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PROJECTION OF HIV PREVALENCE AMONG INDIVIDUALS AGED 15-49 YEARS IN ESTONIA USING HOLT'S EXPONENTIAL SMOOTHING TECHNIQUE

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Abstract
This study uses annual time series data of HIV prevalence among individuals aged 15-49 years for Estonia 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 0.4 respectively based on minimum MSE. The results of the study indicate that annual HIV prevalence among individuals aged 15-49 years will be constant around 0.8% throughout the out of sample period. Therefore, we encourage authorities to address major drivers of HIV spread among this age group.

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

BACKGROUND

According to UNAIDS, approximately 37 million people were estimated to be living with HIV globally by the end of 2014, with 2 million new HIV infections in 2014. Over the period 2000–2014, new infections dropped by more than 33 percent from the 3.1 million (3.0– 3.3 million). Since 2006 the global number of AIDS-related deaths has been gradually declining, in 2014 AIDS still accounted for 1.2 million (980 000–1.6 million) deaths. The epidemic patterns i.e., the level, main transmission mode(s) of the virus, most vulnerable population groups, and AIDS-indicative diagnoses have varied across the different regions of the world, reflecting the diversity in HIV epidemiology. The first case of HIV in Estonia was diagnosed in 1988. By the end of 2014, the estimated number of people living with HIV (PLWHIV) was reported to be 8 993 (EHB, 2015). Estonia has witnessed a fast growing HIV epidemic among young people who inject drugs (PWID) with a rare HIV subtype CRF06_cpx from the year 2000, reaching the highest diagnosis rate in the European Union of 105.3 per 100,000 population in 2001 (EHB, 2016; Adojaan *et al.* 2005; AIDS ECftEMo, 2002).The Estonian government has made significant progress in addressing the rapidly evolving epidemic and implemented several strategies such as demand creation for HIV testing services, implementation of needle exchange programs, and offering free of charge antiretroviral therapy drugs (WHO, 2011; Estonia, 2005). The rate of reported new HIV infections dropped and stabilized at 24.6/100,000 by the end of 2013 (EHB, 2016; Soodla *et al.* 2015).
The objective of this study is to model and forecast HIV sero-prevalence among the 15-49 years age group using Holt's linear method. We anticipate that the results of the study will reflect future trends of HIV prevalence among the 15-49 year age group and this expected to guide allocation of resources towards HIV prevention, treatment and care programs in the country.

LITERATURE REVIEW

Author(s)	Objective (s)	Methodology	Main finding(s)
Uusku¨la et al. (2023)	To cover recent (post-2010) systematic reviews on engagement of PWID in sequential stages of HIV care from uptake, to achieving viral suppression, and to avoiding AIDS-related mortality	Scoping Review	Data on engagement of PWID into antiretroviral therapy (ART) were particularly scarce, but generally indicated very low engagement in ART. Studies of adherence and achieving viral suppression showed varying results, with PWID sometimes doing

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			as well as other patient groups. The severity of social, medical and psychiatric disability in this population poses significant treatment challenges and leads to a marked gap in AIDS mortality between PWID and other population groups
Kase et al. (2021)	To describe the changes in HCV prevalence, the distribution of HCV genotypes (GT), and HCV treatment in Estonian people living with HIV over 15 years	-Used data of subjects included to the Estonian HIV Cohort Study (E-HIV) before 31st of December 2015. -compared two time periods—first, 1st of January 2000 to 31st of December 2008 when the HIV epidemic was mostly spreading among people who inject drugs (PWID) and second, 1st of January 2009 to 31st of December 2015 when HIV started to emerge to the general population	There is a decrease in HCV prevalence but it remains high among HIV positive PWID
Uusku ¨la et al. (2020)	To show the feasibility of using an integrated prevention and care continuum (PCC) model as a complete and improved tool for HIV control measurement and programming	Cross-sectional study	Findings suggested that developing a cohesive model for HIV prevention and treatment is feasible and reflects the bi-directional relationships between prevention and care.
Miadzieles (2020)	To evaluate HIV testing in Estonian health care system in 2018.	Observational retrospective quantitative study of the data from the Estonian Health Insurance Fund's database of treatment invoices. HIV testing was evaluated based on all treatment invoices in 2018 (n = 8.1 million) (including insured and not insured patients).	Different specialties test more than primary care, although patients mostly have their first contact with primary care
Rüütel et al. (2018)	To assess missed opportunities for HIV testing among people	observational retrospective study, we collected data from the	The HIV testing rate in the 2 years before an HIV diagnosis was very

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	newly diagnosed with HIV.	Estonian Health Board on new HIV cases in people aged 16–49 years diagnosed in 2014–15 and from the Estonian Health Insurance Fund database for treatment invoices on their contacts with healthcare services in the 2 years preceding diagnosis.	low, even in the presence of an HIV indicator condition
Ruutel et al. (2018)	To assess indicator condition (IC) guided HIV testing in Estonia from 2012–2015.	Used Estonian Health Insurance Fund (EHIF) data. EHIF is the core purchaser of health care services in Estonia, covering health care costs for insured people (94% of the total population).	Data revealed that IC-guided HIV testing rates are low in Estonia.
Soodla et al. (2016)	to estimate HIV incidence in 2013	Demographic and clinical data were obtained from the Estonian Health Board and the Estonian HIV-positive patient database. Serum samples were tested for recent infection using the LAg-avidity EIA assay. HIV incidence was estimated based on previously published methods	HIV incidence of 0.06%, corresponding to 642 new infections in 2013 among the non-screened population. Incidence was highest (1.48%) among people who inject drugs
Kivimets & Uusküla (2014)	To assess the potential for HIV transmission in Estonian prisons	observational cohort study	This analysis indicated low risk of HIV transmission in Estonian prisons
Jolley et al. (2012)	to examine risk factors associated with HIV prevalence among PWID in Central and Eastern Europe and Central Asia and to describe the response to HIV in this population and the policy environments in which they live	A systematic review of peer-reviewed and grey literature addressing HIV prevalence and risk factors for HIV prevalence among PWID and a synthesis of key resources describing the response to HIV in this population.	The HIV epidemic among PWID in the region is varied, with the greatest burden generally in Eastern Europe.

Methodology

This study utilizes an exponential smoothing technique to model and forecast future trends of HIV prevalence among individuals aged 15-49 years in Estonia. In exponential smoothing forecasts are generated from the smoothed original

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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
$E_t=\mu_t + \rho_t \mathbf{t} + \varepsilon_t$.....[1]
Smoothing equation
$S_t= \alpha E_t + (1-\alpha)(S_{t-1} + b_{t-1})$.....[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]

E_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 Estonia 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	E
Included Observations	31
Smoothing constants	
Alpha (α) for data	0.900
Beta (β) for trend	0.400
Forecast performance measures	
Mean Absolute Error (MAE)	0.036414
Sum Square Error (SSE)	0.074140
Mean Square Error (MSE)	0.002392
Mean Percentage Error (MPE)	-1.134376
Mean Absolute Percentage Error (MAPE)	16.107962

Residual Analysis for the Applied Model

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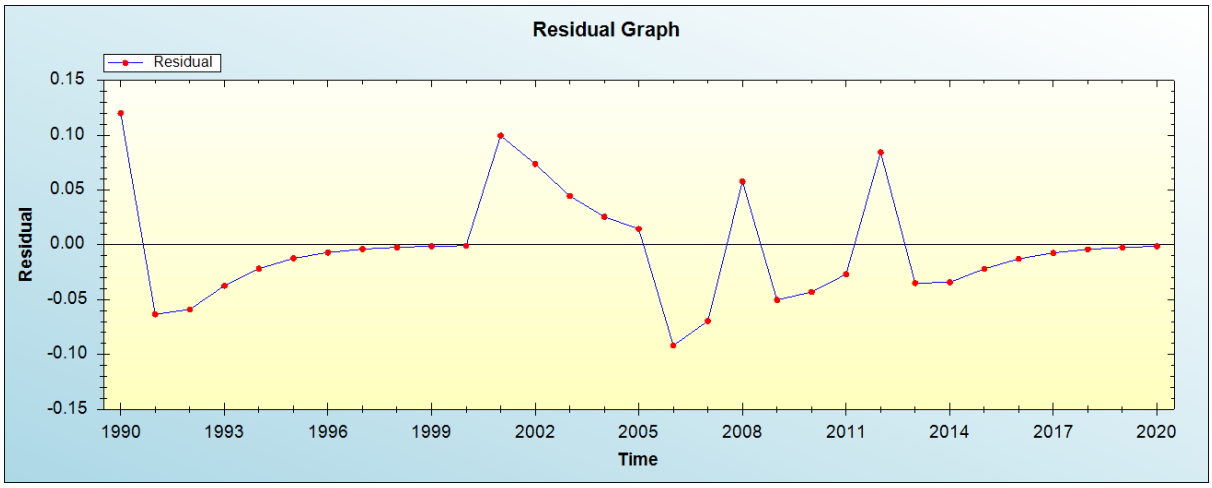

Figure 1: Residual analysis

In-sample Forecast for E

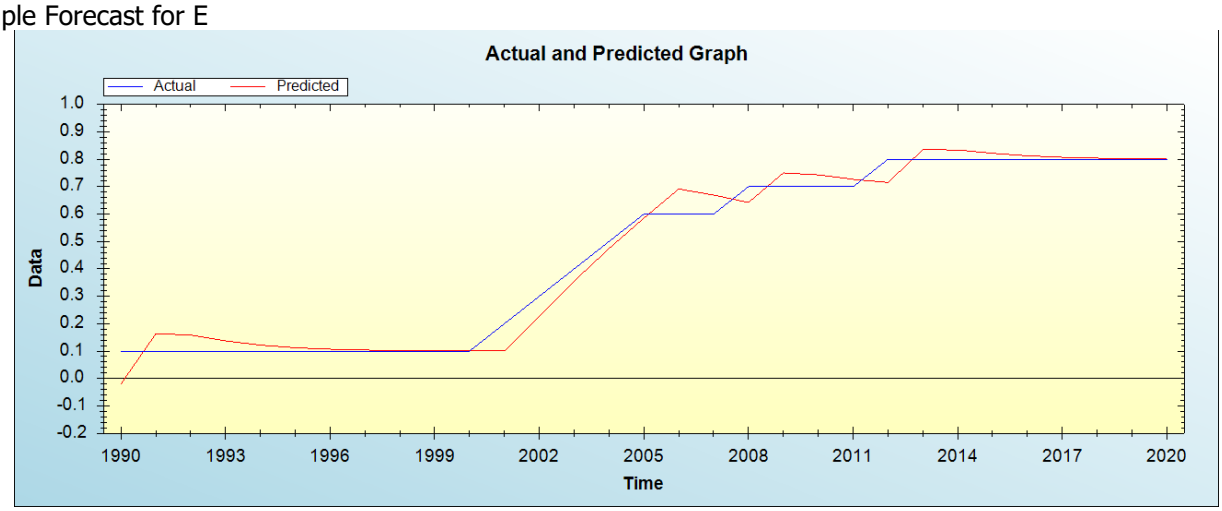

Figure 2: In-sample forecast for the E series

Actual and Smoothed graph for E series

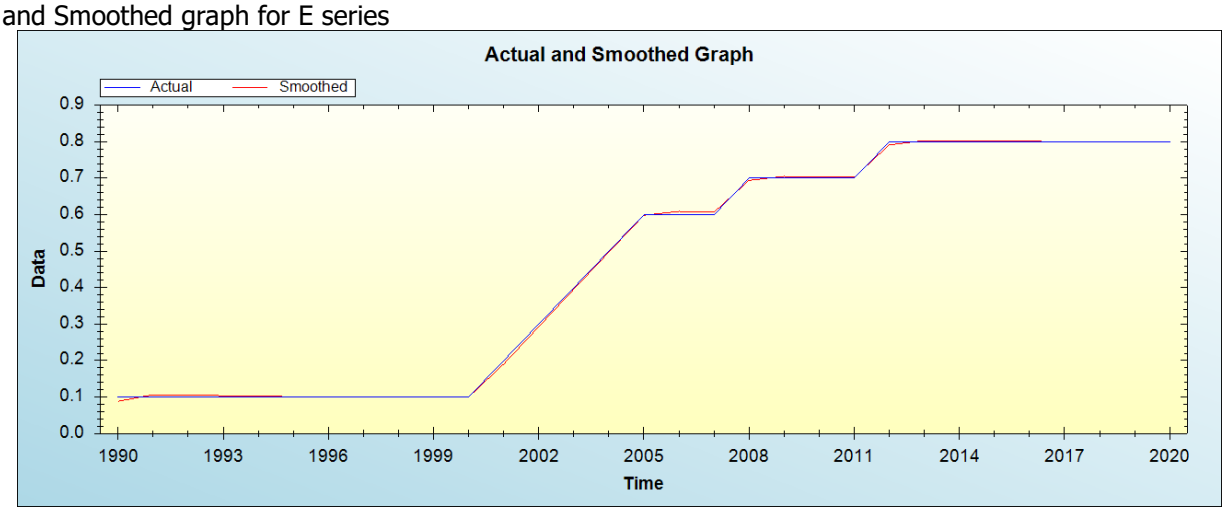

Figure 3: Actual and smoothed graph for E series

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

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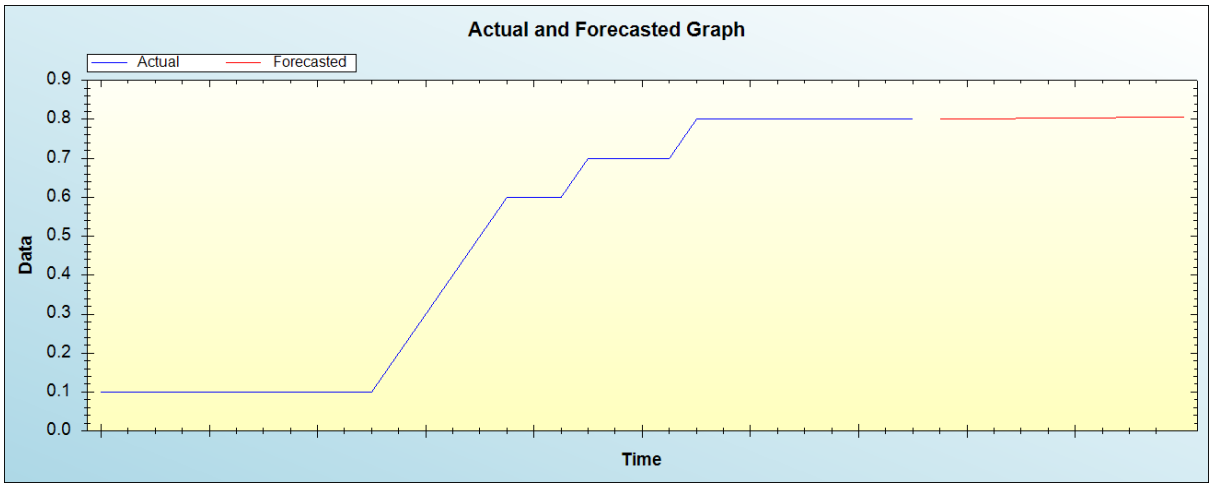

Figure 4: Out-of-sample forecast for E: actual and forecasted graph

Out-of-Sample Forecast for E: Forecasts only

Table 2: Tabulated out-of-sample forecasts

Year	Forecasted HIV prevalence
2021	0.8007
2022	0.8013
2023	0.8019
2024	0.8025
2025	0.8031
2026	0.8037
2027	0.8043
2028	0.8049
2029	0.8055
2030	0.8061

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 be constant around 0.8% throughout the out of sample period.

POLICY IMPLICATION AND CONCLUSION

Our model shows that the annual HIV prevalence among individuals aged 15-49 years will be constant around 0.8% throughout the out of sample period. Therefore, addressing major drivers of HIV spread is a priority particularly among high risk groups.

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