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UTILIZING HOLT'S LINEAR EXPONENTIAL SMOOTHING MODEL TO FORECAST HIV PREVALENCE AMONG INDIVIDUALS AGED 15-49 YEARS IN ETHIOPIA

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Abstract:

This study uses annual time series data of HIV prevalence among individuals aged 15-49 years for Ethiopia 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 *improve on HIV case finding among high risk groups, strengthen prevention measures and ART scale up among individuals aged 15-49 years*

Keywords: *Exponential smoothing, Forecasting, HIV prevalence*

BACKGROUND

HIV/AIDS is a major public health issue and a leading cause of morbidity and mortality in many African countries (Mulugeta & Wassihun, 2022). Africans accounted for more than two-thirds of the total infected worldwide, with 35 million infected, 15 million reported AIDS related deaths (Appiah & Gates, 2010). The youth prevalence of HIV was twice as high among women (15–24 years) in Africa in 2016. In sub-Saharan Africa, Ethiopia has the highest number of people living with HIV/AIDS. It is an important part of emerging nations' health systems (Agegnehu *et al.* 2020; Hapco, 2010). The HIV epidemic in Ethiopia is regarded a generalized epidemic with heterosexual transmission being the predominant mode of transmission (Kebede *et al.* 2000). The HIV epidemic is concentrated among key populations such as female sex workers: FSWs, long-distance truck drivers: LDTD, and soldiers; Mehret, 1990; Mebret et al., 1990). Since 1985, Ethiopia has implemented several community-based HIV prevention programs to improve knowledge about the infection and mode of transmission, and interventions to reduce engagement in risk behavior (Mebret *et al.* 1990; Okubagzhi and Singh, 2002). According to EPHIA 2017-2018, the annual incidence of HIV among adults (ages 15-64 years) in urban Ethiopia was 0.05%, which corresponded to approximately 6,000 new cases of HIV annually among adults living in urban Ethiopia. HIV prevalence in urban Ethiopia varied by age, gender, and geographic region. The prevalence of HIV among adults in urban Ethiopia was 3.0%: 4.1% among women and 1.9% among men. Prevalence of VLS among HIV-positive adults in urban Ethiopia was 70.1%: 71.7% among women and 66.8% among men. Among adults living with HIV who knew their HIV status, 97.1% were on ART. Among adults living with HIV in urban Ethiopia on ART 87.6% achieved VLS. The purpose of this research is to model and forecast HIV prevalence among individuals aged 15-49 years for Ethiopia using Holt's linear method. The findings of this paper will facilitate planning and allocation of resources towards targeted HIV programs in the country in order to effectively control the HIV epidemic.

LITERATURE REVIEW

Author(s)	Objective (s)	Methodology	Main finding (s)
Yilema et al. (2024)	To analyze HIV prevalence using the 2016 Ethiopian Demographic and Health Survey data.	-The study included men aged 15–54 years and women aged 15–49 years who responded to questions about HIV tests. A generalized geo-additive model (GAM) was fitted to HIV data using	The results indicated that there are substantially significant spatial variations in HIV prevalence across Ethiopian zones

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		nonparametric smooth terms for geo-locations -Two smoothing techniques were used in GAMs to evaluate spatial disparities and the probable effects of variables on HIV risk.	
Girma et al. (2023)	To measure HRQoL and associated factors among HIV-positive women on ART follow-up in north Shewa zone public hospitals, central Ethiopia.	An institution-based cross-sectional study was conducted from February 01-April 30, 2022	The study revealed a high magnitude of poor HRQoL among HIV-positive women.
Arimide et al. (2022)	To understand the evolutionary and epidemiological pattern of HIV in Ethiopia	Used Bayesian phylodynamic models to estimate the dynamics of the effective population size (Ne) and reproductive numbers (Re) through time for the HIV epidemic in Ethiopia.	The Ethiopian HIV-1 epidemic originated from two independent introductions at the beginning of the 1970s and 1980s from eastern and southern African countries, respectively, followed by epidemic growth reaching its maximum in the early 1990s.
Gelibo et al. (2022)	To identify geographic locations and drivers of HIV transmission	Utilized data from adults aged 15–64 years who participated in the Ethiopian Population-based HIV Impact Assessment survey (October 2017–April 2018). Location-related information for the survey clusters was obtained from the 2007 Ethiopia population census. Spatial autocorrelation of HIV prevalence data were analyzed via a Global Moran's I test.	The finding indicated that uncircumcised men in certain hotspot towns and divorced or widowed individuals in hotspot woredas/towns might have contributed to the average increase in HIV prevalence in the hotspot areas
Mulugeta & Wassihun (2022)	To determine the prevalence and risk factors of HIV/AIDS infection among sexually active women in Ethiopia	Applied multilevel logistic regression model	The prevalence of HIV infection among sexually active women varies by region, with urban women more likely to contract the virus. Women who had more than one regular sexual partner and had

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			their first sexual encounter at a younger age are at an increased risk of contracting HIV/AIDS.
Biressaw et al. (2021)	to cluster HIV patients and to find out the factors that mostly affect the prevalence of HIV within a group (cluster) and between groups (clusters) of HIV patients	The study was based on the 2016 Ethiopian Demographic Health Survey (EDHS) which was collected by the Central Statistical Agency (CSA) of Ethiopia, and the survey collected a total of 26,753 samples, of which 14,785 were women and 11,968 were men and the age group was between 15 and 49 years for both. Binary logistic regression, principal component analysis, cluster analysis, and ANOVA were applied to analyze the data.	The result of HIV patients are clustered into 3 clusters and determine the status of HIV levels. Mainly, cluster 2 accounts for 50% of HIV patients whereas cluster 3 and 1 accounts for 40% and 10%, respectively
Mirkuzie et al. (2021)	To measure the Fast Track progress in the epidemiology of HIV/AIDS in Ethiopia across ages compared to neighboring countries	Age-standardized and age-specific HIV/AIDS incidence, prevalence, mortality, Disability-Adjusted Life Years (DALYs), incidence: mortality ratio and incidence: prevalence ratio were calculated with corresponding 95% confidence intervals.	Ethiopia and neighboring countries have made remarkable progress towards achieving the 75% HIV/ AIDS mortality reduction target by 2020, although they progressed poorly in reducing HIV incidence. By recording an incidence: prevalence ratio benchmark of less than 0.03, Ethiopia, Rwanda, and Uganda are well heading towards epidemic control
Zewudie et al. (2021)	To investigate depression and Associated Factors among Adult HIV/AIDS-Positive Patients Attending ART Clinics of Ethiopia	Systematic Review	The pooled depression prevalence among adult HIV/AIDS patients attending antiretroviral therapy in Ethiopia was higher than the general population and is alarming for the government to take

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			special consideration for HIV-positive patients.
Endalamaw et al. (2020)	To assess the national burden of human immunodeficiency virus treatment failure and associated factors in the Ethiopian context	Utilized the Ethiopian Universities' online repository library, Google Scholar, PubMed, Web of Science, and Scopus to get the research articles. Used I-squared statistics to see heterogeneity. Publication bias was checked by using Egger's regression test. The pooled prevalence was estimated using the DerSimonian-Laird random-effects model. We employed the sensitivity analysis to see the presence of outlier result in the included studies.	Human immunodeficiency virus treatment failure in Ethiopia found to be high. Being on advanced clinical stage, presence of opportunistic infections, and poor adherence to highly active antiretroviral therapy were the contributing factors of human immunodeficiency virus treatment failure

METHODOLOGY

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

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

Smoothing equation

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

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f_{t+h}= S_t + hb_t.....[4]

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 Ethiopia 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)	0.152007
Sum Square Error (SSE)	2.581770
Mean Square Error (MSE)	0.083283
Mean Percentage Error (MPE)	-0.394226
Mean Absolute Percentage Error (MAPE)	8.031683

Residual Analysis for the Applied Model

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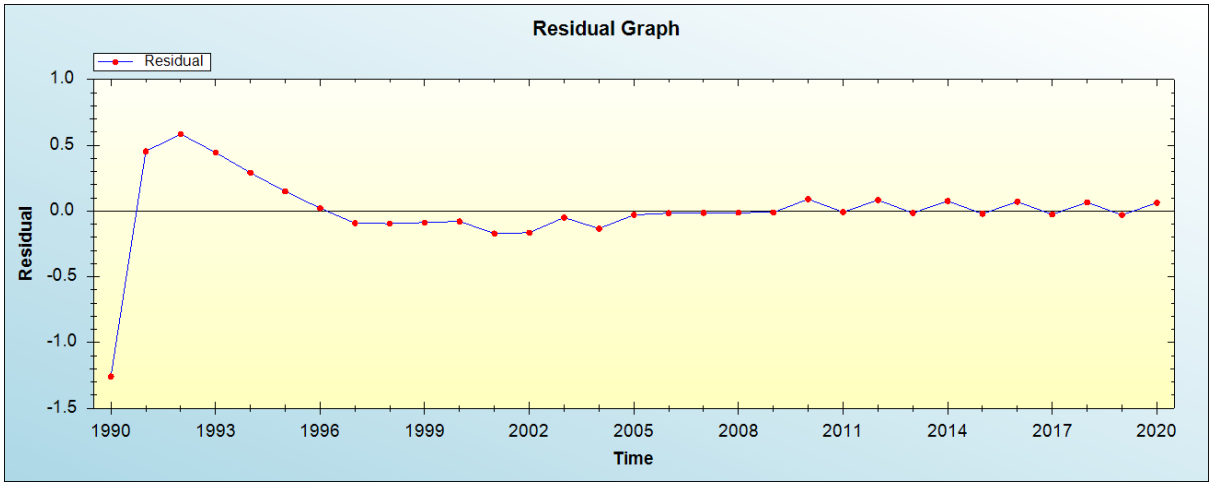

Figure 1: Residual analysis

In-sample Forecast for A

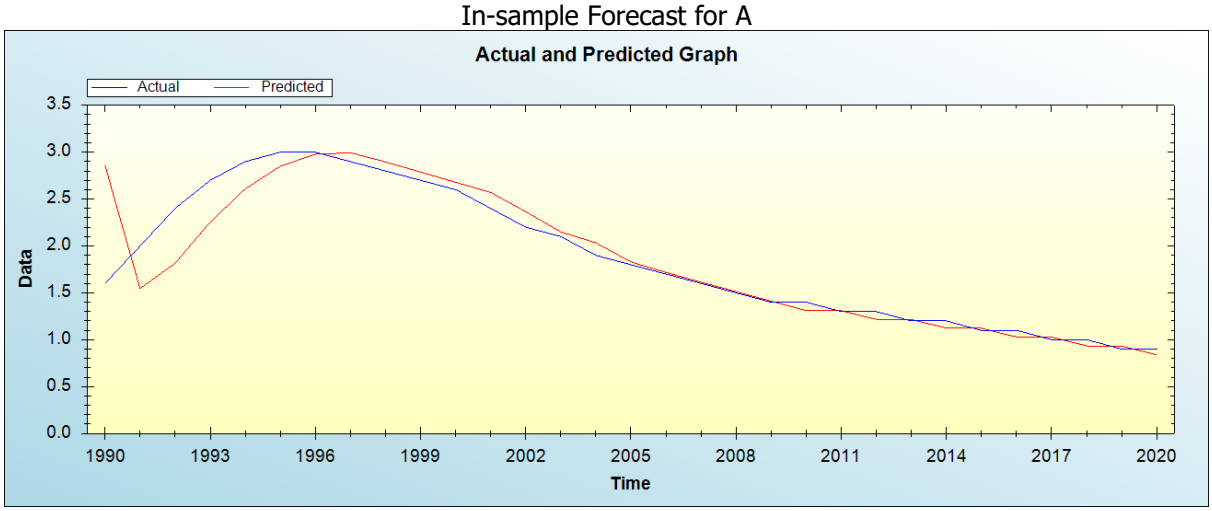

Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

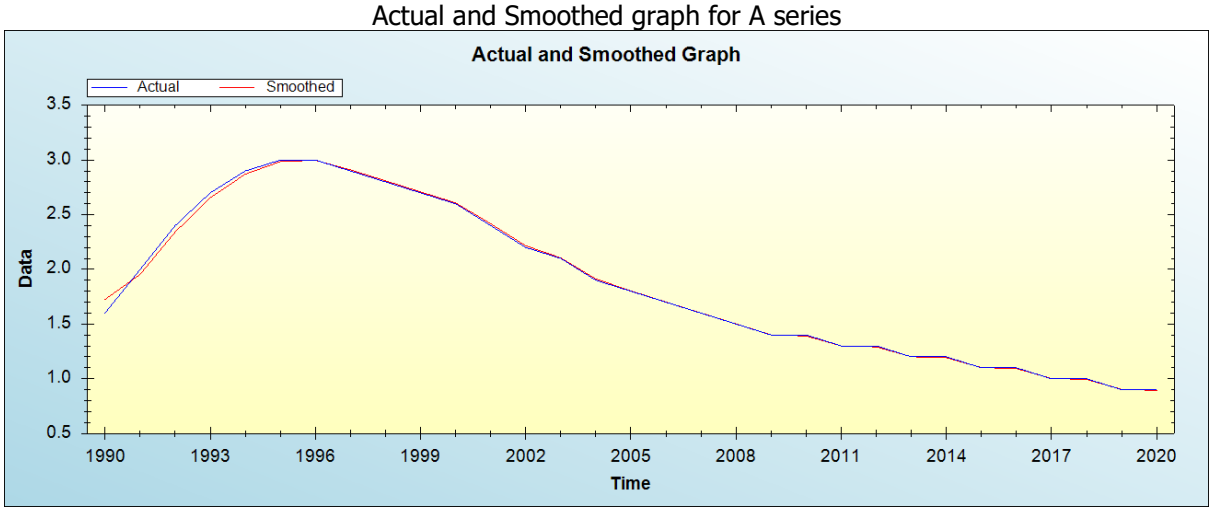

Figure 3: Actual and smoothed graph for A series

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

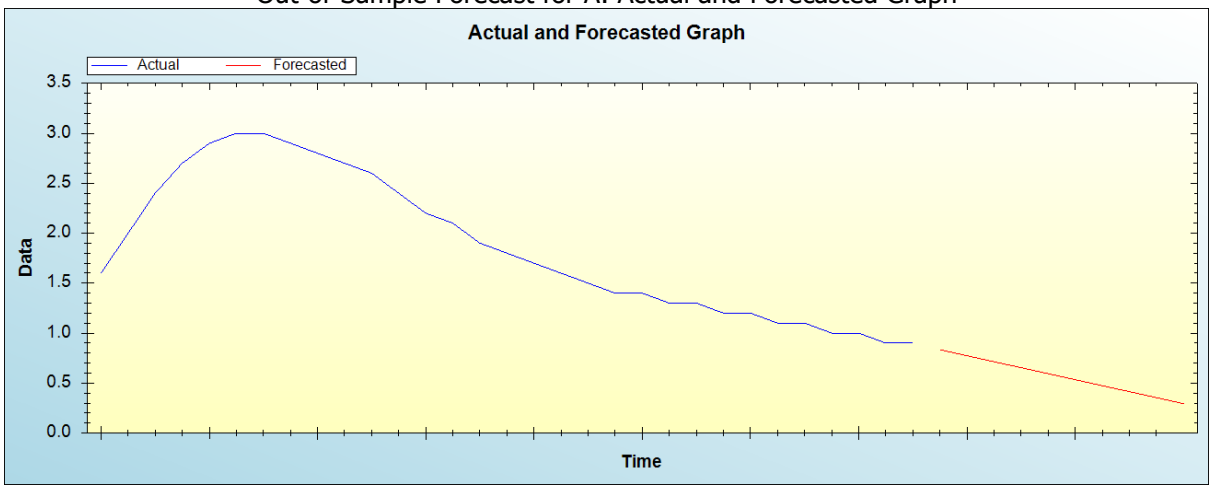

Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	0.8338
2022	0.7738
2023	0.7139
2024	0.6539
2025	0.5940
2026	0.5340
2027	0.4741
2028	0.4141
2029	0.3542
2030	0.2942

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

The study establishes that the annual HIV prevalence among individuals aged 15-49 years will continue to decline in the out of sample period. We therefore, encourage authorities to improve on HIV case finding among high risk groups, strengthen prevention measures and ART scale up among individuals aged 15-49 years.

REFERENCES

[1] A. Appiah and H. L. Gates (2010). Encyclopedia of Africa, Oxford University Press on Demand, Oxford, UK.
[2] F. Hapco, Report on Progress Towards Implementation of the UN Declaration of Commitment on HIV/AIDS, Federal Ministry of Health, Gemany, Switzerland, 2010.

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Available Online at: https://www.scholarexpress.net
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[3] C. D. Agegnehu, B. M. Geremew and M. M. Sisay (2020). "Determinants of comprehensive knowledge of HIV/AIDS among reproductive age (15–49 years) women in Ethiopia: further analysis of 2016 Ethiopian demographic and health survey," AIDS Research and Therapy, vol.17, no.1, pp.51–59, 2020.
[4] Kebede, D., Aklilu, M., and Sanders, E. (2000). The HIV epidemic and the state of its surveillance in Ethiopia. Ethiop. Med. J. 38, 283–302.
[5] Mebret, M., Kbodakcvicb, L., Zewdie, D., Ayebunic, S., Gizaw, G., and Shanko, B. (1990). HIV-1 infection and related risk factors among female sex workers in urban areas of Ethiopia. Ethiop. J. Heal. Dev. 4, 163–170.
[6] Mehret, M. (1990). HIV-1 infection and related risk factors among female sex workers in urban areas in Ethiopia. Ethiop. J. Health Dev. 4(Suppl. 2), 163–170.
[7] Okubagzhi, G., and Singh, S. (2002). Establishing an HIV/AIDS programme in developing countries: the Ethiopian experience. AIDS 16, 1575–1586. doi: 10.1097/00002030-200208160-00002
[8] ETHIOPIA POPULATION-BASED HIV IMPACT ASSESSMENT EPHIA 2017-2018