World Bulletin of Public Health (WBPH)
Available Online at: https://www.scholarexpress.net
Volume-34, May 2024
ISSN: 2749-3644

FORECASTING HIV PREVALENCE AMONG INDIVIDUALS AGED 15-49 YEARS IN CUBA 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

Article history:
Received: March 30th 2024
Accepted: April 26th 2024

Abstract:
This study uses annual time series data of HIV prevalence among individuals aged 15-49 years for Cuba 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 0.8 and 0.1 respectively based on minimum MSE. The results of the study indicate that annual HIV prevalence among people aged 15-49 years will continue on an upward trajectory over the out of sample period. Therefore, we encourage authorities to address major drivers of HIV transmission, scale up HIV testing and ART coverage among this age group.

Keywords: *Exponential smoothing, Forecasting, HIV prevalence*

BACKGROUND

According to UNDP, Cuba is one of the exemplary stories to tell about successful national HIV responses in the Caribbean region. Antiretroviral therapy (ART) coverage for people living with HIV is near 100%, which is significantly above the regional average of 67%. Efforts to provide access to ART have accelerated since 2001 and have resulted in decreased AIDS mortality and incidence of opportunistic infections (Aragonés *et al.* 2011; Pérez *et al.* 2007). By the end of 2017, more than 28,000 individuals were living with HIV in Cuba, above 90% of infected individuals were aware of their HIV status and approximately 80% were on ART (Alemán-Campos *et al.* 2018). Survival rates for those on ART and satisfaction of people living with HIV (PLWHIV) are reportedly high. The majority of newly diagnosed people living with HIV can pursue their life goals thus reflecting improved quality of life (Aragonés-López *et al.* 2012). The persistent low prevalence and incidence of HIV indicates that prevention efforts have been effective. Consistent condom usage rates are gradually increasing among key populations such as MSM, sex workers and young people. All these good results are attributed to decentralization of HIV care and support services, and a rapid scale up of community-based HIV prevention programs (Delatorre & Bello, 2013; Aragonés-López *et al.* 2012). The government of Cuba has managed to reach more than 91% of MSM and over 95% of sex workers with prevention programmes (UNDP, 2014). However the government needs to scale up efforts in reducing the burden of HIV among key populations because HIV prevalence among MSM and sex workers remains high at 4.6% and 0.99%, respectively. The objective of this paper is to model and forecast HIV prevalence among individuals aged 15-49 years for Cuba using Holt's linear method. Study results are expected to guide the national policy, inform decision making and allocation of resources to targeted HIV programs in order to curb new HIV infections especially among key populations.

LITERATURE REVIEW

Author (s)	Objective (s)	Methodology	Key Finding(s)
Morales-Pérez (2021)	To describe adverse reactions attributable to antiretrovirals used in Cuban patients living with HIV/AIDS	Studied notifications of adverse reactions to antiretrovirals used in Cuban patients with HIV/AIDS from January 2003 to December 2017.	Adverse reactions to antiretrovirals in Cuban patients are common and moderate in severity. The drug with the most notifications was nevirapine, and the most common adverse reaction was

World Bulletin of Public Health (WBPH)
Available Online at: https://www.scholarexpress.net
Volume-34, May 2024
ISSN: 2749-3644

			hypersensitivity.
Zhukova et al. (2021)	To analyze a large data set comprising *350 pol and env sequences sampled in Cuba over the last 15 years and *350 from Los Alamos database	used fast maximum likelihood approaches, including: (1) phylogeny reconstruction, (2) spatio-temporal analysis of the virus spread, and ancestral character reconstruction for (3) transmission mode and (4) drug resistance mutations (DRMs	results showed a very early introduction of CRF19 in Cuba, which could explain its local epidemiological success
Alemán-Campos et al. (2018)	To investigate antiretroviral resistance and its relation to subtype distribution in HIV-1 treatment-naïve and previously treated patients in Cuba	Resistance and HIV-1 subtype distribution were determined in 342 antiretroviral treatment-naïve patients and 584 previously treated for HIV-1 whose blood specimens were sent to the Pedro Kourí Tropical Medicine Institute during 2009–2014. Transmitted drug resistance was determined using the Calibrated Population Resistance Tool v.6. Drug resistance analysis was conducted using the algorithm Rega v9.1.0.	Resistance prevalence is high in previously treated patients but appears to be decreasing over time.
Machado-Zaldívar et al. (2017)	Clarify the origin and phylodynamics of HIV-1 subtype B in the Cuban epidemic.	Analyzed phylogenetic relationships among 120 sequences (from different geographic origins) of the pol gene in HIV-1 subtype B isolates from Cuban patients diagnosed from 1987 through 2012. Time of HIV-1 subtype B introduction and viral evolutionary rate were determined using a Bayesian coalescent method. RESULTS	Results suggested multiple introductions of HIV-1B into Cuba in the late 1970s, predominantly strains from North America and Europe.
BEng et al. (2011)	Measure levels of	A cross-sectional study	In Cuba, where

World Bulletin of Public Health (WBPH)
Available Online at: https://www.scholarexpress.net
Volume-34, May 2024
ISSN: 2749-3644

	treatment adherence and its predictive factors in persons with HIV/AIDS receiving antiretroviral therapy in 2006 in Cuba.		treatment is free of charge to patients, adherence is good
Rapatski et al. 2006	To study the HIV transmission dynamics for Cuba.	modified the model of de Arazoza and Lounes according to the background about the virology and the socioeconomic factors that affect the epidemiology of the Cuban HIV outbreak	By comparing the model to the 1986-2000 Cuban HIV/AIDS data and the de Arazoza and Lounes model, results indicated show that socioeconomic aspects are an important factor in determining the dynamics of the epidemic.

METHODOLOGY

This study utilizes Holt's double exponential smoothing technique to model and forecast future trends of annual HIV prevalence among individuals aged 15-49 years in Cuba. 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

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

$0 < \beta < 1$

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 Cuba 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.

World Bulletin of Public Health (WBPH)
Available Online at: https://www.scholarexpress.net
Volume-34, May 2024
ISSN: 2749-3644

Findings of the study

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	Z
Included Observations	31
Smoothing constants	
Alpha (α) for data	0.800
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.021952
Sum Square Error (SSE)	0.035128
Mean Square Error (MSE)	0.001133
Mean Percentage Error (MPE)	-1.464177
Mean Absolute Percentage Error (MAPE)	13.119774

Residual Analysis for the Applied Model

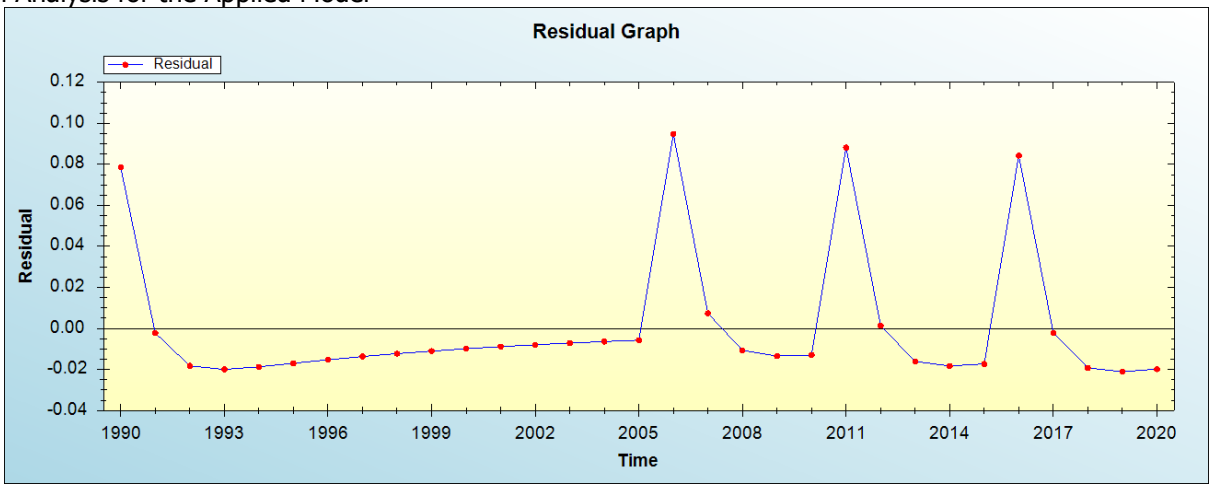

Figure 1: Residual analysis

In-sample Forecast for Z

World Bulletin of Public Health (WBPH)
Available Online at: https://www.scholarexpress.net
Volume-34, May 2024
ISSN: 2749-3644

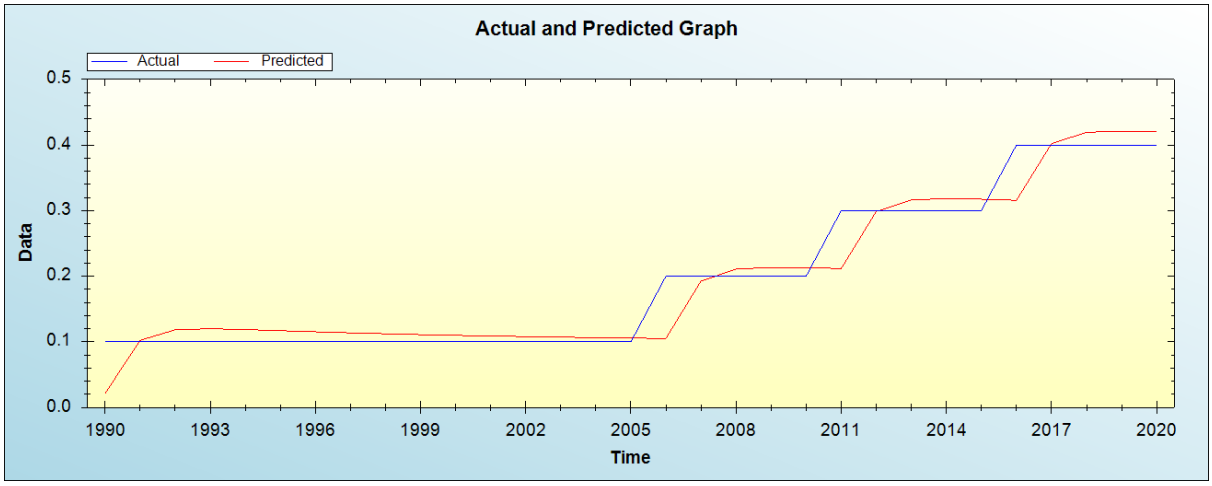

Figure 2: In-sample forecast for the Z series

Actual and Smoothed graph for Z series

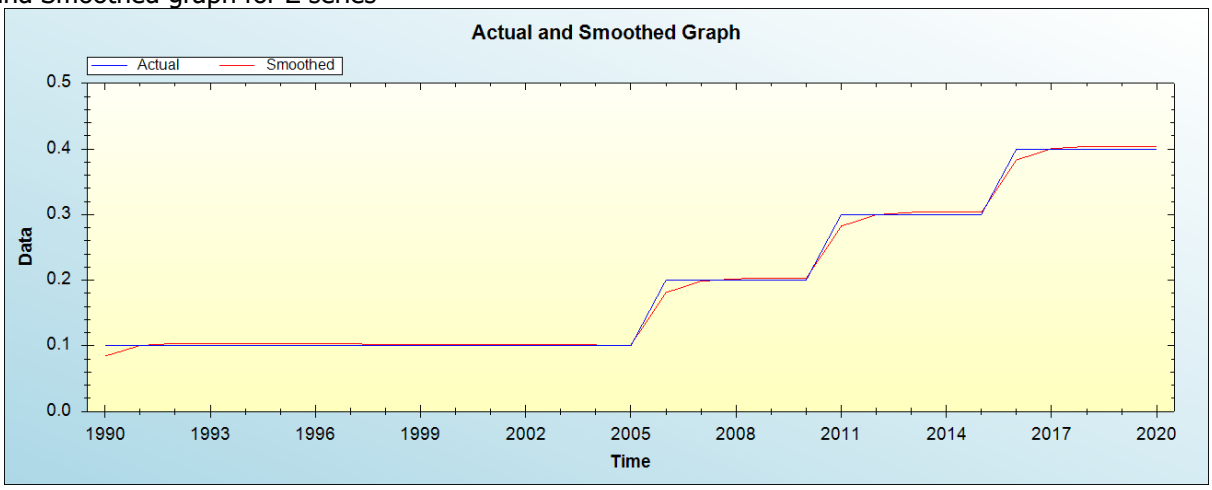

Figure 3: Actual and smoothed graph for Z series

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

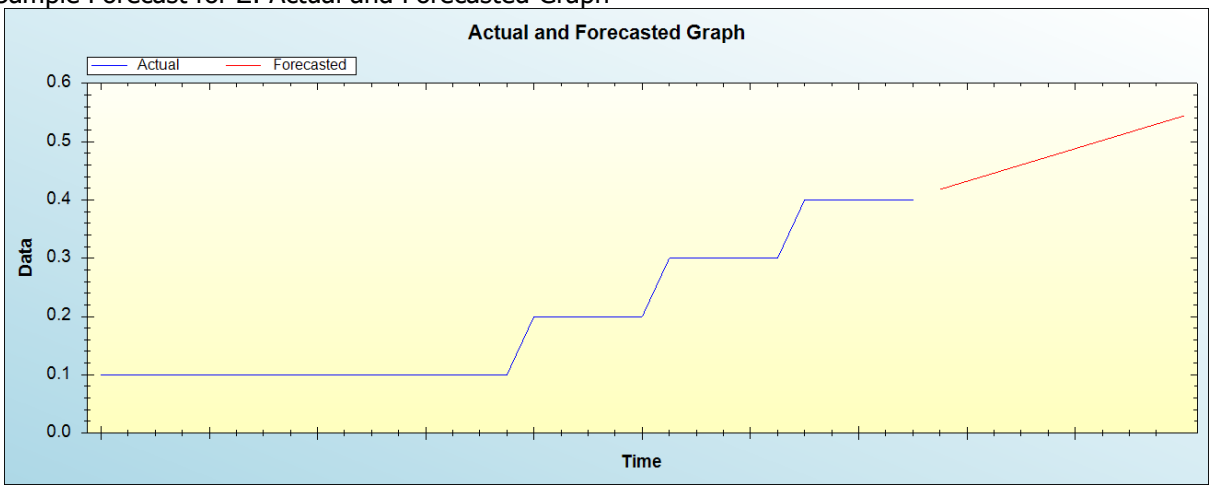

Figure 4: Out-of-sample forecast for Z: actual and forecasted graph

World Bulletin of Public Health (WBPH)
Available Online at: https://www.scholarexpress.net
Volume-34, May 2024
ISSN: 2749-3644

Out-of-Sample Forecast for Z: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	0.4180
2022	0.4320
2023	0.4460
2024	0.4600
2025	0.4740
2026	0.4880
2027	0.5020
2028	0.5160
2029	0.5300
2030	0.5440

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 implication and conclusion

Our model projections suggest that the upward trend of HIV prevalence among individuals aged 15-49 years will continue in the forecast period. Hence, health authorities are encouraged to address major drivers of HIV transmission, scale up HIV testing and ART coverage among this age group.

REFERENCES

[1] UNDP (2014). BUILDING, IMPROVING AND SUSTAINING RESPONSES TO HIV LEARNING FROM CUBA'S SUCCESS, pp. 1-2

[2] Edson Delatorre and Gonzalo Bello (2013). Phylodynamics of the HIV-1 Epidemic in Cuba. PLoS ONE 8:9, e72448.

[3] Carlos Aragonés-López, Jorge Pérez-Ávila, Mary C. Smith Fawzi and Arachu Castro (2012). Quality of Life of People with HIV/AIDS Receiving Antiretroviral Therapy in Cuba: A Cross-Sectional Study of the National Population. American Journal of Public Health 102:5, 884-892

[4] Aragonés C, Sánchez L, Campos JR and Pérez J (2011). Antiretroviral therapy adherence in persons with HIV/AIDS in Cuba. MEDICC Rev. 13(2):17–23. Available from: http://www.medicc.org/medicc review/pdf.php?lang=en&id=192

[5] Pérez L, Álvarez LP, Carmona R, Aragonés C, Delgado E and Thomson MM (2007). Genotypic resistance to antiretroviral drugs in patients infected with several HIV type 1 genetic forms in Cuba. AIDS Res Hum Retroviruses. 23(3):407–14. Available from: https://www.liebertpub.com/doi/pdf/10.1089/aid.2006.0155

[6] Alemán-Campos et al (2018). HIV-1 Antiretroviral Resistance in Cuba, 2009–2014, MEDICC Review, July 2018, Vol 20, No. 3