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FORECASTING OF HIV PREVALENCE AMONG INDIVIDUALS AGED 15-49 YEARS IN PANAMA 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 Panama 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 0.1 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 in the out of sample period. Therefore, we encourage authorities to scale up of HIV testing services, strengthen HIV prevention measures and improvement of ART adherence among people living with HIV.

Keywords: *Exponential smoothing, Forecasting, HIV prevalence*

BACKGROUND

The HIV epidemic is still a global public health problem that requires sufficient resources in order to adequately reduce the number of new HIV infections to zero by 2030. The UNAIDS data report indicated that 1.7 million people [1.2 million– 2.2 million] who acquired HIV globally in 2019 marked a 23% drop in new HIV infections since 2010. Globally, the annual number of new infections has been declining more rapidly among women and girls than among men and boys. There were fewer new infections in 2019 worldwide among women and girls than among men and boys. Children (aged 0 to 14 years) accounted for 9% of new infections in 2019, with 84% of child infections occurring in sub-Saharan Africa (SSA). Most of the 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. Increased access to antiretroviral therapy has averted an estimated 12.1 million AIDS-related deaths since 2010 (UNAIDS, 2020). In 2018, the HIV prevalence in Panama among 15-49-year-old individuals was 0.9% (CDC, 2019, UNAIDS, 2020). The HIV epidemic in Panama is concentrated among key populations such as men who have sex with men (MSM), commercial sex workers and their clients and transgender people. Increasing uptake of HIV testing services, coverage of antiretroviral therapy and HIV prevention services is expected to drastically reduce new HIV infections among these priority groups. The objective of this study is to model and forecast HIV prevalence among 15-49 year age group using Holt's linear exponential smoothing technique. The findings of this study are expected to highlight likely future trends among the sexually active group and guide allocation of resources to HIV prevention and treatment services for this group in the country.

LITERATURE REVIEW

Author(s)	Objective (s)	Methodology	Key finding (s)
Moreno et al. (2023)	HIV-1 Low-Frequency Variants Identified in Antiretroviral-Naïve Subjects with Virologic Failure after 12 Months of Follow-Up in Panama	Sequenced the basal samples retrospectively using next-generation sequencing (NGS), looking for low-frequency mutations that had not been detected before using the Sanger sequencing method (SSM) and describing the response to ART.	Twenty-two subjects developed virologic failure (VF), and thirteen of them had at least one drug-resistance mutation associated with Reverse Transcriptase Inhibitors (RTI) and Protease Inhibitors (PIs) at frequency levels≤1%, not detected previously in their basal

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			genotyping test. No resistance mutations were observed to Integrase Strand Transfer Inhibitors (INSTIs
Ventosa-Cubillo et al. (2022)	To describe the DRM prevalence in HIV-infected pediatric patients in Panama.	During 2018–19, plasma was collected from 76 HIV-infected children/adolescents (5 ART-naive, 71 treated) in Panama for HIV-1 DRM pol analysis, predicted antiretroviral (ARV) susceptibility by Stanford, and HIV-1 variant phylogenetic characterization.	The high DRM prevalence to NRTIs and NNRTIs observed among treated HIV-infected children/ adolescents in Panama justifies the need for routine resistance monitoring for optimal rescue therapy selection in this vulnerable population.
Gabster et al. (2021)	To explore barriers and facilitators to antiretroviral adherence and retention in HIV care among people living with HIV in the Comarca Nga ¨beBugle ´, Panama	Used the Social-Ecological Theory for Health as a framework	Structural barriers included difficult access to ART care due to travel costs, ART shortages, and uncooperative Western/Traditional medical systems. Recommended interventions used in other Low- and Middle-Income settings include increasing peer and family-level support and community knowledge and understanding of HIV infection
Hakre et al. (2012)	To estimate prevalence of HIV and STIs, and factors associated with active syphilis among female sex workers (FSWs).	A cross-sectional study using venue-based, time-space sampling was conducted among FSWs in Panama from 2009 to 2010. FSWs were interviewed about sociodemographic characteristics, sexual risk behavior, health history and drug use using an anonymous structured questionnaire.	Although HIV prevalence is low among FSWs in Panama, unregistered FSWs bear a higher burden of HIV and STIs than registered FSWs.

METHODOLOGY

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

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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

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

Smoothing equation

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

$0 < \alpha < 1$

Trend estimation equation

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

$0 < \beta < 1$

Forecasting equation

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

P_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 Panama 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 this study

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	P
Included Observations	31
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.028713
Sum Square Error (SSE)	0.036323
Mean Square Error (MSE)	0.001172
Mean Percentage Error (MPE)	-0.653333
Mean Absolute Percentage Error (MAPE)	5.067507

Residual Analysis for the Applied Model

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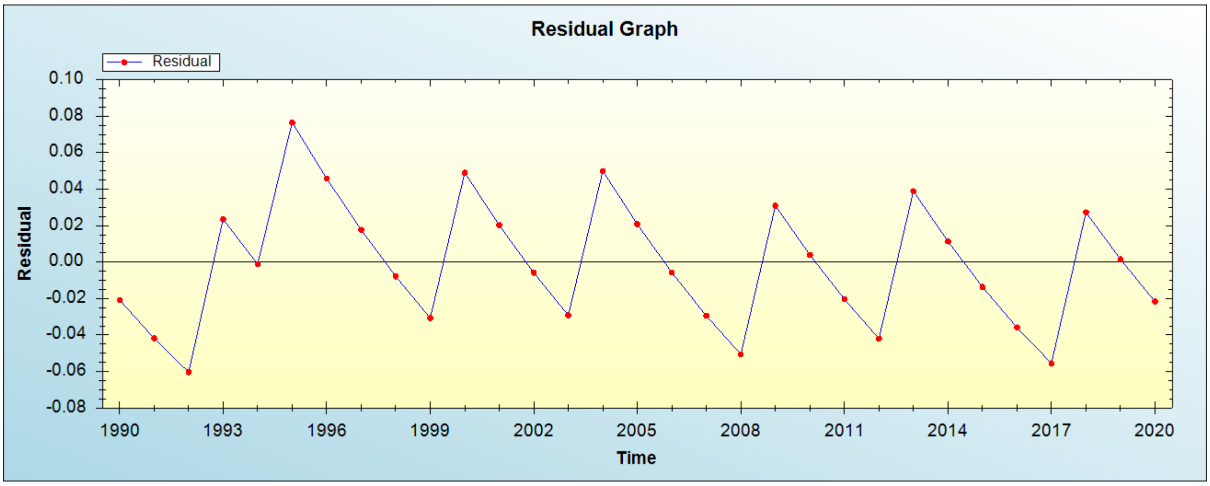

Figure 1: Residual analysis

In-sample Forecast for P

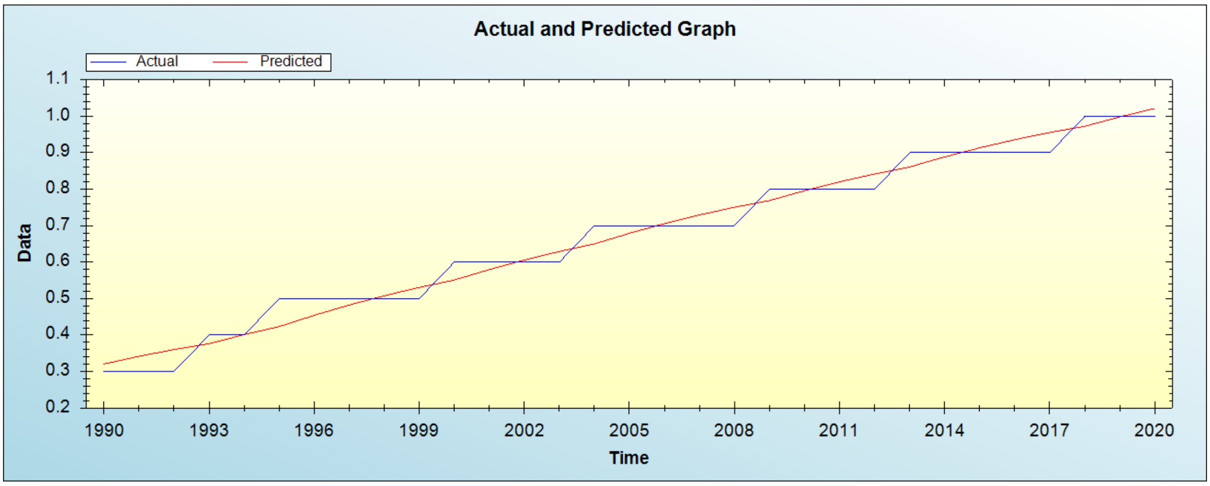

Figure 2: In-sample forecast for the P series

Actual and Smoothed graph for P series

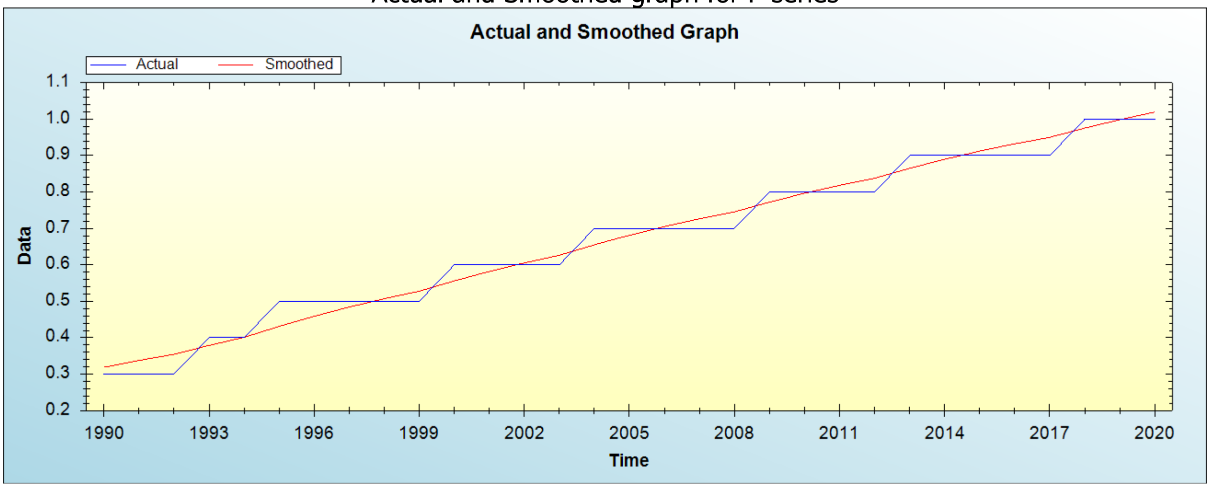

Figure 3: Actual and smoothed graph for P series

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

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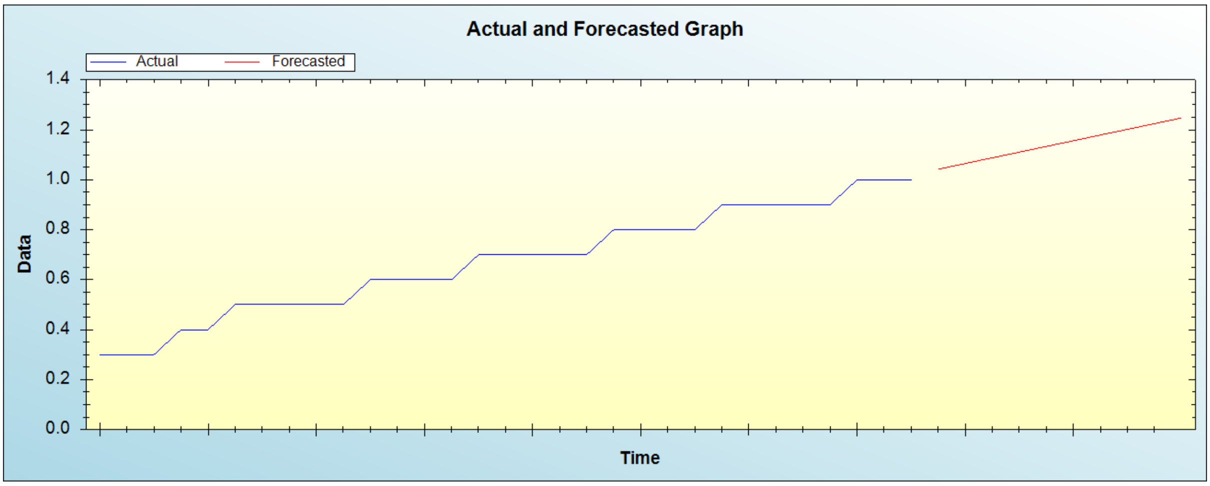

Figure 4: Out-of-sample forecast for P: actual and forecasted graph

Out-of-Sample Forecast for P: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	1.0423
2022	1.0651
2023	1.0879
2024	1.1107
2025	1.1335
2026	1.1563
2027	1.1791
2028	1.2019
2029	1.2247
2030	1.2475

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 in the out of sample period.

Policy implication and conclusion

Our research findings indicate that annual HIV prevalence among individuals aged 15-49 years will continue on an upward trend in the out of sample period. Therefore, this paper calls for a rapid scale up of HIV testing services, strengthening HIV prevention measures and improvement of ART adherence among people living with HIV.

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