International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048
Volume 6, Issue 7, pp 121-125, July-2022
https://doi.org/10.47001/IRJIET/2022.607024

Analysis of Under Five Mortality for Benin Using the Double Exponential Smoothing Model

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***Abstract* - This study uses annual time series data on under five mortality rate (U5MR) for Benin from 1960 to 2020 to predict future trends of U5MR over the period 2021 to 2030. Residuals and forecast evaluation criteria indicate that the applied Holt's linear exponential smoothing model is stable in forecasting under five mortality rate. The optimal values for the smoothing constants α and β are 0.9 and o.1 respectively based on minimum MSE. The Holt's linear exponential smoothing model projections indicate that annual U5MR will continue to drop but still remain high over the out of sample period. Therefore health authorities in Benin should channel more resources to the maternal and child health program in order to address most of the challenges that contribute to the high absolute numbers of under five deaths in the country.**

Keywords: Exponential smoothing, Forecasting, U5MR.

I. INTRODUCTION

Developing countries have demonstrated their commitment to the Agenda 2030 for sustainable development as this is evidenced by the observed downward trajectory of maternal, neonatal and under five mortality (World Bank, 2019). However, some countries are still far away from achieving the set sustainable development goal targets by 2030 (UN, 2020; WHO, 2019; UNICEF, 2019; UNICEF, 2018). The purpose of SDGs is to solve all the issues that were not addressed during the era of Millennium development goals (UN, 2016; UN, 2015). It is prudent for developing countries to channel adequate resources towards maternal and child health as this is the core business of SDGs. Improving the health of a population positively impacts on economic growth (Bloom *et al.* 2020). There has been significant progress made by many countries towards achieving sustainable development goal (SDG) targets including SDG3 which focuses on ensuring good health for all at ages. Target 3.2 aims to reduce under five and neonatal mortality rate (NMR) to 25 deaths per 1000 live births and at least 12 neonatal deaths per 1000 live births respectively (UNICEF, 2019; Kayode *et al.* 2017; UN, 2016; UN, 2015). In line with Agenda 2030 for sustainable development, this paper applies the Holt's linear exponential smoothing to model and forecast future trends of under-five mortality rate in Benin. The findings are expected to highlight likely future trends of U5MR and this will guide policy making and allocation of resources to child health program activities.

II. LITERATURE REVIEW

Gage & Bauhoff (2020) assessed the impact of PBF on early neonatal health outcomes and associated health care utilization and quality in Burundi, Lesotho, Senegal, Zambia and Zimbabwe. Authors utilized data from Demographic and Health Surveys and Multiple Indicator Cluster Surveys and applied difference-in-differences analysis to estimate the effect of PBF projects supported by the World Bank on early neonatal mortality and low birth weight and concluded that PBF had no impact on early neonatal health outcomes in the five African countries studied and had limited and variable effects on the utilization and quality of neonatal health care.Masaba & Phetoe (2020) described the trends of neonatal mortality within the two sub-Saharan countries. The study concluded that in 2018, the neonatal mortality rate for Kenya was 19.6 deaths per 1000 live births. The neonatal mortality rate had fallen gradually from 35.4 deaths per 1000 live births in 1975. On the other hand, South Africa had its neonatal mortality rate fall from 27.9 deaths per 1000 live births in 1975 to 10.7 deaths per 1000 live births in 2018. Biracyaza & Habimana (2019) developed a model of infant mortality and its associated risk factors in Rwanda from 2011 to 2015.A cross-sectional survey was conducted using data from 2014/2015 Rwanda Demographic and Health Survey. Target population was women aged 15-49 years from sampled households. All 492 of the clusters selected were surveyed for 2014/2015 RDHS. STATA version 13 was used to analyze the statistical data. The study concluded that factors associated with IM were grouped into community, ecological, socio-economic and proximate factors and identified that each group consists of multifactor that influence the infant mortality rate. Kayode *et al.* (2017) examined the variation in neonatal mortality and identified underlying causes of variation in neonatal mortality in sub-Saharan Africa (SSA). The ecological study utilized 2012 publicly available data from

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WHO, the US Agency for International Development and the World Bank. Variation in neonatal mortality across 49 SSA countries was examined using control chart and explanatory spatial data analysis. Associations between country-level characteristics and neonatal mortality were examined using linear regression analysis. The findings revealed that there was a wide variation in neonatal mortality in SSA. A substantial part of this variation can be explained by differences in the quality of healthcare governance, prevalence of HIV and socioeconomic deprivation.

III. METHODOLOGY

This study utilizes an exponential smoothing technique to model and forecast future trends of under-five mortality rate in Benin. 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.

$Z_t = \mu_t + b_t t + \varepsilon_t$

Smoothing equation

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

Trend estimation equation

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

Forecasting equation

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

Z_t is the actual value of time series at time t

L_t is the exponentially smoothed value of time series 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

T_t is the trend estimate

Data Issues

This study is based on annual under five mortality rate in Benin 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	Z
Included Observations	61 (After Adjusting Endpoints)
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.990908

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Sum Square Error (SSE)	293.210462
Mean Square Error (MSE)	4.806729
Mean Percentage Error (MPE)	0.216005
Mean Absolute Percentage Error (MAPE)	0.501566

Residual Analysis for the Applied Model

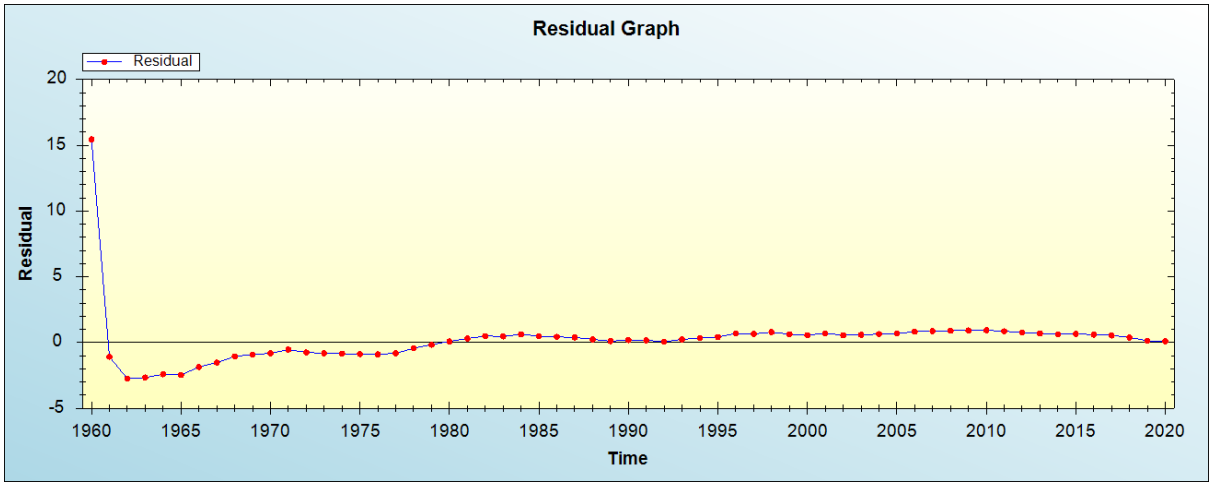

Figure 1: Residual analysis

In-sample Forecast for Z

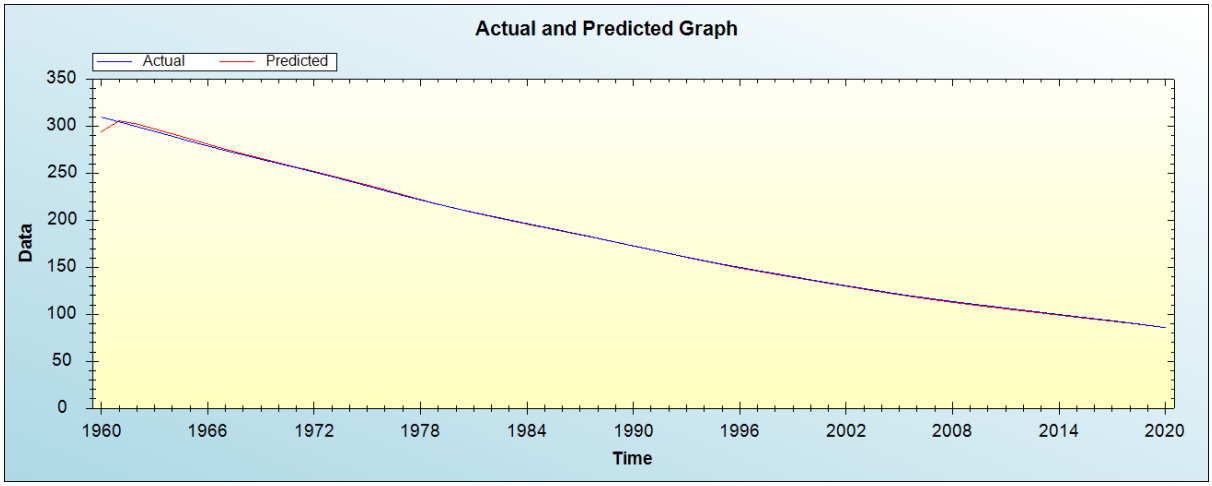

Figure 2: In-sample forecast for the Z series

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Actual and Smoothed Z series

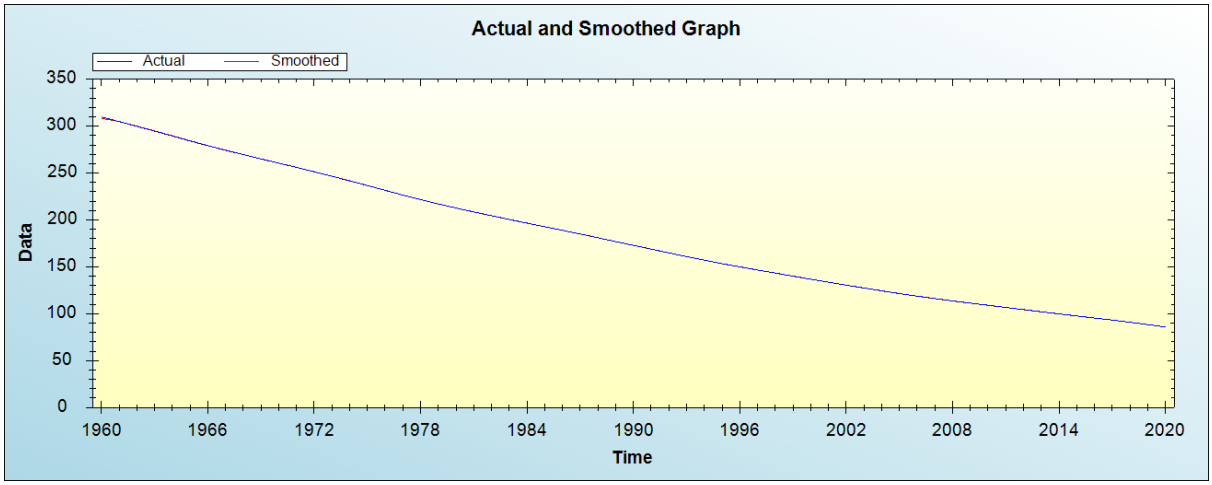

Figure 3: Actual and smoothed Z series

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

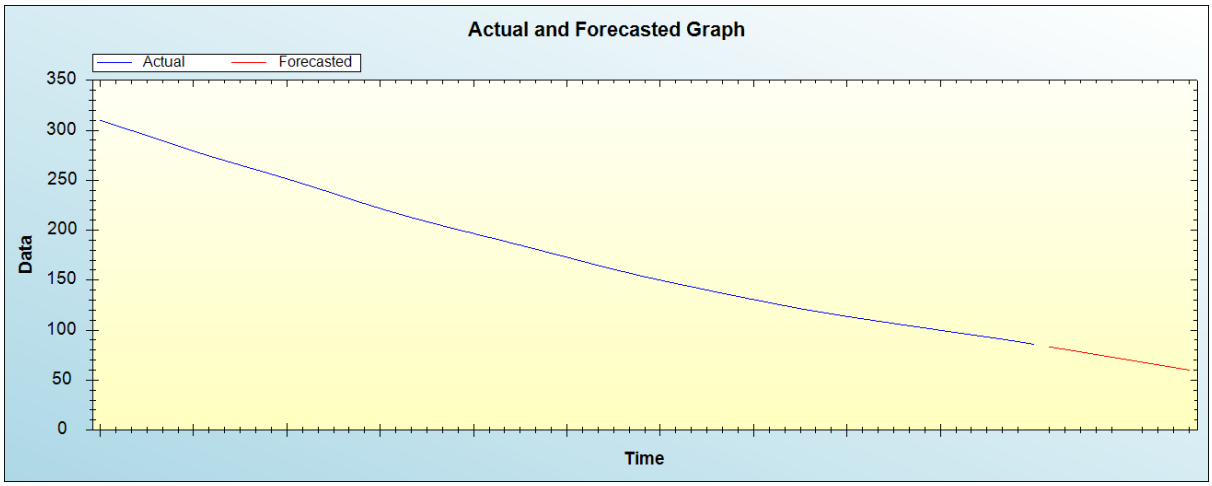

Figure 4: Out-of-sample forecast for Z: actual and forecasted graph

Out-of-Sample Forecast for Z: Forecasts only

Table 2: Tabulated out-of-sample forecasts

2021	83.3123
2022	80.7346
2023	78.1570
2024	75.5793
2025	73.0017
2026	70.4240
2027	67.8463
2028	65.2687
2029	62.6910
2030	60.1134

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 U5MR will continue to drop but still remain high over the out of sample period.

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V. POLICY IMPLICATION & CONCLUSION

Commitment to the Agenda 2030 for sustainable development is critical in the implementation of the 17 SDGs. Although Benin has recorded a commendable decline in under five mortality over the past 2 decades, more needs to be done as the country continues to report high absolute numbers of under five deaths. The double exponential smoothing model (Holt's linear method) was utilized in this study to predict under five mortality rate for Benin. The model projections indicate that annual U5MR will continue to drop but still remain high over the out of sample period. Therefore, we encourage health authorities in Benin to channel more resources to maternal and child health (MNCH) programs in order to substantially reduce under five mortality.

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Citation of this Article:

Dr. Smartson. P. NYONI, Thabani NYONI, "Analysis of Under Five Mortality for Benin Using the Double Exponential Smoothing Model" Published in *International Research Journal of Innovations in Engineering and Technology - IRJIET*, Volume 6, Issue 7, pp 121-125, July 2022. Article DOI https://doi.org/10.47001/IRJIET/2022.607024

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