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Using empirical evidence generated by Holt's linear method to inform HIV programming in Brazil

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Abstract
This study uses annual time series data of HIV prevalence among individuals aged 15-49 years for Brazil from 1990 to 2020 to predict future trends of HIV prevalence over the period 2021 to 2030. The study utilizes Holt's linear method (HLM). The optimal values of smoothing constants α and β are 0.4 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 generally maintain an upward trend over the out of sample period. Therefore, we encourage authorities to scale up educational campaigns among the sexually active age group with particular emphasis on HIV prevention strategies such as correct and consistent use of condoms, behavior change, PrEP and voluntary medical male circumcision.

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

Background

HIV remains a public health threat particularly in low-middle income countries. The government of Brazil has made significant progress in curbing new HIV infections over the past decades, however HIV prevalence among the 15-49 year age is on an upward trajectory (Associated Press, 2014; Greco & Simao, 2007; Oliveira-Cruz *et al.* 2004; Bastos *et al.* 2001). Over the previous decades the detection rate has averaged 20.5 cases per 100,000 persons per year (Brazil, 2015). Between 2004 and 2013, reported AIDS cases in Brazil increased by 53.2% among those aged 15-19 and 10.3% among those aged 20-24 (Brazil, 2015). These increases were greater in men than in women: between 2005 and 2014 reported AIDS case rates per 100,000 persons per year rose from 2.1 to 6.7 for 15-19 year old males and from 3.4 to 4.2 among 15-19 year old females; for 20-24 year olds the rate increased from 16.0 to 30.3 among men but decreased from 15.3 to 12.0 among women. These differences in case rate trends are reflected in the changing ratio of male to female AIDS notifications: among 13-19 year olds this ratio fell from 2.7:1 in 1990 to a low of 0.6:1 in 2005, before rebounding to reach 1.6:1 in 2014.These rising rates are in contrast to older ages: AIDS notification rates fell in all five-year age ranges from 30 to 49 years old between 2005 and 2014 (Saffier *et al.* 2017). In 2015, approximately 830,000 people were living with HIV in Brazil, with a prevalence of 0.40% (Brazil, 2015). Between 2007 and 2015, the proportion of HIV-positive individuals reported to be the age groups 10-14, 15-19 and 20-24 years old rose from 0.3%, 4.3% and 13.4% of all notifications to 0.3%, 6.1% and 18.2%, respectively. Across all ages, the male to female ratio of notified HIV infections increased slightly from 1.9 in 2007 to 2.2 in 2014 (Saffier *et al.* 2017). The HIV epidemic is concentrated among key populations such as men who have sex with men (MSM) (18.4%), sex workers (5.3%), and drug/alcohol users (5.9%). The majority of AIDS cases are men, with a sex ratio of 1.7 to one in 2012. Amongst men, heterosexual transmission increased in the 1990s, but MSM still account for the majority of AIDS cases (36.5%) occurring amongst males (Pereira et al. 2019). The objective of this study is to model and forecast future trends HIV prevalence among the 15-49 years age group using Holt linear method. The findings of this research will guide allocation of resources towards HIV prevention and treatment programs among key populations in this country.

Literature Review

Author (s)	Objective (s)	Methodology	Key finding (s)
Gabster et al. (2022)	To describe the	conducted 21 semi-	Structural barriers

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	facilitators and barriers associated with ART adherence and retention in HIV care among people living with HIV (PLHIV) in the CNB	structured interviews with PLHIV who reside across all three regions of the CNB and have attended an antiretroviral (ART) clinic at least once	included difficult access to ART care due to travel costs, ART shortages, and uncooperative Western/Traditional medical systems.
Huff et al. (2022)	to explore the interplay between substance use (SU) and HIV in Latin America (LA)	Scoping Review	Factors associated with HIV among PWUS included being female, IDU and homelessness, and PWUS were likely to engage in risky sexual behaviors, start antiretroviral treatment late, have poor adherence, have treatment failure, be lost to follow-up, have comorbidities, and experience higher mortality rates and lower quality of life, as has been reported in PLWH with SU in other regions.
Guimarães et al. (2019)	To assess HIV/AIDS knowledge among men who have sex with men (MSM) in 12 Brazilian cities.	-Applied logistic regression	Among 4,176 MSM, the proportion of high level of knowledge was 23.7%. The following variables were positively associated with high knowledge ($p < 0.05$): age 25+ years old, 12+ years of schooling, white skin color, having health insurance, having suffered discrimination due to sexual orientation, having had a syphilis test, and having received educational material in the previous 12 months

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Saffier et al. (2017)	To review all published literature on HIV prevalence and risk factors for HIV infection amongst 10-25 year olds in Brazil	Systematic review	Few published studies have examined HIV amongst young people in Brazil, and those published have been largely cross-sectional and focused on traditional risk groups and the south of the country
Castillo et al. (2011)	To investigate the prevalence of transmitted drug-resistant HIV among adults in Panama by using a modified World Health Organization Threshold Survey (WHO-TS) and to investigate rates of initial resistance among HIV-positive infants in Panama	At the Gorgas Memorial Institute, 47 HIV-positive adults were genotyped for mutations associated with transmitted drug resistance (TDR) in the reverse transcriptase and protease genes of HIV-1, according to WHO-TS guidelines, modified to include patients ≤ 26 years old.	TDR among Panamanian adults was moderate: 6 of 47 HIV-positive adults showed one or more mutations associated with TDR. Horizontal TDR mutations were moderate for NRTIs and NNRTIs and low for protease inhibitors. Vertical transmission of HIV in Panama has decreased for 2002–2007, but vertical HIV TDR prevalence is moderate (12.0%) and is emerging as a problem due to incomplete antiretroviral coverage in pregnancy

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 Brazil. 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

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

Smoothing equation

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

$0 < \propto < 1$

Trend estimation equation

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b_t= β (S_t-S_{t-1}) + (1-β)b_{t-1}……[3]
0<β<1

Forecasting equation

f_{t+h}= S_t + hb_t……[4]

Z_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 Brazil 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	Z
Included Observations	31
Smoothing constants	
Alpha (α) for data	0.400
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.027883
Sum Square Error (SSE)	0.036363
Mean Square Error (MSE)	0.001173
Mean Percentage Error (MPE)	-1.042282
Mean Absolute Percentage Error (MAPE)	7.583221

Residual Analysis for the Applied Model

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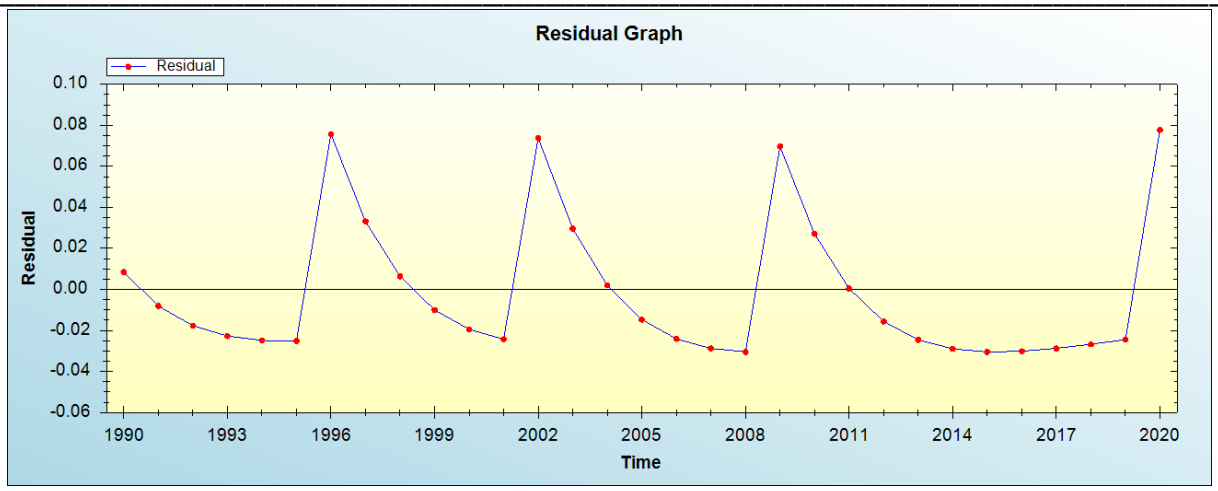

Figure 1: Residual analysis

In-sample Forecast for Z

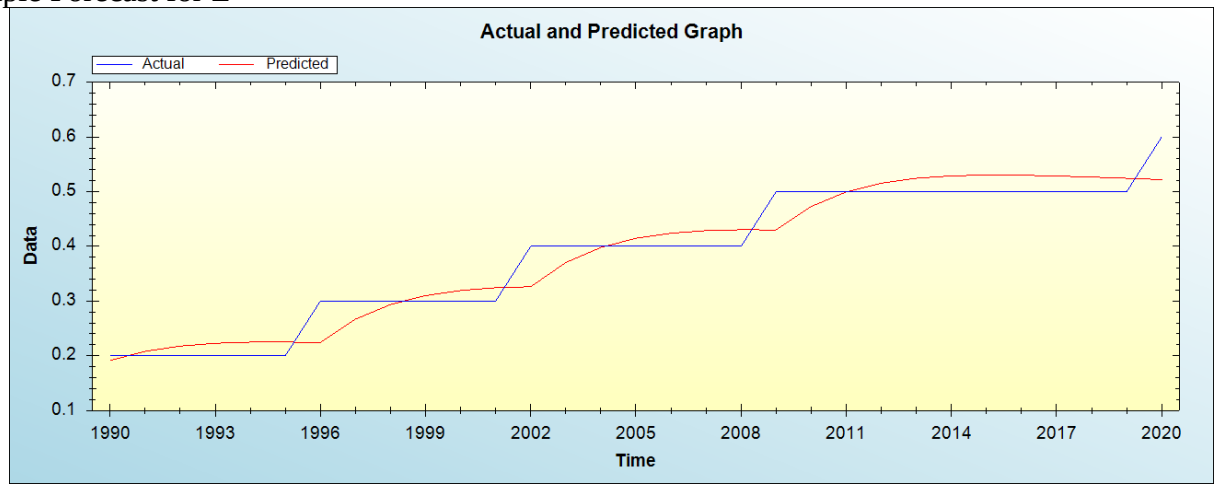

Figure 2: In-sample forecast for the Z series

Actual and Smoothed graph for Z series

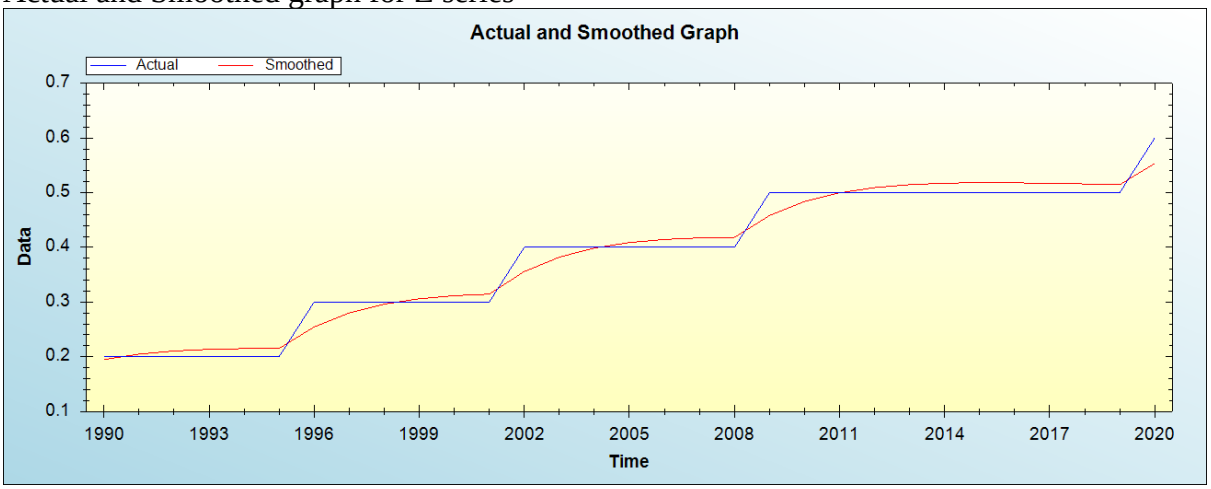

Figure 3: Actual and smoothed graph for Z series

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

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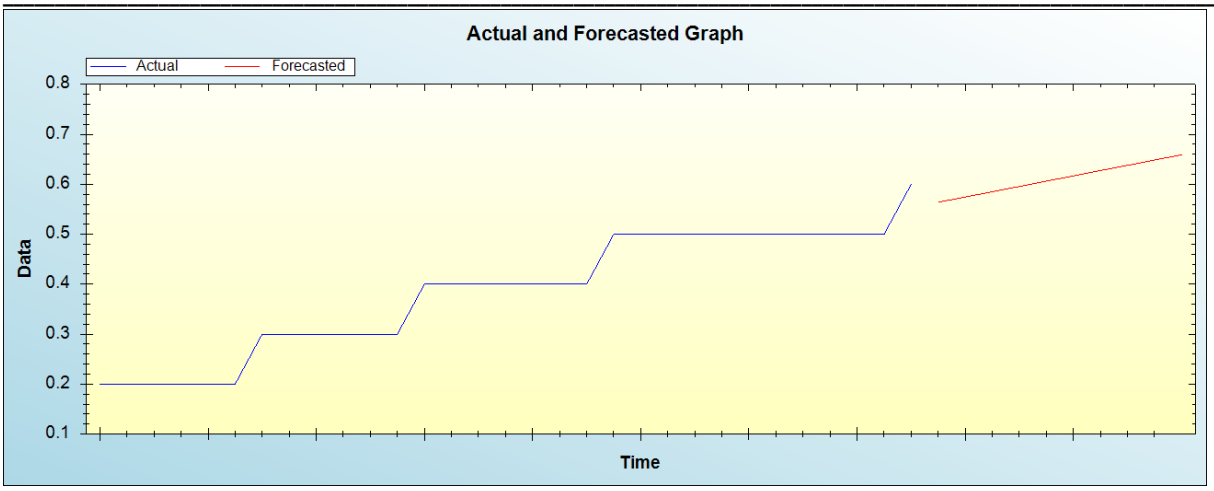

Figure 4: Out-of-sample forecast for Z: actual and forecasted graph

Out-of-Sample Forecast for Z: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Predicted HIV prevalence
2021	0.5639
2022	0.5744
2023	0.5850
2024	0.5956
2025	0.6062
2026	0.6167
2027	0.6273
2028	0.6379
2029	0.6485
2030	0.6590

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 generally maintain an upward trend over the out of sample period.

Policy implication and conclusion

Brazil has made significant steps in identifying and offering antiretroviral therapy to people living with HIV. However, the upward trend of HIV prevalence among individuals aged 15-49 years during the past 2 decades is serious public health concern which needs urgent attention. In addition, the projected upward trend of HIV prevalence among individuals aged 15-49 years highlights the need to scale up educational campaigns among the sexually active age group with particular emphasis on HIV prevention strategies such as correct and consistent use of condoms, behavior change, PrEP and voluntary medical male circumcision among other measures.

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