Demonstrating the Suitability of Holt's Double Exponential Smoothing Technique in Forecasting Adolescent Fertility for the State of Israel

[1]Smartson. P. NYONI, [2]Thabani NYONI

[1]ZICHIRe Project, University of Zimbabwe, Harare, Zimbabwe
[2]Independent Researcher & Health Economist, Harare, Zimbabwe

Abstract - **This research article uses annual time series data of adolescent fertility rate for the State of Israel 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 0.4 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 Israel to address all the factors that contribute significantly to adolescent fertility including socio-cultural, economic and demographic factors**.

Keywords: Exponential smoothing, Forecasting, adolescent fertility rate.

I. INTRODUCTION

Maternal and child mortality is a common problem mainly affecting developing countries in Sub-Saharan Africa and South Asia region (WHO, 2017; Mayor, 2004). Death of pregnant mothers and their newborn babies is totally unacceptable in this era of sustainable development goals. It is very important for UN member countries to allocate appropriate and adequate resources to maternal and child health programs with specific attention being given to low and middle income countries. High maternal mortality rates in developing regions are due to several factors that can be maternal, proximate and health system related. Teenage conception is a global issue of concern because of accompanying complications such as maternal & perinatal morbidity and mortality (Santelli *et al.* 2017; Lee *et al.* 2016; Cavazos-Rehg et al. 2015;Kost & Lindberg, 2015; Chandra-Mouli *et al.* 2014;Nove *et al.* 2014;WHO, 2014;Ezegwui*et al.* 2012;Raj *et al.* 2010). It refers to the conception that occurs between the ages 10-19 (Ganchimeg *et al.* 2014; United Nations Population Fund, 2013). This period is a complex stage in life because it is the phase when important decisions are made (Ajala, 2014). Extensive literature has shown that teenagers who engage in early unprotected sexual intercourse are at risk of STIs, HIV, unintended pregnancy and unsafe abortions (Magnusson *et al.* 2019; Lara & Abdo, 2016; Peltzer & Pengpid, 2015; Pettifor *et al.* 2009). Adverse SRH outcomes cannot be over emphasized. Premature loss of precious lives has negative consequences on the family and the society. Besides obstetric complications, long term psychological disorders have been reported in previous studies (Karataşl*et al.* 2019; Ogawa *et al.* 2019; Hodgkinson *et al.* 2014). A wide range of factors contribute to the high rates of unintended pregnancy and unplanned births among teenagers; poor knowledge of sexual and reproductive health services, legal barriers to accessing services, provider bias, stigma around premarital sex and lower decision making autonomy of married teenagers are among the factors contributing to unintended pregnancies (Bain *et al.*2020; WHO, 2020; Geda, 2019; Wado *et al.* 2019). The State of Israel has made significant progress towards reduction of maternal and under five mortality over the past decades. World Bank reports have revealed that adolescent fertility has also declined drastically to levels below 10 births per 1000 women aged 15-19 by 2020 reflecting improvements in education, increase in contraceptive prevalence and knowledge of sexual and reproductive health knowledge among adolescents.

The objective of this research is to model and forecast future trends of adolescent fertility for the State of Israel using Holt's double exponential smoothing technique. Findings of this piece of work are going to depict the future burden of adolescent births in the out of sample period. This will inform national policies, 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 Israel. 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

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

Smoothing equation

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

$0 < \alpha < 1$

Trend estimation equation

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

$0 < \beta < 1$

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**

$\mathbf{t}$ 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 the State of Israel 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	0.400
Forecast performance measures	
Mean Absolute Error (MAE)	0.536937
Sum Square Error (SSE)	79.137123
Mean Square Error (MSE)	1.297330
Mean Percentage Error (MPE)	0.172711
Mean Absolute Percentage Error (MAPE)	1.499736

Residual Analysis for the Applied Model
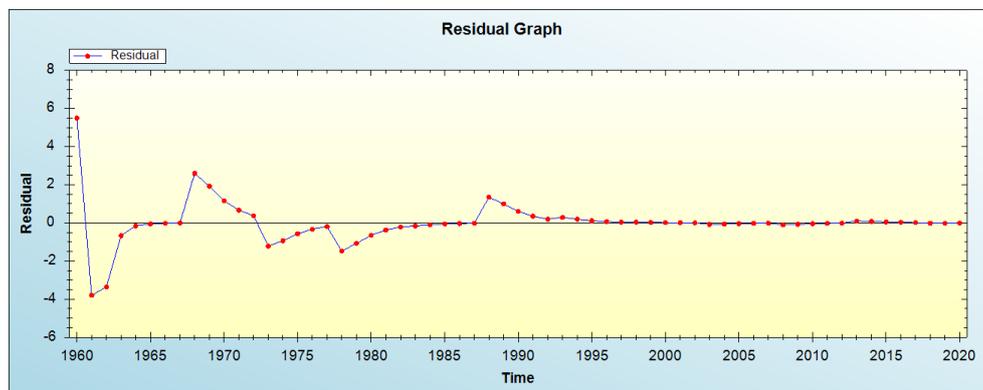
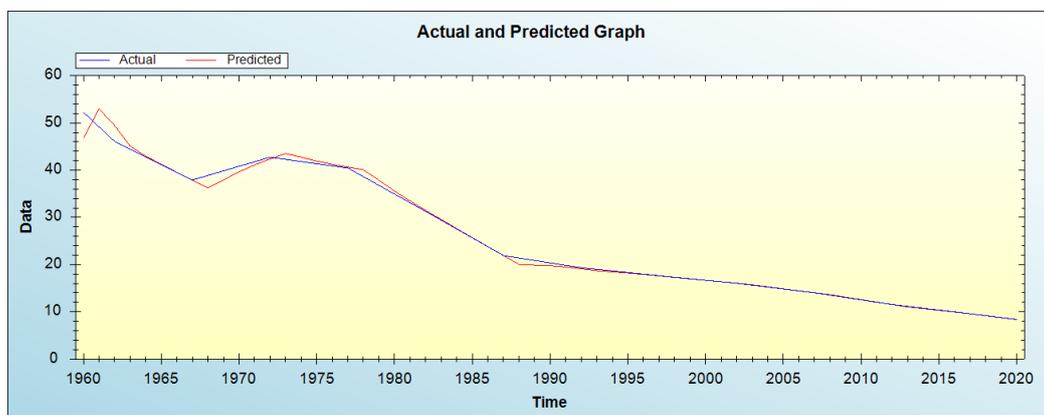Figure 1: Residual analysis

In-sample Forecast for A

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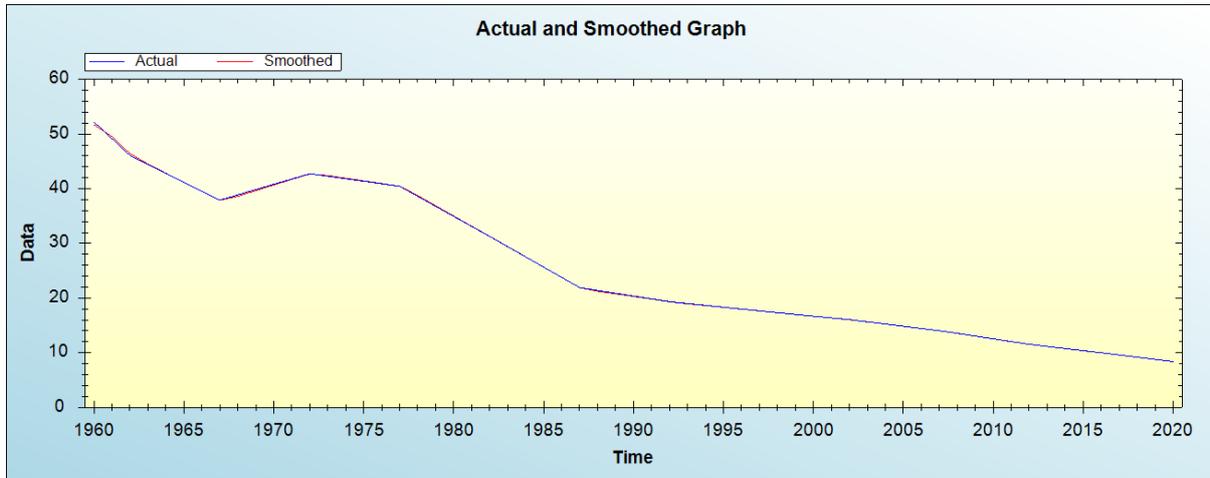
Actual and Smoothed graph for A series

Figure 3: Actual and smoothed graph for A series

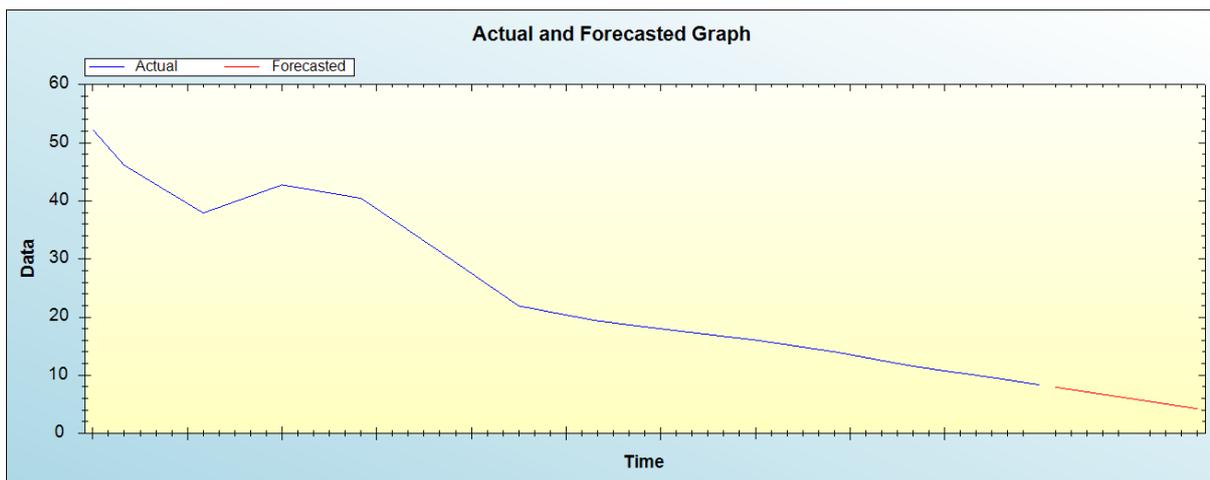Out-of-Sample Forecast for A: Actual and Forecasted Graph

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	Predicted adolescent fertility rate
2021	7.9526
2022	7.5422
2023	7.1319
2024	6.7215
2025	6.3111
2026	5.9008
2027	5.4904
2028	5.0800
2029	4.6697
2030	4.2593

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

The State of Israel has made tremendous progress towards the reduction of maternal and child mortality over the previous decades. Adolescent fertility dropped drastically to levels below 10 births per 1000 women aged 15-19years by 2020 indicating improvements in the education sector, increase in contraceptive prevalence and knowledge of sexual and reproductive health knowledge among adolescents. This study applied the double exponential smoothing technique to forecast future trends of adolescent fertility for the State Israel. Our study results showed that adolescent fertility will continue to decline throughout the out of sample period. Therefore, we encourage the government to address all the factors that contribute significantly to adolescent fertility including socio-cultural, economic and demographic factors.

REFERENCES

[1] Kost K., and Lindberg L (2015). Pregnancy intentions, maternal behaviors, and infant health: investigating relationships with new measures and propensity score analysis. Demography. 2015;52(1):83–111

[2] WHO. Adolescents: Health Risks and Solutions. Geneva: World Health Organization; 2017. Available from: http://www.who.int/mediacentre/ factsheets/fs345/en/.

[3] Ganchimeg T., Ota E., Morisaki N., Laopaiboon M., Lumbiganon P., and Zhang J (2014). Pregnancy and childbirth outcomes among adolescent mothers: a World Health Organization multicounty study. BJOG. 121(Suppl1):40–8. https://doi.org/10.1111/1471-0528.12630 PubMed PMID: 24641534.

[4] Mayor S (2004). Pregnancy and childbirth are leading causes of death in teenage girls in developing countries. BMJ. 328(7449):1152.

[5] WHO. Adolescent Pregnancy. Geneva: World Health Organization; 2014. Available from: http://www.who.int/mediacentre/factsheets/fs364/en/

[6] Santelli J.S., Song X., Garbers S., Sharma V., and Viner R.M (2017). Global trends in adolescent fertility, 1990–2012, in relation to national wealth, income inequalities, and educational expenditures. J Adolesc Health. 60(2):161–8.

[7] Chandra-Mouli V., McCarraher D.R., Phillips S.J., Williamson N.E., and Hainsworth G (2014). Contraception for adolescents in low and middle income countries: needs, barriers, and access. Reprod Health. 11(1):1–15.

[8] Magnusson B.M., Crandall A., and Evans K (2019). Early sexual debut and risky sex in young adults: the role of low self-control. BMC Public Health. 2019. https:// doi. org/ 10. 1186/ s12889- 019- 7734-9.

[9] Pettifor B.A., Brien K.O., Miller C., and Miller W.C (2009). Early coital debut and associated HIV risk factors among young women and men in South Africa. Peer Rev Res. 35(2):74–82.

[10] Peltzer K., and Pengpid S (2015). Early sexual debut and associated factors among in-school adolescents in six Caribbean countries. West Indian Med J. 64(4):1–356.

[11] Hodgkinson S., Beers L., and Southammakosane C (2014). Addressing the mental health needs of pregnant and parenting adolescents. Pediatrics. 133:114–22. doi:10.1542/peds.2013-0927

[12] Ajala A.O (2014). Factors associated with teenage pregnancy and fertility in Nigeria. Journal of Economics and Sustainable Development, 2014; 5(2).

[13] Wado Y.D., Sully E.A., and Mumah J.N (2019). Pregnancy and early motherhood among adolescents in five East African countries: a multi-level analysis of risk and protective factors. BMC Pregnancy and Childbirth, 2019; 19:59.

[14] Geda Y.F (2019). Determinants of teenage pregnancy in Ethiopia: A Case–control study. Curr Med Issues 2019; 17:112‑7.

[15] Ogawa K., Matsushima S., Urayama K.Y., Kikuchi N, Nakamura N., Tanigaki S (2019). Association between adolescent pregnancy and adverse birth outcomes: A multicenter cross sectional Japanese study. Sci Report 2019; 9:2365.

[16] Karataşlı V., Kanmaz A.G., İnan A.H., Budak A., and Beyan E (2019). Maternal and neonatal outcomes of adolescent pregnancy. J Gynecol Obstet Hum Reprod 2019; 48: 347–350.

[17] World Health Organization: Adolescent pregnancy. (2020). Accessed: May 10, 2022: https://www.who.int/news-room/fact-sheets/detail/adolescent-pregnancy.

[18] Bain L.E., Muftugil-Yalcin S., Amoakoh-Coleman M., Zweekhorst M.B., Becquet R., and de Cock Buning T (2020). Decisionmaking preferences and risk factors regarding early adolescent pregnancy in Ghana: stakeholders' and adolescents' perspectives from a vignette-based qualitative study. Reprod Health. 2020, 17:141. 10.1186/s12978-020-00992-x

[19] LaraL.A., and AbdoC.H (2016). Age at time of initial sexual intercourse and health of adolescent girls. J Pediatr Adolesc Gynecol. 29(5):417-423.

[20] Ezegwui H.U., Ikeako L.C., and Ogbuefi F (2012). Obstetric outcome of teenage pregnancies at a tertiary hospital in Enugu, Nigeria. Niger j Clin Pract. 15(2):147-50. https://doi.org/10.4103/11193077.97289 PMid:22718161

[21] Lee S.H., Lee S.M., Lim N.G., Kim H.J., Bae S.H., Ock M., Kim U.N., Lee J.Y., Jo M.W (2016). Differences in pregnancy outcomes, prenatal care utilization, and maternal complications between teenagers and adult women in Korea. Medicine. 2016; 95(34):e4630. https://doi.org/10.1097/MD.0000000000004630 PMid:27559960 PMCid:PMC5400327

[22] Cavazos-Rehg P.A., Krauss M.J., Spitznagel E.L., Bommarito K., Madden T, Olsen MA, Subramaniam H., Peipert J.F., and Bierut L.J (2015). Maternal age and risk of labor and delivery complications. Matern Child Health J. 19(6):1202-1211. https://doi.org/10.1007/s10995-014-1624-7 PMid:25366100 PMCid:PMC4418963

[23] Nove A., Z. Matthews S. Neal., and A. V. Camacho (2014). "Maternal Mortality in Adolescents Compared with Women of Other Ages: Evidence from 144 Countries." The Lancet Global Health 2 (3): 155–164.

[24] Raj A., N. Saggurti., M. Winter., A. Labonte., M. R. Decker,, D. Balaiah,, and J. G. Silverman (2010). "The Effect of Maternal Child Marriage on Morbidity and Mortality of Children under 5 in India: Cross Sectional Study of a Nationally Representative Sample." BMJ 340 (jan21 1): b4258–b4258. doi:10.1136/bmj.b4258

[25] United Nations Population Fund (2013). "Adolescent Pregnancy: A Review of the Evidence." New York. https://www.unfpa.org/sites/default/files/pub-pdf/ADOLESCENT%20PREGNANCY_UNFPA.pdf.

****