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Applying Holt's double exponential smoothing technique to predict HIV prevalence among individuals aged 15-49 years for Burkina Faso

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Abstract
This study uses annual time series data of HIV prevalence among individuals aged 15-49 years for Burkina Faso 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 individuals aged 15-49 years will continue to decline over the out of sample period. Therefore, we encourage authorities to improve HIV case detection among the communities and strengthen preventive measures recommended by WHO.

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

Background

Burkina Faso is a West African country located in the Sahel region with an estimated population greater than 20 million, 40 percent of whom live below the poverty datum line (World Bank, 2020). This country is negatively affected by wars that characterize this part of the continent. Hence all the efforts that are made by the government to achieve set targets of sustainable development goals are disrupted by the insecurity in the north and the east of the country which has caused an upsurge in the number of internally displaced people. The resultant humanitarian crisis has led to disruptions in access to education and health services. According to UNAIDS 2021, the estimated prevalence of HIV infection among adults (15-49) was 0.7% and among all ages approximately 97 000 people were living with HIV (PLHIV). Seventy three per cent of persons living with HIV are aware of their status and the increasing availability of antiretroviral therapy has contributed to a 54% reduction in AIDS related deaths since 2010. Sixty-seven per cent of all persons living with HIV are on highly effective antiretroviral therapy. It is of concern to mention that only 17% of children ages 0-14 are on antiretroviral therapy and more than 95% female adults vs. 62% male adults are on ART). The decline in new HIV infections is attributed to the rapid scale of ART services among key populations and pregnant women living with HIV. In addition, other HIV prevention strategies are condom use, behavioral change interventions, pre-exposure prophylaxis, post-exposure prophylaxis and voluntary male circumcision.

The objective of this paper is to model and forecast HIV prevalence among the age group 15-49 years using Holt's linear method. The findings of this piece of work is expected to provide an insight of future trends of HIV prevalence among the sexually active age group and guide allocation of resources towards HIV prevention, treatment and care interventions in this priority age group.

Literature Review

Author (s)	Objective (s)	Methodology	Key finding (s)
Nshimirimana et al. (2022)	To assess HIV testing uptake and its determinants among adolescents and young adults	Cross-sectional design involving analysis of 2016 Demographic and Health Survey data	Despite the interventions implemented to reach the 90-90-90 UNAIDS goals, HIV testing among youth

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			in Burundi was low
Gelibo et al. (2022)	To identify geographic locations and drivers of HIV transmission in Ethiopia	-used data from adults aged 15–64 years who participated in the Ethiopian Population-based HIV Impact Assessment survey (October 2017–April 2018	uncircumcised men in certain hotspot towns and divorced or widowed individuals in hotspot woredas/towns might have contributed to the average increase in HIV prevalence in the hotspot areas
Njejimana et al. (2021)	To determine and characterize this problem in Burundi.	-qualitative analysis based on an extensive series of 114 interviews	-the problem of HIV/AIDS stigma is widespread in Burundian society, as all participants in the research reported having experienced some kind of HIV stigma
Ouedraogo et al. (2019)	To determine the prevalence and correlates of HIV infection among MSM in Burkina Faso	A cross-sectional biological and behavioral survey was conducted from January to August 2013 among MSM in Ouagadougou and Bobo-Dioulasso	HIV prevalence among MSM under 25years old was 1.3% (95% CI: 0.6–2.8) and 0.9% (95% CI: 0.4–2.5) respectively in Ouagadougou and Bobo-Dioulasso, compared to 5.4% (95% CI: 2.2–12.5) and 6.6% (95% CI: 3.4–12.3) among those 25 years old or older in these cities (p=0.010 and p<0.001
Yé et al. (2018)	To improve equity of access to health care and information among women and PLWHAs by reinforcing community participation.	Using a quasi-experimental approach, a mobile telephone system was set up at five health centres to provide an automated reminder service for health care consultation appointments. Performance evaluations based on key performance indicators were	A 7.34% increase in prenatal coverage, an 84% decrease in loss to follow-up for HIV (P < 0.001) and a 31% increase in assisted deliveries in 2016 (P < 0.0001) were observed in intervention areas.

		subsequently conducted.	
Kirakoya-Samadoulougou et al. (2017)	To examine the influence of both individual and community-level determinants of HIV testing uptake in Burkina Faso	Applied modified Poisson regression models.	For both genders, age, education, religious affiliation, household wealth, employment, media exposure, sexual behaviors, and HIV knowledge were associated with HIV testing

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 Burkina Faso. 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

$$K_t = \mu_t + \rho_t t + \varepsilon_t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots[1]$$

Smoothing equation

$$S_t = \alpha K_t + (1\text{-}\alpha)(S_{t-1} + b_{t-1})\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots[2]$$

$0 < \alpha < 1$

Trend estimation equation

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

$0 < \beta < 1$

Forecasting equation

$$f_{t+h} = S_t + h b_t \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots[4]$$

K_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 Burkina Faso 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

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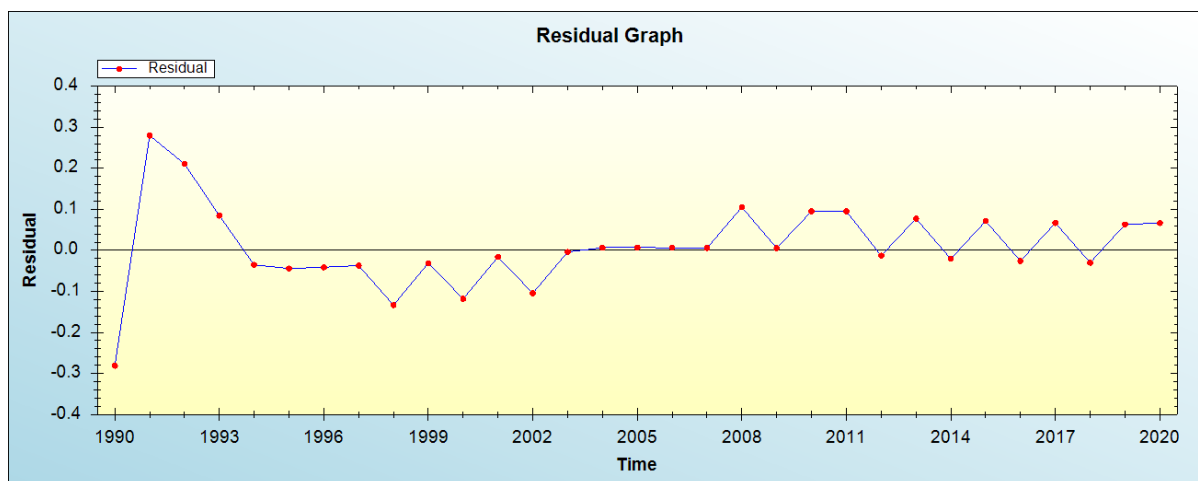| Variable	K
Included Observations	31
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.070425
Sum Square Error (SSE)	0.314718
Mean Square Error (MSE)	0.010152
Mean Percentage Error (MPE)	1.390780
Mean Absolute Percentage Error (MAPE)	4.499884

Residual Analysis for the Applied Model

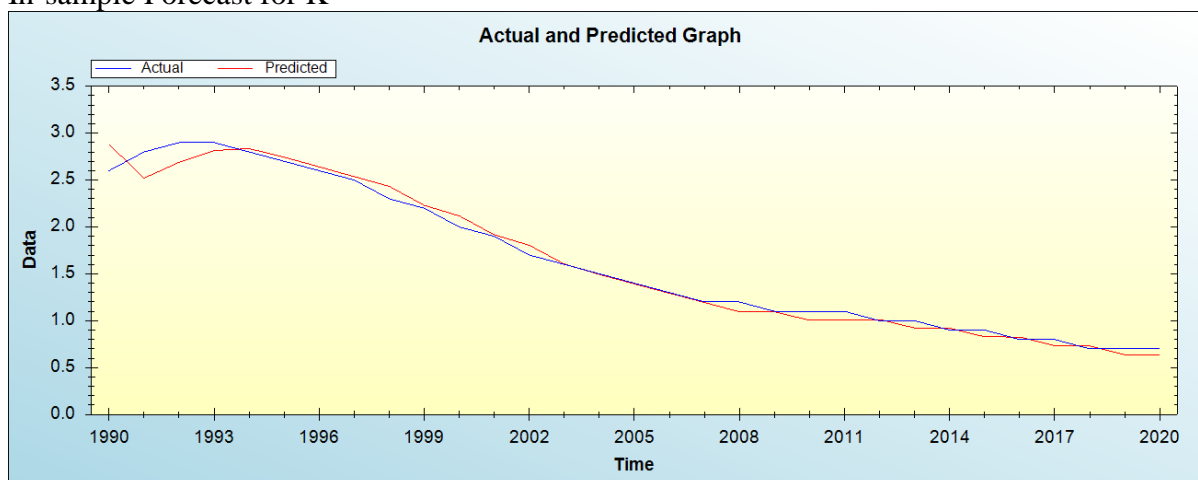

Figure 1: Residual analysis

In-sample Forecast for K

Figure 2: In-sample forecast for the K series

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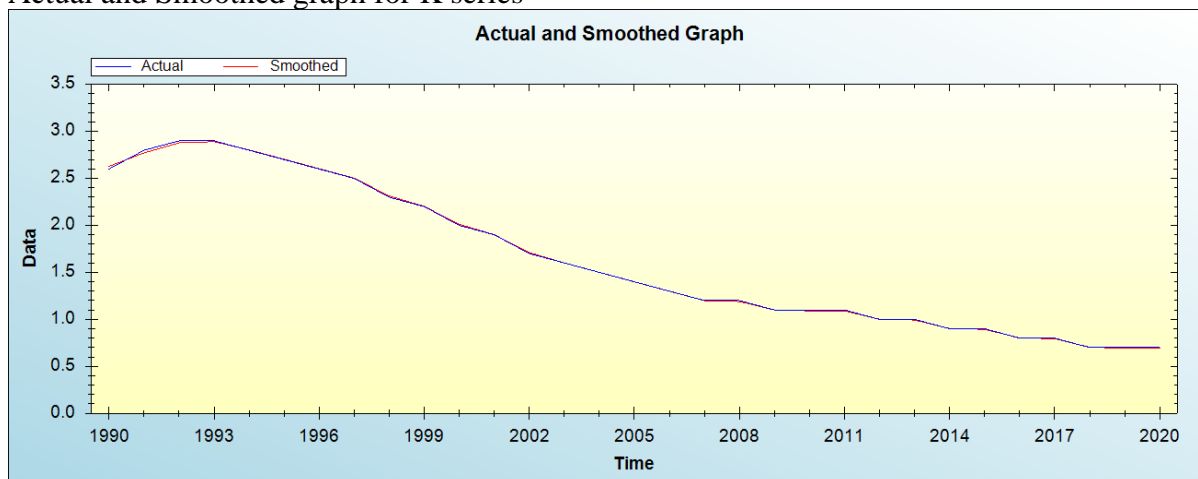Actual and Smoothed graph for K series

Figure 3: Actual and smoothed graph for K series

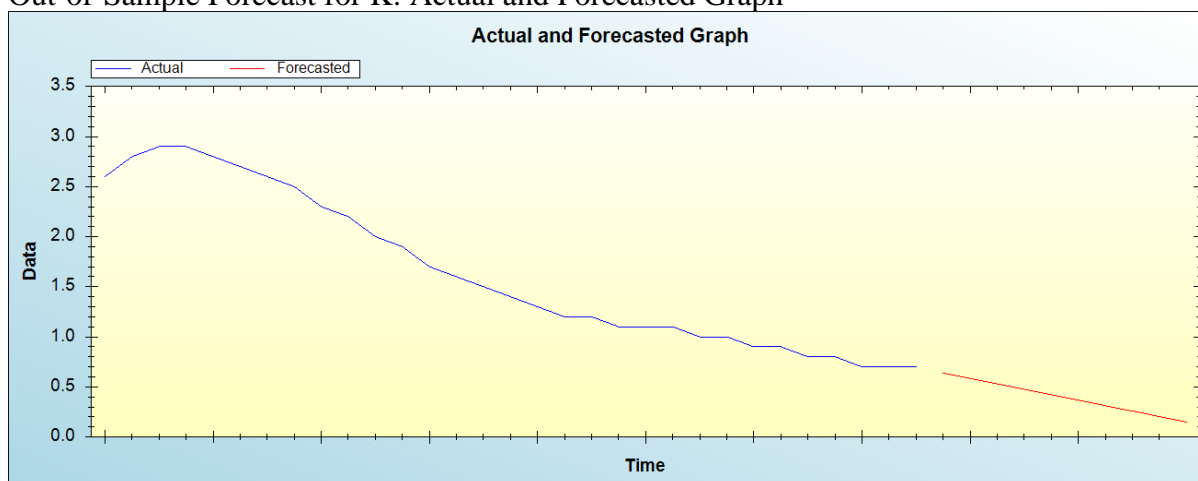Out-of-Sample Forecast for K: Actual and Forecasted Graph

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

Out-of-Sample Forecast for K: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	0.6389
2022	0.5845
2023	0.5301
2024	0.4757
2025	0.4213
2026	0.3669
2027	0.3125
2028	0.2581
2029	0.2037
2030	0.1492

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

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Exponential smoothing techniques have been proven to be reliable time series forecasting techniques. In this study we employed Holt's double exponential smoothing technique and model projections indicate that the annual HIV prevalence among individuals aged 15-49 years will continue to decline over the out of sample period. This study recommends that the policy makers must improve HIV case detection among the communities and strengthen preventive measures recommended by WHO.

References

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[2] UNAIDS (2021). 2021 epidemiological estimates. AIDSINFO Country factsheets, 2021 (https://aidsinfo.unaids. org/)

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