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PROJECTION OF HIV PREVALENCE AMONG INDIVIDUALS AGED 15-49 YEARS IN SUB-SAHARAN AFRICA 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 Africa 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 0.6 respectively based on minimum MSE. The results of the study indicate that annual HIV prevalence among individuals aged 15-49 years will slightly decline over the out of sample period but still remain high. Therefore, we encourage authorities to scale up HIV testing, increase ART coverage and strengthen HIV prevention among this age group.

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

Introduction

Globally, 36.7 million people were living with HIV in 2015 with 70 % of infected people were living in sub-Saharan Africa (UNAIDS, 2016 & Hodgson & Rachanis, 2002). Low-middle income countries account for 97% of global HIV cases and Sub-Saharan Africa is the world's worst affected region (Kautako-Kiambi *et al.* 2015). Approximately 3.9 million young people worldwide were infected with HIV in 2017 (Bekele & Fekadu, 2020). About 2.9 million of the 4.9 million young people living with HIV / AIDS live in eastern and southern Africa (Peltzer K & Matseke, 2013). Young women are more vulnerable to HIV due to extreme peer pressure and the emergence of their sexual and social identities (UNAIDS, 2008). Significant predictors of young people's HIV testing include demographic factors, HIV risk behavior, psychosocial variables associated with HIV awareness and stigma attitudes (Erena *et al.* 2019; Muyunda *et al.* 2018; Paulin *et al.* 2015; Nwachukwu & Odimegwu, 2011). The purpose of this paper is to model and forecast HIV prevalence among individuals aged 15-49 years for Sub-Saharan Africa using Holt's linear method. The results of this paper are envisaged to guide policy, planning and allocation of resources towards targeted HIV prevention, treatment, support and care programs in Africa in order to curb new infections and reduce morbidity and mortality related to HIV/AIDS.

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Literature Review

Author (s)	Objective (s)	Methodology	Main finding (s)
Dadzie et al. (2024)	To assess the socioeconomic inequalities in HIV testing during antenatal care (ANC) in sub-Saharan Africa.	-Benin, Burundi, Cameroon, Ethiopia, Gambia, Guinea, Liberia, Malawi, Mali, Mauritania, Mozambique, Rwanda, Sierra Leone, Uganda, Zambia, and Zimbabwe were the countries included in the study. -This study used current Demographic and Health Surveys data spanning from 2015 to 2022. A total of 70,028 women who tested for HIV as part of antenatal contacts formed the sample for analysis.	There is substantial wealth index-related inequalities in HIV testing, with women of the poorest wealth index disadvantaged in relation to the HIV testing
Ijaiya et al. (2023)	To describe HIV research output in Africa by country from 1986 until 2020.	Applied Poisson regression models 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.A total of 83,527 articles from African countries on HIV indexed in PubMed were included for analysis	-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 -There were major differences in research output across sub-regions in Africa, with the Republic of South Africa having the highest output -factors associated with HIV research output were economic strength, disease epidemiology, and population size
Astawesegn et al. (2022)	To establish the trend and effect of ART coverage during pregnancy on mother-to-child HIV transmission in sub-	-Country-level longitudinal ecological study design was used - Forty-one sub-Saharan Africa countries were included using	ART coverage for HIV positive pregnant women and HIV incidence-to-prevalence ratio were significantly associated with MTCT

	Saharan Africa from 2010 to 2019.	publicly available data from the United Nations Programme on HIV/AIDS, World Health Organization, and World Bank.	rate in sub-Saharan Africa
Worku et al. (2022)	To investigate the pooled prevalence and associated factors of HIV testing among young women in east Africa.	The most recent DHS surveys done among 11 east African countries were pooled and a weighted sample of 73,661 young women were included. -performed bivariate and multivariable analysis	Pooled prevalence of HIV testing among young women was 55.3%: 95% CI (54.97%, 55.69%). In the multilevel multivariable analysis: respondent age, marital status, educational level, occupation, media exposure, having higher and comprehensive knowledge about HIV / AIDS, having some and higher risky sexual behavior, visiting health care facilities, being rural dweller, being from rich households, having multiple sexual partners, early sex initiation and community-level education were significantly associated with HIV testing
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 - Country medians and average annual rates of changes were used to summarize the trends for two sub-regions in sub-Saharan Africa,	HIV prevalence among adolescents declined in almost all countries during the last decade, in both urban and rural settings. The urban–rural gap persisted and HIV transmission to girls, but not boys, is still a major challenge in Eastern and Southern African countries

		Eastern and Southern Africa and West and Central Africa,	
Belachew et al. (2020)	To assess the prevalence of vertical HIV infection and its risk factors among HIV-exposed infants in East Africa.	Systematic review	The pooled prevalence of the mother to child transmission of HIV is way more than the desired target of the World Health Organization, which is less than 5% in breastfeeding populations
Faust and Yaya (2018)	To systematically review and meta-analyze the evidence for the effect of HIV-related knowledge interventions on 1) the improvement of HIV-related knowledge, 2) subsequent risk reduction behavior (condom use), 3) lower incidence of HIV infection	Literature Review	Peer-education-based interventions appear to be particularly effective in facilitating the uptake of HIV-related knowledge, particularly pertaining to transmission routes.

Methodology

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

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

Smoothing equation

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

$0<\propto<1$

Trend estimation equation

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

$0<\beta<1$

Forecasting equation

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

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

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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 Sub-Saharan Africa 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	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)	0.186249
Sum Square Error (SSE)	3.850826
Mean Square Error (MSE)	0.124220
Mean Percentage Error (MPE)	-1.210951
Mean Absolute Percentage Error (MAPE)	6.080814

Residual Analysis for the Applied Model

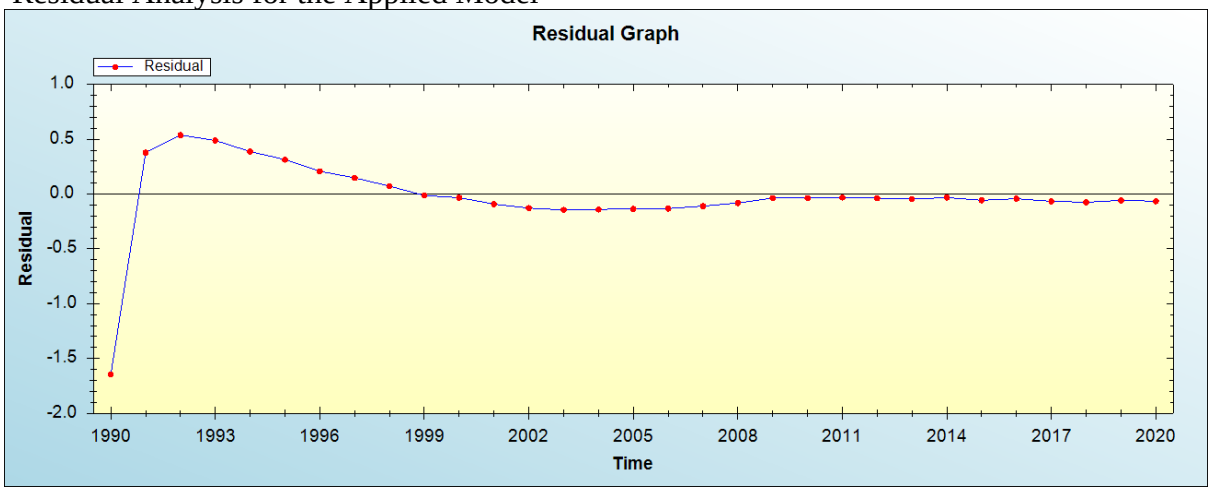

Figure 1: Residual analysis

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In-sample Forecast for A

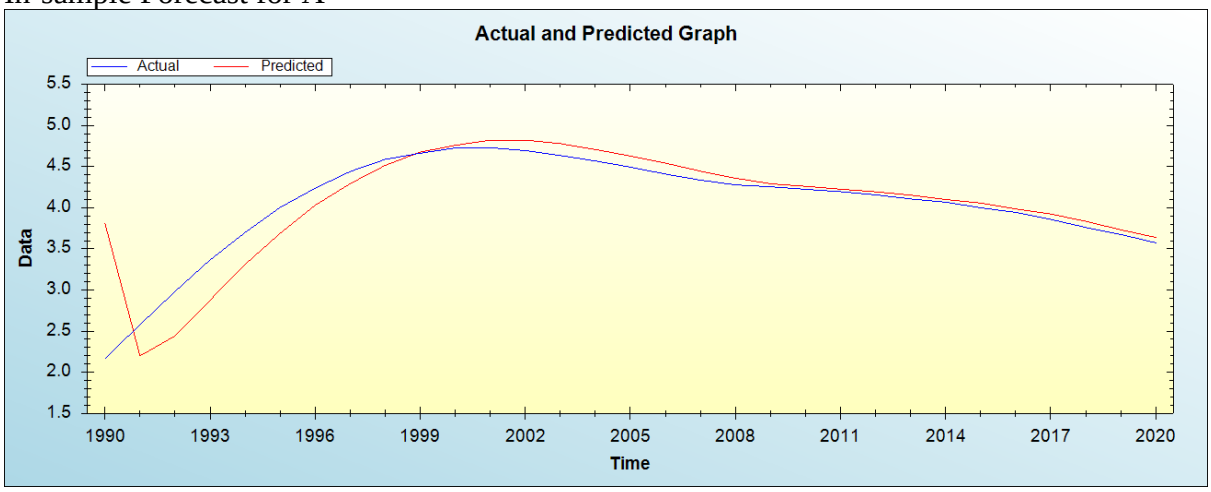

Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

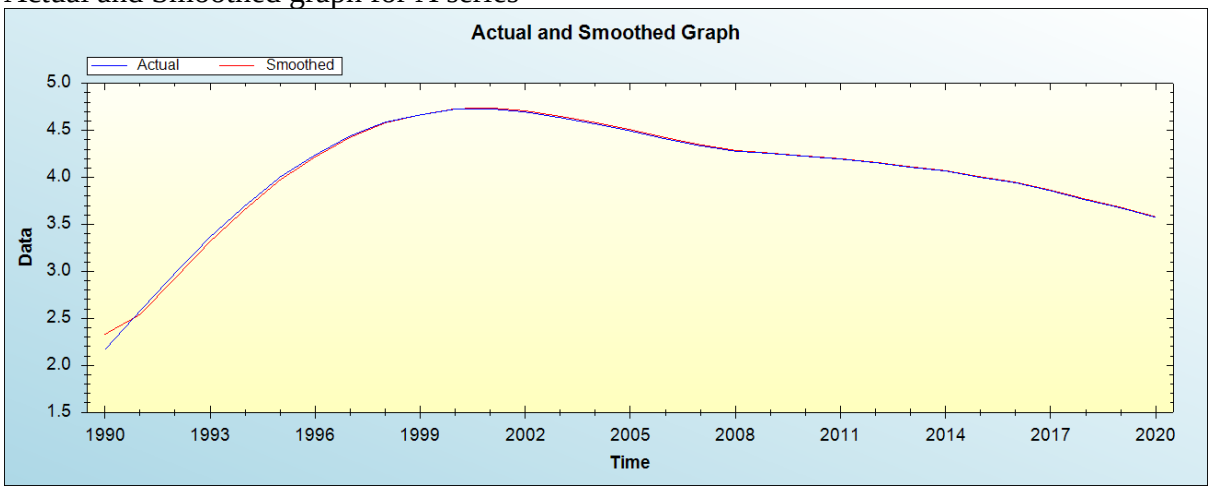

Figure 3: Actual and smoothed graph for A series

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

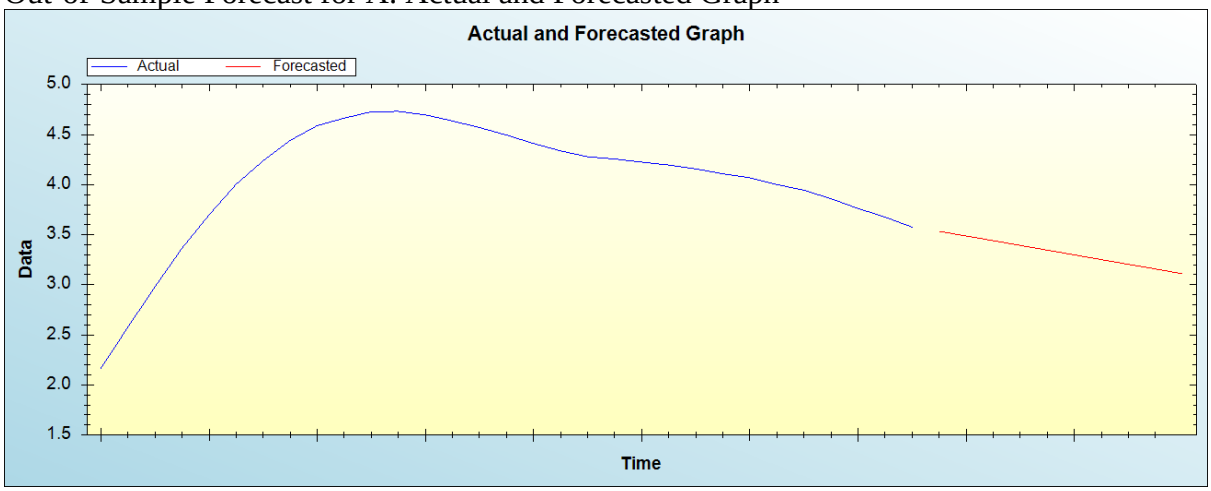

Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	3.5340
2022	3.4868
2023	3.4397
2024	3.3926
2025	3.3454
2026	3.2983
2027	3.2511
2028	3.2040
2029	3.1569
2030	3.1097

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 results that annual HIV prevalence among individuals aged 15-49 years will continue to decline over the out of sample period. Therefore, this paper emphasizes the importance of continuously supporting HIV detection, treatment and prevention among this age group. However, HIV programs should relentlessly target high risk groups to curb HIV spread.

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