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PROJECTION OF HIV PREVALENCE AMONG INDIVIDUALS AGED 15-49 YEARS IN GABON USING HOLT'S LINEAR METHOD

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Abstract
This study uses annual time series data of HIV prevalence among individuals aged 15-49 years for Gabon from 1990 to 2020 to predict future trends of HIV prevalence over the period 2021 to 2030. The study utilizes Holt's linear 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, it is essential to address main factors that contribute to HIV spread among high-risk groups such as adolescents, MSM, sex workers and transgender women. Focus should be directed to HIV prevention strategies and HIV case detection among key populations.

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

Introduction

According to the World Health Organization (WHO) approximately 39 million people were HIV-infected and 650,000 died from AIDS-related illnesses worldwide by the end of 2022. The fatalities were largely due to OIs (UNAIDS, 2023). Antiretroviral therapy (ART) has improved the living conditions of people living with HIV/AIDS (PLWHA) and has led to a significant reduction in morbidity and mortality (Woldegeorgis *et al.* 2023; Mirani *et al.* 2015; Palella *et al.* 2006). Previous studies demonstrated that factors such as late initiation, discontinuation, non-adherence, low CD4 T lymphocyte count, inadequate virological monitoring, gender, age, place of residence, and functional or disclosure or nutritional status are associated with the emergence of opportunistic infections (OIs) among adults (PLWHA) post-ART (Dagnaw *et al.* 2022; Arefaine *et al.* 2020; Solomon *et al.* 2018; Zhou *et al.* 2007). The prevalence of HIV-1 infection was reported to be 4.1% of the general population aged 15 to 49 years old in Gabon (EDSG, 2012). The national HIV response encompasses demand creation using various platforms, HIV testing in the community, ART services at static and outreach points and support services. The purpose of this paper is to model and forecast HIV prevalence among individuals aged 15-49 years for Gabon using Holt's linear method. Study findings are expected to inform allocation of scarce resources towards targeted HIV programs across the country.

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Literature Review

Author(s)	Objective (s)	Methodology	Main Finding (s)
Nzengui-Nzengui et al. (2024)	To determine the profiles of HIV drug resistance mutations related to protease inhibitors in Gabon.	Plasma from 84 PLHIV receiving ARVs was collected from 2019 to 2021, followed by RNA extraction, amplification, and sequencing of the protease gene. ARV resistance profiles were generated using the Stanford interpretation algorithm version 8.9-1 (https://hivdb.stanford.edu) and statistical analyses were performed using EpiInfo software version 7.2.1.0 (CDC, USA).	The study revealed that HIV drug resistance mutations are common in Gabon. The major mutations associated with PIs were M41L, I84V, and V82A.
Davi et al. (2023)	To estimate the prevalence of HIV in Gabon and compare the prevalence of various co-infections between HIV-positive and HIV-negative pregnant women.	Between 2018 and 2019, data for the HIV-prevalence survey were collected retrospectively in 21 Gabonese antenatal care centres (ANCs). Subsequently, for the prospective co-infection study, all HIV-positive pregnant women were recruited who frequented the ANC in Lambaréné and a comparator sub-sample of HIV-negative pregnant women was recruited; these activities were performed from February 2019 to February 2020	There was a trend indicating that HIV-negative women were more often co-infected with sexually transmitted infections (STIs) than HIV-positive women [mean (standard deviation, SD): 2.59 (1.04) vs 2.16 (1.35), respectively; P = 0.056]; this was not the case for vector-borne infections [mean (SD): 0.47 (0.72) vs 0.43 (0.63), respectively; P = 0.59].
Mouinga-Ondeme et al. (2023)	To identify the risk factors that contributed to the onset of OIs in HIV patients undergoing ART in Gabon	Epidemiological and biological data were obtained from medical records (2017 to 2019) found at the outpatient treatment centre (CTA) of Franceville in Gabon. Samples for blood count, CD4, and viral load analysis at CIRMF were collected from PLWHA suffering from other pathogen-induced conditions.	The study revealed a high overall prevalence of OIs
Bongenya et al. (2023)	To determine the reasons behind the loss of patients on Antiretroviral Treatment (ART) after 6 months of follow-up.	descriptive survey	Nearly half of the patients no longer return to the treatment centers where they started
Bekolo et al. (2023)	to review current evidence for declining HIV prevalence despite increasing survival owing to 'universal test and treat' and to explore the reason for the decrease, particularly the role of behavioral change.	conducted a secondary analysis using HIV prevalence, behavioral and social determinants data of the Demographic and Health Survey Program databases	The observed decline in HIV prevalence is statistically valid and reflects the observed decline in risky sexual behavior that need to be sustained by the National HIV programme

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Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of annual HIV prevalence among individuals aged 15-49 years in Gabon. 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

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

Smoothing equation

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

$0<\propto<1$

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]

G_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 Gabon 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.

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Findings of the study

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	G
Included Observations	31
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.336121
Sum Square Error (SSE)	10.534579
Mean Square Error (MSE)	0.339825
Mean Percentage Error (MPE)	-4.839083
Mean Absolute Percentage Error (MAPE)	15.215961

Residual Analysis for the Applied Model

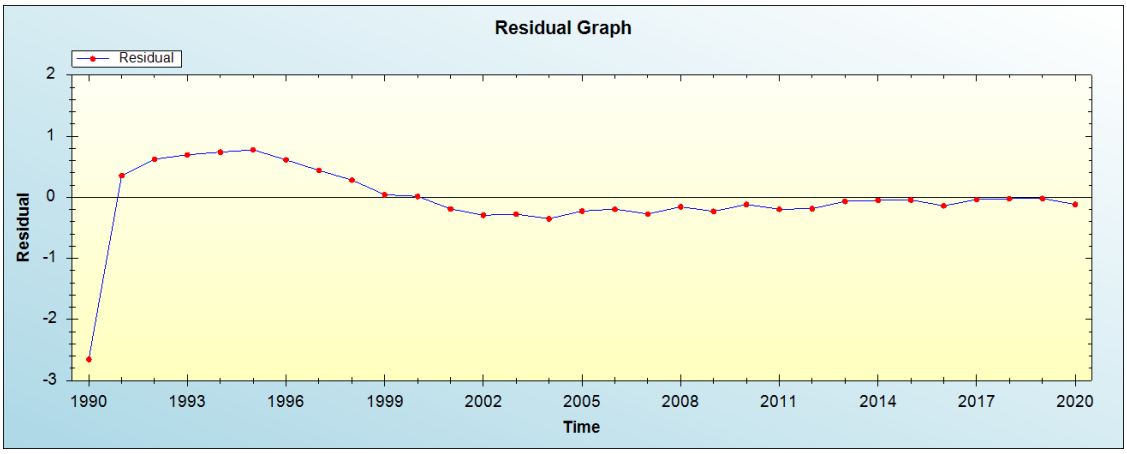

Figure 1: Residual analysis

In-sample Forecast for G

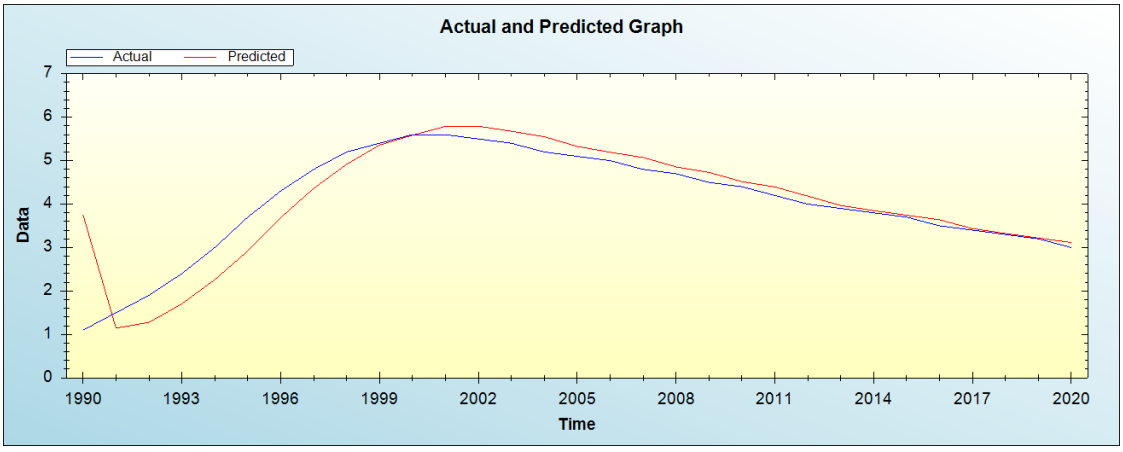

Figure 2: In-sample forecast for the G series

Actual and Smoothed graph for G series

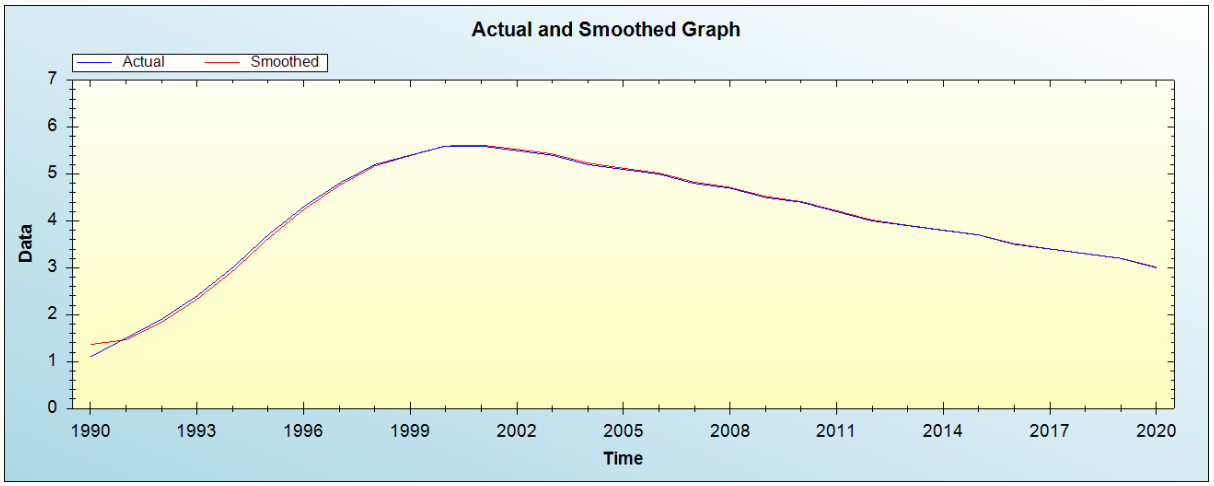

Figure 3: Actual and smoothed graph for G series

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

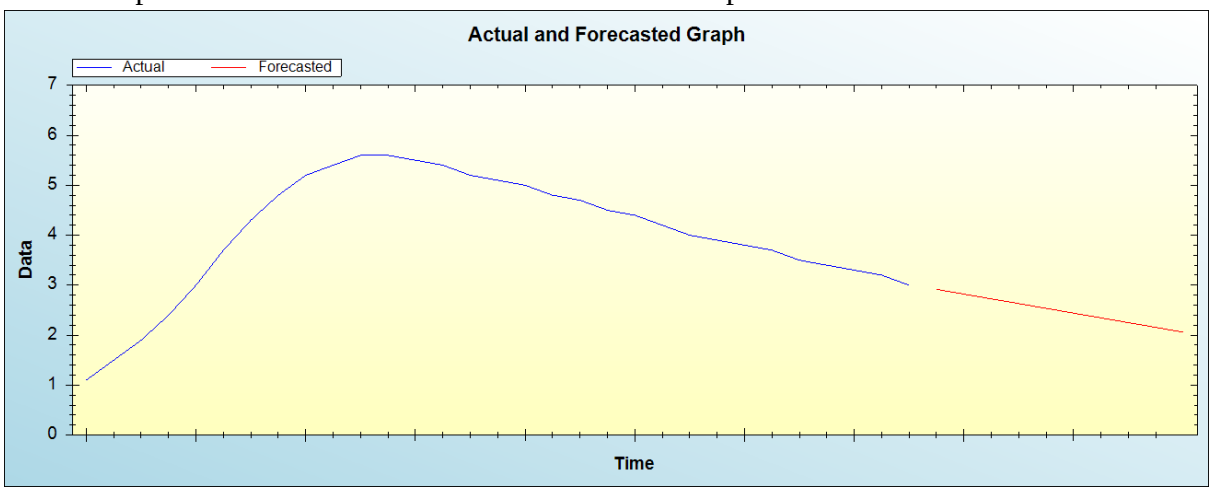

Figure 4: Out-of-sample forecast for G: actual and forecasted graph

Out-of-Sample Forecast for G: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	2.9165
2022	2.8212
2023	2.7260
2024	2.6307
2025	2.5355
2026	2.4402
2027	2.3449
2028	2.2497
2029	2.1544
2030	2.0592

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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

This study established 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 address main factors that contribute to HIV spread among high risk groups such as adolescents, MSM, sex workers and transgender people. Focus should be given to HIV prevention strategies and HIV case detection among key populations.

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