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Projection of HIV prevalence among individuals aged 15-49 years in Chile using Holt's double exponential smoothing model

Dr. Smartson. P. NYONI[1], Thabani NYONI[2]
[1]*ZICHIRe Project, University of Zimbabwe, Harare, Zimbabwe*
[2]*Independent Researcher & Health Economist, Harare, Zimbabwe*

Abstract
This study uses annual time series data of HIV prevalence among individuals aged 15-49 years for Chile 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 0.6 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 on an upward trend over the out of sample period. Therefore, we encourage authorities to scale up demand generation for all HIV services especially among key populations and vulnerable groups.

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

Background

According to UNAIDS, the vision of the global HIV response is to achieve zero new HIV infections, zero AIDS related deaths and zero discrimination. The estimated 1.7 million people living with HIV (PLWHIV) in 2019 marked a 23% drop in new HIV infections since 2010. Worldwide, the annual number of new infections has been declining more rapidly among women and girls (a 27% decrease since 2010) than among men and boys (an 18% decrease). There were fewer new infections in 2019 worldwide among women and girls (48% of total infections) than among men and boys (52%). Children (aged 0 to 14 years) accounted for 9% of new infections in 2019, with 84% of child infections occurring in sub-Saharan Africa. In addition, the majority of new adult HIV infections worldwide in 2019 were among key populations and their sexual partners. These populations include sex workers, people who inject drugs, prisoners, transgender people, and gay men and other men who have sex with men. The risk of contracting HIV among adults is higher among specific ages, genders and subpopulations by region, depending on the type of epidemic within the countries, cities and communities of the region. In sub-Saharan Africa, adolescent girls and young women (aged 15 to 24 years) are at higher risk of HIV infection: they accounted for about one in four new infections, despite comprising only 10% of the population. In the region most affected by HIV, eastern and southern Africa, adolescent girls and young women accounted for 30% of new infections. Approximately 74 000 people are living with HIV in Chile with 0.5% sero-prevalence among people aged 16-49 years (Ferrer *et al.* 2022). The objective of this study is to model and forecast HIV sero-prevalence among the 15-49 year age group using Holt's linear method. Study findings are expected to highlight likely future trends of HIV prevalence among the 15-49 year age group and guide planning and allocation of resources towards HIV prevention, treatment and care programs in the country.

Literature Review

Author(s)	Objective (s)	Methodology	Main Finding(s)
Silva et al. (2023)	To shed light on the meaning of living with HIV for young gay Chilean males.	Qualitative analysis of 11 in-depth interviews, employing Heidegger's hermeneutical	It is imperative to enhance psychological support by integrating it into the HIV program for all

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		approach	clients and families facing crisis situations
Ferrer et al. (2022)	To evaluate the performance of the rapid diagnostic tests for HIV in the general population using mass testing in the community	3102 were included	Mass testing of HIV is feasible
Sanhueza-Sanzana et al. (2021)	to assess the socio-demographic and epidemiological factors associated with AIDS and tuberculosis-HIV co-infection mortality in the Chilean adult population between 2000 and 2017	retrospective observational study, evaluating the incidence density of TB-HIV co-infection mortality in the population over 14 years of age	Mortality was concentrated in TB-HIV co-infected people with increasing mortality among women and indigenous populations
Ceballos et al. (2020)	To describe the clinical characteristics and outcomes of people living with HIV (PLHIV) requiring hospitalization due to COVID-19 in Chile and compare them with Chilean general population admitted with SARS-CoV-2.	Data of a temporally matched-hospitalized general population were used to compare demography, comorbidities, COVID-19 symptoms, and major outcomes	In PLHIV, the study revealed more intensive care unit admission (OR 2.31; IC 95% 1.05–5.07) but no differences in the need for mechanical ventilation or death. In this cohort of PLHIV hospitalized with COVID-19, hypertension and cardiovascular comorbidities, but not current HIV viro-immunologic status, were the most important risk factors for mortality. No differences were found between PLHIV and general population in the need for mechanical ventilation and death.
Ávila et al. (2019)	To identify factors associated with HIV prevalence among	Descriptive and logistic regression analyses were then	The high prevalence of HIV among MSM suggests a re-

	men who have sex with men (MSM) in the metropolitan region (MR) of Santiago, Chile	performed	emergence of the disease in Chile, and cases are specifically concentrated among young MSM.
Gómez et al. (2017)	To explore the association among HIV status; negative psychological symptoms (anxiety, depression, and hostility); and risky sexual behaviors (multiple sexual partners and unprotected sexual intercourse) in a Chilean sample of men who have sex with men (MSM).	cross-sectional design	No statistically significant differences were found for condom use or for the number of sexual partners between HIV-positive men and those who are not infected. In both groups, about 50% reported sexual encounters without condom use in the past six months. There were statistically significant differences in symptoms associated with depression between the two groups.
Irarrázabal et al. (2016)	identified the personal characteristics that affect Chilean health care providers' readiness to adopt HIV Oral Rapid Testing (ORT) in Chile as a new clinical Evidence-based practice (EBP). Methods.	Cross-sectional study design	The providers reported a mean "readiness to implement ORT" score of 15.1 out of a possible value of 20, suggesting only moderate self-perceived readiness to adopt the EBP. Education, beliefs about evidence-based practice, perceived comfort in performing ORT (oral rapid HIV test), and perceived importance of HIV testing explained 43.6% of the variance in readiness to adopt ORT.

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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 Chile. 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

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

Smoothing equation

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

$0 < \alpha < 1$

Trend estimation equation

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

$0 < \beta < 1$

Forecasting equation

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

C_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 Chile 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	C
Included Observations	31
Smoothing constants	
Alpha (α) for data	0.600
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.029519
Sum Square Error (SSE)	0.044314
Mean Square Error (MSE)	0.001429
Mean Percentage Error (MPE)	-1.059209
Mean Absolute Percentage Error (MAPE)	13.969079

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Residual Analysis for the Applied Model
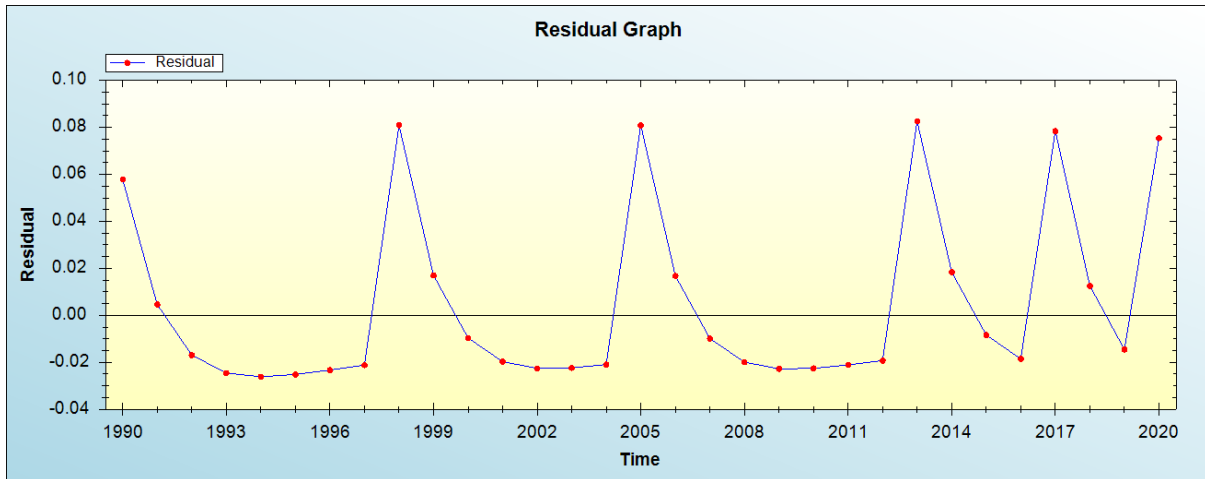

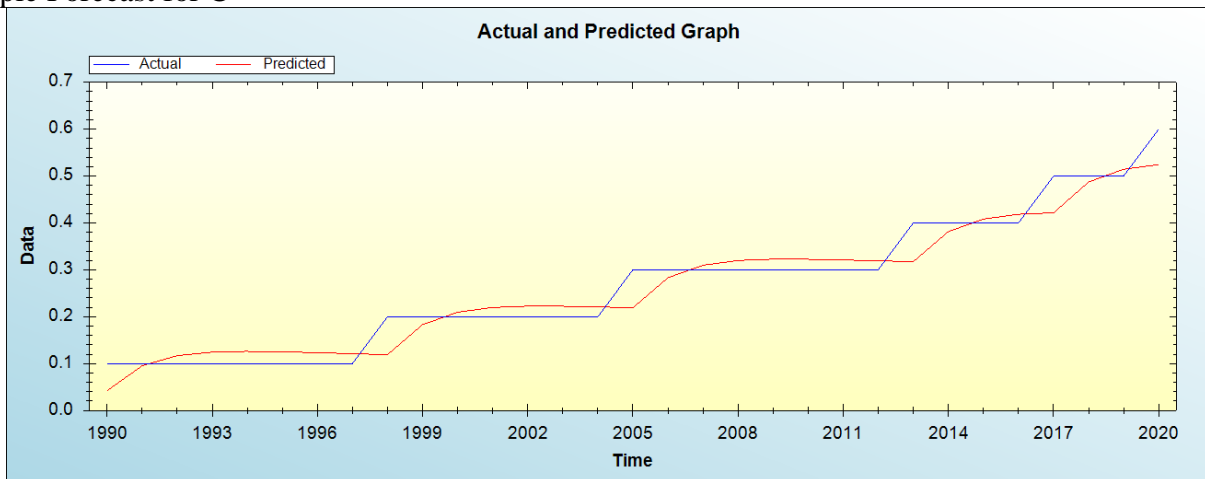Figure 1: Residual analysis

In-sample Forecast for C

Figure 2: In-sample forecast for the C series
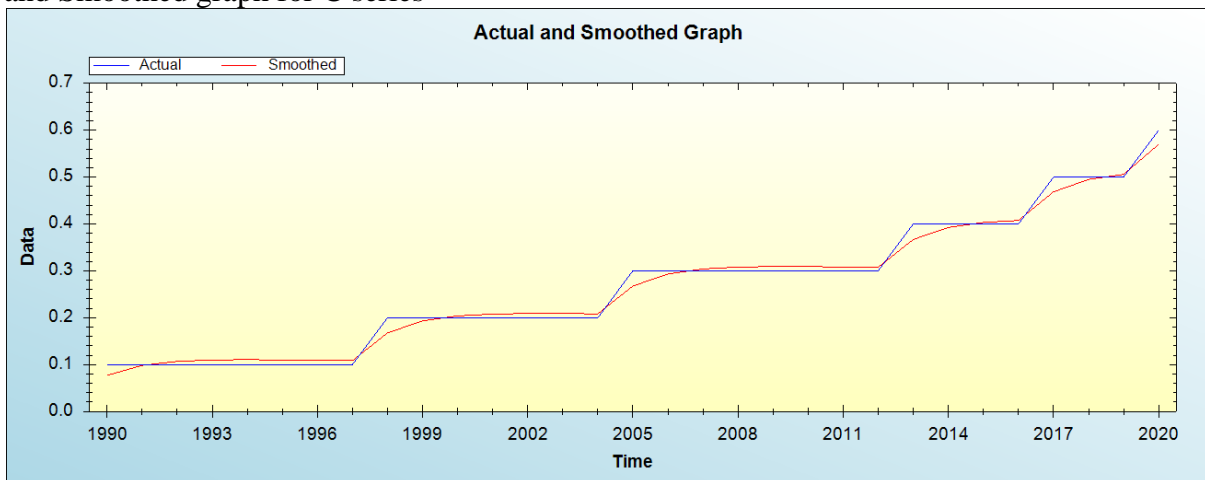
Actual and Smoothed graph for C series

Figure 3: Actual and smoothed graph for C series

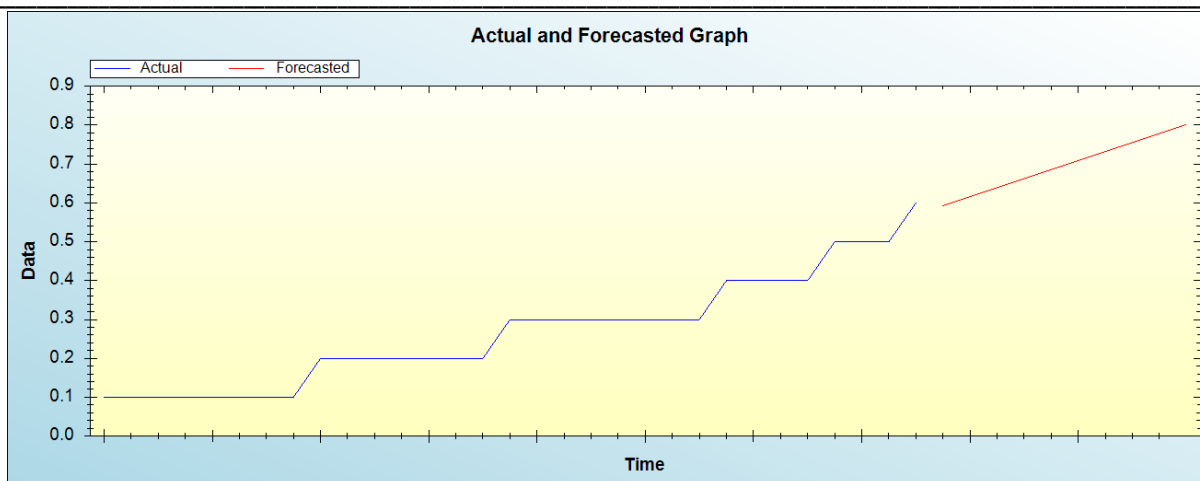Out-of-Sample Forecast for C: Actual and Forecasted Graph

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

Out-of-Sample Forecast for C: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	0.5930
2022	0.6163
2023	0.6395
2024	0.6627
2025	0.6859
2026	0.7092
2027	0.7324
2028	0.7556
2029	0.7788
2030	0.8021

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 on an upward trend over the out of sample period.

Policy implications and conclusion

The upward trend of HIV prevalence among individuals aged 15-49 years is expected to persist in the out of sample period. It is therefore essential for authorities in Chile to scale up demand generation for all HIV services especially among key populations and vulnerable groups.

References

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