

# Projecting HIV prevalence among individuals aged 15-49 years in Bhutan using Holt's double exponential smoothing model

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## **Abstract**

*This study uses annual time series data of HIV prevalence among individuals aged 15-49 years for Bhutan 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  $\alpha$  and  $\beta$  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 generally decline over the out of sample period. Therefore, policymakers must improve HIV case detection among key populations and implement relevant HIV preventive interventions recommended by the World Health Organization (WHO).*

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

## **Background**

The Kingdom of Bhutan is a small landlocked country situated between Tibet, China in the north and India in the south. In 2017, the total population above the age of 18 years was 537,728 (UNAIDS, 2008). The country is divided into 20 districts. The most populous and urbanized districts are the capital Thimphu (105,875 adults) and Pheuntsholing (Chhukha district, 51,888 adults) on the main border crossing with India (Khandu *et al.* 2022). The HIV epidemic in Bhutan is reportedly known as low-level (Becasen *et al.* 2019) and concentrated among key populations just like regional counterparts (Khandu *et al.* 2021) These key populations include female sex workers, people who inject drugs, men who have sex with men, and transgender persons (Khandu *et al.* 2022). As reported by the Ministry of Health, Bhutan has a low adult (15-49 years) HIV prevalence, which is below 0.2%. However, it is worrisome to mention that new HIV cases are continually being reported. Since 2006, above 25 cases have been detected annually and the detection trend has increased with an annual detection rate of more than 55 cases per year since 2015. In 2019, UNAIDS reported 1336 HIV cases in Bhutan but the total cases diagnosed as of June 2020 stood at 741 (58.1% male and 48.2% female) thus creating a case detection gap of 43%. This converts to 559 people are living with HIV in the population without knowing their HIV status. Predictors of HIV transmission in this country include multiple sex partners, low condom use in all types of partnerships, rising incidence of sexually transmitted infections (STIs), and difficulties in accessing HIV prevention and other health services due to sexual and gender-related discrimination (UNAIDS, 2018; Ministry of Health, 2016; UNAIDS, 2016; UNAIDS, 2010). The purpose of this paper is to model and forecast HIV prevalence among individuals aged 15-49 years for Bhutan using Holt's double exponential smoothing model. The study findings are expected to guide policy, planning and allocation of resources towards targeted HIV prevention and treatment programs in order to curb new HIV infections among key populations and vulnerable groups in Bhutan.

## **Literature Review**

Author(s)	Objective (s)	Methodology	Key finding(s)
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Anderle et al. (2024)	To understand how ABMs can model HIV/AIDS complex dynamic structural factors, risk behaviors, biomedical characteristics and interventions	scoping review of HIV applications, highlighting their potentialities	Most studies model Transmission Dynamics (37/154), about Men who have sex with Men (MSM) (41/154), or individuals living in the US or South Africa (84/ 154). Recent studies applied ABM to model PrEP interventions (17/154) and Racial Disparities (12/154). Only six papers declared the use of ODD Protocol (6/154), and 34/154 didn't mention the study limitations
Lyons et al. (2023)	To observe the correlates of HIV testing in Venezuelan migrants residing in Trinidad.	Pearson $\chi^2$ tests examined the associations between study variables, and multivariable logistic regression with backward elimination produced the odds of taking an HIV test.	Migrants still experience difficulties accessing healthcare, which, in turn influences national HIV prevention and control efforts.
Khandu et al. (2022)	to estimate the population size of transgender women (TGW) and transgender men (TGM) in Bhutan from November 2019 to January 2020	Community-based surveys of TGW and TGM integrated several methods to estimate the size of hidden populations, including key informant mapping, wisdom-of-the-crowd, the service multiplier, and the unique object multiplier. Results of the several methods were synthesized using a Bayesian approach.	TGW and TGM are part of Bhutanese society, with TGW constituting 0.03% of adult women and TGM 0.06% of adult men
Gabster et al. (2021)	To describe the facilitators and barriers associated with ART adherence	-semi-structured interviews -. Deductive thematic analysis was used to	Psychological health, social support, and discrimination acted as individual-level

	and retention in HIV care among people living with HIV (PLHIV) in the CNB.	uncover themes related ART adherence and retention in HIV care at the individual, social and structural levels.	facilitators and barriers to adherence and retention. Notably, structural barriers included difficult access to ART care due to travel costs, ART shortages, and uncooperative Western/Traditional medical systems.
Kandu et al. (2020)	To assesses socio cultural determinants of HIV in Bhutan for appropriate responses to end the AIDS epidemic by 2030	Reviewed literature relevant to HIV in Bhutan using appropriate search engines. We adapted Dahlgren and Whitehead's model of social health determinants in the population as a conceptual framework.	Young age played the salient role between rapid sociocultural changes and HIV in Bhutan. Most teens are sexually active, has relaxed sexual norms, low condom use, and has multiple sexual partners. Gender identity and sexual orientation are increasingly fluid among transgender and gay/bisexual men. Worksites with migrants and entertainment venues are nexuses for sexual networking resulting in transactional/sex work.
Tshering et al. (2016)	To describe the HIV epidemiology in Bhutan.	Data from the database of people living with HIV infection in Bhutan, survey reports from the National STI and HIV/AIDS Control Programme from the Ministry of Health and published literature on HIV in Bhutan were reviewed.	Bhutan continues to have a low HIV prevalence with only 470 cases reported by the end of 2015. However, there is a slow but steady recent increase in the number of cases. The main mode of transmission is unsafe heterosexual practice in the general population and is occurring mostly in urban and

**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 Bhutan. 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

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

Smoothing equation

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

$$0 < \alpha < 1$$

Trend estimation equation

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

$$0 < \beta < 1$$

Forecasting equation

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

$A_t$  is the actual value of HIV prevalence at time t

$\varepsilon_t$  is the time varying **error term**

$\mu_t$  is the time varying mean (**level**) term

$\rho_t$  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

$\alpha$  is the exponential smoothing constant for the data

$\beta$  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 Bhutan 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 Findings**

Exponential smoothing Model Summary

Table 1: ES model summary

Variable	A
Included Observations	31
Smoothing constants	
Alpha ( $\alpha$ ) for data	0.900
Beta ( $\beta$ ) for trend	0.100
Forecast performance measures	
Mean Absolute Error (MAE)	0.016352
Sum Square Error (SSE)	0.031357
Mean Square Error (MSE)	0.001012
Mean Percentage Error (MPE)	-2.360545
Mean Absolute Percentage Error (MAPE)	7.970172

Residual Analysis for the Applied Model

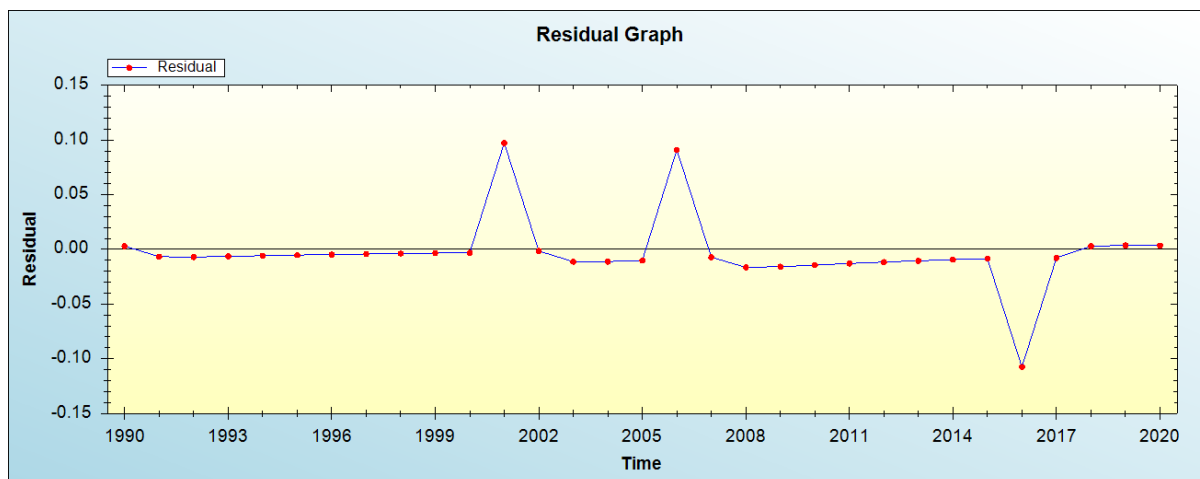


Figure 1: Residual analysis

In-sample Forecast for A

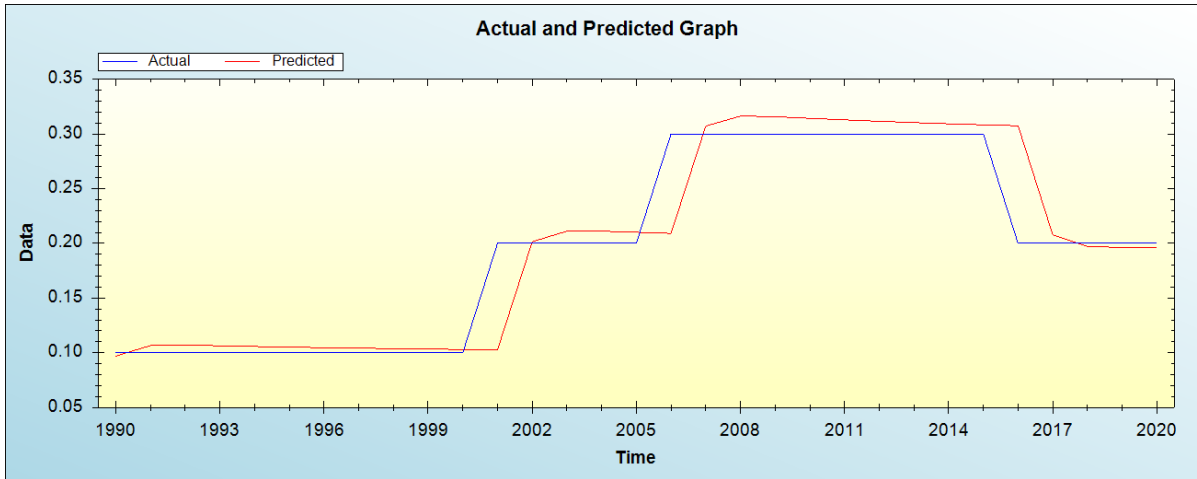


Figure 2: In-sample forecast for the A series

Actual and Smoothed graph for A series

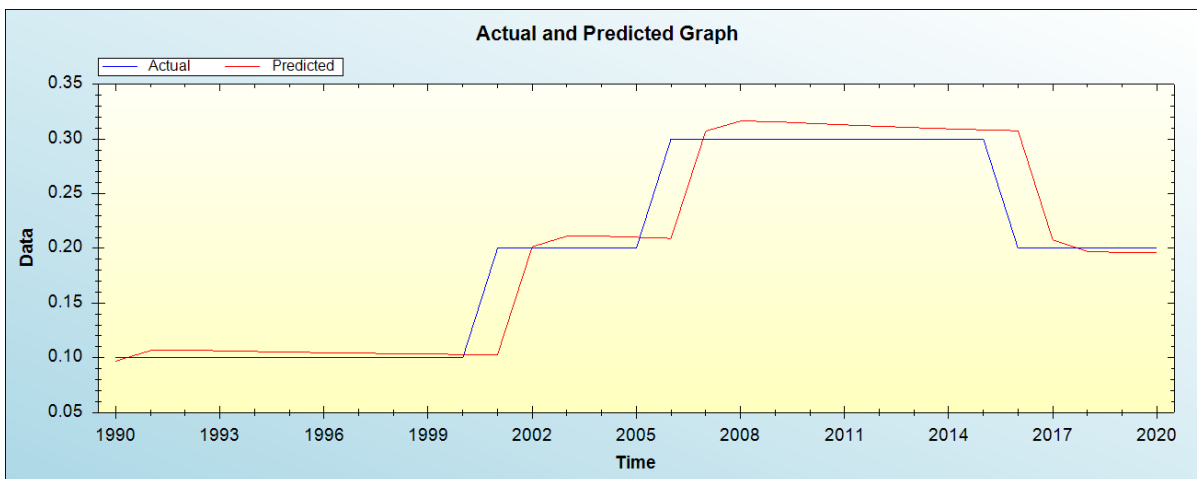


Figure 3: Actual and smoothed graph for A series

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

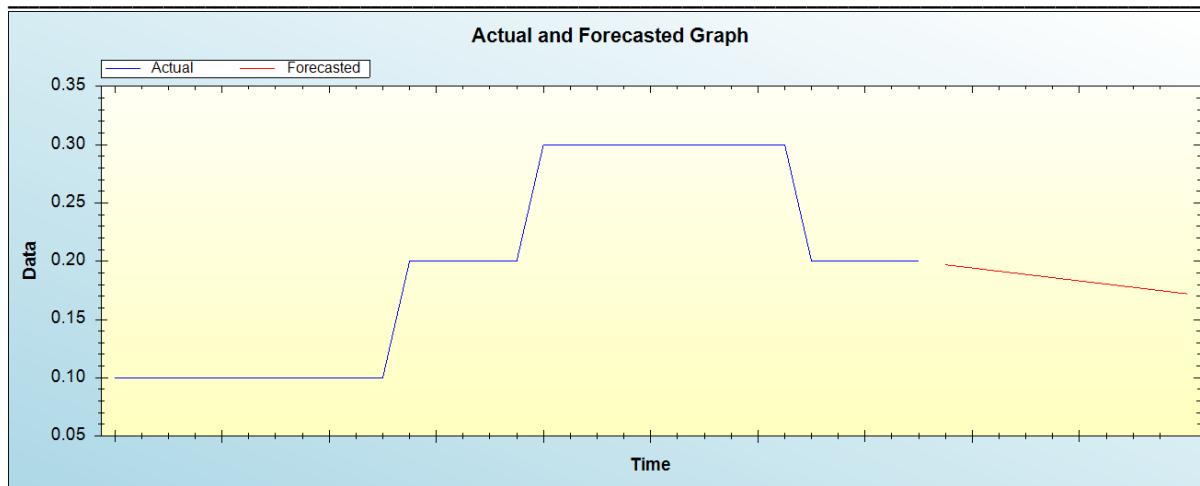


Figure 4: Out-of-sample forecast for A: actual and forecasted graph

Out-of-Sample Forecast for A: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	0.1969
2022	0.1941
2023	0.1914
2024	0.1886
2025	0.1859
2026	0.1831
2027	0.1803
2028	0.1776
2029	0.1748
2030	0.1721

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 decline over the out of sample period.

**Policy implication and conclusion**

The forecasted downward trend of HIV prevalence shows the anticipated positive impact of HIV programs in Bhutan. Hence, policymakers must improve HIV case detection among key populations and implement relevant HIV preventive interventions recommended by the World Health Organization (WHO).

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