TRACKING THE FUTURE PATH OF HIV PREVALENCE AMONG INDIVIDUALS AGED 15-49 YEARS IN GUATEMALA 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 Guatemala 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, policy makers should strengthen HIV case finding and HIV prevention especially among key populations.

Keywords: Exponential smoothing, Forecasting, HIV prevalence.

Introduction

Guatemala has the highest number of people living with HIV (PLHIV) in Central America (Ortíz *et al.* 2021; Ross *et al.* 2017). According to UNAIDS, the country has the highest incidence within the region with 3,700 infections per year and this figure is more than three times the number of new infections in any other Central American country. It was reported that 62% of PLHIV know their HIV status, 69% of all linked to care are taking ART, 80% taking ART are virally suppressed and the percentage of PLHIV in Guatemala with viral suppression is approximately 34% (UNAIDS, 2020; UNAIDS, 2019). The estimated national HIV seroprevalence among adults aged 15 to 49 years was 0.6% in 2015. However, prevalence was higher in key populations including men who have sex with men (MSM) (12%) and sex workers in urban areas (4–15%) (UNAIDS, 2015). Most of HIV infections occurred in Metropolitan Region (WHO, 2005). HIV prevalence among sex workers stood at 4.5% in Guatemala and the prevalence of HIV, syphilis, chlamydia, and gonorrhea has been measured at 1.1%, 9%, 14%, and 12%, respectively, on the Mexico side of the border (UNAIDS, 2011; Morales-Miranda *et al.* 2013). Failure of antiretroviral therapy and non-adherence is reportedly associated with stigma, difficulty in accessing healthcare because of location or financial status, alcohol and substance misuse, education, pill burden, and ART side effects (Ridgway *et al.* 2020; Diress *et al.* 2019; UNAIDS, 2019; Scott *et al.* 2016; Joy *et al.* 2008; Ammassari *et al.* 2001). The objective of this paper is to model and forecast HIV prevalence among individuals aged 15-49 years for Guatemala using double exponential smoothing. The

findings of this study are anticipated to facilitate planning and allocation of resources towards targeted HIV prevention, treatment, care and support programs in the country.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Springfield et al. (2023)	To describe the socio-demographic characteristics and phylogenetic profile of HIV-1 within a cohort of HIV-positive female sex workers (FSW) situated at the Guatemala-Mexico border.	HIV viral sequences were collected from a cohort of FSW ≥18 years of age from San Marcos, Guatemala (n=6) and compared to viral sequences collected as part of the Mesoamerican Drug Resistance Monitoring Programme to assess HIV viral diversity in Mexico and Guatemala (n=3956).	All of the FSW sampled were determined to have genetically unrelated HIV infections, suggesting multiple introductions of the virus and/or the potential existence of populations not captured by current surveillance efforts. Many reported numerous vulnerabilities that may have heightened their risk of acquiring and transmitting HIV through sex work activities. Our phylogenetic analysis indicated that national surveillance programmes may not fully capture the viral diversity among FSW and their clients within this region.
Huff et al. (2022)	To explore the interplay between substance use (SU) and HIV in Latin America (LA)	scoping review	Factors associated with HIV among PWUS included being female, IDU and homelessness, and PWUS were likely to engage in risky sexual behaviors, start antiretroviral treatment late, have poor adherence, have treatment failure, be lost to follow-up, have comorbidities, and experience higher mortality rates and lower quality of life, as has been reported in PLWH with SU in other regions.
Rocha-Jiménez et al. (2022)	To determine the association between traveling to engage in sex work in another country and recent access to HIV testing among substance-using female sex workers (FSWs) in the Mexico–Guatemala border region	Crude and adjusted logistic regression models were used to evaluate the relationships between mobility experiences and HIV testing in the past year	Overall HIV testing was low (41%); after considering relevant covariates (i.e., interaction with health services and organizations, and sex work characteristics) traveling to engage in sex work in another country was found to be positively associated with HIV testing in the past year.
Medina et al. (2021)	To analyze the situation of AHD and OIs in a cohort of newly diagnosed HIV patients from Guatemala.	Patients were screened for tuberculosis (TB), non-tuberculous mycobacteria (NTM), histoplasmosis, and cryptococcal disease ,independently of their CD4 cell count	The overall OI incidence was 21%. Histoplasmosis was the most frequent OI (7.9%), followed by TB (7.1%); 94.4% of these infections occurred in patients with a CD4 < 350 cells/mm3. Mortality at 180 days was significantly higher in those with OIs than without OIs (29.7% vs. 5.9%, p < 0.0001).
Ortíz et al. (2021)	To evaluated factors associated with viral non suppression (VNS) and persistent viremia (PV) in people living with HIV	Conducted a cross sectional analysis using data from an ongoing cohort of PLHIV attending the largest	Socio-economic and clinical factors influence viral suppression in this cohort and vary between men and women.

		(PLHIV) receiving antiretroviral therapy (ART) in Guatemala.	HIV clinic in Guatemala	
García et al. (2020)	-To evaluate the performance of the lipoarabinomannan antigen test (LAM-test) with and without α-mannosidase pre-treated urine in a cohort of PLWH in primary care clinics in Guatemala. -To determine TB incidence, and mortality rates and its risk factors in PLWH with TB symptoms.	Prospective longitudinal study of PLWH with TB symptoms	α-mannosidase treatment of urine did not significantly increase the LAM-test performance
García et al. (2018)	To describe and compare trends in prevalence, sexual behavior and HIV transmission knowledge data related to sexually transmitted infections (STI) and HIV in patients attending three STI clinics over an 8-year period in Escuintla Department, Guatemala.	Annual cross-sectional analysis and multivariable Poisson regression adjusted for socio-demographic variables were used for prevalence comparisons and adjusted prevalence trends for HIV/STI outcomes and used for adjusted trends in proportions in sexual behaviour and HIV transmission knowledge outcomes.	FSW show a decreasing trend in HIV, syphilis and chlamydia prevalence. Gonorrhoea prevalence in FSW and HRH did not decrease over time

Methodology

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

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

Smoothing equation

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

$0 < \alpha < 1$

Trend estimation equation

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

$0 < \beta < 1$

Forecasting equation

$$f_{t+h} = S_t + \mathrm{h}b_t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots[4]$$

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 Guatemala 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)	0.028531
Sum Square Error (SSE)	0.081878
Mean Square Error (MSE)	0.002641
Mean Percentage Error (MPE)	-4.713480
Mean Absolute Percentage Error (MAPE)	14.162940

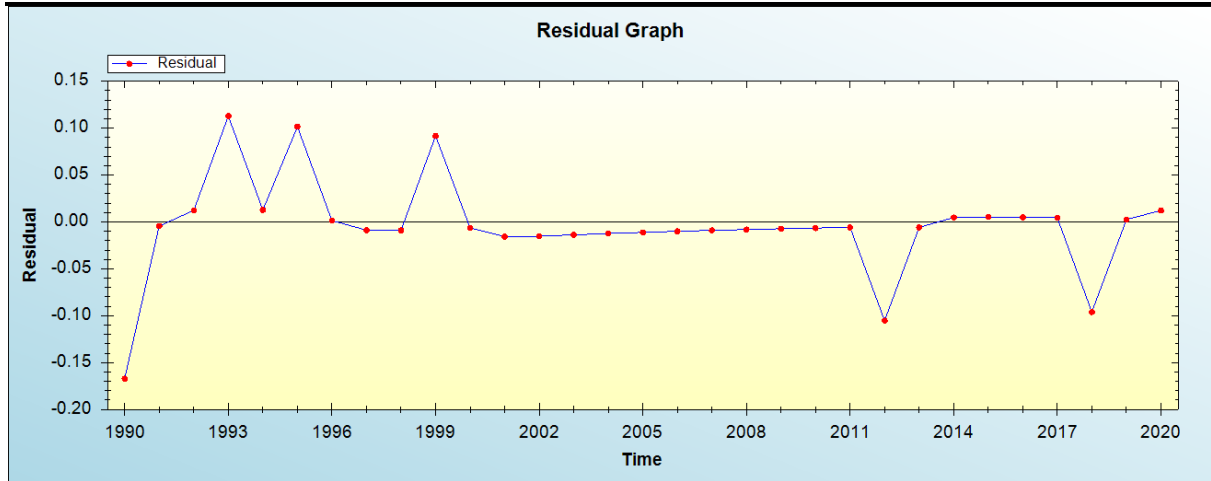Residual Analysis for the Applied Model

Figure 1: Residual analysis
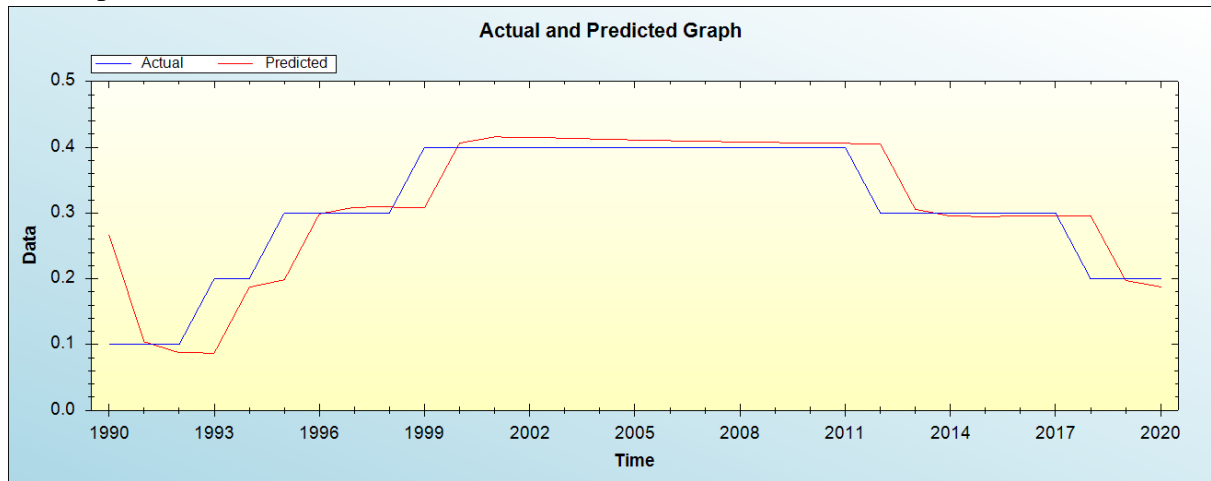
In-sample Forecast for G

Figure 2: In-sample forecast for the G series

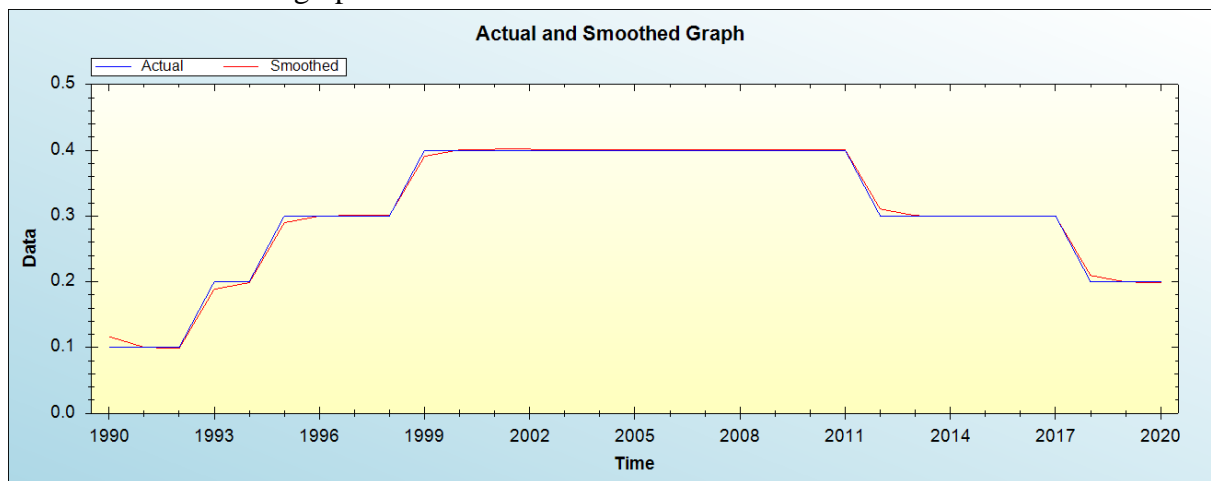Actual and Smoothed graph for G series

Figure 3: Actual and smoothed graph for G series

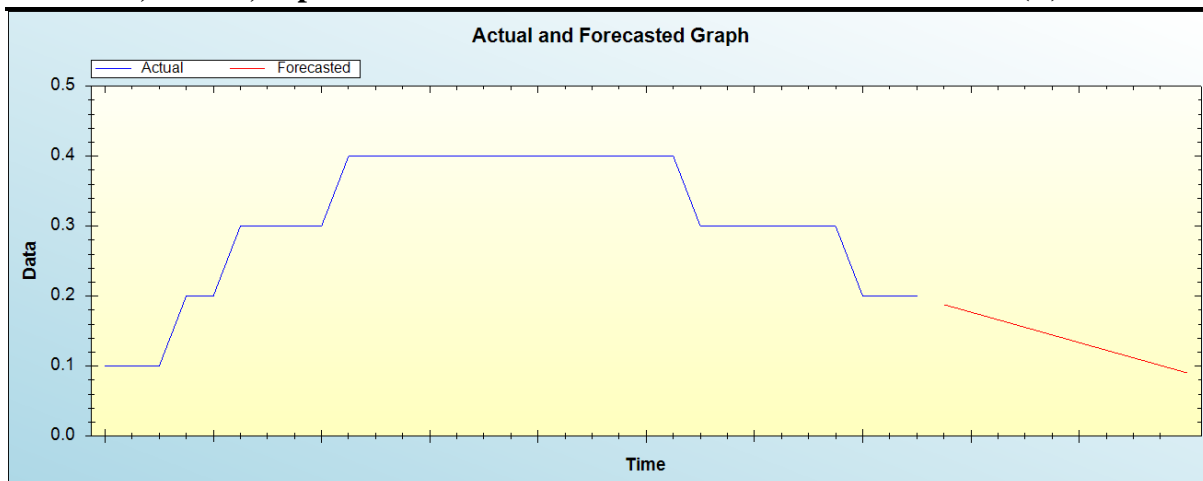Out-of-Sample Forecast for G: Actual and Forecasted Graph

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	0.1879
2022	0.1770
2023	0.1662
2024	0.1553
2025	0.1445
2026	0.1336
2027	0.1227
2028	0.1119
2029	0.1010
2030	0.0901

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 study results indicate that annual HIV prevalence among individuals aged 15-49 years will continue to decline in the out of sample period. Therefore, policy makers should strengthen HIV case finding and HIV prevention especially among key populations.

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