011). There are initiatives such as condom distribution in

schools, access to free family planning services and awareness campaigns conducted by health care workers (Mudonhiet *al.* 2019; Naomi, 2016). Although these services are available barriers such as religion, culture and adolescent unfriendly health institutions have hampered access to these services by adolescents (Langhaug *et al.* 2003). In addition, it has been observed that adolescents in areas that mostly depend on indigenous health systems and practice cultural initiations usually report higher prevalence of STIs and teenage pregnancy(Naomi, 2016).The purpose of this research is to model and forecast adolescent fertility for Zimbabwe using the double exponential smoothing technique (HLM) because it is suitable for modelling linear data with a trend component. This is anticipated to provide an insight of expected future trends of adolescent births in the country that will guide adolescent health policy making, planning and resource allocation to teenage pregnancy prevention programs.

II. LITERATURE REVIEW

Author (s)	Topic	Objectives	Methodology	Main findings
Monari et al. (2022)	Adolescent fertility and its determinants in Kenya: Evidence from Kenya demographic and health survey 2014	To establish determinants of adolescent fertility in Kenya.	Chi square test	age at first sex, current age, marital status, and contraceptive use are the main determinants of adolescent childbearing
Mutea et al. (2022)	Trends and determinants of adolescent pregnancy: Results from Kenya demographic health surveys 2003–2014	To analyze the trends in prevalence and factors associated with adolescent pregnancy in Kenya using data from three national Demographic Health Surveys (2003, 2008/2009, and 2014).	Binary Logistic regression and pooled regression analysis were used to explore factors associated with adolescent pregnancy.	Education status, marital status, religion and wealth quintile were associated with adolescent pregnancy. Trend analysis shows that there was an overall decreasing trend in adolescent pregnancy between 2003 and 2014.
Seidu (2021)	Factors associated with early antenatal care attendance among women in Papua New Guinea: a population- based cross- sectional study	to assess the prevalence and factors associated with early initiation of ANC among women in Papua New Guinea (PNG	population-based cross-sectional study	The study found a relatively low prevalence of early ANC uptake among women in PNG. The factors associated with early ANC attendance were region of residence, parity, and working status of mothers.
Riley et al. (2020)	Estimating abortion incidence and unintended pregnancy among adolescents in Zimbabwe, 2016: a cross- sectional study	To estimate age-specific abortion incidence and unintended pregnancy in Zimbabwe, and to examine differences among adolescents	a cross- sectional study -an indirect estimation approach, to estimate age-specific abortion incidence	Adolescent women aged 15–19 years had the lowest abortion rate at five abortions per 1000 women aged 15–19 years compared with other age

		by marital status and residence.		groups. Adolescents living in urban areas had a higher abortion ratio compared with adolescents in rural areas, and unmarried adolescent women had a higher abortion ratio compared with married adolescent
Nunu et al. (2020)	Strategies to facilitate safe sexual practices in adolescents through integrated health systems in selected districts of Zimbabwe: a mixed method study protocol	To develop strategies that will facilitate the integration of IHSs and MHS in Mberengwa and Umguza districts.	mixed methods design with both qualitative and quantitative approaches	Most programmes on sexual health have ignored the role of IHSs and MHSs in influencing safe sexual practices leading to them failing to attain desired goals

III. METHODOLOGY

This study utilizes an exponential smoothing technique to model and forecast future trends of adolescent fertility in Zimbabwe. 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 (**HLM**) because it is an appropriate technique for modeling linear data.

Holt’s linear method is specified as follows:

Model equation

$$X_t = \mu_t + \rho_t t + \varepsilon_t \dots \dots \dots [1]$$

Smoothing equation

$$L_t = \alpha X_t + (1-\alpha)(L_{t-1} + b_{t-1}) \dots \dots \dots [2]$$

$$0 < \alpha < 1$$

Trend estimation equation

$$b_t = \beta (L_t - L_{t-1}) + (1-\beta)b_{t-1} \dots \dots \dots [3]$$

$$0 < \beta < 1$$

Forecasting equation

$$f_{t+h} = L_t + hb_t \dots \dots \dots [4]$$

X_t is the 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 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 slope of the trend at time t

b_{t-1} is the slope of the trend at time period t-1

Data Issues

This study is based on annual adolescent fertility rate in Zimbabwe 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.

IV. FINDINGS OF THE STUDY

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	X
Included Observations	61
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.800
Forecast performance measures	
Mean Absolute Error (MAE)	1.045371
Sum Square Error (SSE)	318.905028
Mean Square Error (MSE)	5.227951
Mean Percentage Error (MPE)	0.021248
Mean Absolute Percentage Error (MAPE)	0.782397

Residual Analysis for the Applied Model

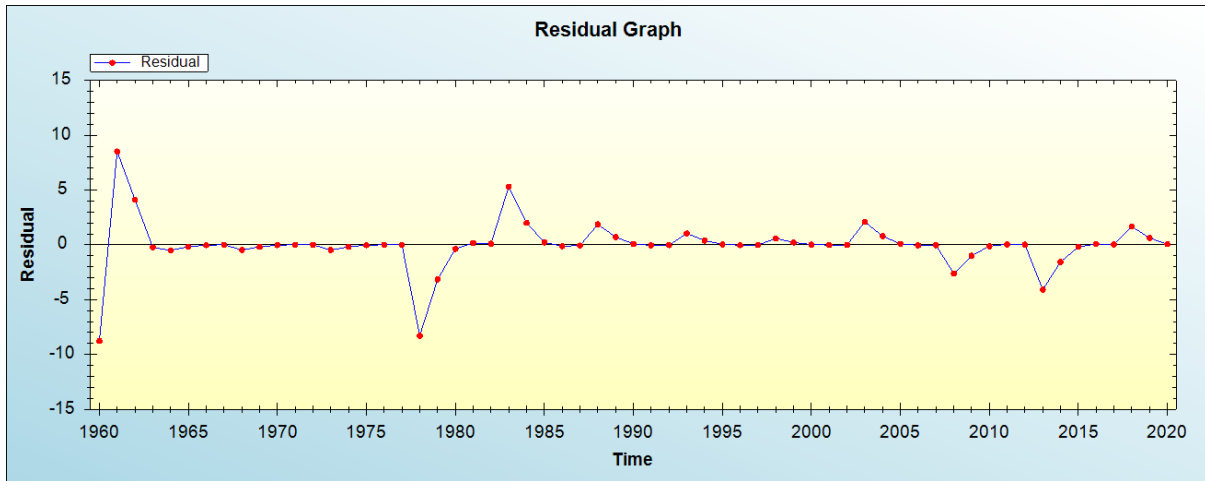


Figure 1: Residual analysis

In-sample Forecast for X

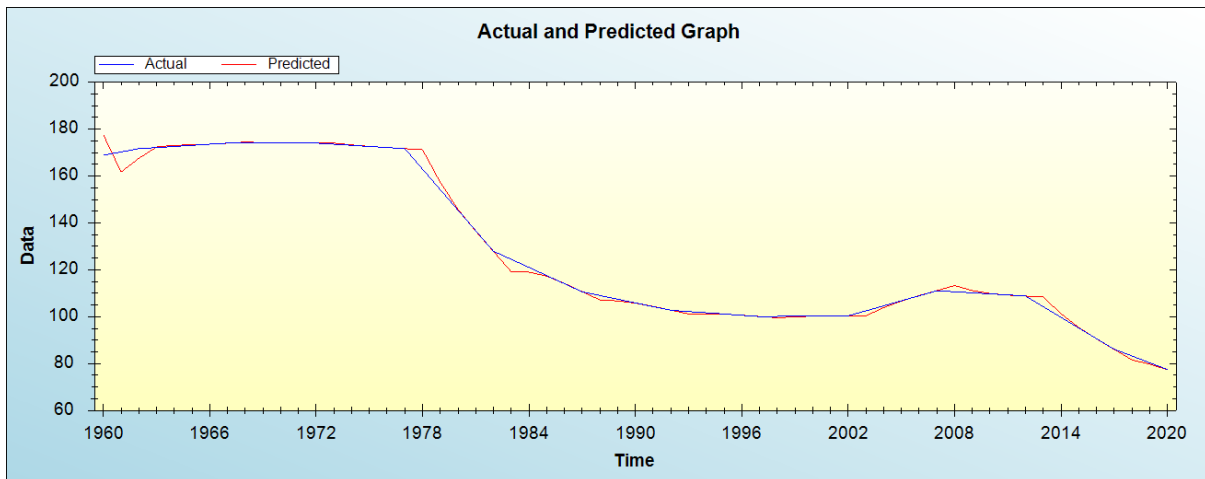


Figure 2: In-sample forecast for the X series

Actual and Smoothed graph for X series

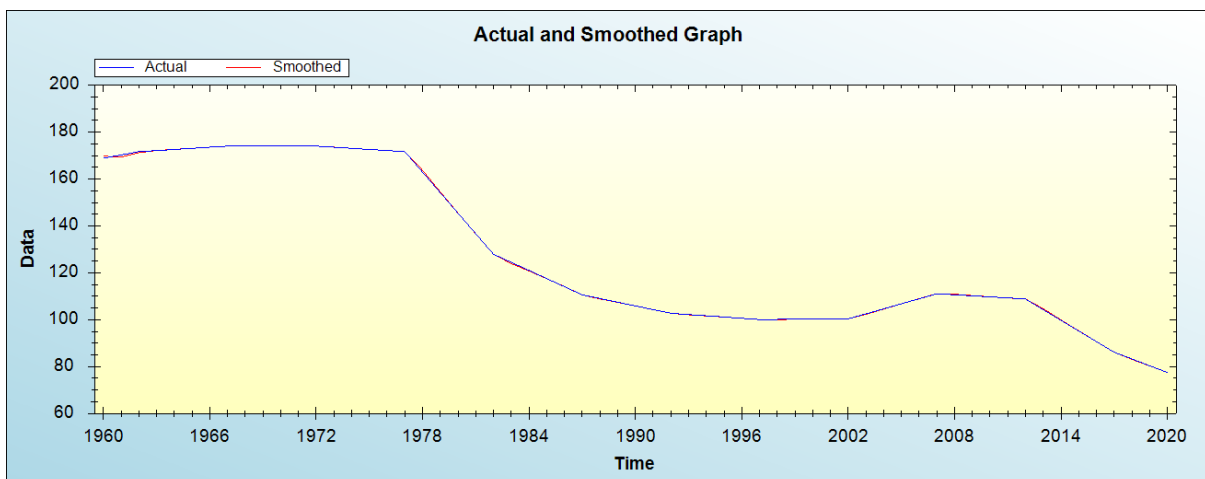


Figure 3: Actual and smoothed graph for X series

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

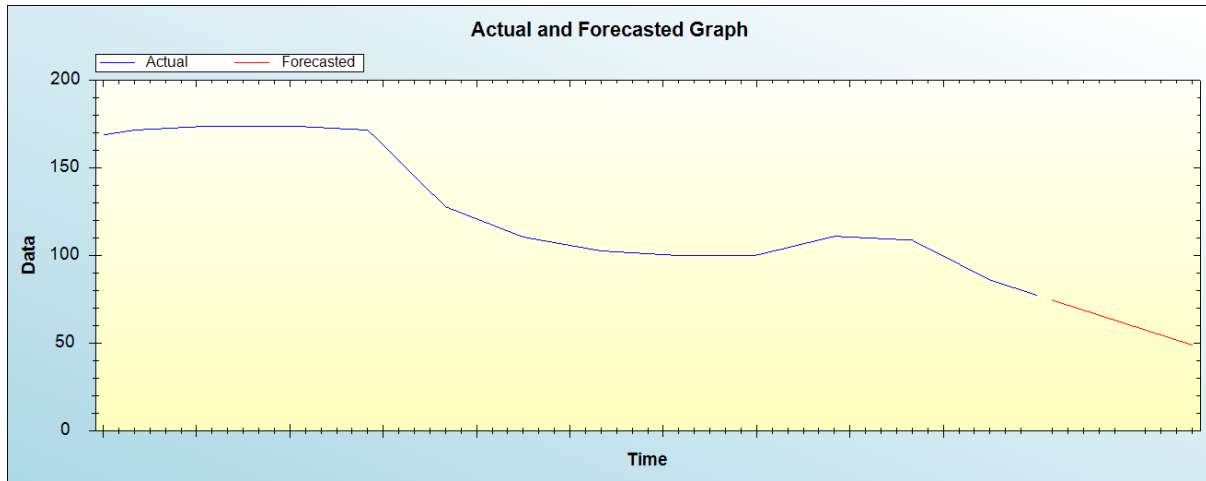


Figure 4: Out-of-sample forecast for X: actual and forecasted graph

Out-of-Sample Forecast for X: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted adolescent fertility rate
2021	74.6248
2022	71.7811
2023	68.9373
2024	66.0935
2025	63.2497
2026	60.4060
2027	57.5622
2028	54.7184
2029	51.8746
2030	49.0309

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 gradually from approximately 75 to around 50 births per 1000 women aged 15-19 years by the end of 2030.

V. POLICY IMPLICATION & CONCLUSION

Use of statistical techniques for early detection of future trends of different health phenomena remains an important part of public health programming. Exponential smoothing models have gained prominence in time series forecasting because they can be easily applied in any field and forecast results are accurate and reliable. This study applied Holt’s Linear Method (HLM) to predict future trends of adolescent fertility for Zimbabwe using historical time series data on adolescent fertility rate from 1960-2020. Forecast results revealed that adolescent fertility is expected to decline from approximately 75 births per 1000 women aged 15-19 years in 2021 down to around 50 births per 1000 women aged 15-19 years by the end of 2030. Authorities in this country are therefore encouraged to continuously support girl child education, strictly enforce laws that protect women’s rights, address local factors that significantly contribute to high teenage pregnancies, ensure availability of adolescent friendly health facilities, increase financial support to youth empowerment programs and scale up campaigns against gender-based violence and early child marriages among communities.

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Citation of this Article:

Dr. Smartson. P. NYONI, Thabani NYONI, “Using Holt’s Linear Method to Calculate Anticipated Future Values of Annual Adolescent Fertility Rate to Inform Adolescent Health Initiatives in Zimbabwe” Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 7, Issue 8, pp 534-541, August 2023. Article DOI <https://doi.org/10.47001/IRJIET/2023.708077>
