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Prediction of HIV prevalence among individuals aged 15-49 years in Eritrea using Holt's linear exponential smoothing model

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Abstract
This study uses annual time series data of HIV prevalence among individuals aged 15-49 years for Eritrea 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. Therefore, we encourage authorities to focus on prevention measures especially among high risk groups such as adolescents and key populations.

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

Background

According to UNAIDS, in 2020, approximately 37.7 million people globally were living with HIV with adults constituting 36.2 million. The data reveals that there is a disproportionate number of people living with HIV (PLWHIV in sub-Saharan Africa (SSA). In addition, approximately 36.3 million people have died of HIV/AIDS-related illnesses in the past 3 decades, and a disproportionate number of these deaths were witnessed in SSA. The rapid scale up of antiretroviral therapy and HIV testing services has significantly reduced HIV/ AIDS related morbidity and mortality. It is essential to highlight the massive global expansion of ART coverage from around 7% in 2010 to 77% in 2020 has increased adult life expectancy. Research evidence has shown that reduction of community viral load through massive rollout of ART in SSA has curbed HIV transmission at the population level (Das *et al.* 2010). Eritrea has played a pivotal role in the HIV response in the region and at continental level. The government focuses on rolling out antiretroviral therapy services to every corner of the country and the package consists of HIV testing, supplying ART medication to people living with HIV, implementation of the combined HIV prevention strategy, and offering support services. The objective of this paper is to model and forecast HIV prevalence among individuals aged 15-49 years for Eritrea using Holt's linear method. The research findings are expected to guide policy, planning and allocation of resources towards targeted HIV prevention, treatment and care programs in the country.

Literature Review

Author(s)	Objective (s)	Methodology	Key finding(s)
Bekolo et al. (2023)	To review current evidence for declining HIV prevalence despite increasing survival owing to 'universal test and treat' and to explore the reason for the decrease, particularly the role of behavioral change	conducted a secondary analysis using HIV prevalence, behavioral and social determinants data of the Demographic and Health Survey Program databases	The observed decline in HIV prevalence is statistically valid and reflects the observed decline in risky sexual behavior that need to be sustained by the National HIV programme

ISSN NO: 2770-2936
July 2024

Mengistu et al. (2023)	To investigate the prevalence, incidence, and factors associated with first-line cART failure using the virologic (plasma viral load), immunologic and clinical criteria among HIV-infected children	A retrospective cohort study of children (<18 years of age on treatment for a period of>6 months) enrolled in the pediatric HIV/AIDs treatment program at Orotta National Pediatric Referral Hospital from January 2005 to December 2020 was conducted Applied Pearson Chi-Squire ($\chi 2$) tests or Fishers exacts test, Kaplan– Meier (KM) estimates, and unadjusted and adjusted Cox-proportional hazard regression models were employed.	Seven in one hundred children on first-line cART are likely to develop treatment failure (TF) every year
Mengistu et al. (2023)	To describe the incidence, patterns, and factors associated with cART modifications in HIV patients enrolled in four treatment centers in Asmara, Eritrea from 2005 to 2021.	-Retrospective cohort study combining data from 5020 [males, 1943 (38.7%) vs. females, 3077 (61.3%)] patients were utilized. Data on multiple demographic and clinical variables were abstracted from patient's charts and cART program registry - multi-variable Cox-proportional hazards model and Kaplan–Meier analysis.	Prominent reasons for cART substitution included toxicity/intolerance, drug-shortage, new drug availability, treatment failure, tuberculosis and pregnancy. The most common adverse event (AEs) associated with cART modification included lipodystrophy, anemia and peripheral neuropathy, among others - NRTI backbone (D4T-based: aHR = 1.849, 95% CI 1.449–2.360, p value < 0.001) were associated with increased cumulative hazard of treatment modification.

ISSN NO: 2770-2936
July 2024

Mengistu et al. (2022)	To explore the rates and predictors of attrition in children started on cART in Asmara, Eritrea.	This was a retrospective cohort study using data from all paediatric patients on cART between 2005 and 2020, conducted at the Orotta National Referral and Teaching Hospital. Kaplan- Meier estimates of the likelihood of attrition and multivariate Cox proportional hazards models were used to assess the factors associated with attrition.	A low incidence of attrition was observed in this study. However, there was high mortality rate in the first 24 months of treatment and late presentation
Mengistu et al. (2022)	To examine the risk factors associated with treatment failure (TF) in Asmara, Eritrea from 2001 to 2020	A multicenter, retrospective 1:2 matched (by age and gender) case–control study was conducted in four major hospitals in Asmara, Eritrea on adults aged ≥ 18 years who were on treatment for at least 6 months.	factors associated with increased likelihood of treatment failure (TF) included initial nucleoside reverse transcriptase inhibitors (NRTI) backbone (Zidovudine + Lamivudine (AZT + 3TC): adjusted odds ratio (aOR) = 2.70, 95% Confidence interval (CI): 1.65–4.41, P-value < 0.001), (Abacavir + lamivudine (ABC + 3TC): aOR = 4.73, 95%CI: 1.18–18.92, P-value = 0.028], and (Stavudine + Lamivudine (D4T + 3TC): aOR = 5.00; 95% CI: 3.03–8.20, P-value < 0.001) in comparison to Emtricitabine and Tenofovir diproxil fumarate (FTC + TDF)
Akuoko et al. (2021)	The study focused on Cameroon, Ethiopia,	2019 data by UNAIDS were	The results revealed a disproportionate

ISSN NO: 2770-2936
July 2024

	Ghana, and Zambia to give a general overview of the HIV situation in the region.	assessed and compared with the 2018 data	burden of the disease among women aged 15 years and above, as compared to men of the same ages and children below 15 years. Also, it was revealed that ARV services among pregnant women are effective in reducing the number of new infections among newborns.

Methodology

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

$E_t=\mu_t + \rho_t \mathbf{t} + \varepsilon_t$……...……[1]

Smoothing equation

$S_t= \alpha E_t + (1-\alpha) (S_{t-1} + b_{t-1})$……..……[2]

$0<\propto<1$

Trend estimation equation

$b_t= \beta (S_t-S_{t-1}) + (1-\beta) b_{t-1}$……[3]

$0<\beta<1$

Forecasting equation

$f_{t+h}= S_t + hb_t$……..……[4]

E_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 Eritrea 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.

ISSN NO: 2770-2936
July 2024

Findings of the study

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	E
Included Observations	31
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.099306
Sum Square Error (SSE)	0.783369
Mean Square Error (MSE)	0.025270
Mean Percentage Error (MPE)	-1.011845
Mean Absolute Percentage Error (MAPE)	9.655520

Residual Analysis for the Applied Model

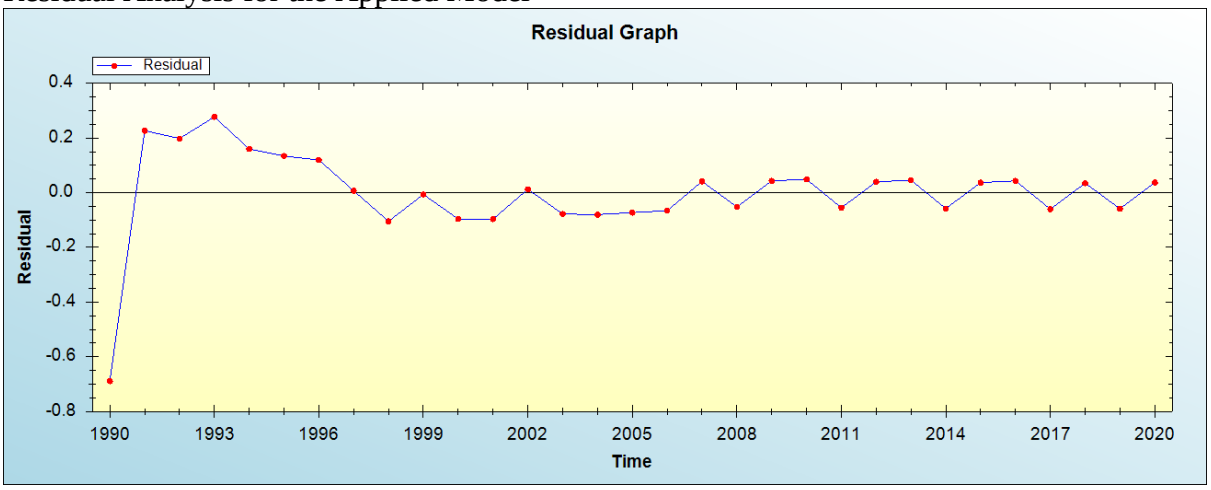

Figure 1: Residual analysis

In-sample Forecast for E

ISSN NO: 2770-2936
July 2024

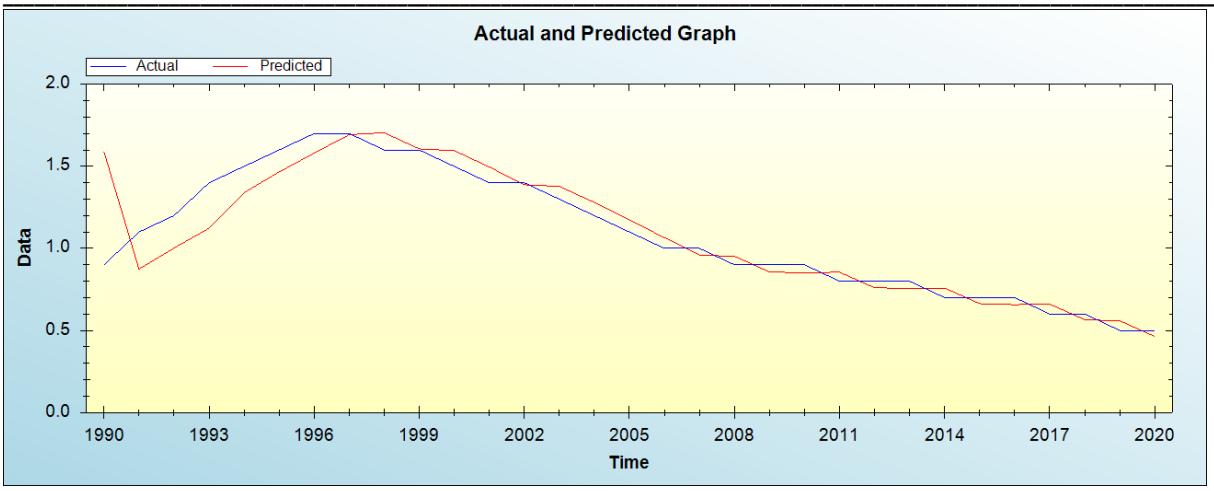

Figure 2: In-sample forecast for the E series

Actual and Smoothed graph for E series

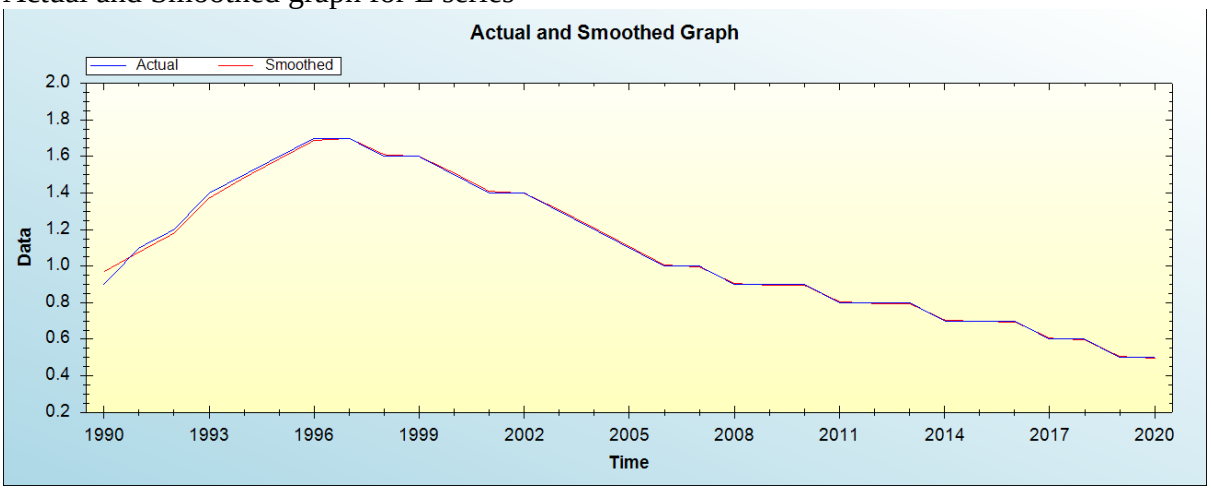

Figure 3: Actual and smoothed graph for E series

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

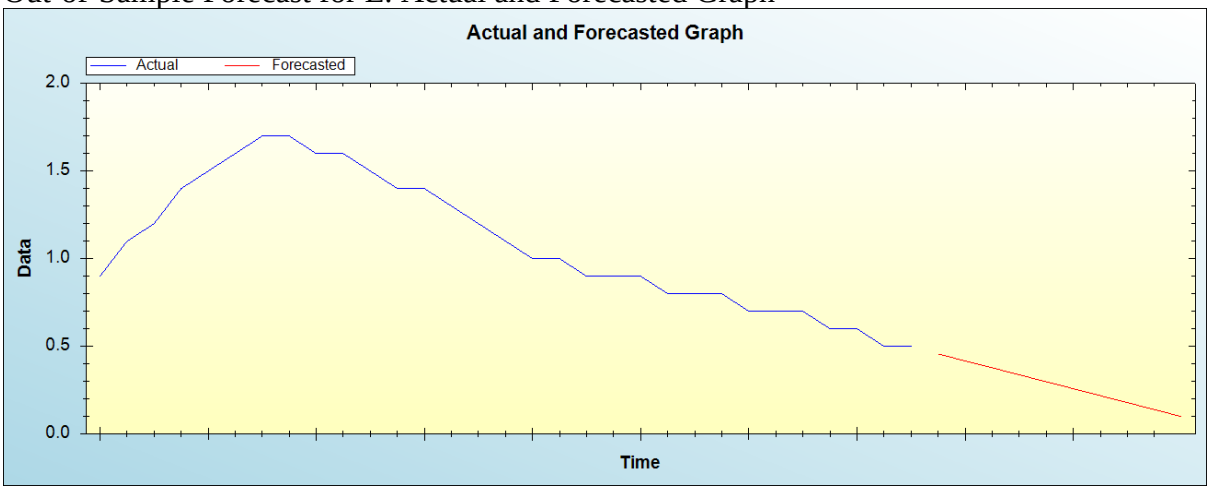

Figure 4: Out-of-sample forecast for E: actual and forecasted graph

Out-of-Sample Forecast for E: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence

ISSN NO: 2770-2936
July 2024

2021	0.4566
2022	0.4168
2023	0.3771
2024	0.3374
2025	0.2977
2026	0.2580
2027	0.2183
2028	0.1785
2029	0.1388
2030	0.0991

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

This paper applied double (Holt's) exponential smoothing to predict annual HIV prevalence among individuals aged 15-49 years and results indicate that will continue to decline over the out of sample period. Therefore, policy makers must focus on prevention measures especially among high risk groups such as adolescents and key populations.

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