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APPLYING HOLT'S LINEAR METHOD TO FORECAST HIV PREVALENCE AMONG INDIVIDUALS AGED 15-49 YEARS IN GHANA

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 Ghana 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, there is need to scale up HIV testing and strengthen HIV prevention among this age group.

Keywords: - Exponential smoothing, Forecasting, HIV prevalence.

Introduction

According to UNAIDS data, in 2020 Ghana reported 19,000 new HIV infections, national prevalence of 1.7% among adults, 350,000 PLHIV and 13,000 AIDS related deaths. Top priority strategies in Ghana's national HIV response include advocacy, communication, and community awareness to promote HIV testing & counseling, behavioral change, to identify and treat STIs, elimination of mother-to-child transmission; and address barriers to HIV testing and ART adherence (Ghana, 2020). The government of Ghana has managed to swiftly respond to the HIV epidemic because it has support from various partners which include the Global Fund to fight AIDS, Tuberculosis, and Malaria (Boah et al. 2023). UNAIDS revealed that only 60% of people living with HIV (PLWHIV) in Ghana were initiated on highly effective antiretroviral therapy in 2020 (UNAIDS, 2021). Available evidence indicates that low ART coverage is attributed to low levels of knowledge and misconceptions about HIV and AIDS, gaps in the quality of HIV/AIDS care, discrimination and stigmatization of PLHIV, and low use of HIV testing services (Boah et al. 2022; Alhassan et al. 2021; Gyamerah et al. 2020; Ankrah et al. 2016; Sano et al. 2016; Boateng et al. 2013). The aim of this paper is to model and forecast HIV prevalence among individuals aged 15-49 years for Ghana using Holt's linear method. The findings of this research are expected to facilitate allocation of resources towards targeted HIV programs in order to effectively control the HIV epidemic.

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Literature Review

Author (s)	Objective (s)	Methodology	Main finding(s)
Alhassan et al. (2023)	Determine the predictors of HIV status disclosure among people living with HIV (PLHIV) and stimulate policy discourse on support systems for self-disclosure in Africa.	descriptive cross-sectional study	HIV status self-disclosure was reported by 50% of the respondents; nearly 65% disclosed their status to non- family members and non-partners. Significant correlates of HIV status disclosure either to partners or non-partners were marital status, monthly income, type of occupation, and being divorced due to HIV status ($p < 0.05$).
Boah et al. (2023)	To examine HIV/AIDS trends in Ghana before (1990–2004) and after (2004–2020) the implementation and expansion of ART	-obtained HIV/AIDS epidemiology and treatment data for the years 1990–2020 from the United Nations Programme on HIV/AIDS	The most significant HIV declines occurred after the introduction of ART, suggesting that the scale-up of ART may have contributed to the decline in HIV/AIDS in Ghana.
Boadu et al. (2023)	To synthesize available evidence on adherence to ART among HIV/AIDS patients in Ghana	Systematic review	The pooled estimate of optimal adherence to ART among HIV patients in Ghana was lower than is recommended to achieve viral suppression. Adherence was lower among young persons living with HIV/AIDS.
Appiaha et al. (2021)	To identify and compares child HIV disclosure barriers and facilitators in Upper East, Northern and Ashanti regions of Ghana	A bivariate and binary multiple logistic regression analysis was performed to test child and caregiver related variable with disclosure.	The barriers to disclosure involved limited caregiver knowledge and caregiver notion of non-disclosure as a best interest and child protection decision. Difference in region of residence of the child contributes to enhance or impede child HIV disclosure
Moreira et al. (2016)	To characterize late presenters to HIV care in Santiago (Cape Verde) between 2004 and 2011, and identifies factors associated with late presentation for care.	-unmatched case-control study	Results showed that 51.9% were late presenters for HIV. No differences were found in gender distribution, marital status, or access to health services between cases and controls

Methodology

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

$$G_t=\mu_t + \rho_t \mathbf{t} + \varepsilon_t \quad [1]$$

Smoothing equation

$$S_t= \alpha G_t + (1-\alpha)\,(S_{t-1} + b_{t-1}) \quad [2]$$

$0<\propto<1$

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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]

G_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 Ghana 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	G
Included Observations	31
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.118060
Sum Square Error (SSE)	1.518867
Mean Square Error (MSE)	0.048996
Mean Percentage Error (MPE)	-1.112838
Mean Absolute Percentage Error (MAPE)	7.052614

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Residual Analysis for the Applied Model

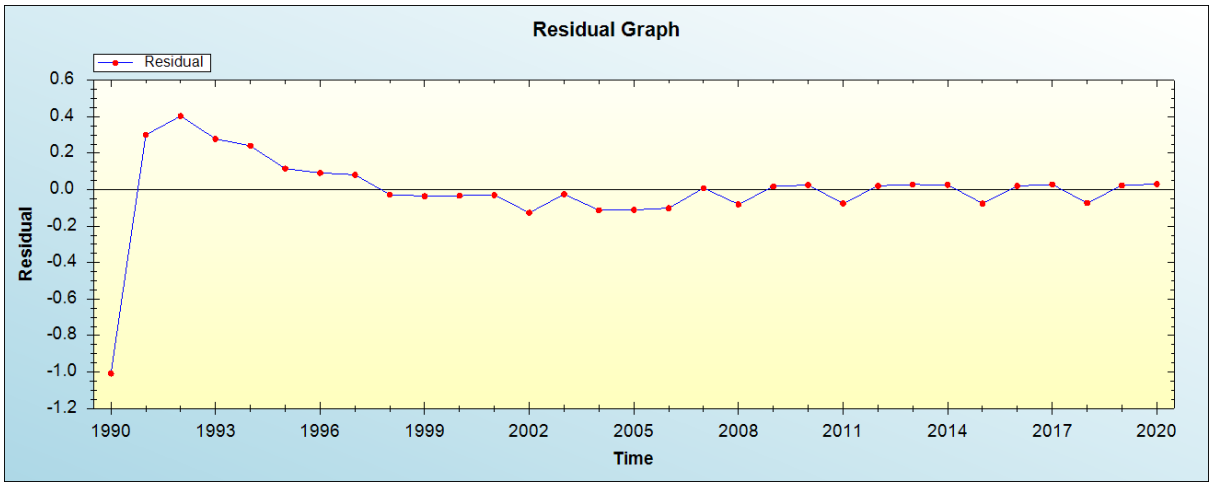

Figure 1: Residual analysis

In-sample Forecast for G

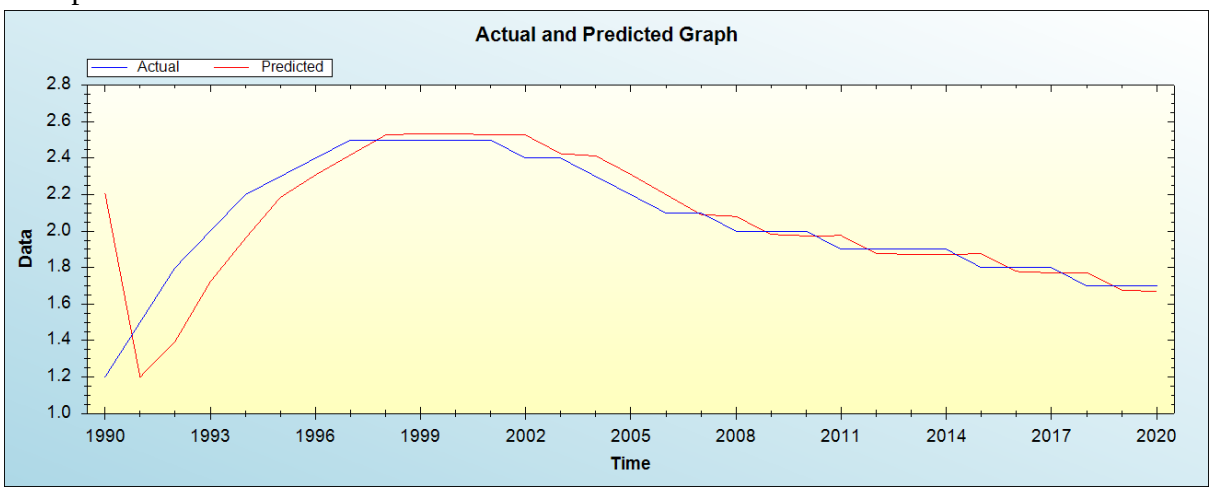

Figure 2: In-sample forecast for the G series

Actual and Smoothed graph for G series

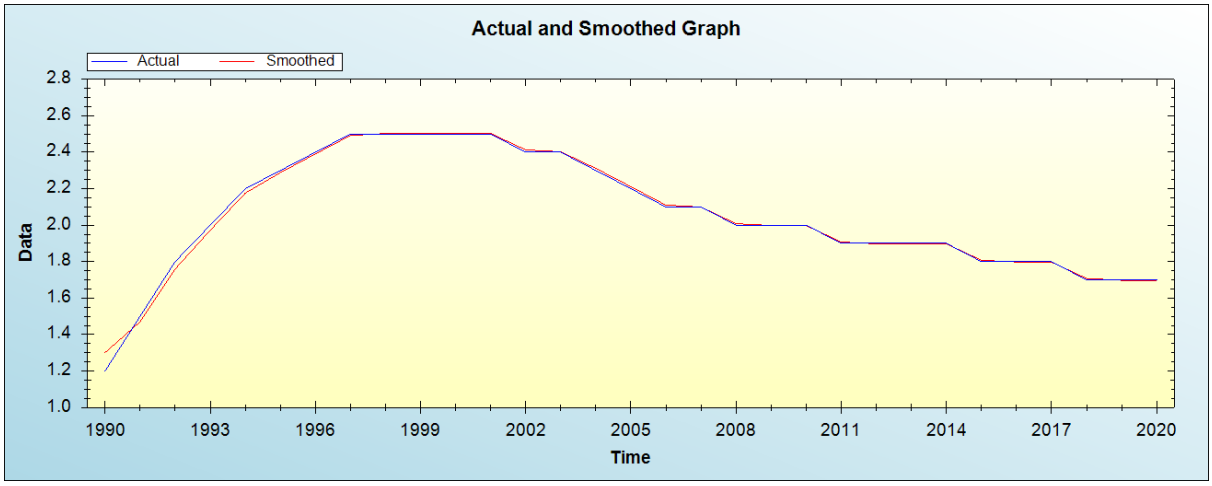

Figure 3: Actual and smoothed graph for G series

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

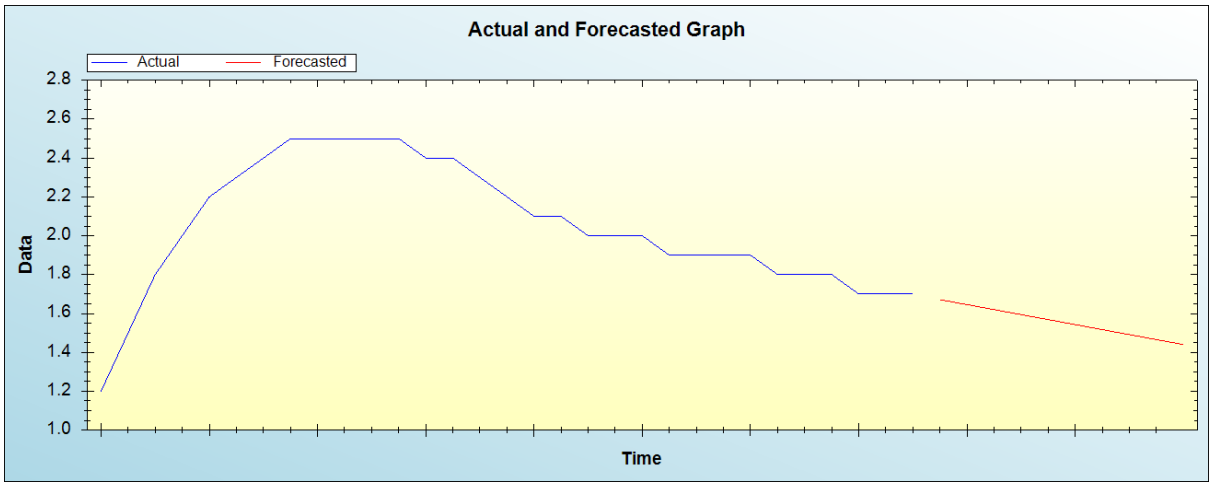

Figure 4: Out-of-sample forecast for G: actual and forecasted graph

Out-of-Sample Forecast for G: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	1.6712
2022	1.6455
2023	1.6198
2024	1.5941
2025	1.5684
2026	1.5426
2027	1.5169
2028	1.4912
2029	1.4655
2030	1.4398

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 model predictions suggest a gradual decline of HIV prevalence among individuals aged 15-49 years throughout the forecast period. Hence, authorities are encouraged to scale up HIV testing and strengthen HIV prevention among this age group.

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