

PREDICTION OF HIV PREVALENCE AMONG INDIVIDUALS AGED 15-49 YEARS IN SOUTH SUDAN 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 South Sudan 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 increase from around 2.3% in 2021 to about 2.5% in 2030. Therefore, we encourage authorities to scale up HIV testing services, ART coverage and HIV prevention programs in order to curb HIV transmission among this age group.

Keyword: - Exponential smoothing, Forecasting, HIV prevalence

Background

HIV continues to be a public health concern in South Sudan. The recurrent armed conflicts and humanitarian situation has negatively impacted health service delivery across the country. The government usually prioritizes emergency health needs, nutrition and shelter for internally displaced persons (Hakim *et al.* 2020). The majority of people in this nation live below the poverty datum line. According to UNAIDS, HIV prevalence among individuals aged 15-49 years in South Sudan is estimated to be 2.4% and there are approximately 194,000 PLHIV, less than 20% of whom are on antiretroviral therapy. The Sudan Ministry of Health revealed that the ANC sentinel surveillance data indicated that HIV prevalence is highest in the three former Greater Equatoria states in the south of the country. UNAIDS data shows that the number of both new infections and AIDS-related deaths in South Sudan are estimated to have increased by 3% since 2010 whereas other countries in Sub-Saharan Africa have witnessed a decline over the period 2010-2019. Documented evidence shows that social factors like poverty and prevailing gender relations contribute to HIV infection in the country (Firstday, 2016). The HIV epidemic in South Sudan is mostly concentrated among commercial sex workers (Hakim *et al.* 2020). The Eagle surveys in 2016 and 2017 indicated that the seroprevalence of HIV among female sex-workers in Juba, the capital, was estimated at 37.9% and at 24.0% in Nimule. In addition, syphilis prevalence was 7.3% in Juba and 9.2% in Nimule. It is worrying to note that the coverage of antiretroviral therapy services remains very low in South Sudan and more needs to be done in order to control the HIV epidemic in this country (UNAIDS, 2019).

The aim of this paper is to model and forecast HIV prevalence among the 15-49 year age group using Holt's linear method. The study findings are expected to guide policy, planning and



allocation of resources to HIV programs that focus on the sexually active age group (15-49 years).

Literature Review

Author (s)	Objective (s)	Methodology	Key finding (s)
Ijaiya et al. (2023)	To describe HIV research output in Africa by country from 1986 until 2020.	-Poisson regression models were used to explore the trends in countries' HIV research output over the study period -The Pearson correlation analysis assessed the association between research output, population size, GDP, and the number of PLHIV	There was a strong positive and statistically significant correlation between the total indexed HIV publications and countries' GDP ($r = 0.59$, $P < 0.01$), population ($r = 0.58$, $P < 0.01$), and the estimated number of PLHIV ($r = 0.72$, $P < 0.01$). The study found that Africa's contribution to global HIV research output increased over the 35 years, but it remains relatively low compared to the continent's burden of HIV infections.
Maulide Cane et al. (2021)	To assess the trends in HIV prevalence by gender in adolescents, as well as urban-rural disparities in SSA	HIV prevalence data at ages 15-19 years were obtained for 31 countries with a national survey since 2010 and for 23 countries with one survey circa 2005 and a recent survey circa 2015	HIV prevalence among adolescents declined in almost all countries during the last decade, in both urban and rural settings
Daw et al. (2020)	To analyze the epidemiological characterization and spatial trends of HIV infection in the Northern African region	A systematic review was carried out on all the published data regarding HIV/AIDS in Northern African countries over a ten year period (2008-2017) following the PRISMA guidelines	The overall prevalence of HIV in northern African countries ranged from 0.9% (95% CI (0.8-1.27) to 3.8% (95% CI (1.17-6.53)). The highest prevalence was associated with vulnerable groups, particularly drug abusers and sexual promiscuity
Hakim et al. (2020)	To determine HIV and syphilis prevalence among female sex workers in Juba, South Sudan	-conducted a respondent-driven sampling bio behavioral survey in Juba of female sex workers (FSW) aged 15 years who sold or exchanged sex in the last 6 months to learn more about this population	-Prevalence of active syphilis was 7.3%. FSW were from South Sudan and most neighboring countries. Comprehensive knowledge of HIV was 11.1% and 64.2% of FSW had never spoken with an outreach worker. In multivariable analysis, HIV was associated with being from Uganda



			(aOR: 3.3, 95% CI: 1.7–6.1) or Kenya (aOR: 4.3, 95% CI: 1.5–13.0) versus from South Sudan
Kempton et al. (2019)	To analyze data from 2017 and to compare HIV incidence, AIDS-related deaths and provision of antiretroviral therapy to adults, pregnant women and children living with HIV in lower- and higher-prevalence countries.	-least squares linear regression, weighted by epidemic size and controlled for gross domestic product/capita, was used to compare HIV prevalence with estimated ART coverage in adults (≥ 15 years), children (0–14 years), pregnant women, and EID rates and MTCT rates.	Most new HIV infections, MTCTs and AIDS-related deaths occurred in countries with an HIV prevalence rate below 4.5%.
Firstday (2016)	To determine HIV prevalence in South Sudan	Cross-sectional study	The HIV prevalence for the general population was found to be 2.7 % and 14 % among vulnerable 15-49 year olds.

Methodology

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

$$Y_t = \mu_t + \rho_t t + \varepsilon_t$$

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

Y_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 South Sudan 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

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	Y
Included Observations	31
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.093261
Sum Square Error (SSE)	0.741256
Mean Square Error (MSE)	0.023911
Mean Percentage Error (MPE)	-1.734403
Mean Absolute Percentage Error (MAPE)	8.324138

Residual Analysis for the Applied Model

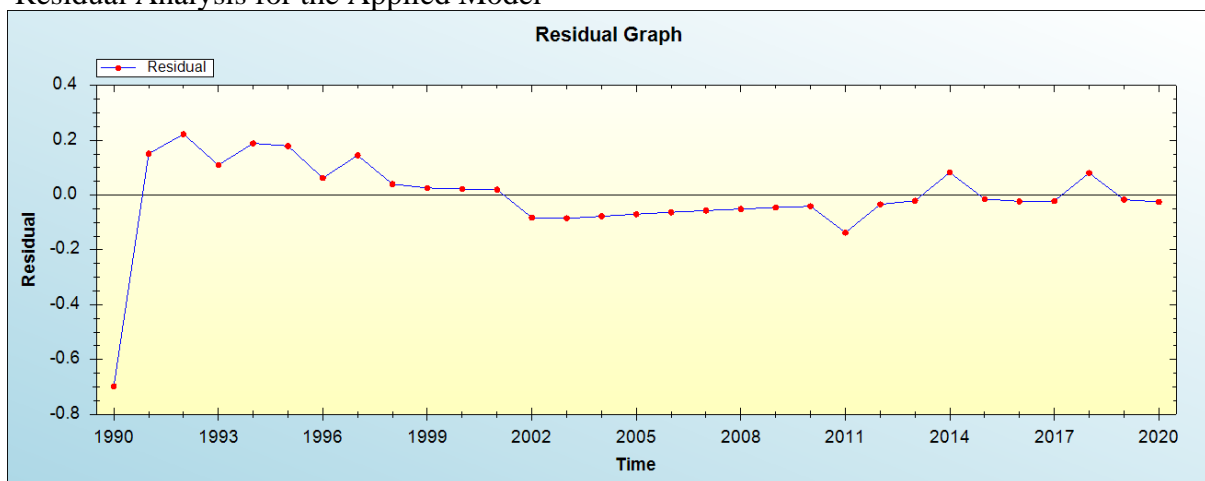


Figure 1: Residual analysis



In-sample Forecast for Y

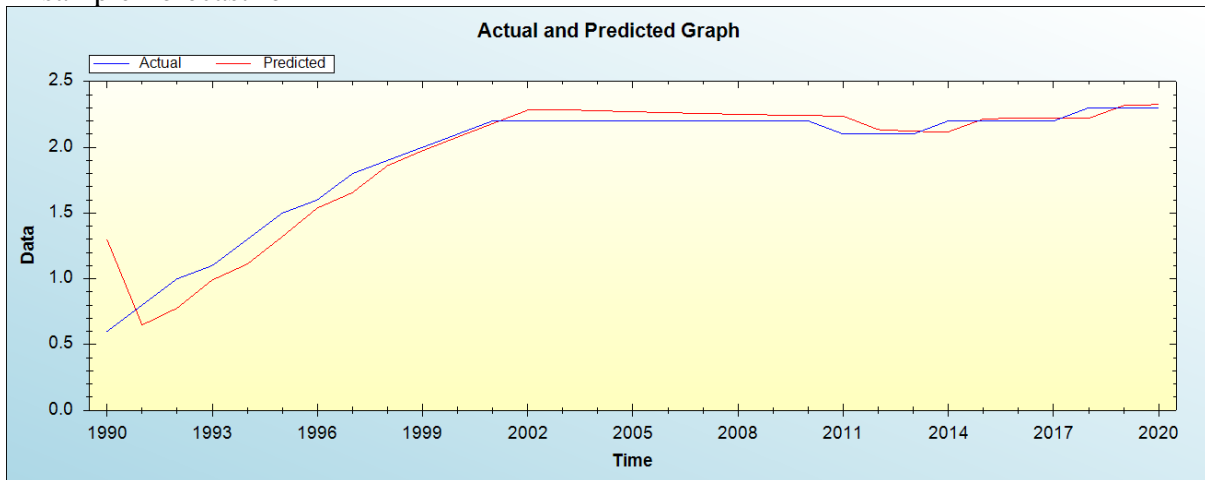


Figure 2: In-sample forecast for the Y series

Actual and Smoothed graph for Y series

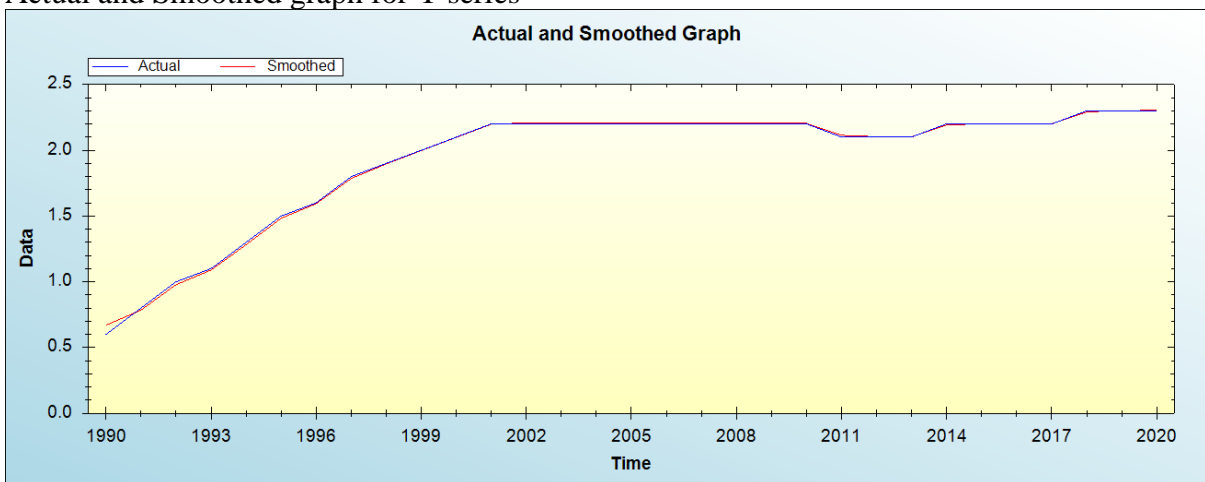


Figure 3: Actual and smoothed graph for Y series

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

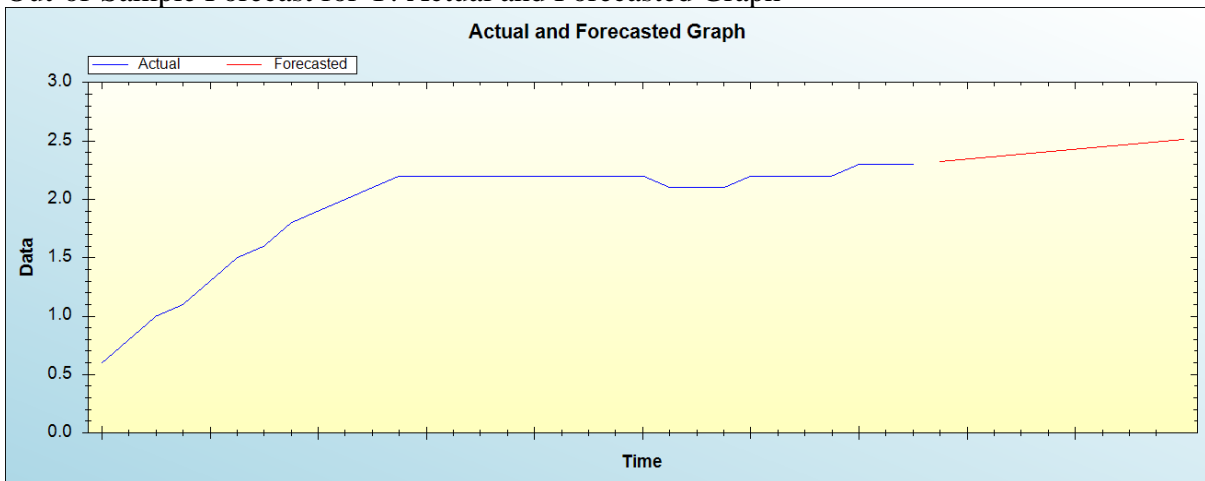


Figure 4: Out-of-sample forecast for Y: actual and forecasted graph



Out-of-Sample Forecast for Y: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	2.3235
2022	2.3445
2023	2.3655
2024	2.3865
2025	2.4075
2026	2.4285
2027	2.4496
2028	2.4706
2029	2.4916
2030	2.5126

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 increase from 2.3 % around 2021 to 2.5% in 2030.

Policy implication and conclusion

This paper establishes that annual HIV prevalence among individuals aged 15-49 years will increase from 2.3 % around 2021 to 2.5% in 2030. Hence, it is crucial for authorities to scale up HIV testing services, ART coverage and HIV prevention programs in order to curb HIV transmission among this age group.

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