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ANALYZING HIV PREVALENCE AMONG INDIVIDUALS AGED 15-49 YEARS IN LESOTHO USING HOLT'S LINEAR METHOD

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Abstract
This study uses annual time series data of HIV prevalence among individuals aged 15-49 years for Lesotho 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 0.3 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, we encourage authorities to scale up HIV testing services, prevention and treatment among the 15–49-year age group. There is need to address main drivers of HIV spread in this age group.

Keywords: - Exponential smoothing, Forecasting, HIV prevalence.

Introduction

According to Lesotho Bureau of Statistics, Lesotho has a population of approximately 2 million people with 66 percent of the population living in rural areas. In 2014, the sero-prevalence of HIV infection among people aged 15–49 years was 24.6%, with an incidence of 1.9 new infections per 100 person-years of exposure, and low ART coverage (42%) (Schwitters, 2017; UNAIDS, 2016; LDHS, 2014). LePHIA 2016–2017 revealed that the annual incidence of HIV among adult ages 15 to 59 years in Lesotho is 1.10%: 1.22% among females and 1.00% among males. HIV prevalence peaks at 49.9% among female ages 35 to 39 as compared to 46.9% among male ages 40 to 44 years. The disparity in HIV prevalence by sex is most pronounced among young adults: HIV prevalence among 20- to 24-year-olds is four times as high among females (16.7%) as among males (4.0%). In addition, among adult ages 15 to 59 years, prevalence of HIV varies geographically across Lesotho, ranging from a low of 17.8% in Botha-Bothe to a high of 29.3% in Mohale's Hoek. In April 2016, Lesotho became the first country in sub-Saharan Africa to adopt the World Health Organization (WHO) recommendations for universal initiation of ART for all HIV-positive persons, regardless of CD4 count, with nationwide implementation occurring in June 2016 (WHO, 2016; Lesotho, 2016). The national HIV response focuses on reduction of new infections to zero by targeting high risk groups such as commercial sex workers, men who have sex with men, transgender, and injecting drug users. It is made up of HIV testing services, combination HIV prevention strategies, treatment care and support and demand generation for HIV services. The government emphasizes integration of TB, HIV and STI treatment services at all levels of healthcare (Coburn *et al.* 2013).

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The objective of this paper is to model and forecast HIV prevalence among 15-49 year age group using Holt's linear method. The research findings are expected to highlight future trends of HIV seroprevalence among persons in the age group 15-49 years. This will guide planning and allocation of resources to support HIV prevention, treatment and care services for the 15-49 year age group.

Literature review

Author (s)	Objective (s)	Methodology	Key finding (s)
Schwitters et al. (2022)	To better understand the impact of Lesotho's national HIV response and significant predictors associated with HIV infection	-The Lesotho Population-based HIV Impact Assessment was conducted -Multivariate logistic regression models for men and women were constructed for each outcome using variables known to be or plausibly associated with recent or chronic infection.	Overall annualized incidence among people aged 15– 49 was 1.19% (95% CI 0.73–1.65) per year. The overall prevalence of HIV was 25.6% with women having significantly higher prevalence. Multiple variables, including decreased wealth status, lower education levels, marital status, condom use at first sex, and circumcision (men only) were identified as being significantly associated with HIV infection for both men and women.
Orel et al. (2022)	To predict the HIV status of individuals living in Angola, Burundi, Ethiopia, Lesotho, Malawi, Mozambique, Namibia, Rwanda, Zambia and Zimbabwe with the highest precision and sensitivity for different policy targets and constraints based on a minimal set of socio-behavioral characteristics.	Analyzed the most recent Demographic and Health Survey from these 10 countries to predict individual's HIV status using four different algorithms (a penalized logistic regression, a generalized additive model, a support vector machine, and a gradient boosting tree	The gradient boosting trees algorithm performed best in predicting HIV status with a mean F1 score of 76.8% [95% confidence interval (CI) 76.0%-77.6%] for males (vs [CI 67.8%-70.6%] for SVM) and 78.8% [CI 78.2%-79.4%] for females (vs [CI 73.4%-75.8%] for SVM).
Risher et al. (2021)	-To assess trends in age-specific HIV incidence in six population-based cohort studies in eastern and southern Africa, reporting changes in mean age at infection, age distribution of new infections, and birth cohort cumulative incidence	-Bayesian model was applied to reconstruct age-specific HIV incidence from repeated observations of individuals' HIV serostatus and survival collected among population HIV cohorts in rural Malawi, South Africa, Tanzania, Uganda, and Zimbabwe, in a collaborative analysis of the ALPHA network. The study modelled HIV incidence rates by age, time, and sex using smoothing splines functions	-HIV incidence declined in all age groups and shifted slightly to older ages. Disproportionate new HIV infections occur among women aged 15–24 years and men aged 20–29 years
LESOTHO POPULATION-BASED HIV IMPACT ASSESSMENT LePHIA 2016–2017	To measure HIV incidence, prevalence, and viral load suppression (VLS) in the population 15 to 59 years of age and prevalence in the population 0 to 14 years of age.	LePHIA offered HIV counseling and testing with return of results, and collected information about uptake of HIV care and treatment services	Annual incidence of HIV among adults ages 15 to 59 years in Lesotho is 1.10%: 1.22% among females and 1.00% among males.

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Methodology

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

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

Smoothing equation

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

$0<\propto<1$

Trend estimation equation

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

$0<\beta<1$

Forecasting equation

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

A_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 Lesotho 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.

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Findings of the study

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	A
Included Observations	31
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.300
Forecast performance measures	
Mean Absolute Error (MAE)	1.045443
Sum Square Error (SSE)	112.935642
Mean Square Error (MSE)	3.643085
Mean Percentage Error (MPE)	-9.256511
Mean Absolute Percentage Error (MAPE)	24.059246

Residual Analysis for the Applied Model

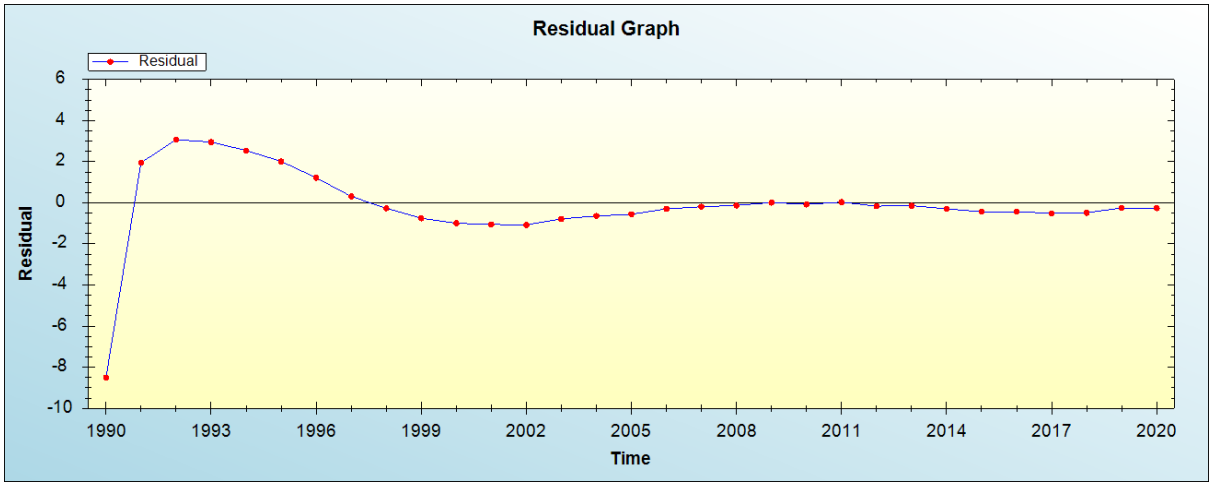

Figure 1: Residual analysis

In-sample Forecast for A

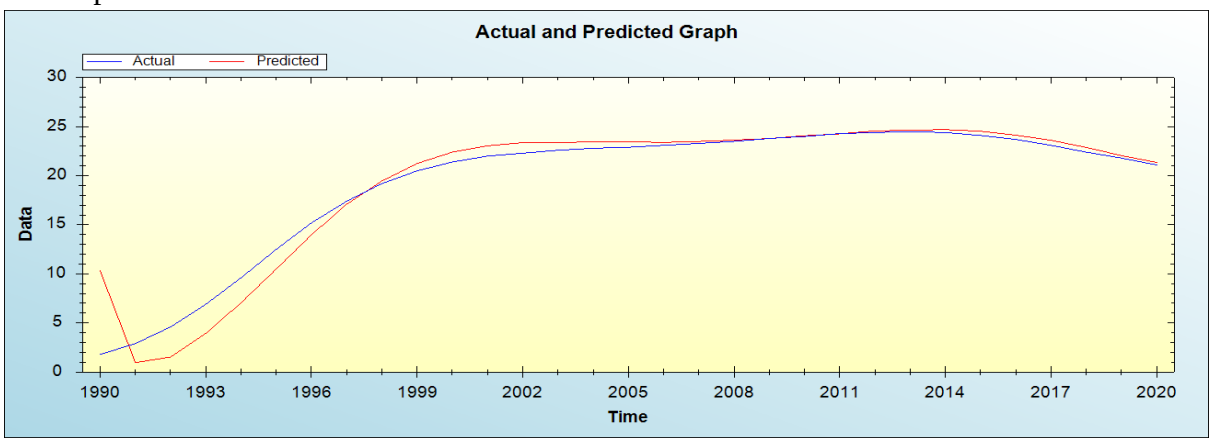

Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

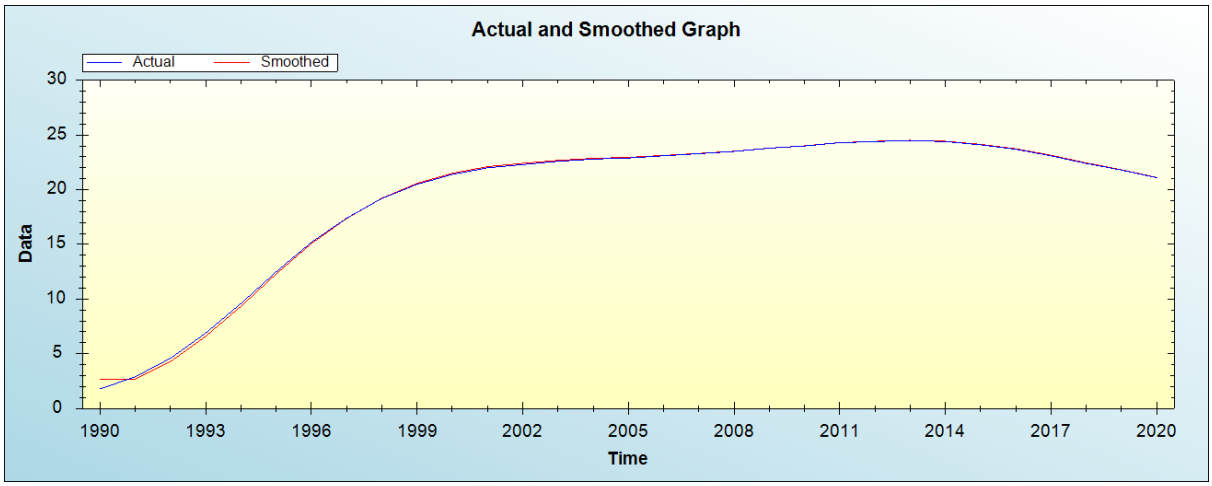

Figure 3: Actual and smoothed graph for A series

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

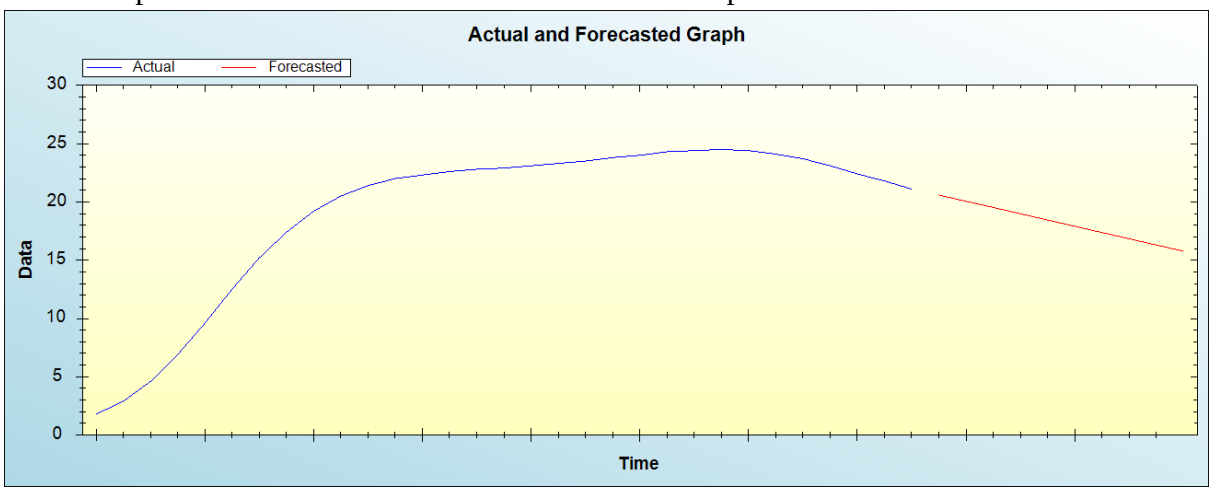

Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	20.5901
2022	20.0542
2023	19.5183
2024	18.9825
2025	18.4466
2026	17.9108
2027	17.3749
2028	16.8391
2029	16.3032
2030	15.7673

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

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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 research calls for authorities in Lesotho to scale up HIV testing services, prevention and treatment among the 15–49-year age group. There is need to address main drivers of HIV spread in this age group.

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