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Forecasting HIV prevalence among individuals aged 15-49 years in Benin using Holt's double exponential smoothing technique

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Abstract
This study uses annual time series data of HIV prevalence among individuals aged 15-49 years for Benin 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 continue to decline over the out of sample period. Therefore, policy makers must continue implementing effective HIV control strategies as well as strengthen HIV detection and treatment among key populations.

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

Background

Developing countries continue to bear a disproportionate burden of the HIV epidemic (Nshimirimana *et al.* 2022; Dwyer- Lindgren *et al. 2019*). Sub-Saharan Africa (SSA) has the highest burden of HIV with approximately 71% of all people living with HIV (PLWHIV) residing in this region, 75% of AIDS- related deaths and 65% of new infections occurred in this region in 2017 (GBD, 2017). According to UNAIDS, among the 3.9 million young people living with HIV globally, 78% are living in SSA. Approximately 37% of new HIV infections were among adolescents and young adults (15–24 years) in SSA. Young women in the countries with a high burden of HIV infection are twice as likely as young men to acquire HIV infection. In the case of Benin, HIV prevalence among the 15-49 years age group gradually declined during the past 2 decades as a result of the national response strategy which includes HIV testing services, combination HIV prevention strategy and, treatment care and support among people living with HIV. The aim of this paper is to model and forecast HIV prevalence among the 15-49 years age group using Holt's linear method. The research findings will guide planning and allocation of resources towards HIV prevention and treatment initiatives targeting this priority age group.

Literature Review

Author (s)	Objective (s)	Methodology	Main finding (s)
Adu et al. (2023)	To examine the uptake of HIV testing and counselling (HTC) and its associated factors among women in Benin.	Multilevel binary logistic regression analysis was used to examine the predictors of HTC uptake	The overall uptake of HTC among women in Benin was found to be 46.4% (44.4%–48.4%). The odds of HTC uptake was higher among women covered by health insurance (aOR 3.04, 95% CI 1.44 to 6.43) and those with comprehensive HIV knowledge (aOR 1.77, 95% CI 1.43 to

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			2.21).
Boisvert Moreau et al. (2022)	To assess HIVST acceptability and feasibility in Benin. -To explore the elements influencing HIVST implementation, distribution and use among FSWs	qualitative study	There was a very high level of acceptability for HIVST among FSWs in Cotonou and its surroundings.
Ahouada et al. (2020)	To identify the potential facilitators and barriers to the use of PrEP.	-cross-sectional study conducted in 2018 among male-born MSM aged 18years or older who reported being HIV-negative or unaware of their HIV status	The intention to use PrEP was expressed by 90% of MSM. If PrEP effectiveness were 90% or more, 87.8% of the respondents thought they would decrease condom use. In multivariate analysis, the facilitators associated with PrEP acceptability were: not having to pay for PrEP (odds ratio (OR)=2.39, 95% CI: 1.50–4.46) and its accessibility within MSM networks (OR=9.82, 95% CI: 3.50–27.52). Only one barrier was significant: the concern that taking PrEP be perceived as marker of adopting HIV risky behaviors (OR=0.11, 95% CI: 0.04–0.30).
Geidelberg et al. (2020)	To assess TasP and PrEP feasibility among female sex workers (FSW) in Cotonou, Benin	-developed a compartmental HIV transmission model featuring PrEP and antiretroviral therapy (ART) among the high-risk (FSW and clients) and low-risk populations, calibrated to historical epidemiological and	The demonstration study impact was modest, and mostly from TasP. Increasing PrEP adherence and coverage improves impact substantially among FSW, but little overall

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		demonstration study data	
Hessou et al. (2019)	To identify contributing factors that affect HIV incidence in the MSM population.	Univariate analyses and a Cox proportional hazards multivariate regression were used to examine the association between bio-behavioral, socio-demographic and knowledge-related characteristics with HIV incidence	-HIV incidence is high within MSM population and particularly among young people -Factors associated with the high risk of HIV were age (HR = 0.4; 95% CI: 0.2–0.8), living in couple (HR = 0.5 95% CI: 0.2–0.96) and the lack of condom systematic use with a male partner during high-risk sex (HR = 3.9; 95% CI: 1.4–11.1).
Fofana et al. (2018)	To assess the frequency and patterns of HIV drug resistance among children with virological ART failures.	Dried blood spots from 62 HIV-infected children with virological failure were collected at the paediatric clinic of the National Hospital Center in Cotonou for genotyping and plasma drug concentration determination.	Only 4% of the children had major resistance mutations to PIs and none had major resistance mutations to integrase inhibitors. Among the participants, 25% had undetectable antiretroviral concentrations.
Zannou et al. (2017)	To determine the prevalence of late presentation to care in Benin, describe its trends and identify risk factors associated.	-conducted a retrospective analysis from 2003 to 2014 at the National HIV Referral Centre in Benin	The prevalence of late presentation to care in Cotonou is alarming. This prevalence has been on a declining trend, but it remains extremely high.

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 Benin. 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

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

Smoothing equation

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

0<∝<1

Trend estimation equation

$b_t= \beta (S_t - S_{t-1}) + (1-\beta) b_{t-1}$……..……[3]

0<β<1

Forecasting equation

$f_{t+h}= S_t$ + hb_t…….……[4]

X_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 Benin 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

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Exponential smoothing Model Summary

Table 1: ES model summary

Variable	X
Included Observations	31
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.068115
Sum Square Error (SSE)	0.443881
Mean Square Error (MSE)	0.014319
Mean Percentage Error (MPE)	-1.186565
Mean Absolute Percentage Error (MAPE)	6.484909

Residual Analysis for the Applied Model

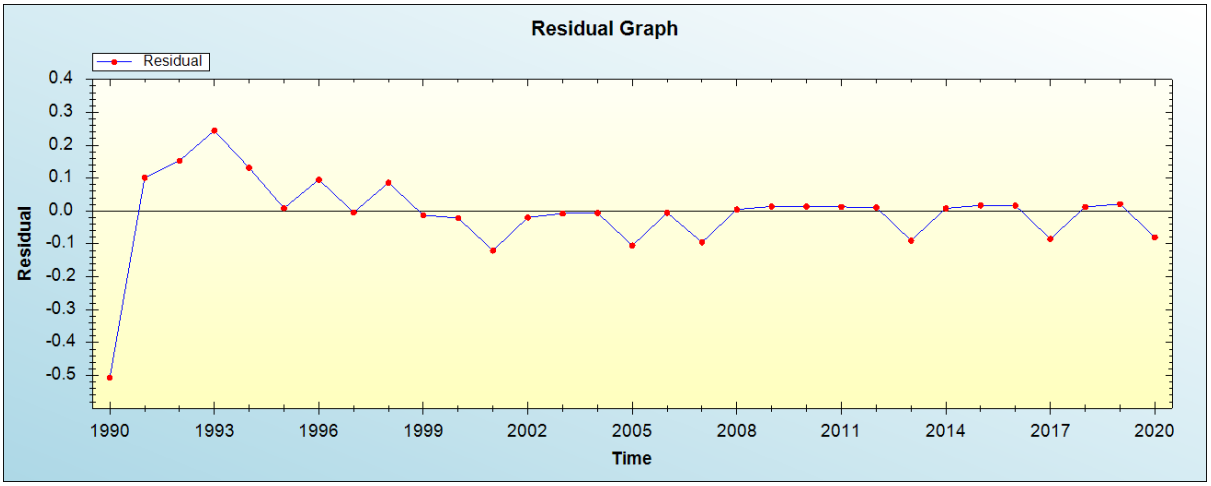

Figure 1: Residual analysis

In-sample Forecast for X

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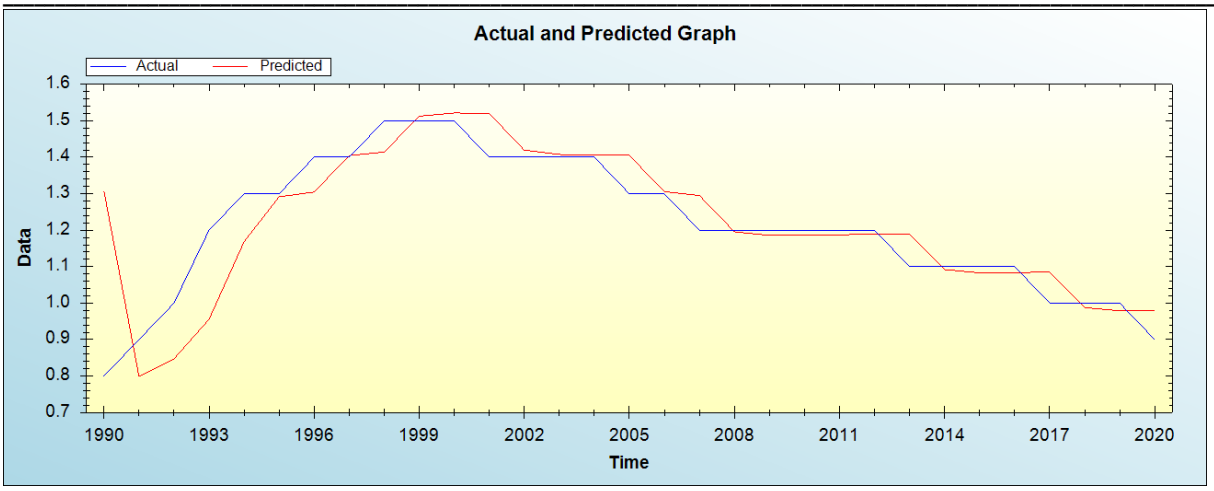

Figure 2: In-sample forecast for the X series

Actual and Smoothed graph for X series

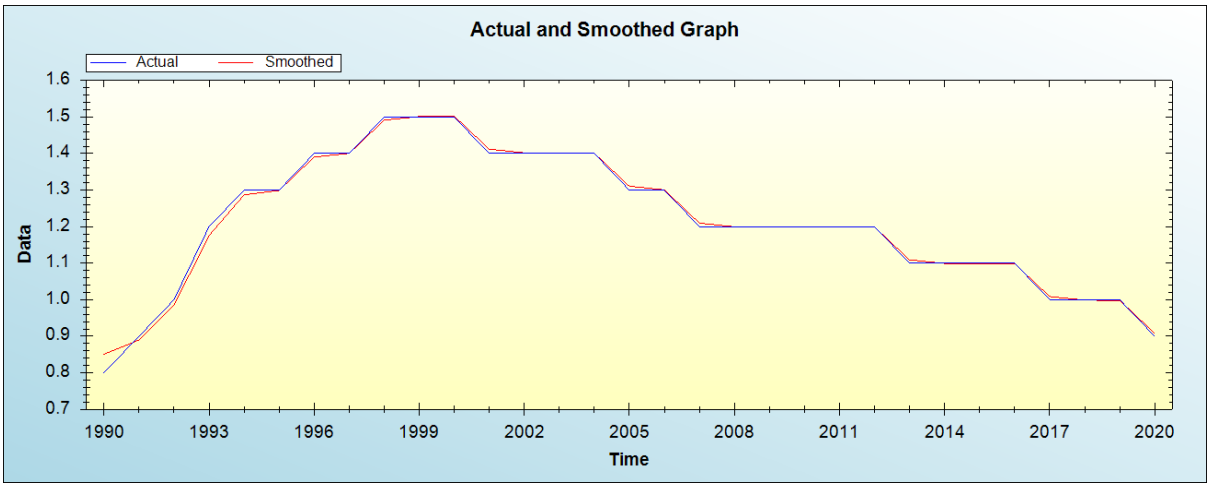

Figure 3: Actual and smoothed graph for X series

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

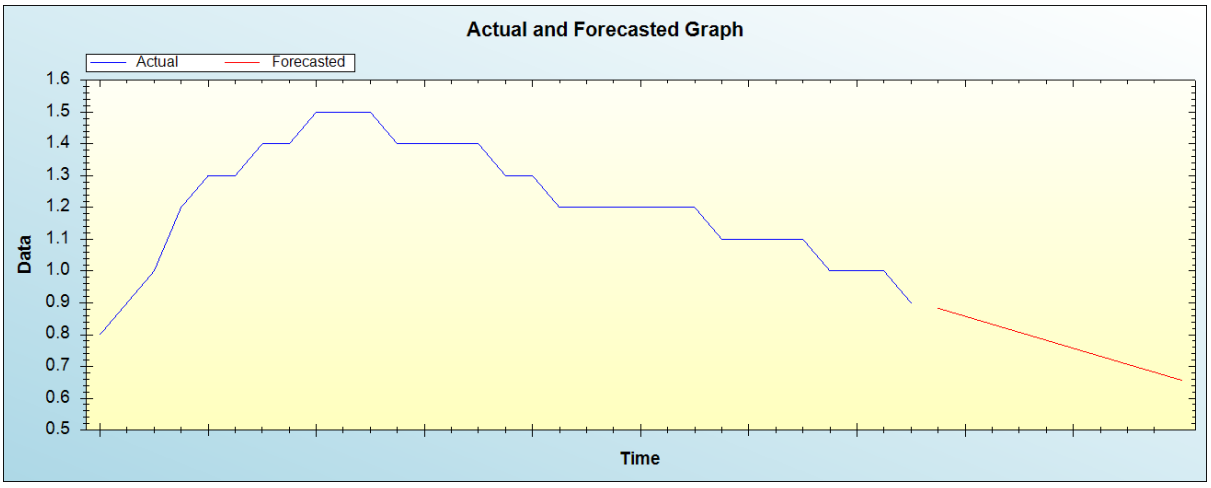

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Figure 4: Out-of-sample forecast for X: actual and forecasted graph

Out-of-Sample Forecast for X: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Predicted HIV prevalence
2021	0.8828
2022	0.8577
2023	0.8326
2024	0.8074
2025	0.7823
2026	0.7571
2027	0.7320
2028	0.7068
2029	0.6817
2030	0.6565

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

HIV testing services, combination HIV prevention strategy and, treatment care and support have significantly contributed to the reduction in new HIV cases and prevalence in Benin. In this study, Holt's linear method projections indicate that annual HIV prevalence among individuals aged 15-49 years will continue to decline over the out of sample period. Therefore, policy makers must continue implementing effective HIV control strategies as well as strengthen HIV detection and treatment among key populations.

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