PREDICTION OF HIV PREVALENCE AMONG INDIVIDUALS AGED 15-49 YEARS IN LATIN AMERICA AND THE CARIBBEAN 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 Latin America and the Caribbean 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 on an upward trend over the out of sample period. Therefore, it is important to address main drivers of HIV transmission in the region targeting adolescents, men who have sex with other men and commercial sex workers. Moreover, it is essential to ensure ART treatment adherence among young adults living with HIV to minimize emergence of drug-resistant HIV strains and control HIV spread.

Keywords: - Exponential smoothing, Forecasting, HIV prevalence.

Introduction

The Joint United Nations Programme on HIV/AIDS (UNAIDS) revealed that 1,900,000 adults and children were living with HIV in Latin America and the Caribbean in 2018, with an overall seroprevalence of 0.5% (UNAIDS data, 2019). The HIV epidemic in Latin America is concentrated among men who have sex with men, transgender women, sex workers and people who inject drugs (UNAIDS, 2019; Degenhardt *et al.* 2017). People living with HIV in the Caribbean are less than those in Latin America and its reported HIV seroprevalence in the general population is 1.2%, women accounting for fifty percent of all infections (UNAIDS, 2017). Despite several challenges, there was rapid scale up of antiretroviral therapy over the past decades. Over the period 2003-2008, the number of people on ART doubled and gradually increased thereafter. In 2017, about 1.2 million PLHIV (61%) were receiving ART, lagging only after high-income countries (78%) (UNAIDS data, 2019). In addition, HIV/AIDS related deaths after ART initiation has declined and is very similar to that among Latinos receiving HIV care in the USA (Cesar *et al.* 2016; Carriquiry *et al.* 2015; Aran-Matero *et al.* 2011). AIDS-related conditions continue to be the leading causes of death among PLHIV in Latin America despite achievements in access to ART (UNAIDS data, 2019). This might be explained by the consistently high numbers of late HIV

diagnosis, which still occurs in almost half of diagnosed adults in Latin America (Belaunzaran-Zamudio *et al.* 2019; Pineirua *et al.* 2015).

The objective of this paper is to model and forecast HIV prevalence among the 15-49 years age group using Holt's linear exponential smoothing technique. The findings of this research are expected to inform policy, planning and allocation of resources to HIV prevention, treatment and care programs for the 15-49 years age group.

Literature review

Author(s)	Objective (s)	Methodology	Key finding (s)
Huff et al. (2022)	To explore the interplay between substance use (SU) and HIV in Latin America (LA)	Literature 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.
Gabster et al. (2022)	To explore barriers and facilitators to antiretroviral adherence and retention in HIV care among people living with HIV in the Comarca Ngä ¨beBugle ´, Panama	Used the Social-Ecological Theory for Health as a framework	Structural barriers included difficult access to ART care due to travel costs, ART shortages, and uncooperative Western/Traditional medical systems.
Local Burden of Disease HIV Collaborators (2021)	To address this gap and provide novel estimates of the HIV mortality rate and the number of HIV deaths by age group, sex, and municipality in Brazil, Colombia, Costa Rica, Ecuador, Guatemala, and Mexico.	performed an ecological study using VR data ranging from 2000 to 2017, dependent on individual country data availability	-subnational estimates of HIV mortality revealed significant spatial variation and diverging local trends in HIV mortality over time and by age
Montana et al. (2021)	To study the behavior of the epidemic in the Colombian territory.	Applied join point regression model to analyze the annual HIV/AIDS incidence and AIDS mortality rates	There was an upward trend in HIV/AIDS incidence and a stable trend in the AIDS mortality rate in Colombia. The downward trend in HIV/AIDS incidence and AIDS mortality rate in the 0–14 age group reflects the downwards mother-to-child HIV transmission.
Mangala et al. (2019)	To use Brazil's integrated health systems data to develop a mathematical model, reproducing the complex surveillance systems and providing estimates of HIV incidence, number of people living with HIV (PLHIV), reporting rates and ART initiation rates.	An age-structured deterministic model with a flexible spline was used to describe the natural history of HIV along with reporting and treatment rates	The results showed a second wave of infections occurring after 2001 and 56,000 (95% Credible Interval 43,000–71,000) new infections in 2015, 37,000(95%CrI28,000–54,000) infections in men and 16,000(95% CrI 10,000–23,000) in women.
Saffier et al. (2017)	To review all published literature on HIV prevalence and risk factors for HIV infection amongst 10-25 year olds in Brazil	Literature review	Literature shows raised HIV prevalence amongst MSM and FSW, as well as amongst those using drugs.
Álvarez Barreneche et al. (2017)	To describe the patient population, admission diagnosis and hospital course of HIV patients in Colombia in the ART era.	Patients admitted with HIV/AIDS at six hospitals in Medellin, Colombia between August 1, 2014 and July 31, 2015 were included. Demographic, laboratory, and clinical data were prospectively collected	Similar to other countries in the developing world, in Colombia, the leading cause of hospitalization among HIV-infected patients remain opportunistic infections. However, in-hospital mortality was low, similar to those described for high-income countries.

Methodology

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

$A_t = \mu_t + \rho_t t + \varepsilon_t$………………………………………………………………...…[1]

Smoothing equation

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

$0 < \alpha < 1$

Trend estimation equation

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

$0 < \beta < 1$

Forecasting equation

$f_{t+h} = S_t + hb_t$………………………………………………………………………[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 Latin America and the Caribbean 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)	0.014186
Sum Square Error (SSE)	0.011325
Mean Square Error (MSE)	0.000365
Mean Percentage Error (MPE)	-0.273870
Mean Absolute Percentage Error (MAPE)	4.118185

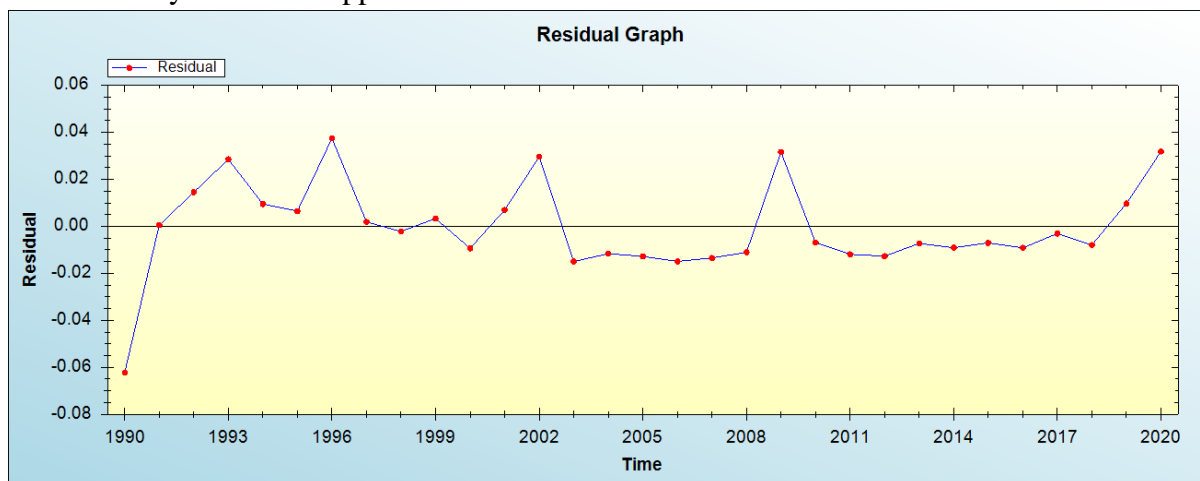Residual Analysis for the Applied Model

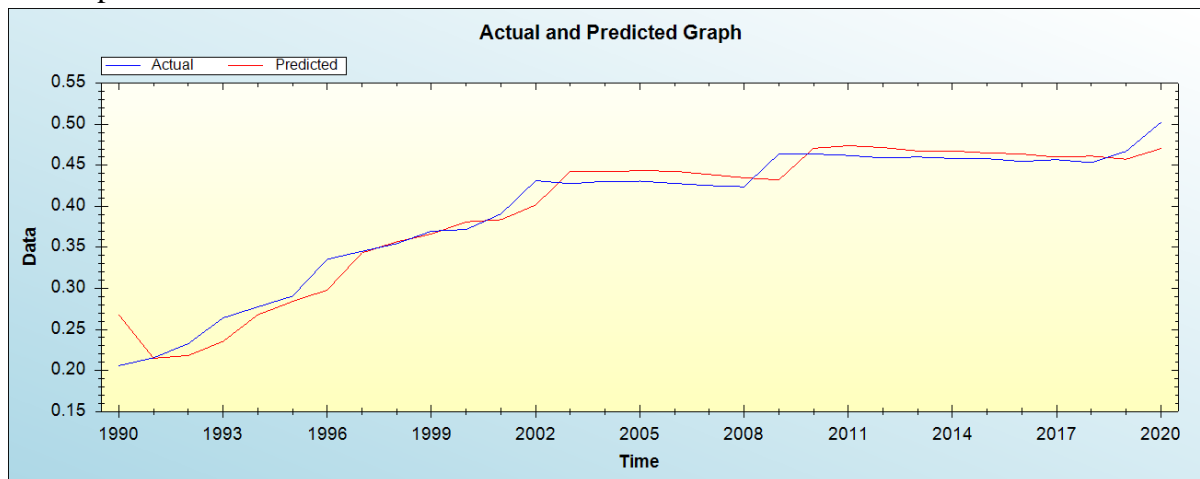Figure 1: Residual analysis

In-sample Forecast for A

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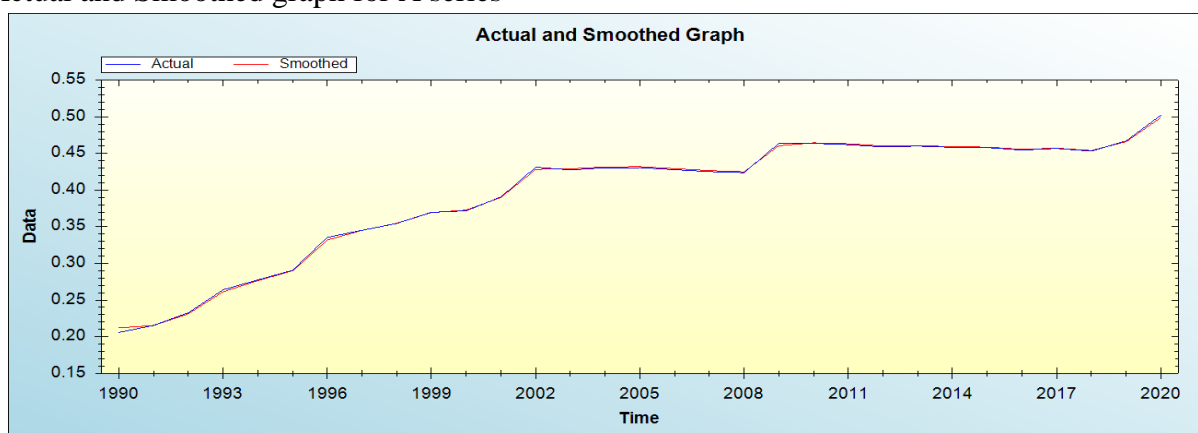
Actual and Smoothed graph for A series

Figure 3: Actual and smoothed graph for A series

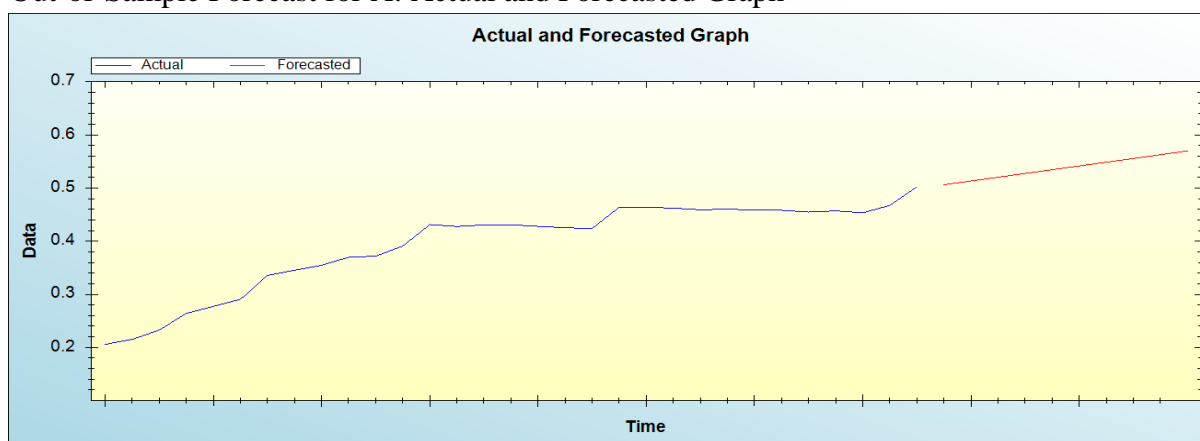Out-of-Sample Forecast for A: Actual and Forecasted Graph

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	0.5062
2022	0.5133
2023	0.5203
2024	0.5274
2025	0.5344
2026	0.5415
2027	0.5486
2028	0.5556
2029	0.5627
2030	0.5697

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 on an upward trend over the out of sample period.

Policy implication and conclusion

Our research findings suggest that annual HIV prevalence among individuals aged 15-49 years will continue on an upward trend in the out of sample period. This paper calls for the regional authorities to scale up HIV case detection, prevention and treatment among high risk groups. It is also important to address main drivers of HIV transmission in the region targeting adolescents, men who have sex with other men and commercial sex workers. Moreover, it is essential to ensure ART treatment adherence to minimize emergence of drug resistant HIV strains and control HIV transmission.

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