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Applying Brown's double exponential smoothing technique to forecast HIV prevalence among people aged 15-49 years in Belize

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Abstract
This study uses annual time series data on HIV prevalence among people aged 15-49 years for Belize from 1990 to 2020 to predict future trends of HIV prevalence over the period 2021 to 2030. The study utilizes double (Brown) exponential smoothing model. The optimal value of the smoothing constant α is 0.7 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, we encourage policy-makers to strengthen HIV case detection, behavioral change interventions and other HIV prevention measures especially among key populations.

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

Background

Belize reported its first AIDS case in 1986, since then HIV has spread gradually among the general population. The transmission of the HIV virus is propagated by poverty, low levels of condom use, and cultural attitudes that promote multiple sexual partnerships for men. The government has previously reported that poor and migrant families are among the high risk groups for contracting and transmitting HIV across Belize. In addition, Sex between men is also a major risk factor for HIV transmission in Belize. According to USAID, infection rates in the general population is estimated to be between 2 and 4 percent, the epidemic is growing quickly among the heterosexual population. Red Cross Belize reported that the HIV virus is spread mainly through the heterosexual community, with factors such as sexual and gender based violence and gender disparities significantly contributing to the increase in the prevalence rate. The purpose of the national HIV response is to prevent further HIV infection, expanding HIV care, treatment and support, and reducing HIV stigma and discrimination. The aim of this paper is to model and forecast future trends of HIV prevalence among the 15-49 years age group using Brown exponential smoothing model. The results of this study are expected to provide an insight of the likely future trends of HIV prevalence among the sexually active age group and assist in planning and allocation of resources to HIV prevention and treatment programs targeting this age group.

Literature Review

Author (s)	Objective (s)	Methodology	Main finding (s)
Leonardo and Chien et al. (2023)	To examine the factors associated with HIV testing among women of reproductive age in Belize and trends in HIV testing in 2006, 2011, and 2015–2016	-Cross-sectional data were analyzed using three Belize Multiple Indicator Cluster Surveys. The number of participants were 1,675, 4,096, and 4,699 women aged	Women aged 15–24 years were less likely to have been tested for HIV compared to women aged 25–34 years. Women from the Mayan ethnic group were less

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		15–49 years in 2006, 2011, and 2015–2016, respectively.	likely to have been tested than those from other ethnic groups. Compared to women who spoke Spanish, those who spoke English/Creole were more likely to have been tested for HIV
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 PLWH with SU in other regions
Ortíz et al. (2021)	To evaluated factors associated with viral non suppression (VNS) and persistent viremia (PV) in people living with HIV (PLHIV) receiving antiretroviral therapy (ART) in Guatemala	Conducted a cross sectional analysis using data from an ongoing cohort of PLHIV attending the largest HIV clinic in Guatemala	Socio-economic and clinical factors influence viral suppression in this cohort and vary between men and women
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	Prospective longitudinal study of PLWH with TB symptoms	α-mannosidase treatment of urine did not significantly increase the LAM-test performance

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	in Guatemala. -To determine TB incidence, and mortality rates and its risk factors in PLWH with TB symptoms		
Gough & Edwards (2009)	To determine the seroprevalence of HIV and identify associated risk factors among inmates at the Belize Central Prison, managed by the Kolbe Foundation, Belize.	Demographic and risk behavior data were collected using an interviewer administered pre-tested questionnaire. A multivariate logistic regression was used to adjust for potential confounders and to identify independent associations with HIV seropositivity.	The seroprevalence in the Central Prison was almost twice that estimated for the adult population of Belize in 2004 (2.4%). However, the social variables of importance to inmates appeared to reflect the epidemic in the general population, with the exception that male-to-male sex outside prison is likely more important to the male inmate population in Belize.

Methodology

This study utilizes double (Brown) exponential smoothing technique to model and forecast future trends of HIV prevalence among people aged 15-49years in Belize. In exponential smoothing forecasts are generated from the smoothed original series with the most recent historical data points having greater influence than those in the more distant past as more recent values are allocated more weights than those in the distant past.

Double (Brown) exponential smoothing is specified as follows:

Model equation

$Y_t=\mu_t + \beta_t \mathbf{t} + \varepsilon_t$……...……[1]

Smoothing equation

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

$0<\propto<1$

Trend estimation equation

$T_t= \alpha (S_t-S_{t-1}) + (1-\alpha)T_{t-1}$……...……..[3]

Forecasting equation

$f_{t+h}= S_t + [(h-1) + 1/\alpha\ ]\ T_t$……[4]

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Y_t is the actual value of HIV prevalence among people aged 15-49 years at time t

ε_t is the time varying **error term**

μ_t is the time varying mean (**level**) term

β_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 among people aged 15-49 years at time t (used to estimate the level term)

α is the exponential smoothing constant for the data and trend

f_{t+h} is the h step ahead forecast

T_t is the trend estimate (used to estimate the **slope term**) at time t

T_{t-1} is the trend estimate at time t-1

Data Issues

This study is based on annual HIV prevalence among people aged 15-49 years in Belize 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	Y
Included Observations	31
Smoothing constant	
Alpha (α) for data	0.700
Forecast performance measures	
Mean Absolute Error (MAE)	0.046689
Sum Square Error (SSE)	0.108014
Mean Square Error (MSE)	0.003600
Mean Percentage Error (MPE)	6.632726
Mean Absolute Percentage Error (MAPE)	10.359672

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Residual Analysis for the Applied Model

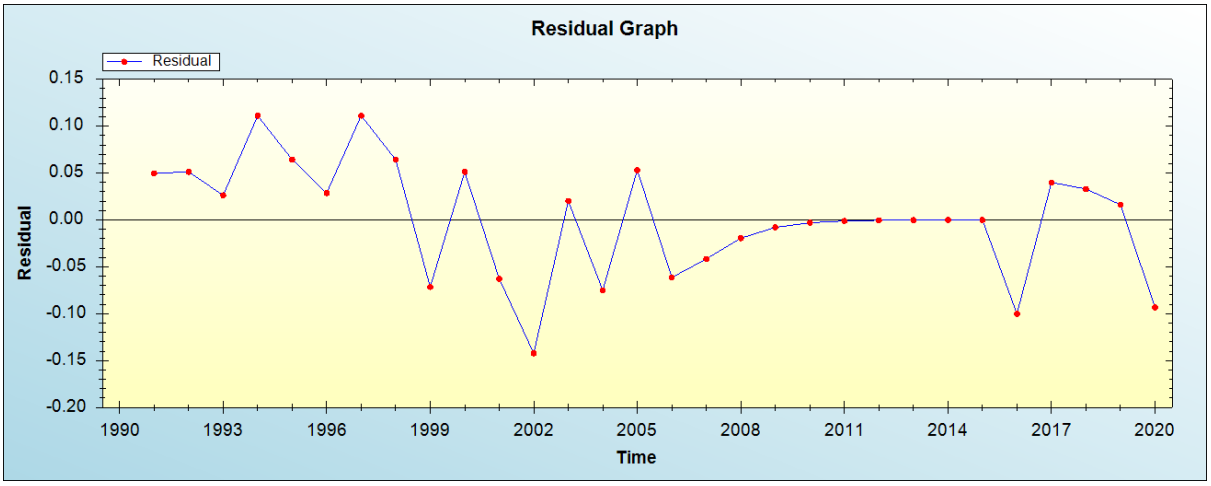

Figure 1: Residual analysis

In-sample Forecast for Y

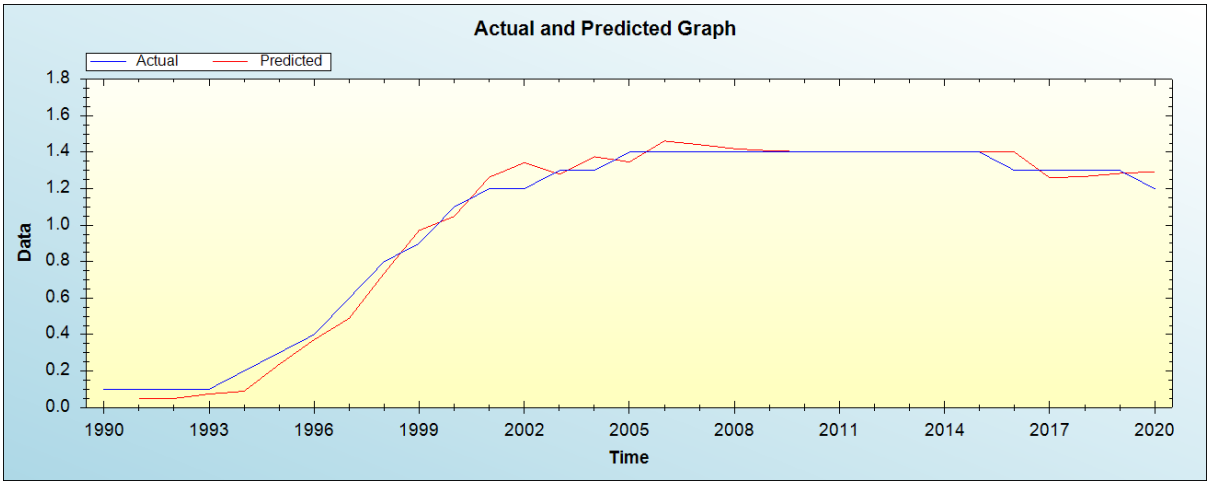

Figure 2: In-sample forecast for the Y series

Actual and Smoothed graph for Y series

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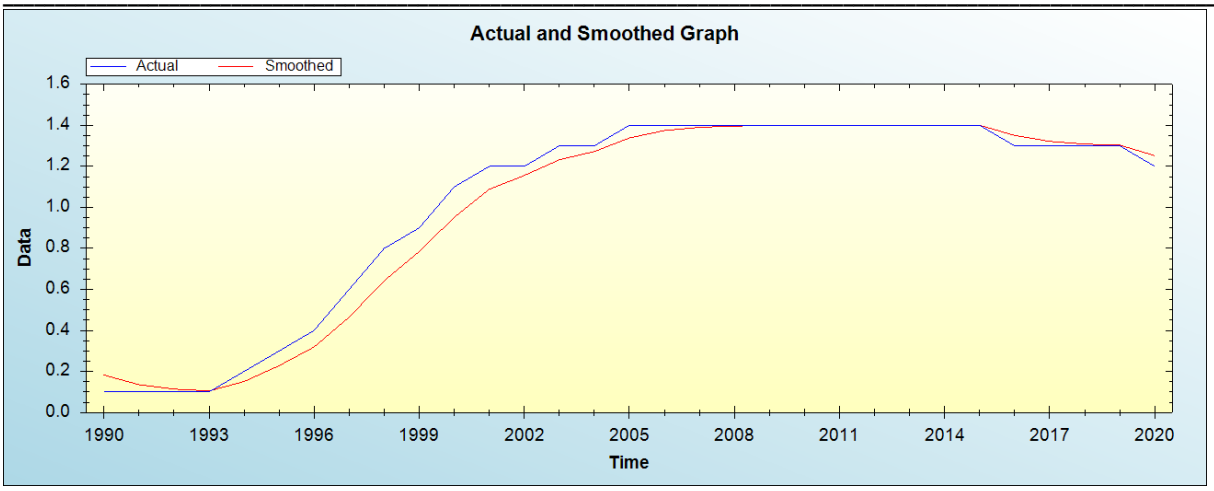

Figure 3: Actual and smoothed graph for Y series

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

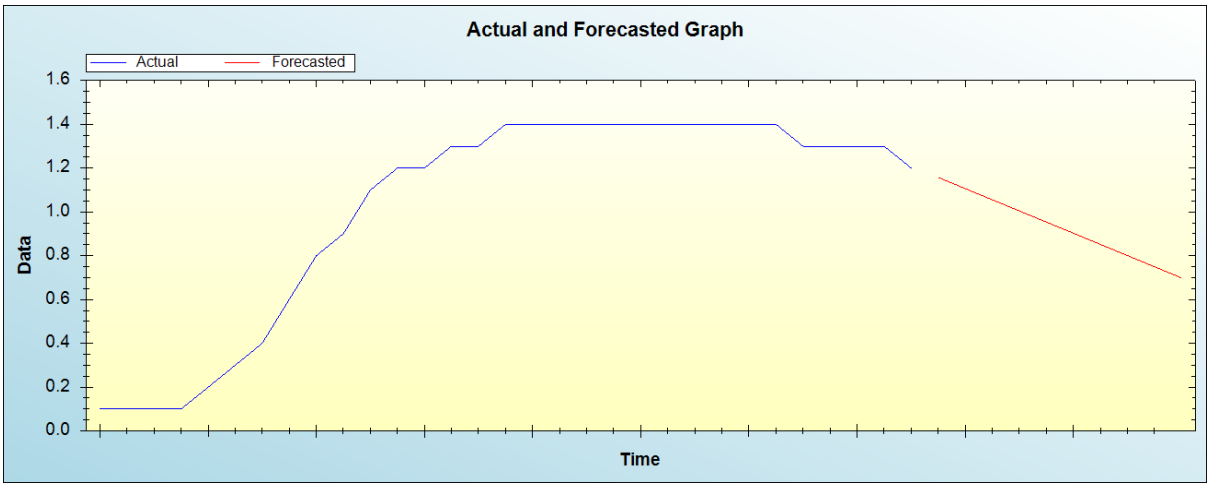

Figure 4: Out-of-sample forecast for Y: actual and forecasted graph

Out-of-Sample Forecast for Y: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	1.1574
2022	1.1064
2023	1.0554
2024	1.0045
2025	0.9535
2026	0.9025
2027	0.8515

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2028	0.8005
2029	0.7495
2030	0.6985

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 people aged 15-49 years will continue to decline over the out of sample period.

Policy implication and conclusion

The projected downward trend of HIV prevalence in Belize indicates the expected positive impact of the National HIV program in this country. Therefore, policy makers are encouraged to strengthen HIV case detection, behavioral change interventions and other HIV prevention measures especially among key populations.

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