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# APPLYING HOLT'S LINEAR METHOD TO PREDICT HIV PREVALENCE AMONG INDIVIDUALS AGED 15-49 YEARS FOR LIBERIA 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 Liberia 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 0.8 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, we encourage authorities to scale up of HIV case detection, prevention and treatment especially among high risk groups.

**Keywords:** - Exponential smoothing, Forecasting, HIV prevalence.

## Introduction

The World Health Organization (WHO) estimated in 2020 that 37.7 million people worldwide were living with HIV (PLHIV), of whom a significant majority of 25.4 million are living in the WHO African region. At the end of 2020, 27.5 million PLHIV received antiretroviral therapy (WHO, 2020). While some countries in Eastern and Southern Africa have high rates of ART coverage among PLHIV, retaining patients on ART has been a major problem for many national ART programs. In West and Central Africa, where 3.5 million people are accessing ART (UNAIDS, 2021), retention in care by 12 months of follow-up has been reported at 76% (Makurumidze *et al.* 2021). According to the 2018/2019 integrated bio-behavioral surveillance survey, the HIV epidemic in Liberia is concentrated among key populations such as female sex workers (FSWs) (16.7%), men who have sex with men (MSM) (37.9%), transgender (TG) (27.6%) and people who inject drugs (PWID) (14.4%). The 2019–2020 Liberia Demographic and Health Survey (DHS) indicated that HIV testing among the general population was significantly lagging behind. It revealed that among respondents 15–49 years of age, 66% of men and 45% of women had never been tested for HIV. Liberia's HIV seroprevalence dropped from 2.7–12.4% in 2004 (UNDP, 2010) to 1.3% in 2016 (Liberia, 2016). The downward trend was as a result of the National AIDS Control Program that supported training of health care providers and creation of sites for voluntary counseling and testing (VCT), implementation of programs to prevent maternal to child transmission (PMTCT), condom promotion and scale up ART services (PERPFAR, 2019; UNDP, 2010). Furthermore, the downward spiral could be attributed to poor testing rates leading



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to underestimation of the disease prevalence (Ogbuagu *et al.* 2021). UNAIDS revealed that in 2022, the proportion of people living with HIV who know their status in Liberia was 74%, with 72% of them been on antiretroviral therapy, and those of them with suppressed viral loads were unknown. The purpose of this paper is to model and forecast HIV prevalence among individuals aged 15-49 years for Liberia using Holt's double exponential smoothing technique. The study results are expected to inform policy, planning and allocation of resources towards targeted HIV prevention and treatment programs especially for key populations and vulnerable groups in Liberia.

## Literature Review

| Author(s) | Objective (s) | Methodology | Key finding (s) |
|---|---|---|---|
| Seifu et al. (2024) | To assess the level of comprehensive knowledge about HIV/AIDS and its associated factors among reproductive age women in Liberia | The prevalence and associated factors of comprehensive knowledge about HIV/AIDS among reproductive age women in Liberia were determined using secondary data analysis of 2019–2020 Liberia Demographic and Health Surveys (LDHS). | The prevalence of comprehensive HIV/AIDS knowledge among Liberian women aged 15–49 was 33.5%. Women's age and education, and distance to health facility were positively associated with comprehensive knowledge about HIV/AIDS among Liberian reproductive age women |
| Gray et al. (2021) | To estimate retention of patients along the HIV care cascade in Liberia, and identify factors associated with loss-to-follow-up (LTFU), death, and suboptimal treatment adherence | conducted a nationwide retrospective cohort study utilizing facility and patient-level records | Loss-to-follow-up and poor adherence remain major challenges to achieving viral suppression targets in Liberia |
| Loubet et al. (2015) | To assess the prevalence of acquired drug resistance in HIV-1-infected patients living in Monrovia, Liberia, who had clinical and/or immunological failure of first-line ART according to WHO criteria. | Sequencing of protease and reverse transcriptase regions was performed using Agence Nationale de Recherche sur le SIDA et les he ´patites virales (ANRS) procedures and sequences were interpreted using the ANRS resistance algorithm. | There was high prevalence of acquired drug resistance in patients followed in two centres of the Liberian capital city, documented afteramedianof3 years on a first-line ART regimen |
| Loubet et al. (2014) | To assess the prevalence of TDR in HIV-1 from recently diagnosed and untreated patients living in Monrovia, Liberia | Drug resistance mutations (DRM) were identified according to the 2009 updated WHO surveillance DRM list | One DRM was observed in six samples, leading to a TDR prevalence of 5.9% (CI 95%=1.7–10.1). DRM were observed in two patients (2.0%; CI 95%=0.0–4.7), four patients (3.9%; CI 95%=0.1–7.7), and one patient (0.9%; CI 95%=0.0–2.7) for nucleoside RT inhibitors (NRTI), non-NRTI (NNRTI), and protease inhibitors, respectively. |

## Methodology

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



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*Model equation*

$V_t=\mu_t + \rho_t \mathbf{t} + \varepsilon_t$

*Smoothing equation*

$S_t= \alpha V_t + (1-\alpha)(S_{t-1} + b_{t-1})$

$0<\alpha<1$

*Trend estimation equation*

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

$0<\beta<1$

*Forecasting equation*

$f_{t+h}= S_t + hb_t$

$V_t$ is the actual value of HIV prevalence at time t

$\varepsilon_t$ is the time varying **error term**

$\mu_t$ is the time varying mean (**level**) term

$\rho_t$ is the time varying **slope terms**

**t** is the trend component of the time series

$S_t$ is the exponentially smoothed value of HIV prevalence at time t

$\alpha$ is the exponential smoothing constant for the data

$\beta$ 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 Liberia 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 | V |
|---|---|
| Included Observations | 31 |
| | |
| Smoothing constants | |
| Alpha (α) for data | 0.800 |
| Beta (β) for trend | 0.100 |
| | |
| Forecast performance measures | |
| | |
| Mean Absolute Error (MAE) | 0.140444 |
| Sum Square Error (SSE) | 2.242943 |
| Mean Square Error (MSE) | 0.072353 |
| Mean Percentage Error (MPE) | -1.168124 |
| Mean Absolute Percentage Error (MAPE) | 7.435610 |





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Residual Analysis for the Applied Model

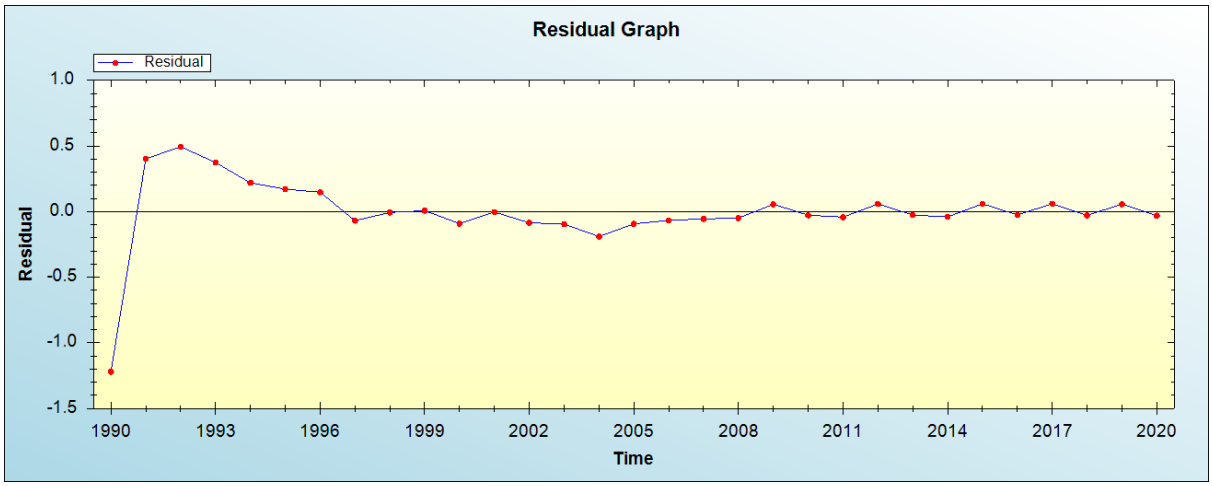


Figure 1: Residual analysis

In-sample Forecast for V

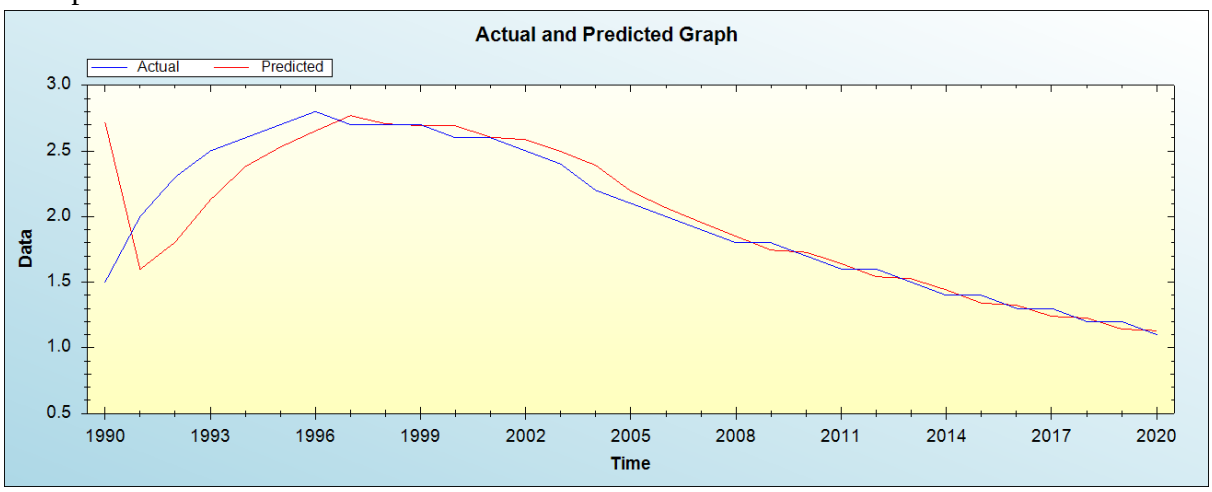


Figure 2: In-sample forecast for the V series

Actual and Smoothed graph for V series

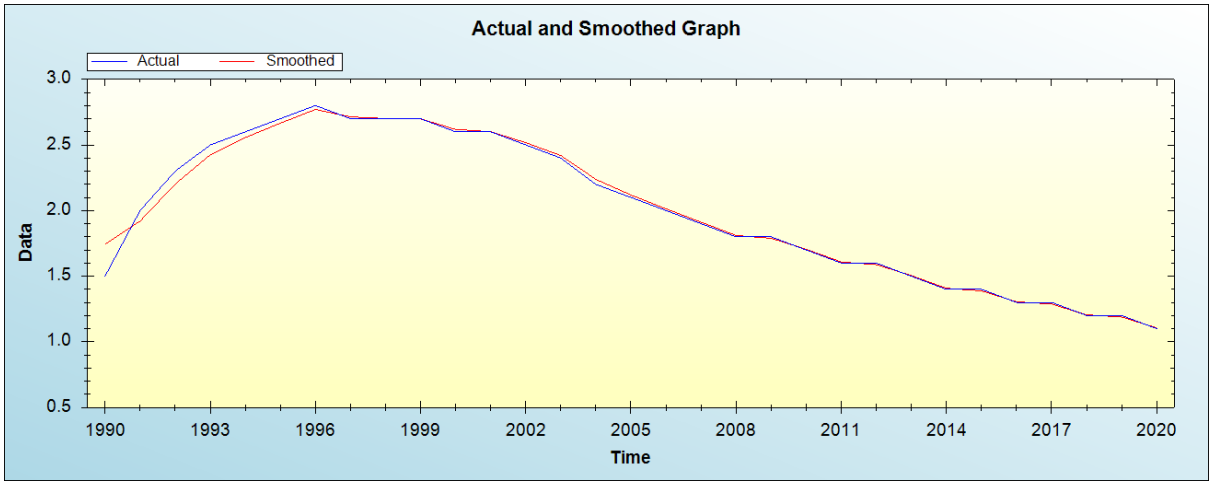


Figure 3: Actual and smoothed graph for V series

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

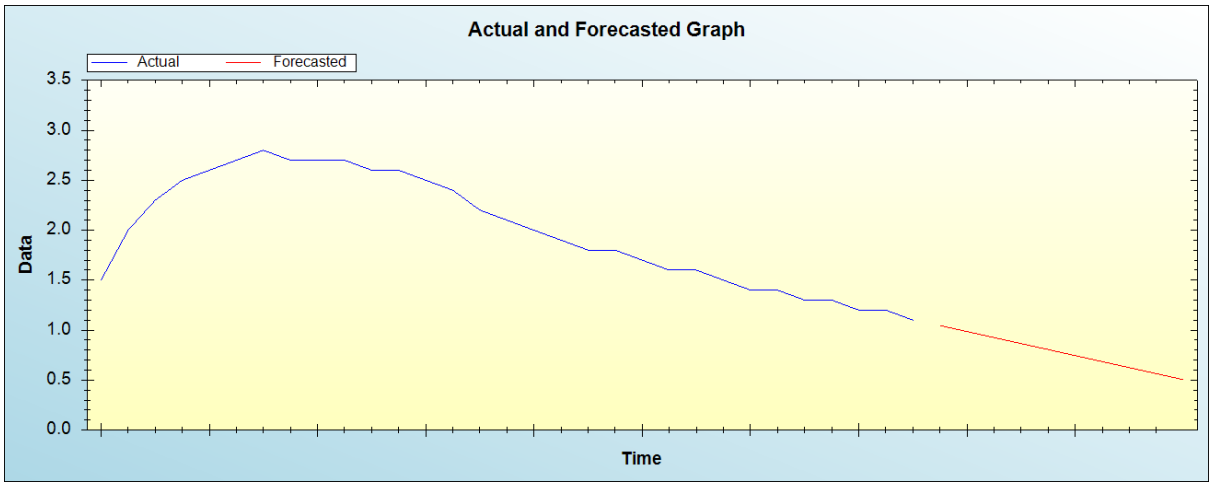


Figure 4: Out-of-sample forecast for V: actual and forecasted graph

Out-of-Sample Forecast for V: Forecasts only

Table 2: Tabulated out-of-sample forecasts

| Year | Predicted HIV prevalence |
|---|---|
| 2021 | 1.0460 |
| 2022 | 0.9857 |
| 2023 | 0.9255 |
| 2024 | 0.8653 |
| 2025 | 0.8051 |
| 2026 | 0.7449 |
| 2027 | 0.6847 |
| 2028 | 0.6244 |
| 2029 | 0.5642 |
| 2030 | 0.5040 |

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 suggests that annual HIV prevalence among individuals aged 15-49 years will continue to decline over the out of sample period. This paper calls for scale up of HIV case detection, prevention and treatment especially among high risk groups.

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