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APPLYING HOLT'S DOUBLE EXPONENTIAL SMOOTHING MODEL TO FORECAST FUTURE TRENDS OF HIV PREVALENCE AMONG INDIVIDUALS AGED 15-49 YEARS IN DJIBOUTI

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Abstract:
This study uses annual time series data of HIV prevalence among individuals aged 15-49 years for Djibouti 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 0.5 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, we encourage authorities to improve on HIV case detection particularly among key populations and vulnerable groups.

Keywords: *Exponential smoothing, Forecasting, HIV prevalence*

BACKGROUND

According to the International Federation of Red Cross and Red Crescent societies, Djibouti is a volcanic country measuring 23,000 square kilometers with an estimated population of approximately 740,000. The lack of cultivable land has forced almost 75% of the population to move to urban areas where up to 50% of the population lives in shanty towns around the capital, Djibouti Ville. Poor sanitary conditions, lack of access to water, and an intolerably hot climate encourage the spread of communicable diseases such as diarrheal diseases. The UNAIDS statistics indicate that HIV/AIDS prevalence remains at 11.5% of the population in the 15-49 age group. The aim of this paper is to model and forecast HIV prevalence among individuals aged 15-49 years for Djibouti using Holt's linear Method. The findings of this paper are expected to guide national policy, planning and allocation of national resources to targeted HIV prevention, treatment and care programs in order to effectively control the HIV epidemic.

LITERATURE REVIEW

Author(s)	Objective (s)	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.
Utheim et al. (2023)	To investigate whether "Provider-initiated HIV testing and counselling" (PITC) could be implemented in a family planning clinic in an active conflict zone in	Applied Logistic regression	PITC can be successfully implemented in the patient flow in a family planning clinic, without compromising contraception uptake.

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	the Central African Republic to reach women of reproductive age and assess whether socioeconomic status was associated with testing uptake.		Within the PITC framework in a conflict setting, socioeconomic status was not found to be associated with testing uptake in women of reproductive age
Ngbale et al. (2020)	Assess the impact of B + option on mother-to-child HIV's transmission at the community university hospital center after 4 years of use	retrospective and analytical study from January 1st 2015 to December 31st 2018	Mother-to-child HIV's transmission still remains a public health problem at the Community University Hospital
Crellen et al. (2019)	To present results from a cohort in Zemio, Haut-Mboumou prefecture.	Applied logistic regression	Chronic conflict did not appear to adversely affect rates of mortality in this cohort, and that mortality was driven predominantly by patient-specific risk factors. The risk of mortality and recovery of CD4 T-cell counts observed in this conflict setting are comparable to those in stable resource poor settings
Nyasenu et al. (2017)	To determine the virological and immunological profiles and biological anomalies of HIV-positive people on antiretroviral therapy (ART) in Bangui, Central African Republic.	analytical, descriptive study between 4 April and 30 September 2017	The abnormalities observed in this study concerned the hematopoietic system, the liver and the kidneys
Moreira et al. (2016)	To characterize late presenters to HIV care in Santiago (Cape Verde) between 2004 and 2011, and identifies factors associated with late presentation for care.	unmatched case-control study	Results showed that 51.9% were late presenters for HIV. No differences were found in gender distribution, marital status, or access to health services between cases and controls

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 Djibouti. 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.

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Holt's linear method is specified as follows:

Model equation

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

Smoothing equation

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

D_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 Djibouti 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	D
Included Observations	31
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.500
Forecast performance measures	
Mean Absolute Error (MAE)	0.213059
Sum Square Error (SSE)	4.651863
Mean Square Error (MSE)	0.150060
Mean Percentage Error (MPE)	-32.197398
Mean Absolute Percentage Error (MAPE)	81.361101

Residual Analysis for the Applied Model

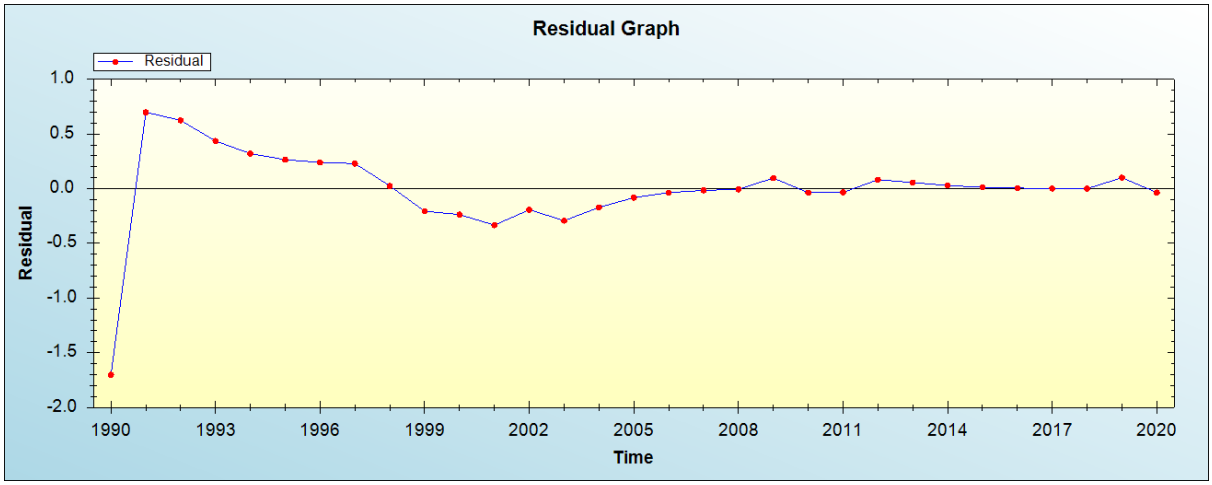

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Figure 1: Residual analysis

In-sample Forecast for D

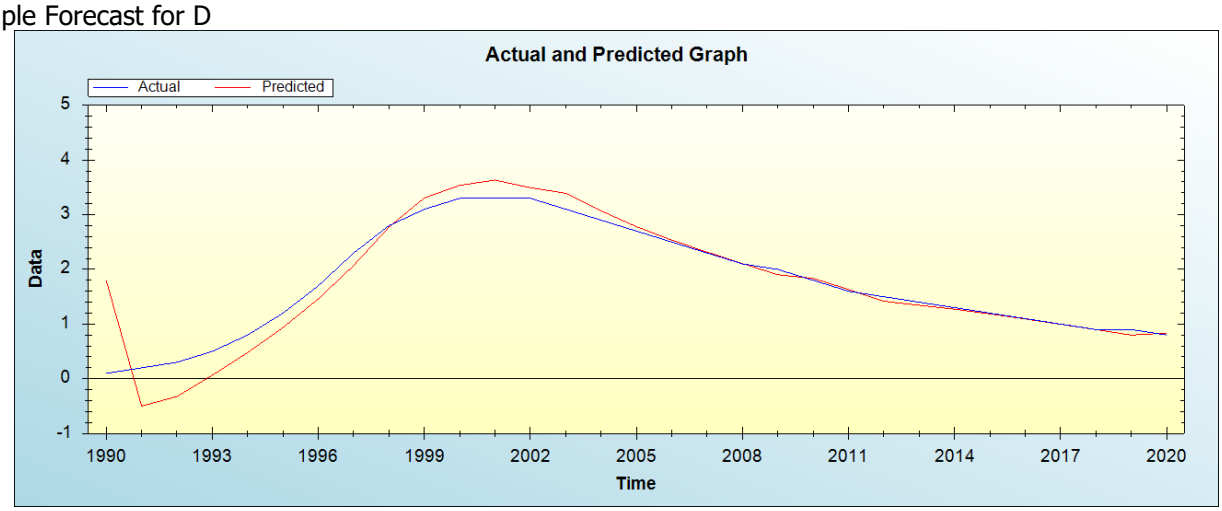

Figure 2: In-sample forecast for the D series

Actual and Smoothed graph for D series

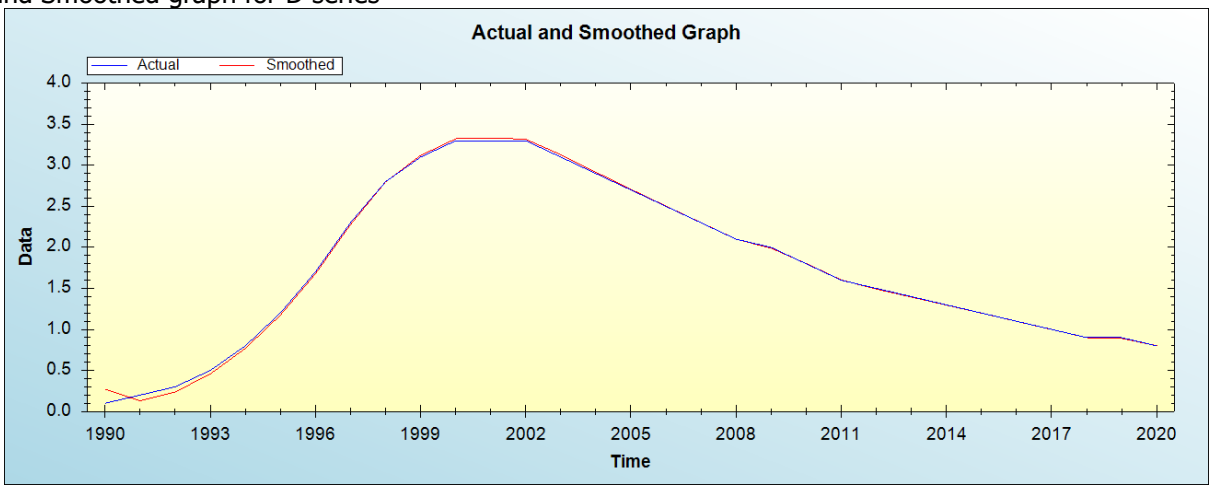

Figure 3: Actual and smoothed graph for D series

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

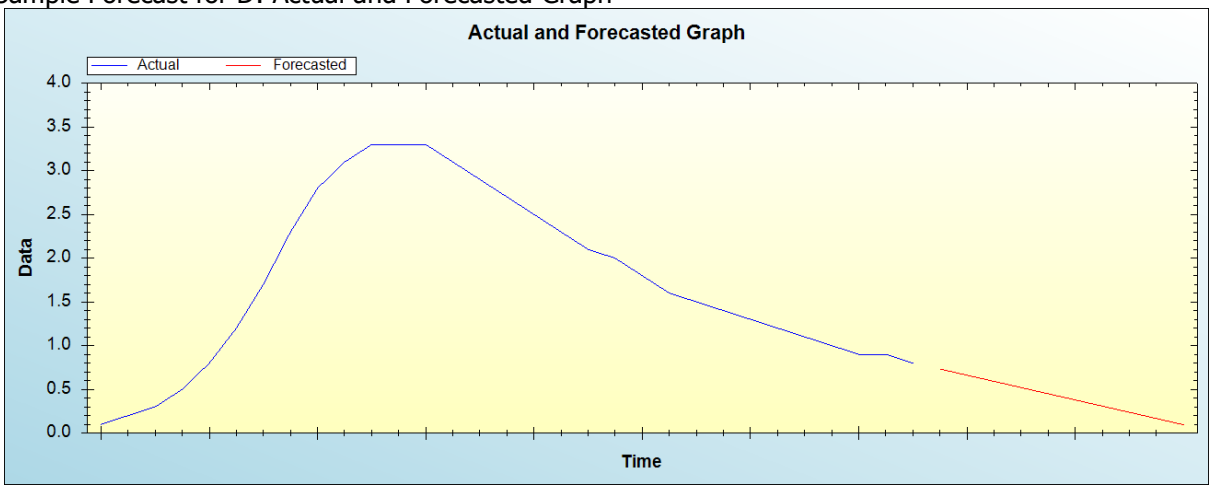

Figure 4: Out-of-sample forecast for D: actual and forecasted graph

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Out-of-Sample Forecast for D: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	0.7327
2022	0.6619
2023	0.5911
2024	0.5203
2025	0.4495
2026	0.3787
2027	0.3079
2028	0.2371
2029	0.1663
2030	0.0955

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

Exponential smoothing techniques are essential early surveillance tools for the detection of future trends of health phenomena. This paper applied Holt's double exponential smoothing technique to project annual HIV prevalence among individuals aged 15-49 years and model projections suggest that annual HIV prevalence among this group will continue to decline in the out of sample period. Therefore, health authorities are encouraged to improve on HIV case detection particularly among key populations and vulnerable groups.

REFERENCES

[1] International Federation of Red Cross and Red Crescent societies (2003). Appeal 2003-2004, pp. 1