_____

Tracking the future path of HIV prevalence among individuals aged 15-49 years in Sierra Leone using Holt's linear method

Dr. Smartson. P. NYONI[1], Thabani NYONI[2]
[1]ZICHIRe Project, University of Zimbabwe, Harare, Zimbabwe
[2]Independent Researcher & Health Economist, Harare, Zimbabwe

Abstracts

This study uses annual time series data of HIV prevalence among individuals aged 15-49 years for Sierra Leone 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 remain constant at around 1.5% throughout the out of sample period. Therefore, we encourage authorities to scale up HIV diagnosis, prevention and treatment especially among key populations.

Keyword (s): - _Exponential smoothing, Forecasting, HIV prevalence_

Background

Approximately 78, 667 people are living with HIV (PLHIV) in Sierra Leone (Dwomoh _et al_ 2023). Sierra Leone Demographic and Health Survey 2019 revealed that the HIV epidemic in Sierra Leone is regarded as mixed, generalized, and heterogeneous but concentrated in KPs with an estimated HIV seroprevalence in the general population of 1.6%. The prevalence among the general population seems low, but has almost doubled from 0.9% from 2002 to 1.7% in 2020 and the AIDS-related mortality was 33 per 100 000 population (UNAIDS, 2020). This undesired upward trend was attributable to the increasing activities of key populations (MSM, FSWs, Transgender, PWID) who may be heterosexual and are at a higher risk of spreading infection. The focus of HIV prevention and testing interventions in Sierra Leone is on key populations (men who have sex with men, female sex workers) (Welfare, 2004). Besides expanding HIV testing and increasing access to prevention, care and treatment services the government also adopted WHO recommendations which encourages immediate ART commencement and adherence, as well as pre-exposure prophylaxis for seronegative partners (WHO & UNAIDS, 2017; On, 2016; Witzel _et al._ 2016; Catania _et al._ 2015). The purpose of this study is to model and forecast HIV prevalence among individuals aged 15-49 years for Sierra Leone using Holt's linear method. The findings of this paper will inform policy, planning and allocation of resources towards HIV programs targeting Key populations and other vulnerable groups in order to effectively control the HIV epidemic in Sierra Leone.

Literature Review

Author (s)	Objective (s)	Methodology	Key finding (s)
Lakoh et al. (2024)	To assess the impact of COVID-19 on HIV testing and linkage to treatment services (HTS) at Connaught Hospital (CH-tertiary), Lumley Government Hospital (LGH-	Intra-pandemic HTS (2020) and HTS during recovery (2021) were compared with pre-pandemic HTS (2019).	There were significant disruptions in HIV testing and linkage services at different levels of service delivery during the COVID-19 pandemic

_____

_____

	secondary) and George Brooke Community Health Center (GBC-primary) in Freetown.		
Baldeh et al. (2023)	To examine stroke types, presentation, risk factors and outcome in HIV stroke patients compared with controls.	A case control design was used to compare stroke type, presentation, risk factors and outcome in sero-positive HIV patients with HIV negative stroke controls	In the case-control group, ischaemic stroke is the major type reported in both populations, HIV-negative population: 77 (53.5%) versus HIV-positive: 25 (69.4%) (p = 0.084). Hypertension is the most prevalent risk factor in both groups, HIV-positive: 23 (63.9%) versus HIV-negative: 409 (86.1%) (p = 0.001). Lower CD4+ count is associated in-hospital mortality (p = <0.001).
Dwomoh et al. (2023)	To estimate HIV prevalence and model the risk factors of HIV positivity rate among the aforementioned KPs in Sierra Leone.	multivariable modified Poisson regression model that adjusts for RDS survey weights was used and sensitivity analysis was conducted using a multivariable logistic regression model with cluster robust standard errors	-The prevalence of HIV among FSWs in the six regional headquarter towns was estimated to be 11.8%; MSM was 3.4%; TGs was 4.2%; PWIDs was 4.2% and PI was 3.7%. -The correlates of HIV test positivity among KPs and PIs include HIV-related knowledge, marital status, district, income, age and sex of KP, level of education, alcohol intake, injecting drugs, and use of lubricants.
Luwedde & Quraish (2022)	to assess the knowledge of HIV transmission and	Multivariable logistic regression was applied to determine	The weighted prevalence of comprehensive

_____

	associated factors among Sierra Leonean women of reproductive age	factors associated with HIV transmission knowledge.	knowledge of HIV transmission was 39.73%. The odds of having comprehensive knowledge of HIV were significantly higher with increasing age, 25–30 years old, 30–49 years, having secondary education, richer wealth status, residing in the southern region, reading newspapers or magazine, and using the internet.
Lakoh et al. (2019)	assessing partner testing and HIV prevalence among adults (≥ 15 years)	HIV tests done using Determine and SD Bioline	The study reported high HIV prevalence and low partner testing

Methodology

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

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

_____

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 Sierra Leone 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	A
Included Observations	31
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.070823
Sum Square Error (SSE)	0.461142
Mean Square Error (MSE)	0.014876
Mean Percentage Error (MPE)	-1.504409
Mean Absolute Percentage Error (MAPE)	7.155486

Residual Analysis for the Applied Model
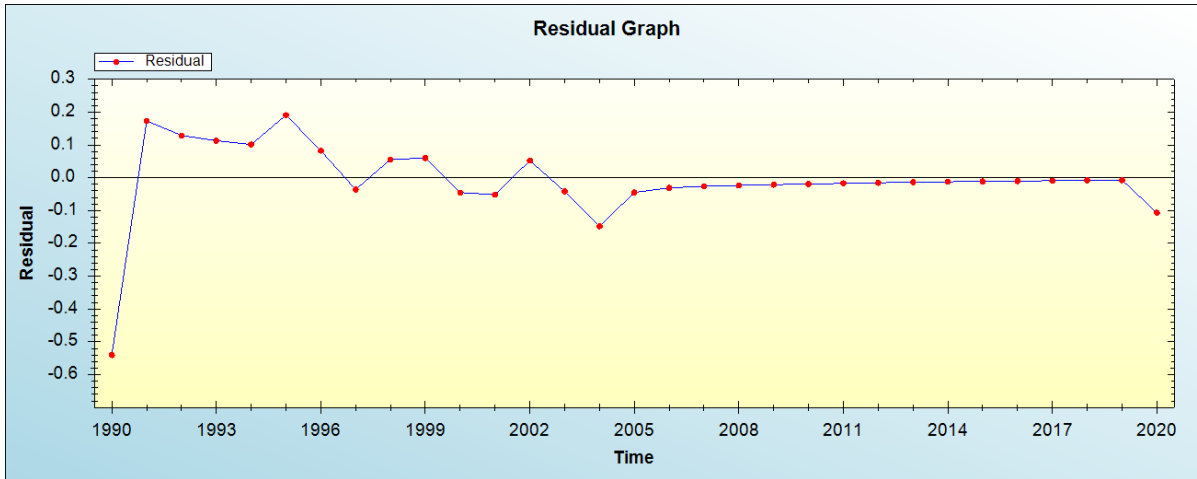
_____

_____

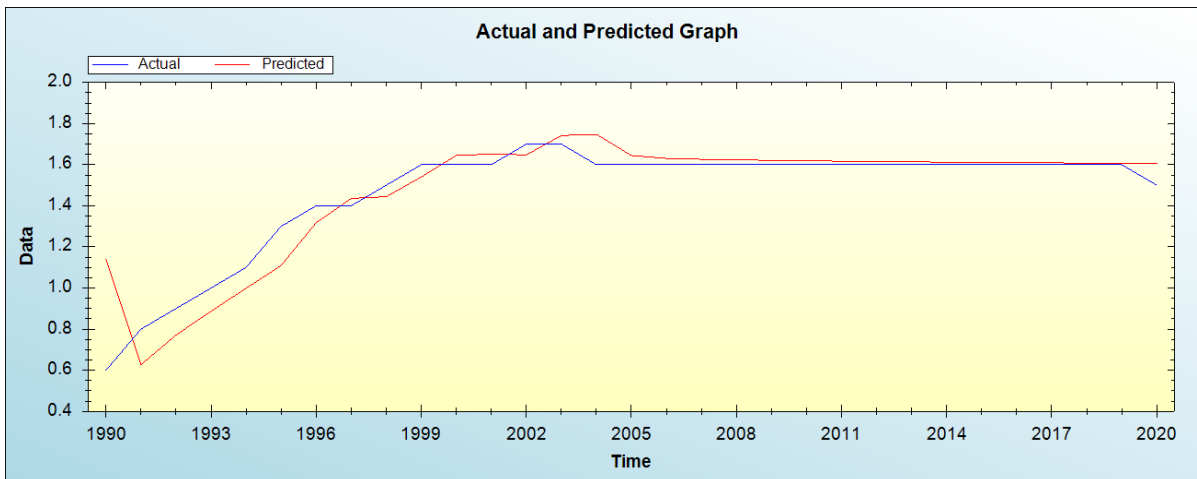Figure 1: Residual analysis

In-sample Forecast for A

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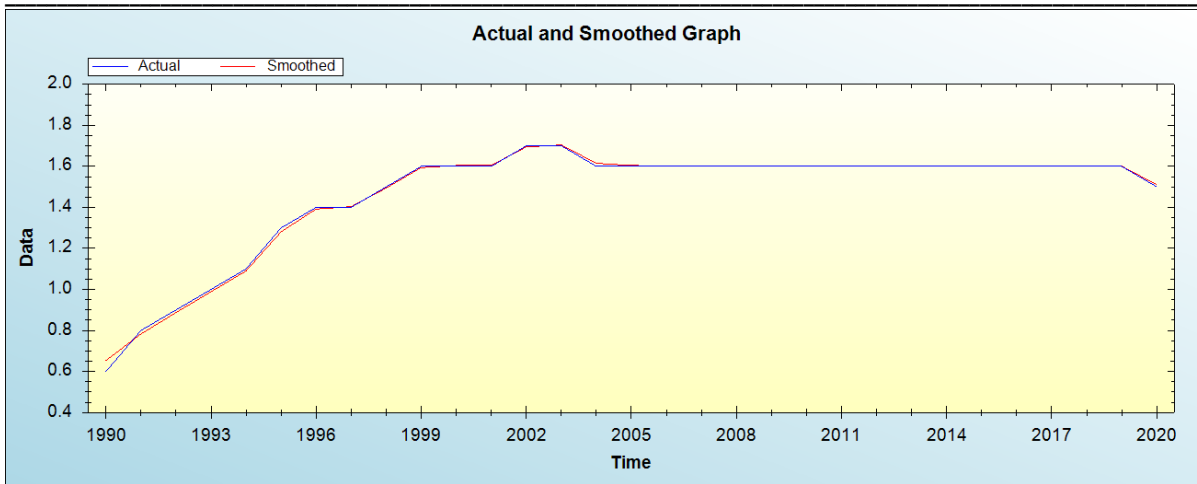
Actual and Smoothed graph for A series

_____

Figure 3: Actual and smoothed graph for A series

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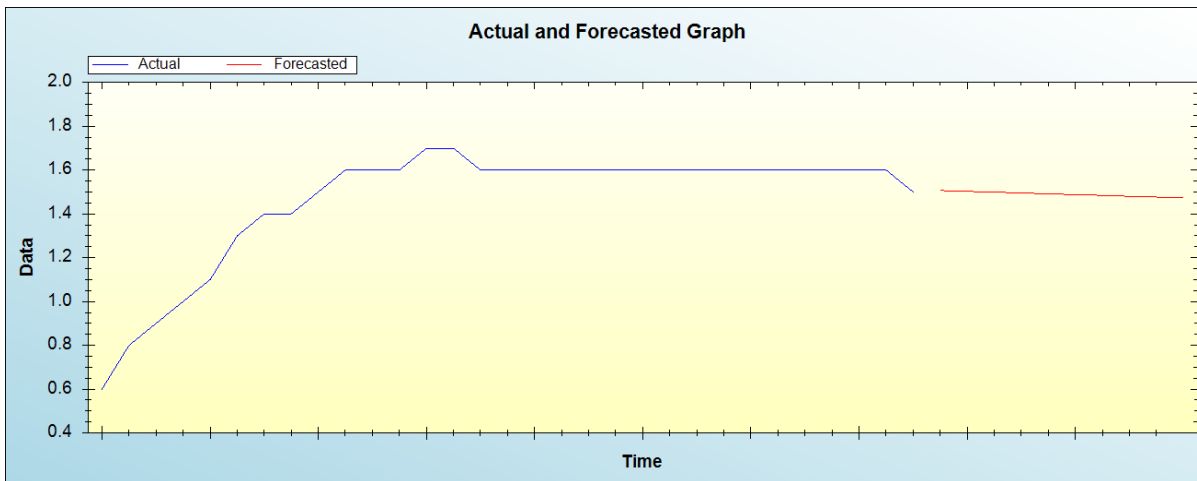

Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	1.5069
2022	1.5031
2023	1.4993
2024	1.4955
2025	1.4917
2026	1.4880
2027	1.4842
2028	1.4804
2029	1.4766

2030	1.4728

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 remain constant at around 1.5% throughout the out of sample period.

Policy implication and conclusion

Our model results indicate that annual HIV prevalence among individuals aged 15-49 years will remain constant at around 1.5% throughout the out of sample period. Hence authorities scale up HIV diagnosis, prevention and treatment especially among key populations.

References

[1] Statistics Sierra Leone - StatsSL, ICF. Sierra Leone Demographic and Health Survey 2019. Freetown/Sierra Leone: StatsSL/ICF; 2020.

[2] UNAIDS (2020). Country progress report - Sierra Leone: Global AIDS monitoring 2020. United Nations Programme on HIV/AIDS.

[3] Duah Dwomoh., Issata Wurie., Yvonne Harding., Kojo Mensah Sedzro., Joseph Kandeh., Henry Tagoe., Christabel Addo., Daniel Kojo Arhinful., Abdul Rahman Cherinoh Sessay., James Lahai Kamara., Kemoh Mansaray and William Kwabena Ampofo (2023). Estimating prevalence and modelling correlates of HIV test positivity among female sex workers, men who have sex with men, people who inject drugs, transgender people and prison inmates in Sierra Leone, 2021, AIDS Research and Therapy (2023) 20:70 https://doi.org/10.1186/s12981-023-00566-4

[4] Welfare G (2004). Sierra Leone. Time. 2004;3(April 2011):2003–4.

[5] World Health Organization & UNAIDS (2017). WHO, UNAIDS statement on HIV testing services: new opportunities and ongoing challenges. 2017;2. http://www.unaid s.org/sites /defau lt/files /media _asset /2017_WHOUNAID S_state ment_HIV-testi ng-servi ces_en.pdf.

[6] Witzel TC, Rodger AJ, Burns FM, Rhodes T & Weatherburn P (2016). HIV self-testing among men who have sex with men (MSM) in the UK : a qualitative study of barriers and facilitators, intervention preferences and perceived impacts. PLoS ONE. 2016; 11:e0162713.

[7] Catania JA, Dolcini MM, Harper GW, Dowhower DP, Dolcini-Catania LG, Towner SL, Timmons A, Motley DN & Tyler DH (2015). Bridging barriers to clinicbased HIV testing with new technology: translating self-implemented testing for African American youth. Transl Behav Med. 2015; 5:372–83.

[8] On G. HIV testing services HIV self-testing and partner. 2016.