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DETERMINING THE FUTURE TRENDS OF HIV PREVALENCE AMONG INDIVIDUALS AGED 15-49 YEARS FOR ZAMBIA USING HOLT'S LINEAR METHOD

Dr. Smartson. P. NYONI1,
Thabani NYONI2
1ZICHIRe Project, University of Zimbabwe, Harare, Zimbabwe
2Independent Researcher & Health Economist, Harare, Zimbabwe

Abstract:

This study uses annual time series data of HIV prevalence among individuals aged 15-49 years for Zambia from 1990 to 2020 to predict future trends of HIV prevalence 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 0.1 respectively based on minimum MSE. The results of the study indicate that annual HIV prevalence among individuals aged 15-49 years will continue to decline over the out of sample period but still remain high. Therefore, there is need for a rapid scale up of HIV testing services in the community, strengthening HIV prevention among this age group and improving ART adherence among people living with HIV.

Keyword(s): - Exponential smoothing, Forecasting, HIV prevalence

Background

According to WHO, in 2019 there were approximately 38 million people living with HIV reported worldwide. The majority of people living with HIV reside in low and middle-income countries, with around 66% living in sub-Saharan Africa. Among this group 19.6 million are living in East and Southern Africa. The Zambia statistical Agency revealed that Zambia witnessed a decline in the prevalence of HIV from 13.3% in 2014 to 11.6% in 2016. Furthermore, the report indicated an antiretroviral therapy coverage which stood at 72% reflecting an urgent need to scale up ART services among the population. UNAIDS reported that in 2018 approximately 1.2 million people in Zambia were living with HIV and there 17,000 HIV related deaths. In addition, 78% of all people living with HIV were on treatment. As of 2019, 87% of people living with HIV were aware of their status, and 89% on treatment and 75% were virally suppressed. The UNAIDS reported also highlighted that AIDS related mortality dropped from 26,000 in 2010 deaths to 17,000 deaths in 2018. There was an impressive decrease in the number of new HIV infections from 56,000 to 48,000 over the same period. In Zambia, in 2018 there were approximately 62,000 children living with HIV, 79% of them were on ART and there were 3,000 AIDS related annual deaths. The rapid scale up of antiretroviral therapy services and prompt initiation of pediatric ART in Zambia increased gradually from 24,000 in 2010 to 49,116 in 2018. This resulted in reduction in HIV-related

mortality from 3,600 in 2016 to 3,000 in 2018 (UNAIDS, 2018; AVERT, 2017). Approximately 6.6% of young people are living with HIV and prevalence is higher among young women (8%) than men (5%). Annual HIV incidence among people aged 15–24years is 57 new infections per 10,000 uninfected persons per year (Nakazwe et al. 2019). Monitoring HIV prevalence and associated risk factors in Zambia is based on a comprehensive ANC-based surveillance system, population-based surveys in selected communities, and nationally representative population-based surveys. ANC-based data covering the period of 1994–2011 showed declining overall prevalence trends among young women; however, these trend patterns differed significantly according to place and educational attainment (Kayeyi et al. 2012; Fylkesnes et al. 2001). The objective of this study is to model and forecast HIV prevalence among individuals aged 15-49 years for Zambia using Holt's double exponential smoothing technique. The findings of this study are envisaged to inform policy, planning and allocation of resources towards targeted HIV programs with particular focus being given to key populations.

Literature Review

Author (s)	Objective (s)	Methodology	Key finding (s)
Moyo et al. (2021)	To determine an ARIMA model and advance counterfactual forecasting at a point of policy intervention.	Applied ARIMA model	The model predicts a reduction from an average of 3500 to 3177 representing 14.29% in HIV/AIDS cases from 2017 (year of policy activation) to 2019, but the actual recorded cases dropped from 3500 to 1514 accounting for 57.4% in the same time frame
Munthali et al. (2020)	To assess survival experiences and the factors associated with survival in CLHIV on ART in Zambia	-conducted a retrospective cohort analysis of CLHIV (aged up to 15 years) using routinely collected data from health facilities across Zambia, over 13 years to ascertain mortality rates -applied Cox regression model	Children with HIV in Zambia are surviving much longer than was predicted before ART was introduced 14 years ago
Nakazwe et al. (2019)	To examine geographical and sub-population differences in HIV prevalence trends among young people aged 15–24years in Zambia.	-The study analyzed data from Zambia Demographic and Health Surveys (ZDHSs) that were conducted in 2001–2, 2007, and 2013–14 - Log binomial regression analysis of generalized linear models was used to test for trends.	The increase in HIV prevalence among urban young men over the past 12years, contrasting declining trends among young women in both urban and rural populations, suggests differential effects of prevention efforts
Mutale et al. (2019)	To report the research capacity building activities in SSA	reviewed program data and conducted interviews with program leaders and	Despite some challenges, UVP has achieved positive outcomes over

	conducted by the University of Zambia (UNZA)-Vanderbilt Training Partnership for HIV Nutrition-Metabolic Research (UVP), drawing lessons and challenges for a wide global health audience	participants to understand and document the progress and outcomes of the partnership	its first four years. Longstanding partnerships and local institutional ownership were the main drivers. Challenges are expected to be mitigated as the project continues and produces more UNZA researchers and teams and more funded projects, collectively building the local research community
Thomas et al. (2017)	To compare HRQoL between HIV-positive and HIV-negative people in Zambia and South Africa.	Cross sectional study	ART is successful in helping to reduce inequalities in HRQoL between HIV-positive and HIV-negative individuals in this general population sample
Chanda-Kapata et al. (2016)	To estimate the adult prevalence of HIV among the adult population in Zambia and determine whether demographic characteristics were associated with being HIV positive.	A cross sectional population based survey to asses HIV status among participants aged 15 years and above in a national tuberculosis prevalence survey	HIV prevalence was lower than previously estimated in the country. The burden of HIV showed soci-odemographic disparities signifying a need to target key populations or epidemic drivers.

Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of HIV prevalence among individuals aged 15-49 years in Zambia. 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 specified as follows:

Model equation

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

Smoothing equation

$S_t= \alpha Z_t + (1-\alpha)(S_{t-1} + b_{t-1})$

$0<\alpha<1$

Trend estimation equation

$b_t= \beta (S_t-S_{t-1}) + (1-\beta)b_{t-1}$

$0<\beta<1$

Forecasting equation

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

Z_t is the actual value of HIV prevalence 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
S_t is the exponentially smoothed value of HIV prevalence 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 (slope of the trend) at time t
b_{t-1} is the trend estimate at time t-1

Data Issues

This study is based on annual HIV prevalence among individuals aged 15-49 years in Zambia for the period 1990 – 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.

Findings of the study

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	Z
Included Observations	31
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.446914
Sum Square Error (SSE)	27.387464
Mean Square Error (MSE)	0.883467
Mean Percentage Error (MPE)	-0.612137
Mean Absolute Percentage Error (MAPE)	4.299349

Residual Analysis for the Applied Model

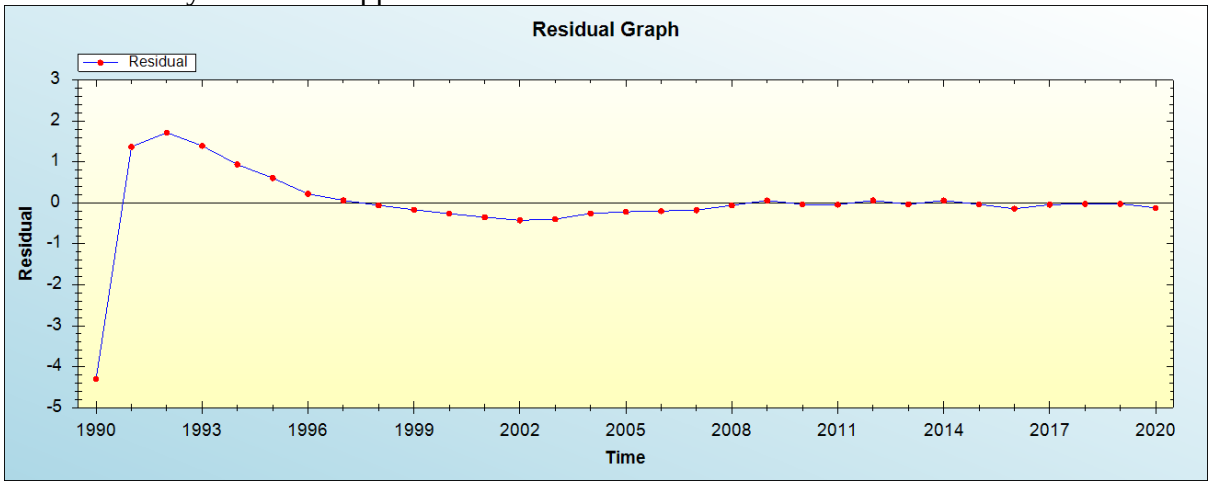

Figure 1: Residual analysis

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In-sample Forecast for A

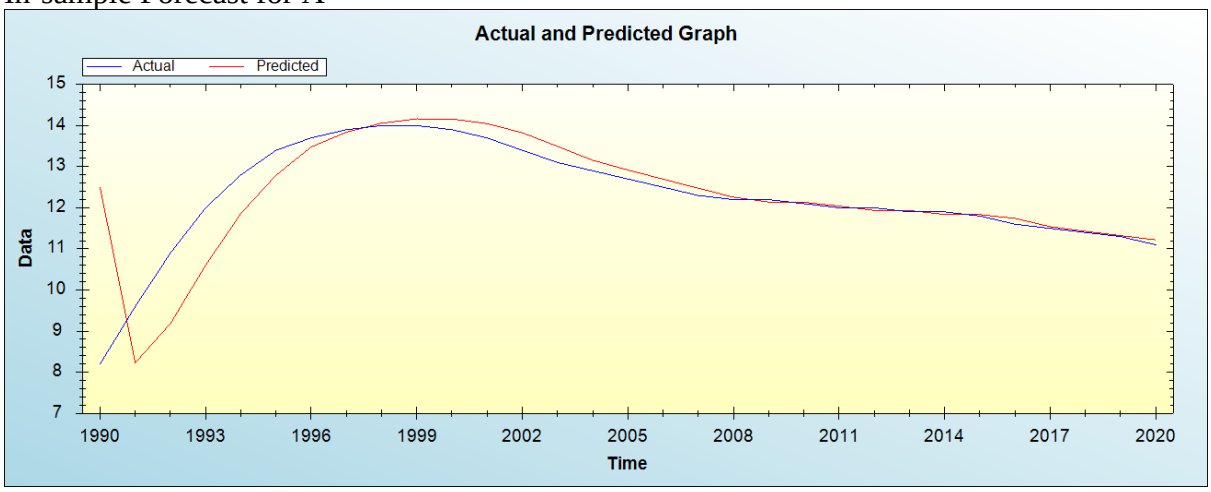

Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

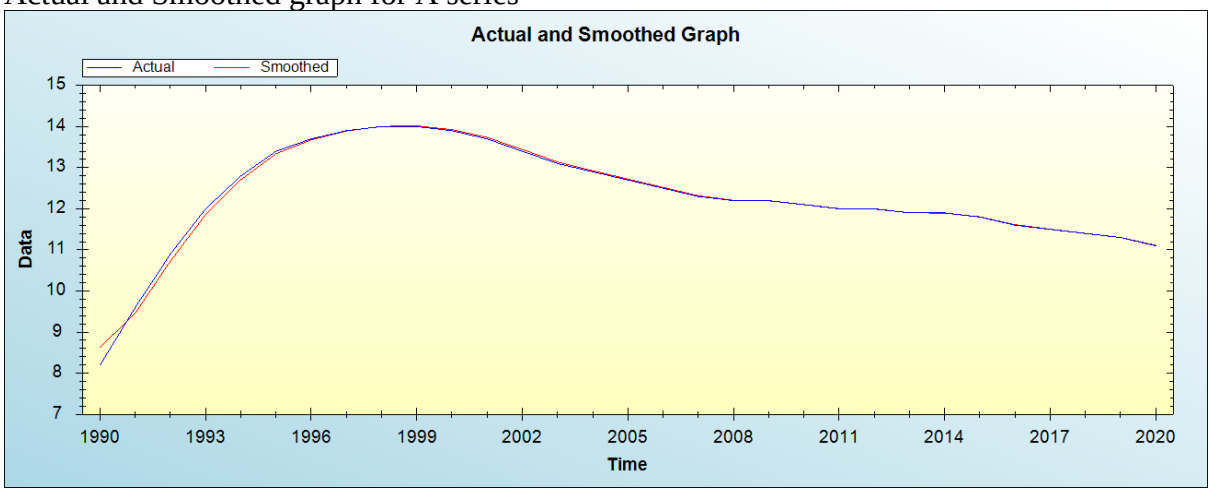

Figure 3: Actual and smoothed graph for A series

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

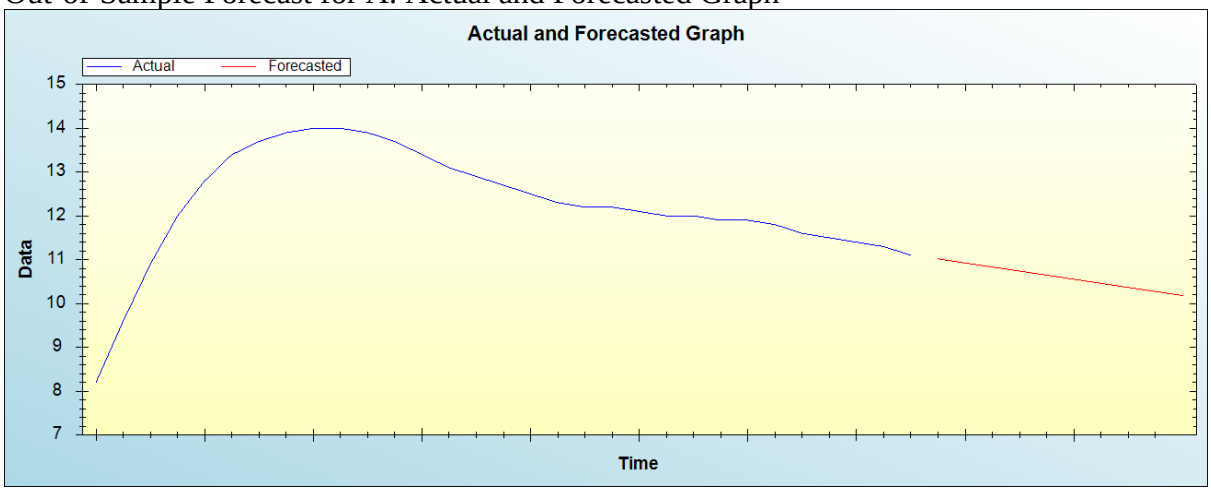

Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	11.0190
2022	10.9259
2023	10.8329
2024	10.7399
2025	10.6468
2026	10.5538
2027	10.4607
2028	10.3677
2029	10.2747
2030	10.1816

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 HIV prevalence among individuals aged 15-49 years will continue to decline over the out of sample period.

Policy implication and conclusion

Our research findings indicate that annual HIV prevalence among individuals aged 15-49 years will continue to decline in the out of sample period but still remain high. Therefore, this paper calls for a rapid scale up of HIV testing services in the community, strengthening HIV prevention among this age group and improving ART adherence among people living with HIV.

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