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Applying Holt's linear method to estimate future trends of HIV prevalence among individuals aged 15-49 years in Cabo Verde

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Abstract
This study uses annual time series data of HIV prevalence among individuals aged 15-49 years for Cabo Verde from 1990 to 2020 to predict future trends of HIV prevalence over the period 2021 to 2030. The study utilizes Holt's linear method. 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 to decline over the out of sample period. Therefore, policy-makers are encouraged to scale up HIV testing services and antiretroviral therapy coverage among key populations.

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

Background

According to the UNAIDS 36.9 million people were living with HIV and 2 million became newly infected in 2014 around the entire world. In addition, with 25.8 million people living with HIV and 1.4 million new HIV infections, Sub-Saharan Africa (SSA) remains the most affected region in the global AIDS epidemic. However, SSA, has improved access to antiretroviral therapy (ART). It has been revealed that more than 10.7 million adults and children infected with HIV received lifesaving treatment in 2014. In Cape Verde the majority (72%) of HIV cases are caused by HIV-1, 22% are caused by HIV-2, and 6% by both infections (De Pina-Araujo *et al*. 2014; CCSSIDA, 2010). As revealed by CCSSIDA, the first case of HIV in Cape Verde was identified in 1986 and by the end of 2012, there were 4049 people living with HIV (PLWHIV), with a mortality of 866 AIDS related deaths. HIV prevalence in Cape Verde in 2005 was 0.8%, being higher amongst men (1.1%) than amongst women (0.4%). HIV prevalence in sex workers is estimated at 5.3% and in pregnant women tested at sentinel sites is less than 1%. Moreover, the mortality rate among HIV patients receiving ART continues to decline. The aim of this study is to model and forecast HIV prevalence among individuals aged 15-49 years in Cabo Verde. The results of the study are anticipated to highlight likely future trends of HIV prevalence among individuals aged 15-49 years. This will guide allocation of resources to targeted HIV programs for this particular age group.

Literature Review

Author(s)	Objective	Methodology	Main finding(s)
Taveira et al. (2023)	To characterize the genetic diversity and drug resistance profiles of people with HIV-1 failing ART in Cape Verde (CV).	This cross- sectional study was conducted between January 2019 and December 2021 in 24 health centres on the islands of Santiago and Sa˜o Vicente	The most common mutations were M184V/I (43%), K103N/S (36%) and G190A/S (19%). NNRTI resistance was associated with younger age and exposure to two or more drug regimens.
Moreira et al. (2016)	To characterize late presenters to HIV	-unmatched case-control study	Results showed that 51.9% were late

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	care in Santiago (Cape Verde) between 2004 and 2011, and identifies factors associated with late presentation for care.		presenters for HIV. No differences were found in gender distribution, marital status, or access to health services between cases and controls
Dovlo et al. (2016)	To understand the interplay between policy dialogue and policy-making in Cabo Verde, Chad and Mali.	The specific methods used to gather data were key informant interviews and document review. Data were analyzed inductively and deductively using thematic content analysis.	Policy dialogues have proved to be an effective tool in health sector management and could be a crucial component of the governance dynamics of the sector.
Isabel Ine ˆs et al. (2014)	To characterize the molecular epidemiology of HIV-1 and HIV-2 and describe the occurrence of drug resistance mutations (DRM) among antiretroviral therapy naı ¨ve (ARTn) patients and patients under treatment (ARTexp) from different Cape Verde islands	Blood samples, socio-demographic and clinical-laboratory data were obtained from 221 HIV-positive individuals during 2010–2011. Phylogenetic and bootscan analyses of the pol region (1300 bp) were performed for viral subtyping. HIV-1 and HIV-2 DRM were evaluated for ARTn and ARTexp patients using the Stanford HIV Database and HIV-GRADE e.V.	Cape Verde has a complex and unique HIV-1 molecular epidemiological scenario dominated by HIV-1 subtypes G, CRF02_AG and F1 and HIV-2 subtype A. The occurrence of TDRM and the relatively high level of DRM among treated patients are of concern

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 Cabo Verde. 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

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

Smoothing equation

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

$0<\alpha<1$

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]

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 Cabo Verde 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

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Smoothing constants	
Alpha (α) for data	0.800
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.025637
Sum Square Error (SSE)	0.087791
Mean Square Error (MSE)	0.002832
Mean Percentage Error (MPE)	-1.203906
Mean Absolute Percentage Error (MAPE)	4.919371

Residual Analysis for the Applied Model

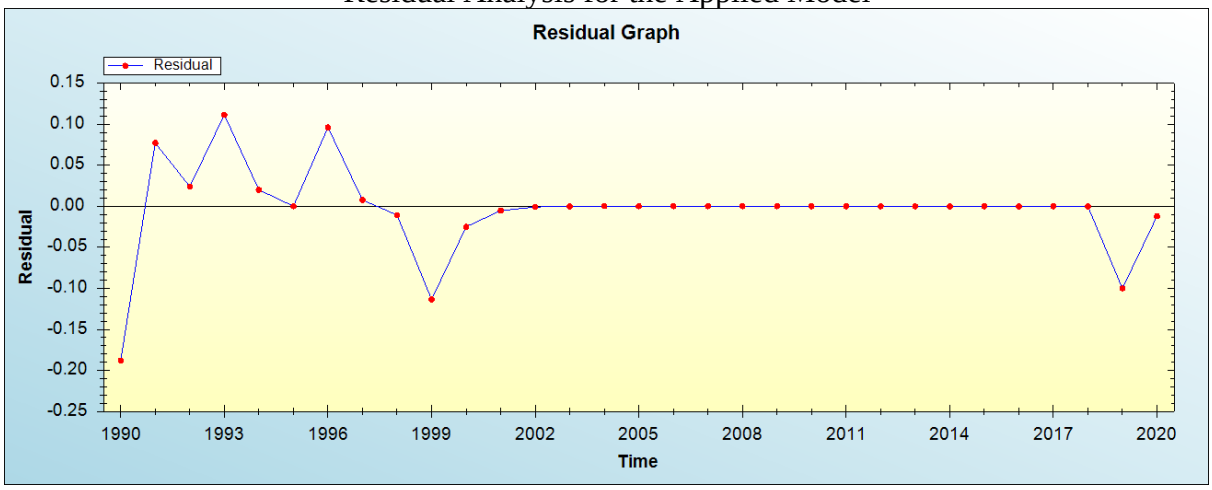

Figure 1: Residual analysis

In-sample Forecast for A

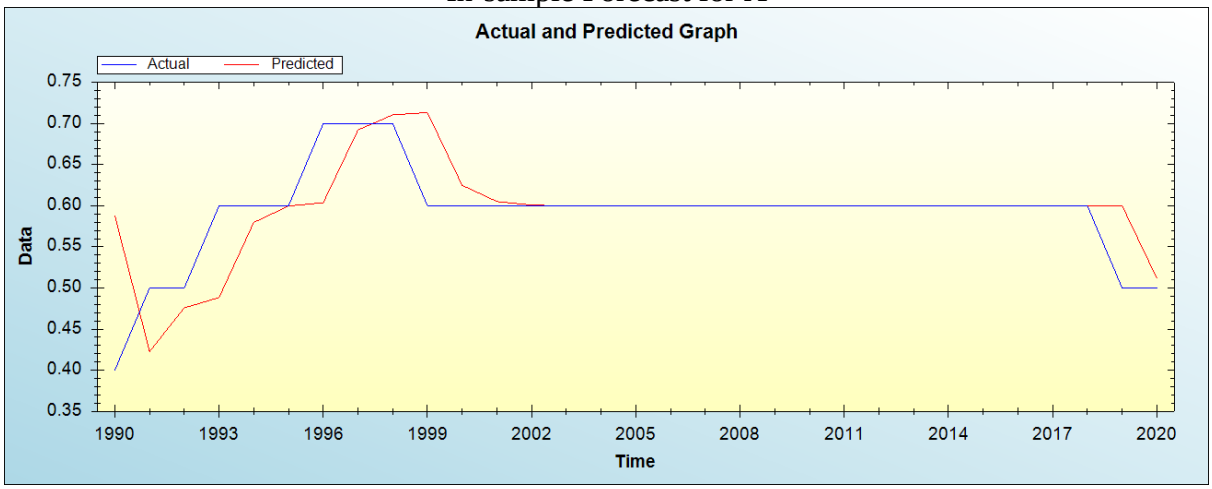

Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

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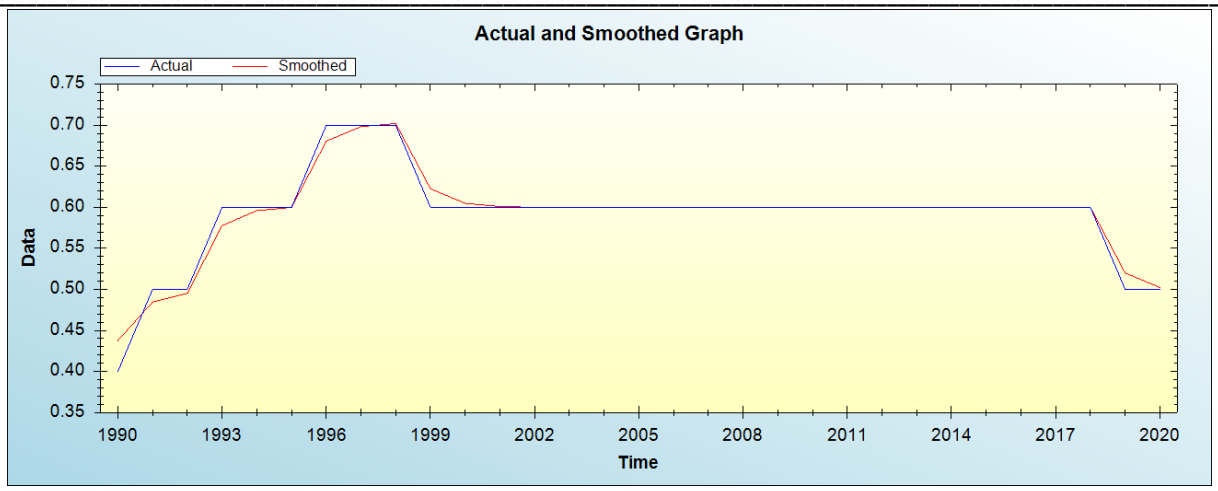

Figure 3: Actual and smoothed graph for A series

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

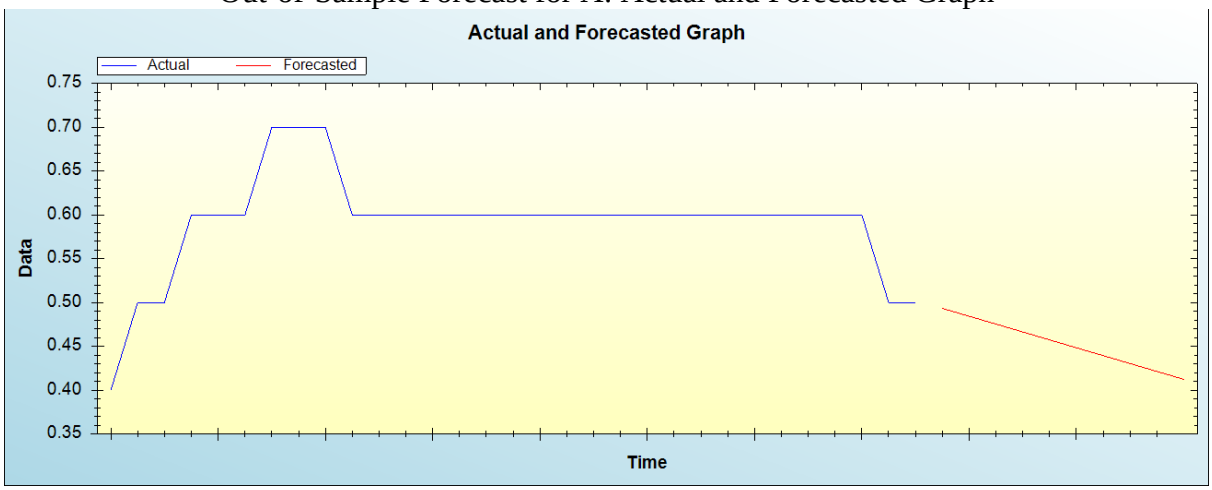

Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	0.4934
2022	0.4844
2023	0.4754
2024	0.4664
2025	0.4574
2026	0.4484
2027	0.4394
2028	0.4304
2029	0.4214
2030	0.4124

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

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Our model projections indicate that the annual HIV prevalence among individuals aged 15-49 years will continue to decline over the out of sample period. Therefore, policy-makers are encouraged to scale up HIV testing services and antiretroviral therapy coverage among key populations.

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