ESTIMATING ANTICIPATED ANNUAL HIV PREVALENCE AMONG INDIVIDUALS AGED 15-49 YEARS FOR COTE D'LVOIRE USING HOLT'S DOUBLE EXPONENTIAL SMOOTHING TECHNIQUE

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Article history:		Abstract:
		This study uses annual time series data of HIV prevalence among individuals aged 15-49 years for Cote d'Ivoire 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 people aged 15-49 years will continue to decline over the out of sample period. Therefore, we encourage authorities to increase HIV case detection, prevention and treatment among key populations.

BACKGROUND

HIV infection continues to be an important public health issue in West Africa including Côte d'Ivoire whose HIV prevalence has declined from 3.7% to 2.5% among adults aged 15 to 49 (EDS CI, 2012). The HIV epidemic is concentrated among key populations namely men who have sex with men, transgender women, male and female sex workers, migrants, and armed forces (Becquet et al. 2020; Moran et al. 2020; Maheu-Giroux et al. 2018; Stahlman et al. 2016; Hakim et al. 2015; Vuylsteke et al. 2012; PNDS, 2008; Vuylsteke et al. 2003; PNDS, 1995). Literature shows that HIV prevalence is higher among key populations including female sex workers (11.7% – 28.7%), men who have sex with men (18%) and people who inject drugs (9%) (World Bank,

2016). Documented predictors of HIV infection include sexually transmitted infections, unprotected sex, multiple partnerships, risky casual sex, early sex and lack of circumcision (Richard et al. 2020; Rouet et al. 2004; Diallo, 1992). HIV prevalence has been shown to vary according to sex, regions, ethnic groups and living environments. The objective of this study is to model and forecast HIV prevalence among individuals aged 15-49 years for Cote d'Ivoire using Holt's linear method. The results of this paper are anticipated to facilitate allocation of resources to targeted HIV programs in the country in order to effectively control the HIV epidemic.

LITERATURE REVIEW

Author(s)	Objective (s)	Methodology	Key finding(s)
Silhol et al. (2023)	To predict the potential impact of ATLAS and of national HIVST scale-up strategies among KP.	A deterministic model of HIV transmission was calibrated to country-specific empirical HIV and intervention data over time. Simulated scenarios reflecting 1) the actual ATLAS HIVST distribution only over 2019-2021 (~2% of all tests done in	ATLAS was predicted to substantially increase HIV diagnosis among KP by the end of 2021, especially among MSM in Mali (9·3 percentage point [pp] increase), and a 1·0pp increase overall.

		countries), and 2) ATLAS followed by a Scale-up of HIVST distribution to KP (total of ~570 000 kits distributed each year). Impacts on HIV diagnosis, new HIV infections and deaths were derived using counterfactual scenarios without HIVST.	
Akoku et al. (2022)	To assess the distribution of HIV-program staff and the extent to which their availability influences HIV programmatic and patient outcomes	The study was a facility level cross-sectional survey. Data from October 2018 to September 2019 were abstracted from HIV program reports conducted in 18 districts of Côte d'Ivoire.	HCWs in the laboratory and lay cadre categories were associated with an increase in HIV-positive case identification and initiation on ART.
Essis et al. (2022)	To analyze explanatory factors for the difference in HIV prevalence observed in men in Côte d'Ivoire's regions.	A multivariate analysis was conducted to assess the relationship between HIV prevalence and each variable.	The explanatory factors for the difference in HIV prevalence observed in men in the regions of the country were union, condom use, mean age at first sexual intercourse, sexual infection, sexual activity, and multiple sexual partnerships. However, only union and condom use were effective in reducing HIV prevalence by preventing new infections.
Nouaman et al. (2022)	To estimate, using an HIV Recent Infection Testing Algorithm (RITA), the HIV incidence and its associated factors among female sex workers (FSW) in Coˆte d'Ivoire	A cross-sectional study was conducted in 2016–2017 in Abidjan and San Pedro's region among FSW aged 18 years	FSW remain highly exposed to HIV infection. Exposure to HIV is also clearly associated with certain sex-work factors and the material conditions of sex work.
Jaquet et al. (2021)	To compare HIV related invasive cervical cancer (ICC) over a decade and document factors	A repeated cross-sectional study design	Despite a persistently high proportion of HIV-related ICC over time in Cˆote d'Ivoire, HIV was associated with

	associated with HIV infection in women with ICC		less advanced clinical stage at ICC diagnosis
Kra et al. (2021)	-To examine temporal trends in HIVST distribution and their evolution in the context of the COVID-19 health crisis. -to investigate the impact on, the adaptation of and the disruption of field activities.	Quantitative and qualitative analysis	In all three countries, the pre-COVID-19 period was marked by a gradual increase in HIVST distribution. The period corresponding to the initial emergency response (March-May 2020) witnessed an important disruption of activities: a total suspension in Senegal, a significant decline in Côte d'Ivoire, and a less pronounced decrease in Mali. Secondary distribution was also negatively impacted
Inghels et al. (2021)	Measuring access and preferences to Men who have Sex with Men focused community- based HIV testing sites (MSM-CBTS) in Côte d'Ivoire.	A respondent- driven sampling telephone survey.	Community- based HIV testing is well suited for MSM who identify as homosexual and those close to the MSM community, while maintaining undifferentiated HIV testing is essential for others
Minchella et al. (2020)	To examine long-term responses to HIV-2 treatment	Survival analyses were employed to examine the relationship between HIV type and time to achieving CD4≥500 cells/µl during follow up.	Sub-optimal responses to long-term HIV-2 treatment underscore the need for more research into improved and/or new treatment options for patients with HIV-2.

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 Cote d'lvoire. 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
$$A_t = \mu_t + \rho_t \mathbf{t} + \varepsilon_t \ldots\ldots[1]$$
Smoothing equation
$$S_t = \alpha A_t + (1-\alpha)(S_{t-1} + b_{t-1})\ldots\ldots[2]$$
$$0 < \alpha < 1$$
Trend estimation equation

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

$0 < \beta < 1$

Forecasting equation

$f_{t+h} = S_t + h b_t$... ....[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 people aged 15-49 years in Cote d'Ivoire 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 Results

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	A
Included Observations	31
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.373418
Sum Square Error (SSE)	17.361973
Mean Square Error (MSE)	0.560064
Mean Percentage Error (MPE)	-0.849601
Mean Absolute Percentage Error (MAPE)	7.705508

Residual Analysis for the Applied Model

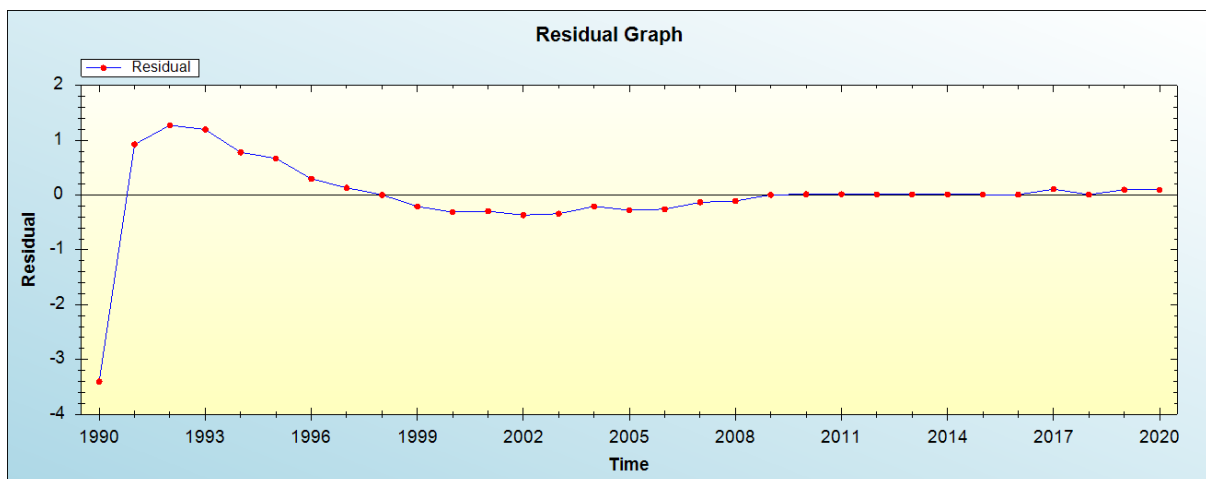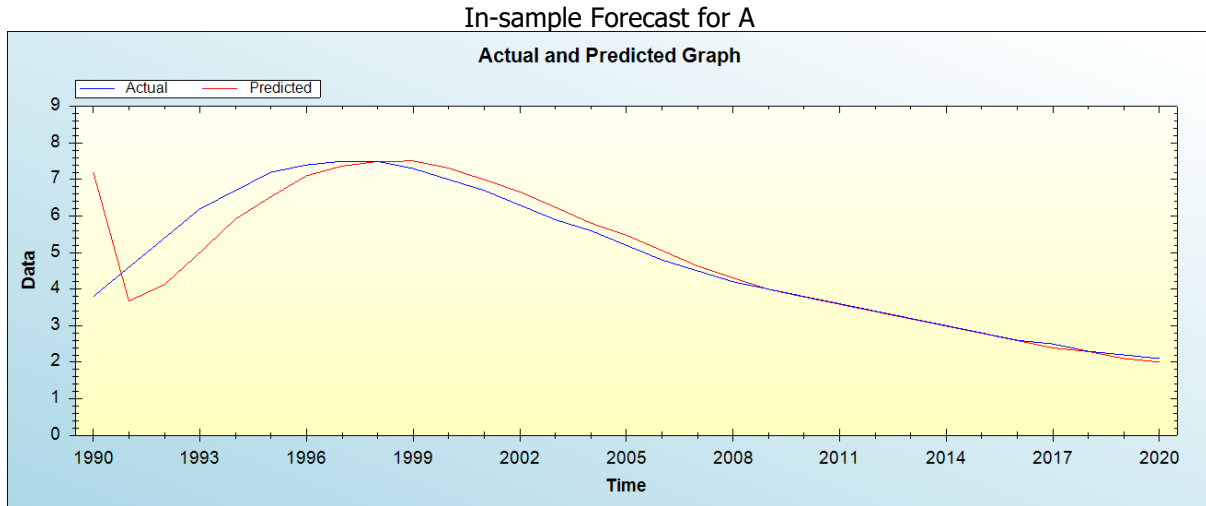Figure 1: Residual analysis

In-sample Forecast for A

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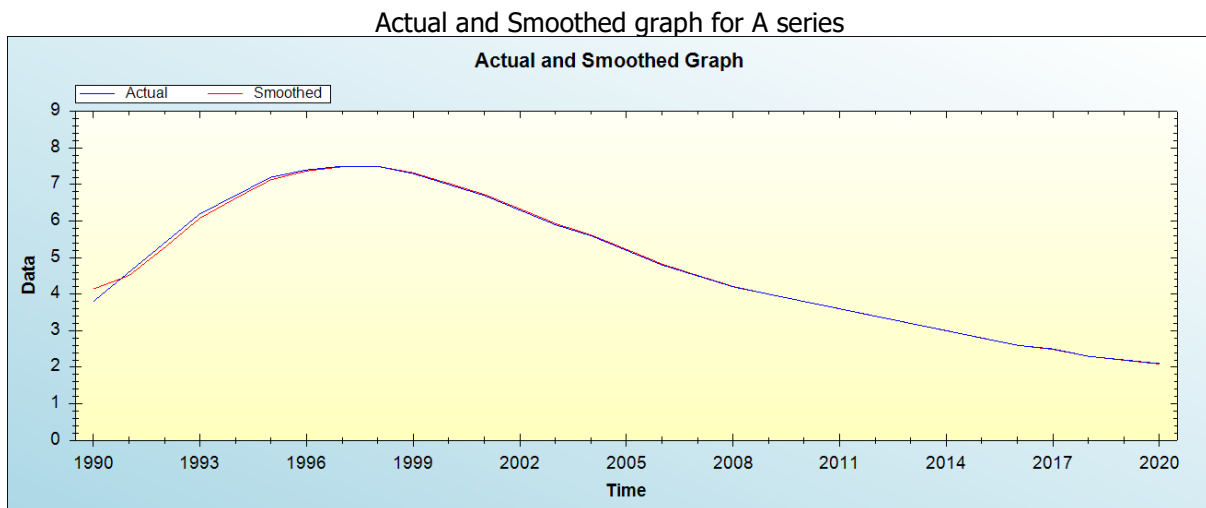
Actual and Smoothed graph for A series

Figure 3: Actual and smoothed graph for A series

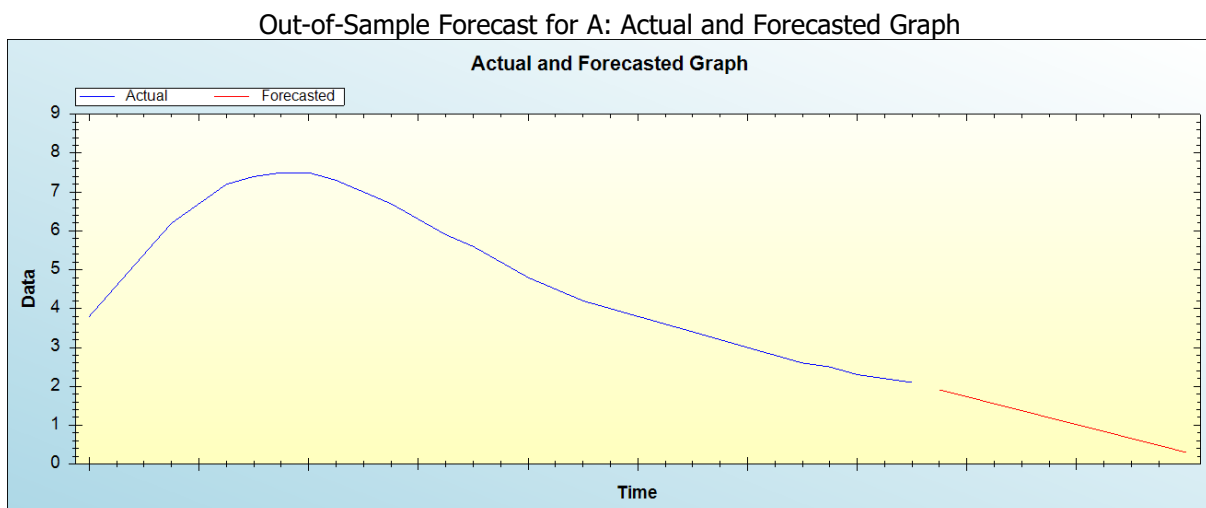Out-of-Sample Forecast for A: Actual and Forecasted Graph

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	1.9111
2022	1.7320
2023	1.5529
2024	1.3738
2025	1.1947
2026	1.0155
2027	0.8364
2028	0.6573
2029	0.4782
2030	0.2991

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
Our model predictions suggest a downward trend of annual HIV prevalence among individuals aged 15-49 years. Therefore, authorities must increase HIV case detection, prevention and treatment among key populations.

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