ESTIMATING FUTURE TRENDS OF HIV PREVALENCE AMONG INDIVIDUALS AGED 15-49 YEARS IN COSTA RICA USING HOLT'S DOUBLE EXPONENTIAL SMOOTHING MODEL

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Article history:		Abstract:
		This study uses annual time series data of HIV prevalence among individuals aged 15-49 years for Costa Rica 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 0.8 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, we encourage authorities to must scale up HIV testing, prevention and treatment among high risk and vulnerable groups in the country.

BACKGROUND

HIV and its associated AIDS related medical conditions are the leading causes of morbidity and mortality globally. Sub-Saharan Africa bears the highest burden of the HIV epidemic. Latin America also continues to battle the HIV epidemic from various fronts that include political leadership (WHO, 2020). In 2017, the Global Burden of Disease reported more than 30,000 HIV/AIDS-related deaths in Latin America (Renjith, 2022; Local Burden of Disease HIV Collaborators, 2021). Access to highly active antiretroviral therapy has significantly improved in Latin America, however few countries have reported a significant decline in HIV/AIDS related deaths since 2000. Costa Rica has the lowest HIV mortality rates in the greater Central American region and this is attributable to its diligent healthcare system (Renjith, 2022. It is important to mention that funding of the national ART program is purely domestic and produced good results when compared to regional counterparts (Baird, 2023; Noy,

2021; Pesec *et al.* 2021; Baker & Gallicchio, 2020; Spigel *et al.* 2020; Pesec *et al.* 2017; García *et al.* 2014). In addition, the rapid decentralization of ART services to primary care level and community centered harm reduction strategies has seen huge numbers of people living with HIV being enrolled into the national ART program (Rojas, 2015). This increased access to, and dissemination of ARV and timely HIV-specific primary care has resulted in the reduction of mortality due to HIV/AIDS in the region by at least 50 % between 2001 and 2010 (Pesec *et al.* 2021; Noy *et al.* 2021). The objective of this paper is to model and forecast HIV prevalence among individuals aged 15-49 years for Costa Rica using Holt's linear method. The findings of this study will guide policy, planning and allocation of resources to targeted HIV programs in the country.

LITERATURE REVIEW

Author(s)	Objective(s)	Methodology	Main finding(s)
Day et al. (2023)	to shed light on the complexities and factors contributing to the success or failure of harm reduction treatment strategies within the United States and what can be learned by Costa Rica's unique,	ethnographic report	The success of Hogar de la Esperanza can be directly linked to the national commitment to community care, quality improvement and universal access to free ART, coupled with the cooperative union of

	primary Care-centric approach to healthcare for all.		medical and harm reduction treatment models within the Costa Rican healthcare system
Correa-Salazar et al. (2023)	to 1) understand how violence is associated with newly reported HIV/AIDS case rates for women in Colombian 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	Mixed methods design	-The study found that newly reported HIV cases in women were 25% higher for every increase of 18 homicides per 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
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	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.
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

METHODOLOGY

This study utilizes Holt's double exponential smoothing technique to model and forecast future trends of annual prevalence of HIV among the 15-49 years age group in Costa Rica. 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

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

Smoothing equation

$S_t = \alpha C_t + (1-\alpha)(S_{t-1} + b_{t-1})$..[2]

$0<\alpha<1$
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]

C_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 Costa Rica 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	C
Included Observations	31
Smoothing constants	
Alpha (α) for data	0.800
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.019485
Sum Square Error (SSE)	0.030818
Mean Square Error (MSE)	0.000994
Mean Percentage Error (MPE)	-0.751532
Mean Absolute Percentage Error (MAPE)	10.625995

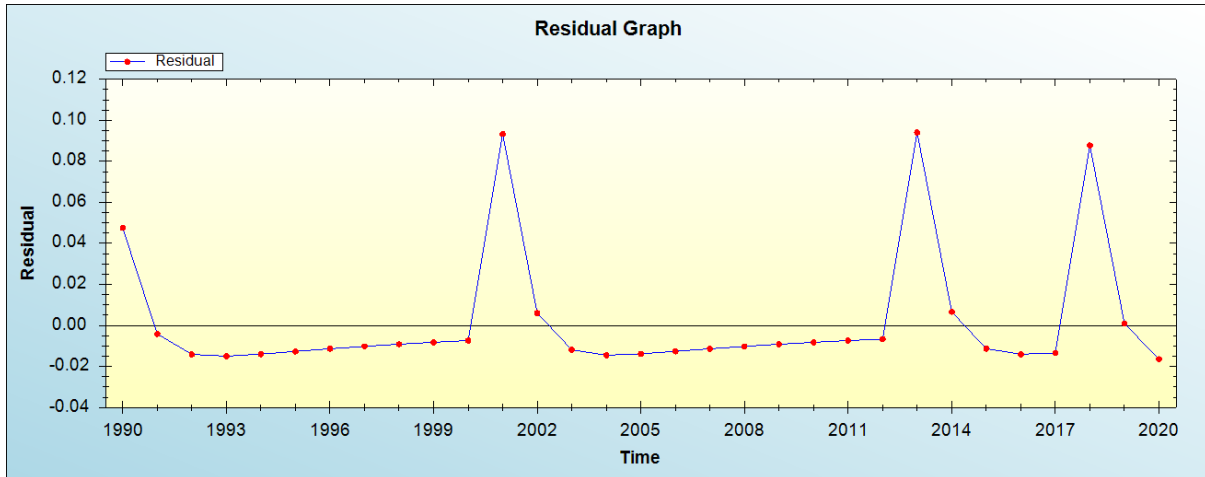Residual Analysis for the Applied Model

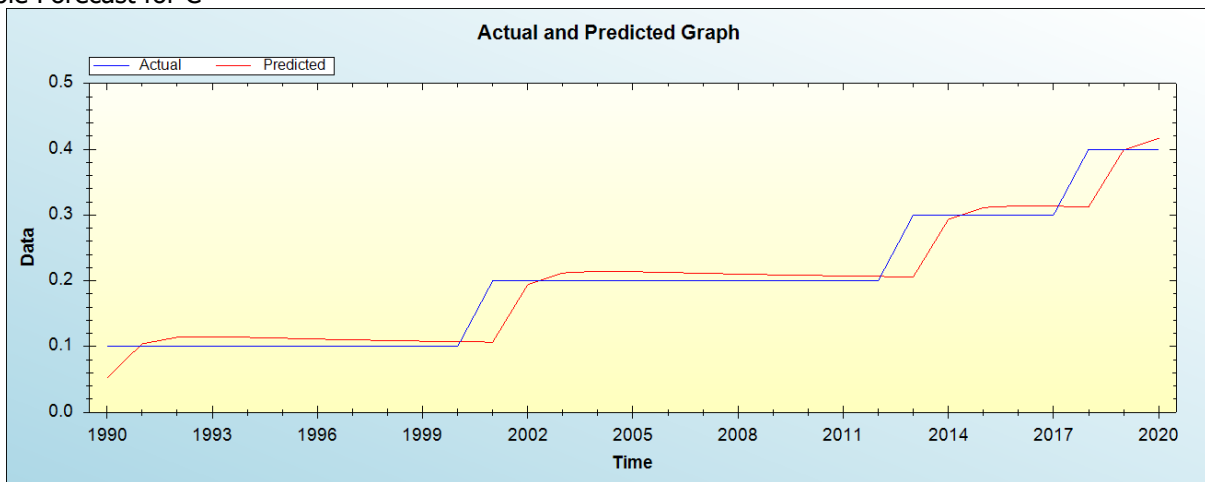Figure 1: Residual analysis

In-sample Forecast for C

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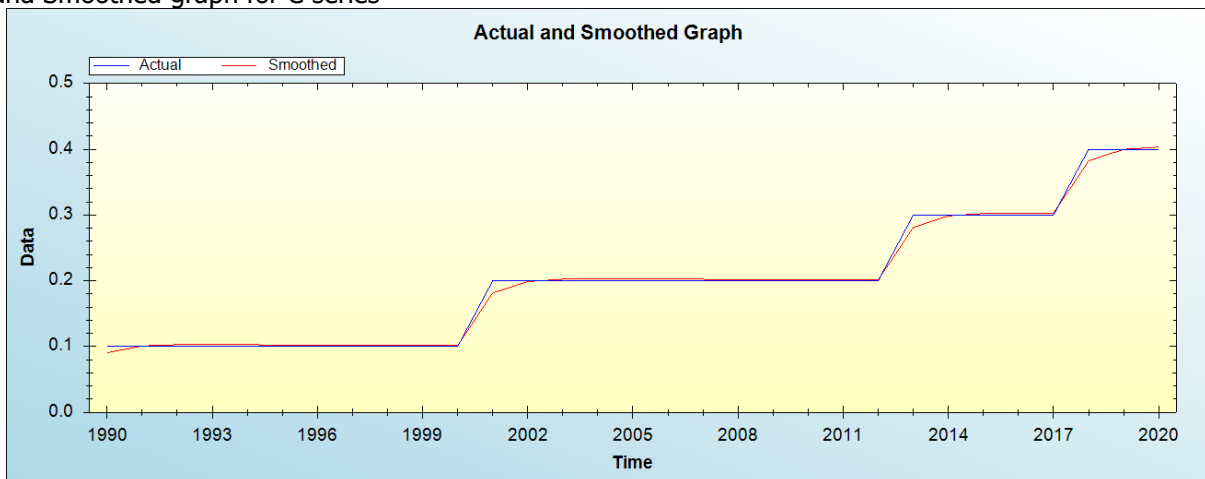
Actual and Smoothed graph for C series

Figure 3: Actual and smoothed graph for C series

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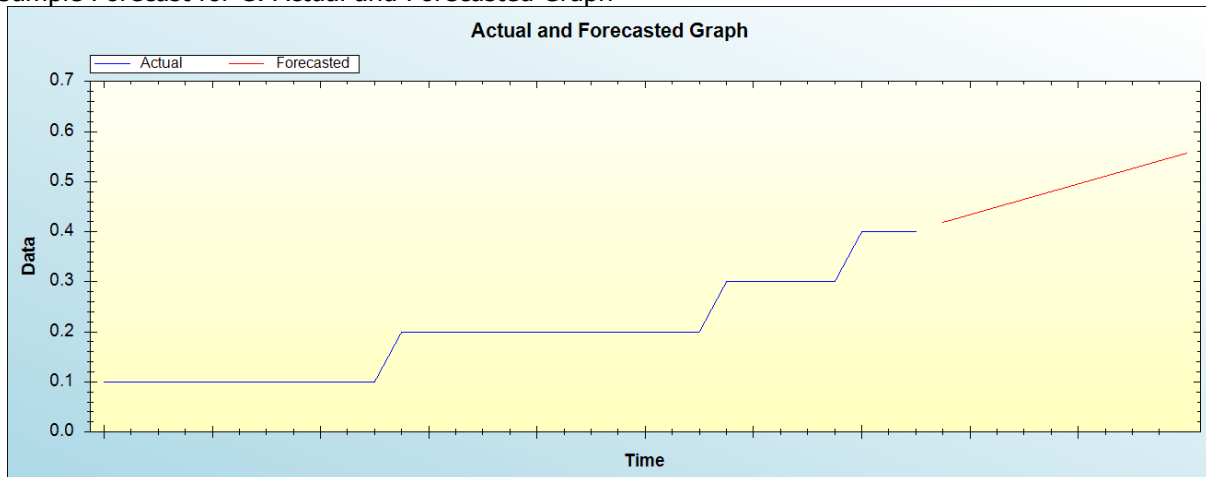

Figure 4: Out-of-sample forecast for C: actual and forecasted graph

Out-of-Sample Forecast for C: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	0.4186
2022	0.4340
2023	0.4493
2024	0.4647
2025	0.4800
2026	0.4954
2027	0.5107
2028	0.5261
2029	0.5414
2030	0.5568

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

The predicted upward trajectory of annual HIV prevalence among individuals aged 15-49 years in Costa Rica calls for an urgent HIV response as new HIV infections are expected to rise in the out of sample period among the sexually active and reproductive age group (15-49). In order to reduce morbidity and mortality among this age group authorities must scale up HIV testing, prevention and treatment among high risk and vulnerable groups in the country.

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