Proceedings of Online International Conference on Innovative Solutions and Advanced Research
Organized by Novateur Publications, Pune, Maharashtra, India
JournalNX- A Multidisciplinary Peer Reviewed Journal
ISSN: 2581-4230, Website: journalnx.com, October 11th, 2020

TOTAL NEW HIV INFECTIONS IN ESWATINI: A BOX-JENKINS ARIMA APPROACH

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Abstract

Using annual time series data on the total number of new HIV infections in Eswatini from 1990 – 2018, the study makes predictions for the period 2019 – 2030. The study applies the Box-Jenkins ARIMA methodology. The diagnostic ADF tests show that, A, the series under consideration is an I (0) variable. Based on the AIC, the study presents the optimal model, the ARIMA (5, 0, 2) model, also known as the ARMA (5, 2) model. The diagnostic tests further reveal that the presented model is stable and its residuals are not serially correlated. The results of the study indicate that the total number of new HIV infections in Eswatini will continue on an upwards trajectory from 7970 new infections in 2019 to approximately 12350 new infections by 2026, after which new infections might start declining slowly and gradually to almost 11203 new infections by 2030. This projected increase in new HIV infections in the country calls for immediate drastic action to be taken by responsible authorities with regards to HIV prevention and control in the country.

1.0INTRODUCTION

Human Immunodeficiency Virus (HIV) is one of a group of viruses known as retroviruses. After getting into the body, the virus kills or damages the cells of the body's immune system. The body tries to keep up by making new cells or trying to contain the virus, but eventually the virus wins out and progressively destroys the body's ability to fight infections and certain cancers (WHO, 2006; WHO, 2011). Most commonly, HIV infection is spread by having sex with an infected partner. The virus can enter the body through the lining of the vagina, vulva, penis, rectum or mouth during sex. HIV frequently spreads among injection-drug users who share needles or syringes that are contaminated with blood from an infected person (UN, 2013). HIV infection has now spread to every country in the world (Sharma et al., 2015). World-wide, at least 40 million people are living with HIV infection, and approximately 25 million have died from this disease (UN, 2011). The scourge of HIV has been particularly devastating in Sub-Saharan Africa (Sharma et al., 2015) where Eswatini belongs to. Eswatini has one of the highest HIV prevalence in the world with 26% of the 15-49 year olds living with HIV. Women are disproportionately affected, with prevalence as high as 31% compared to 20% in men. Heterosexual sex remains the main mode of transmission of HIV in Eswatini, accounting for 94% of all new HIV infections. Risk factors in the country, include but are not limited to, multiple and concurrent sexual partnerships, intergenerational and transactional sex, gender inequalities and gender based violence, low and inconsistent condom use and low uptake of male circumcision (UNAIDS, 2014). The main goal of this study is to predict the number of new HIV infections in Eswatini over the period 2019 – 2030. This paper will go a long way in assessing the possibility of ending the HIV scourge in the country.

2.0 LITERATURE REVIEW

Literature on forecasting new HIV infections in Eswatini is scanty. Closely related papers such as Hussain et al. (2018), Nyoni & Nyoni (2019) and Adedimeji et al. (2019) have been reviewed. In a review paper, Hussain et al. (2018) investigated the causes and consequences of HIV/AIDS in Pakistan and also examined the role of the Pakistani government in controlling the menace. The study averred that Pakistan exhibits a low level of education regarding the topic of Sexually Transmitted Diseases (STDs) and HIV/AIDS. In a Rwandan study, Adedimeji et al. (2019) carried out a study on the prevalence of risky sexual practices of MSM and the concomitant socio-contextual determinants using an explorative qualitative design. The research found out that risky sexual practices were common, and that the knowledge of STIs was poor, but prevalence, especially of HPV was high. In a Zimbabwean study, Nyoni & Nyoni (2019) analyzed new HIV infections in the rural community of Silobela. The study used monthly time series data covering the period January 2014 to December 2018. The SARIMA $(0, 1, 1)(0, 1, 1)_{12}$ model was applied. The study showed that new HIV infections in the community of Silobela will continue to decline over the period 2019 to 2021. No similar study has been in Eswatini, this paper is the first its kind in the country.

3.0 METHODODOLOGY

3.1 The Box – Jenkins (1970) Methodology

The first step towards model selection is to difference the series in order to achieve stationarity. Once this process is over, the researcher will then examine the correlogram in order to decide on the appropriate orders of the AR and MA components. It is important to highlight the fact that this procedure (of choosing the AR and MA components) is biased towards the use of personal judgement because there are no clear – cut rules on how to decide on the appropriate AR and MA components. Therefore, experience plays a pivotal role in this regard. The next step is the estimation of the tentative model, after which diagnostic testing shall follow. Diagnostic checking is usually done by generating the set of residuals and testing whether they satisfy the characteristics of a white noise process. If not, there would be need for model re – specification and repetition of the same process; this time from the second stage. The process may go on and on until an appropriate model is identified (Nyoni, 2018c). This approach will be used to analyze, A, the series under consideration.

3.2 The Applied Box – Jenkins ARIMA Model Specification

If the sequence $\Delta^d A_t$ satisfies an ARMA (p, q) process; then the sequence of A_t also satisfies the ARIMA (p, d, q) process such that:

$$\Delta^d A_t = \sum_{i=1}^{p} \beta_i \Delta^d L^i A_t + \sum_{i=1}^{q} \alpha_i L^i \mu_t + \mu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

where Δ is the difference operator, vector $\beta \in \mathbb{R}^p$ and $\alpha \in \mathbb{R}^q$.

3.3 Data Collection

This study is based on annual observations (that is, from 1990 – 2018) on the total number of new HIV infections, that is, adults (ages 15+) and children (ages 0 – 14) [denoted as A] in Eswatini. Out-of-sample forecasts will cover the period 2019 – 2030. All the data was collected from the World Bank online database.

3.4 Diagnostic Tests & Model Evaluation

3.4.1 The ADF Test in Levels

Table 1: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
A	-3.226476	0.0289	-3.689194	@1%	Non-stationary
			-2.971853	@5%	Stationary
			-2.625121	@10%	Stationary

Table 1 shows that the series under consideration is stationary in levels, hence, it is said to be I (0).

3.4.2 Evaluation of ARIMA models (with a constant)

Table 2: Evaluation of ARIMA Models (with a constant)

Model	AIC	U	ME	RMSE	MAPE
ARIMA (1, 0, 1)	487.5402	0.80498	59.487	1363	15.292
ARIMA (1, 0, 0)	505.5627	0.93869	192.11	1576.5	15.893
ARIMA (0, 0, 1)	525.6506	0.92335	24.581	2187.7	24.384
ARIMA (1, 0, 2)	483.1875	0.82817	51.844	1268.8	14.15
ARIMA (2, 0, 1)	474.11	0.60342	-185.19	1705.6	17.571
ARIMA (3, 0, 1)	475.8725	0.60164	-186.95	1707.5	17.566
ARIMA (4, 0, 1)	475.2325	0.60511	-190.32	1697.2	17.569
ARIMA (5, 0, 1)	472.3099	0.56337	-177.71	1671.3	17.101
ARIMA (6, 0, 1)	471.7967	0.55119	-217.37	1733.8	17.685
ARIMA (5, 0, 2)	470.6716	0.55363	-190.58	1677.6	17.222

A model with a lower AIC value is better than the one with a higher AIC value (Nyoni, 2018b) Similarly, the U statistic can be used to find a better model in the sense that it must lie between 0 and 1, of which the closer it is to 0, the better the forecast method (Nyoni, 2018a). In this research paper, only the AIC is used to select the optimal model. Therefore, the ARIMA (5, 0, 2) model is finally chosen. It is essential, however, to note that this model is also called the ARMA (5, 2) model. But for consistency purposes, throughout the paper, the model is described as the ARIMA (5, 0, 2) model.

3.5 Residual & Stability Tests

3.5.1 Correlogram of the Residuals of the ARIMA (5, 0, 2) Model

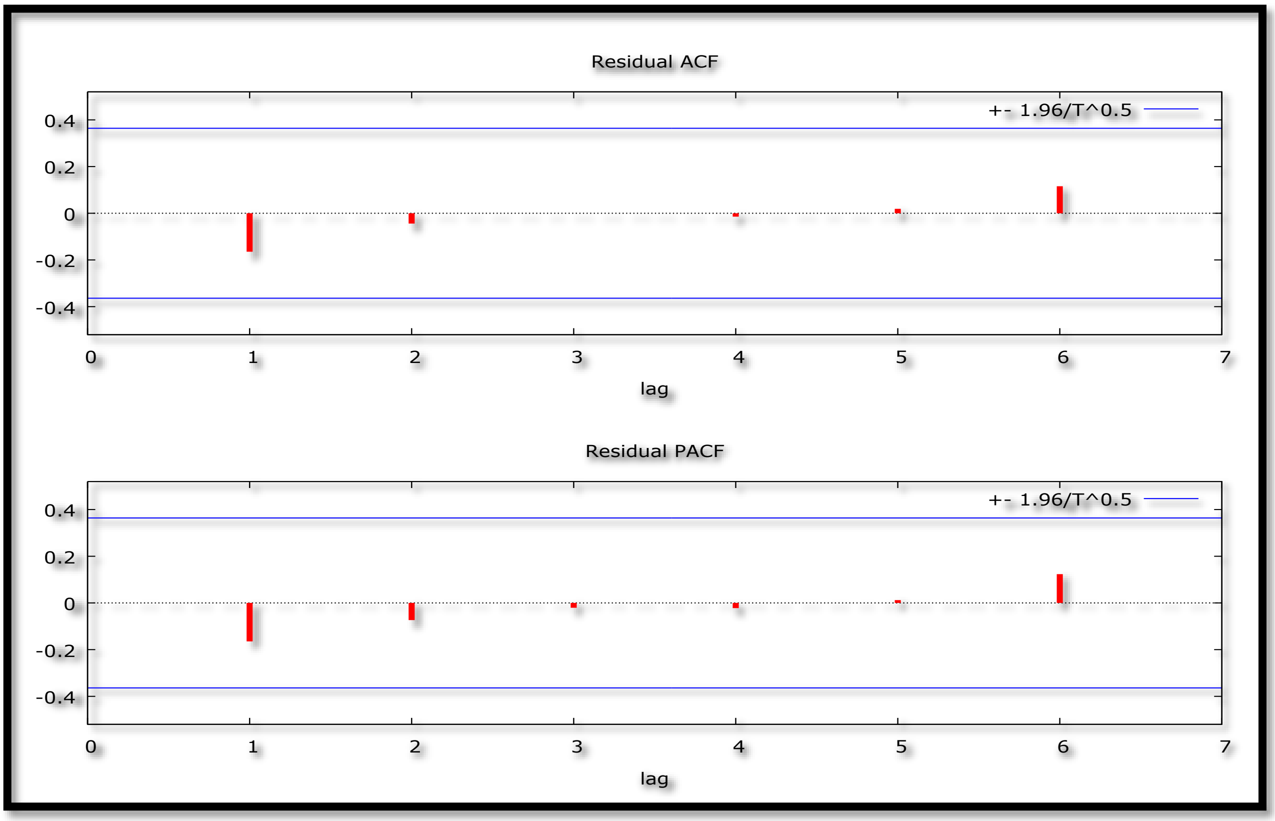

Figure 1: Correlogram of the Residuals

Figure 5 indicates that the estimated ARIMA (5, 0, 2) model is adequate since ACF and PACF lags are quite short and within the bands.

4.0 FINDINGS OF THE STUDY

4.1 Results Presentation

Table 3: Main Results

ARIMA (5, 0, 2) Model				
The chosen optimal model, the ARIMA (5, 0, 2) model can be expressed as follows: $A_t = 10818 + 1.20662A_{t-1} - 0.126801A_{t-2} + 0.289886A_{t-3} - 1.0016A_{t-4} + 0.453836A_{t-5} + 0.54399\mu_{t-1} + 0.614855\mu_{t-2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$ [2]				
Variable	Coefficient	Standard Error	z	p-value
constant	10818	473.26	22.86	0.0000***

β_1	1.20662	0.25067	4.814	0.0000***
β_2	-0.126801	0.292174	-0.434	0.6643
β_3	0.289886	0.287765	1.0007	0.3138
β_4	-1.0016	0.221831	-4.515	0.0000***
β_5	0.453836	0.193895	2.341	0.0193**
α_1	0.54399	0.244202	2.228	0.0259**
α_2	0.614855	0.26716	2.301	0.0214**

Table 9 shows the main results of the ARIMA (5, 0, 2) model.

Forecast Graph

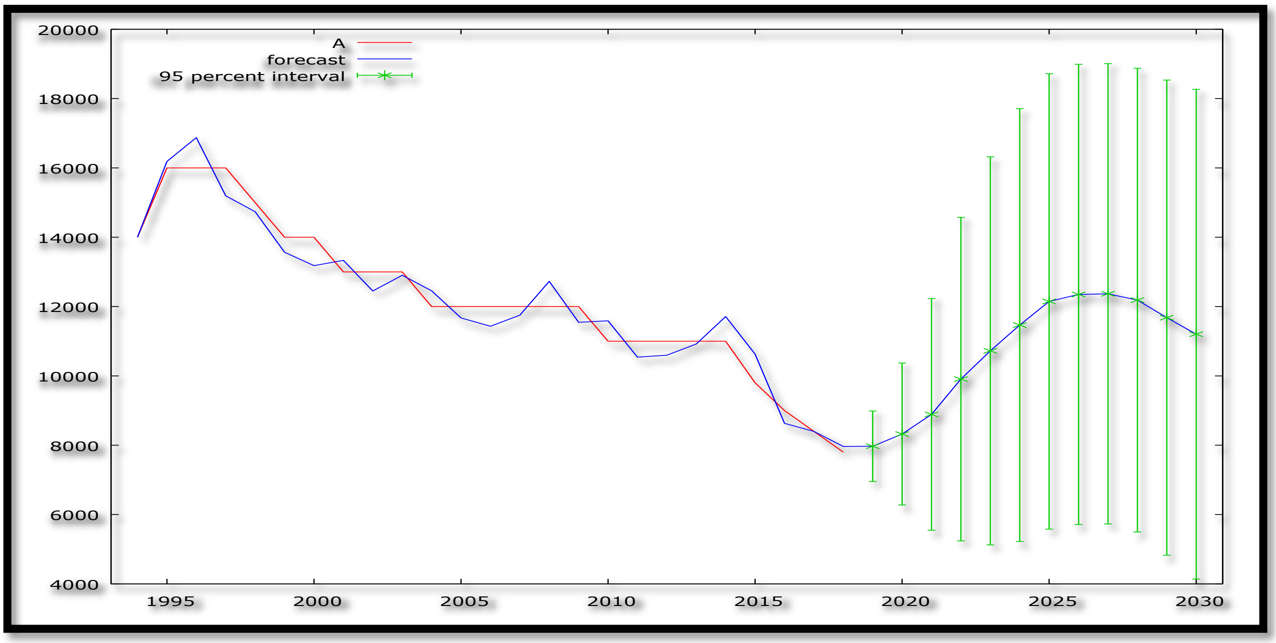

Figure 2: Forecast Graph – In & Out-of-Sample Forecasts

Figure 2 shows the in-and-out-of-sample forecasts of the A series. The out-of-sample forecasts cover the period 2019 – 2030.

Predicted B– Out-of-Sample Forecasts Only

Table 4: Predicted A

Year	Predicted A	Standard Error	95% Confidence Interval
2019	7970.27	518.290	(6954.44, 8986.10)
2020	8321.52	1044.92	(6273.52, 10369.5)
2021	8888.72	1705.37	(5546.26, 12231.2)
2022	9906.59	2380.88	(5240.15, 14573.0)
2023	10721.8	2856.18	(5123.82, 16319.8)
2024	11466.3	3185.33	(5223.20, 17709.5)
2025	12147.7	3352.35	(5577.17, 18718.1)
2026	12349.6	3387.54	(5710.14, 18989.1)
2027	12368.1	3387.75	(5728.23, 19008.0)
2028	12186.6	3412.44	(5498.36, 18874.9)
2029	11679.3	3497.07	(4825.16, 18533.4)
2030	11202.5	3604.47	(4137.83, 18267.1)

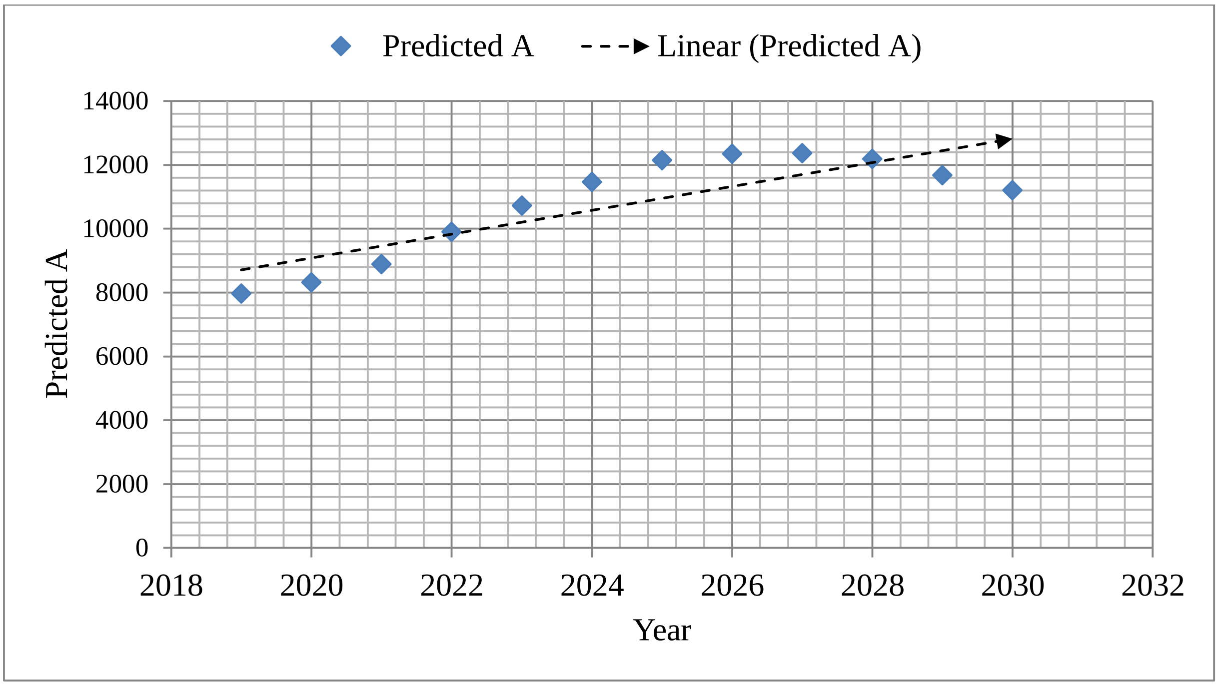

Figure 3: Graphical Analysis of Out-of-Sample Forecasts

Table 4 and figure 3 show the out-of-sample forecasts only. The number of total new HIV infections in Eswatini is generally projected to increase over the out-of-sample period, with a possible decrease somewhere around 2026 towards 2030.

5.0 CONCLUSION

The study shows that the ARIMA (5, 0, 2) model is not only stable but also the most suitable model to forecast the total annual number of new HIV infections in Eswatini over the period 2019 – 2030. The paper recommends that the government of the Kingdom of Eswatini should continue scaling up HIV prevention and treatment access. Special emphasis ought to be directed towards behavior change interventions such as increased condom use as well as reduction of sexual partners. Eswatini, being a low circumcision country (UNAIDS, 2014); should up scale voluntary medical male circumcision as an additional HIV prevention strategy.

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