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Forecasting the future path of HIV prevalence among individuals aged 15-49 years in Colombia using Holt's double 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 Colombia from 1990 to 2020 to predict future trends of HIV prevalence over the period 2021 to 2030. The study utilizes Holt's double 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 remain around 0.4% throughout the out of sample period. Therefore, we encourage authorities to scale up HIV case detection, treatment and prevention especially among key populations and vulnerable groups.

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

Background

According to statistics reported by UNAIDS, since 1980, 74.9 million is the accumulated number of people living with HIV accompanied by 32 million AIDS related deaths. Despite the significant progress made in the reduction of global AIDS-related deaths by more than 50% after Antiretroviral Therapy (ART) was implemented, the HIV/AIDS incidence rate achieved only a slight decrease (UNAIDS, 2019; GBD 2017 HIV collaborators; Trickey *et al*. 2017). Between 2010 and 2018, a 7% increase in new HIV infections was reported throughout LA (UNAIDS, 2019; GBD 2017 HIV collaborators; Piñeirúa *et al*. 2015). Among all Latin American countries, Colombia has the fourth highest HIV/AIDS prevalence rate. Its national HIV/ AIDS prevalence is approximately 0.7%, but much higher among key populations – men who have sex with men, sex workers, injection drug users and prisoners (Montana *et al.* 2021). Furthermore, Colombia is part of the Caribbean region, which has the second-highest prevalence of HIV/AIDS in the world after sub-Saharan Africa. In this region, by the end of 2019, there were 330,000 PLWHA, 6900 AIDS-related deaths and 13,000 new HIV infections recorded in the same year. Approximately 50% of Colombian people living with HIV still have not been diagnosed for the virus, and only 55% of PLWHA are on ART. Of those receiving treatment, only 68% are virally suppressed (Montana *et al.* 2021; UNAIDS, 2019). The noticeable spread of HIV in Colombia is attributable to social inequalities with the majority of its population living in poverty and with low access to the healthcare system, social discrimination and stigmatization of PLWHA, the forced displacement of the population by internal armed conflicts, the high level of violence against women and sexual tourism (Arrieta-Gómez, 2018; Rivillas *et al.* 2018; Djellouli & Quevedo-Gómes, 2015). The aim of this paper is to model and forecast HIV prevalence among individuals aged 15-49 years for Colombia using Holt's linear method. Study findings are expected to guide policy, planning and allocation of resources to targeted HIV programs in the country.

Literature Review

Author(s)	Objective(s)	Methodology	Main finding(s)
Correa-Salazar et al. (2023)	to 1) understand how violence is associated with newly reported HIV/AIDS case rates for women in Colombian	Mixed methods design	-The study found that newly reported HIV cases in women were 25% higher for every increase of 18 homicides per

ISSN NO: 2770-2936
August 2024

	municipalities; and 2) describe how social violence impacts HIV risk, treatment, and prevention for Venezuelan migrant and refugee women undergoing transnational migration and resettlement in Colombia		100,000, after adjusting for covariates -participants cited armed actors' control, lack of government accountability, gender-based violence and stigmatization of HIV as sources of increased HIV risk for VMRW
Montana et al. (2021)	To study the behavior of the HIV epidemic in the Colombian territory.	The study employed the join point regression model to analyze the annual HIV/AIDS incidence and AIDS mortality rates. In the spatial analysis, they used univariate autocorrelation techniques and the Kernel density estimator.	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. The upward trend in HIV/AIDS incidence in older women and AIDS mortality in younger women rates, compared with men, may be due to late diagnosis and treatment.
Kuhlmann et al. (2017)	To estimate the societal costs of HIV/AIDS in Bogota, Colombia	Cross-sectional cost of illness study	HIV/AIDS represents a high societal burden in Colombia The largest part of HIV/AIDS costs were attributed to drugs and productivity costs
Álvarez Barreneche et al. (2017)	To describe the patient population, admission diagnosis and hospital course of HIV patients in Colombia in the ART	Patients admitted with HIV/AIDS at six hospitals in Medellin, Colombia between August 1, 2014 and July 31,	The leading cause of hospitalization among HIV-infected patients remain opportunistic infections. However,

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	era	2015 were included. Demographic, laboratory, and clinical data were prospectively collected	in-hospital mortality was low, similar to those described for high-income countries.

Methodology

This study utilizes Holt's double exponential smoothing technique to model and forecast future trends of HIV prevalence among individuals aged 15-49 years in Colombia. 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

$f_{t+h}= S_t + hb_t$……[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 Colombia 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.

Study Findings

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

ISSN NO: 2770-2936
August 2024

Forecast performance measures	
Mean Absolute Error (MAE)	0.021426
Sum Square Error (SSE)	0.056067
Mean Square Error (MSE)	0.001809
Mean Percentage Error (MPE)	-3.284300
Mean Absolute Percentage Error (MAPE)	10.595913

Residual Analysis for the Applied Model

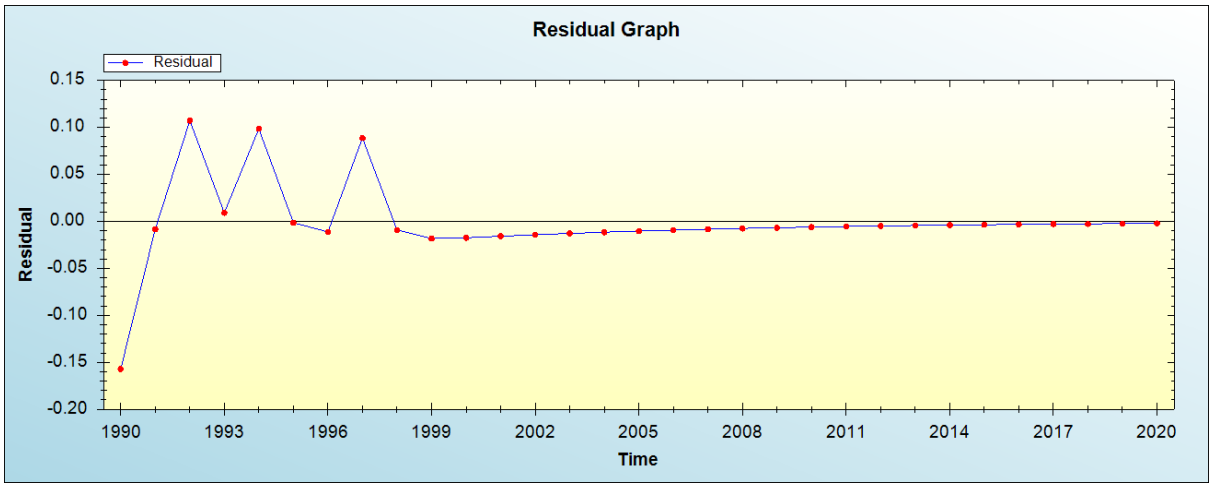

Figure 1: Residual analysis

In-sample Forecast for A

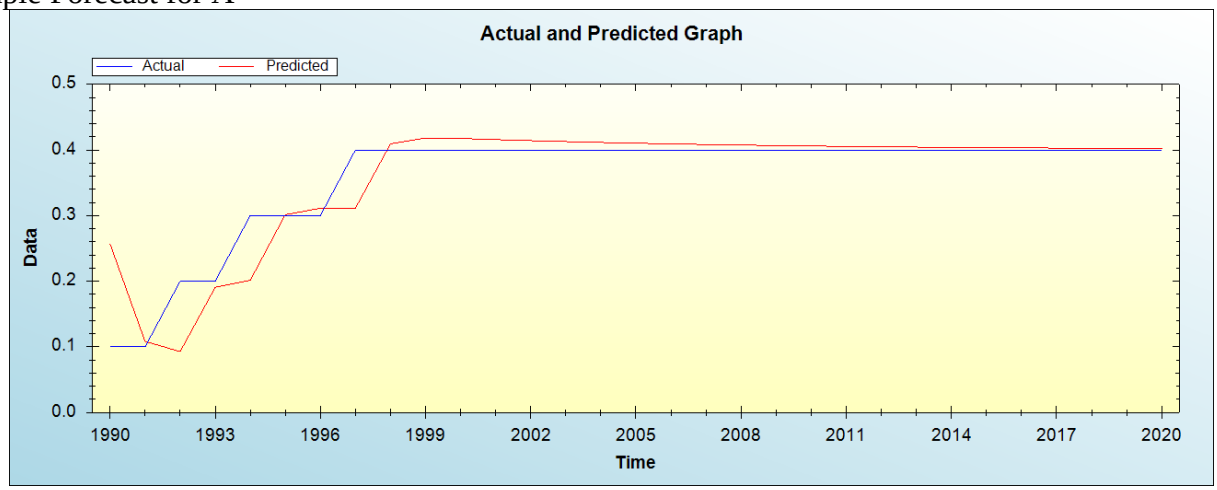

Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

ISSN NO: 2770-2936
August 2024

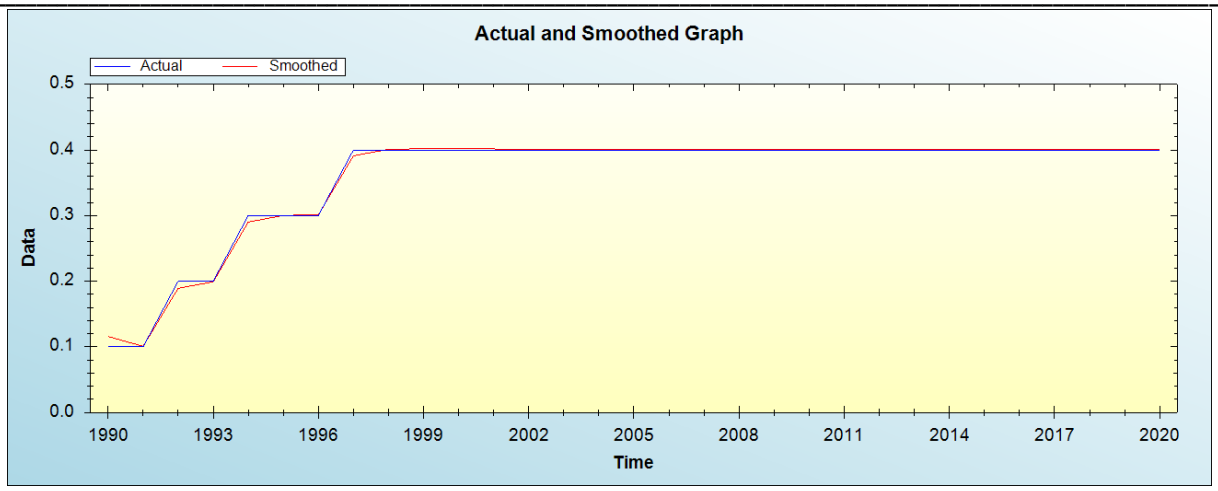

Figure 3: Actual and smoothed graph for A series

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

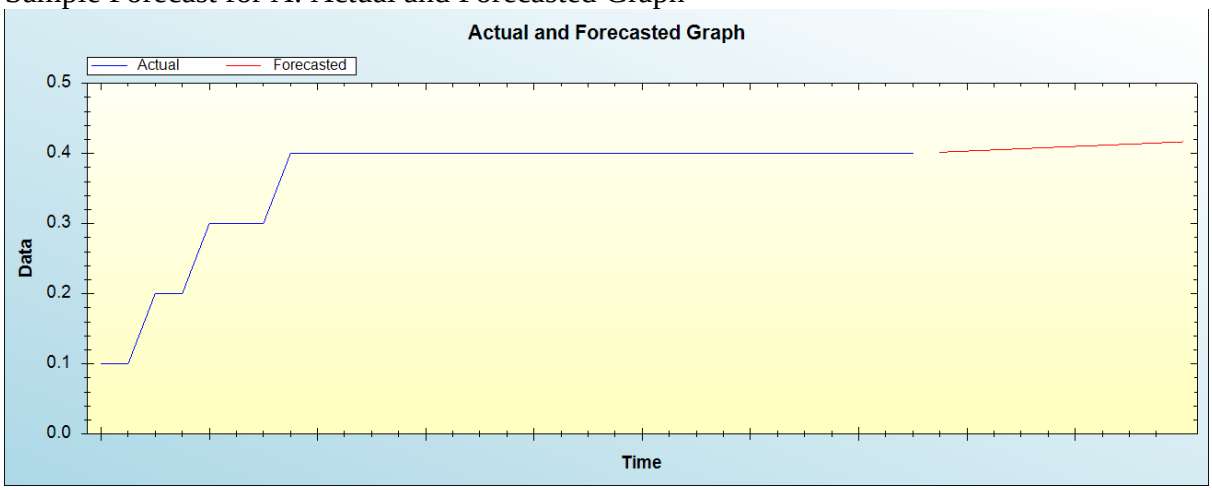

Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	0.4019
2022	0.4035
2023	0.4052
2024	0.4068
2025	0.4085
2026	0.4102
2027	0.4118
2028	0.4135
2029	0.4151
2030	0.4168

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 remain around 0.4 % throughout the out of sample period.

Policy implication and conclusion

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Exponential smoothing techniques are widely applied in time series forecasting including public health. This paper applied Holt's double exponential smoothing technique to detect future trends of annual HIV prevalence among individuals aged 15-49 years and model projections suggest that it will remain around 0.4 % throughout the forecast period. Therefore, policymakers are encouraged to scale up HIV case detection, treatment and prevention especially among key populations and vulnerable groups.

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