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# ADULTS NEWLY INFECTED WITH HIV IN BOTSWANA: A BOX-JENKINS ARIMA APPROACH

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**ABSTRACT:**

**Using annual time series data on the number of adults (ages 15 and above) newly infected with HIV in Botswana from 1990 – 2018, the study predicts the annual number of adults who will be newly infected with HIV over the period 2019 – 2025. The paper applies the Box-Jenkins ARIMA technique. The diagnostic ADF tests show that the K series under consideration is an I (1) variable. Based on the AIC, the study presents the ARIMA (4, 1, 0) model as the optimal model. The residual correlogram shows that the presented model is very stable and suitable for forecasting new HIV infections in adults in Botswana. The findings of the study reveal that the numbers of new HIV infections in adults in the country are likely to go up from about 7907 in 2019 to almost 8262 new infections by 2025. This means that Botswana's quest for an AIDS free society will remain a pipeline dream at least from the next 5 years. This is not a desirable public health outcome but rather a warning signal for policy makers so that they make the necessary decisions now before the situations goes out of hand. If nothing is done now, Botswana's HIV/AIDS burden will definitely rise and possibly overwhelm the country's limited resources. We basically encourage the government of Botswana to intensify its HIV prevention and control programs in order to possibly reserve the projected trajectory and save precious lives.**

**INTRODUCTION:**

The Human Immunodeficiency Virus (HIV) is a retrovirus that infects cells of the immune system, destroying their function (Awoleye & Thron, 2015). Currently, antiretroviral drugs slow down replication of the virus and can greatly enhance quality of life, but they do not eliminate HIV infection (Commission on HIV/AIDS and Governance in Africa, 2008). HIV has remained a global public health challenge since the epidemic began in 1970s (Avert, 2017). In Botswana, the HIV epidemic was discovered in the early 1980s. The country now has one of the highest levels of HIV prevalence in the world (Stover et al., 2008) estimated to be around 17.6% (Thigpen et al., 2012). The epidemic has imposed a terrible burden due to lives lost, reduced quality of life and a large number of orphans (NACA, 2008). Botswana became the first African country to establish a national Antiretroviral Therapy (ART) program and began providing treatment free of charge to its HIV – infected population early in 2002 (Farahani et al., 2014). The country's ART program has been touted as successful in controlling the HIV epidemic. Botswana, being one of those countries with the highest HIV prevalence in the world; has an estimated 24% of adults (in ages 15 and above) infected (UNAIDS, 2006; Statistics Botswana, 2013; Karim, 2016; UNAIDS, 2017) and yet no study has been carried out to model and forecast the trends of new HIV infections in this high risk adult cohort. The main goal of this study is to

predict the number of adults newly infected with HIV in Botswana over the period 2019 – 2025. This paper will go a long way in assessing the possibility of ending the HIV epidemic in the country.

**LITERATURE REVIEW:**

Stover et al. (2008) estimated past trends and current levels of HIV in Botswana and the effects of treatment and prevention programs, through the use of surveillance, survey and program data over the period 1980 – 2007. The study results showed that the number of new HIV infections in adults was continuing to rise to higher levels. Using data from the BAIS III, Keetile (2014) explored high risk behaviors of adults and how they affect government efforts to stop the spread of HIV/AIDS in Botswana. Both descriptive and binary logistic analyses were used for analysis. The study found out that there was statistically significant association between multiple current partners and alcohol consumption. The study also indicated that there was inconsistent condom use in the country. Tenforde et al (2017) determined the national incidence of cryptococcal meningitis and described the characteristics of cases during 2000-2014 and temporal trends at 2 national referral hospitals. UNAIDS population estimates were used to calculate national incidence. The findings of the study showed that despite excellent ART coverage in Botswana, there is still a substantial burden of advanced HIV. Recently, Matlho et al (2019) examined HIV related characteristics and behaviors of the older cohort (50-64 years). The study revealed that there was inconsistent condom use among older adults, of at least 59%. Furthermore, the paper also showed that there was a dramatic increase in HIV prevalence, especially among older men. No study has attempted to model and forecast new HIV infections in Botswana. This paper will be the first of its kind in the country. We focus on new HIV infections in adults, guided by the fact that HIV prevalence in Botswana is skewed towards adults within the age range of 15 – 49 years old.

**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 the J series under consideration.

**3.2 The Moving Average (MA) model:**

Given:

$$K_t = \sum_{i=1}^{q} \alpha_i \mu_{t-i} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots [1]$$

where $\mu_t$ is a purely random process with mean zero and varience $\sigma^2$. Equation [1] is reffered to as a Moving Average (MA) process of order q, commonly denoted as MA (q). K is the annual number of adults newly infected

with HIV in Botswana at time t, $\alpha_0$ … $\alpha_q$ are estimation parameters, $\mu_t$ is the current error term while $\mu_{t-1}$ … $\mu_{t-q}$ are previous error terms.

### 3.3 The Autoregressive (AR) model:

Given:

$$K_t = \sum_{i=1}^{p} \beta_i K_{t-i} + \mu_t \dots\dots\dots\dots\dots\dots\dots\dots\dots [2]$$

Where $\beta_1$ … $\beta_p$ are estimation parameters, $K_{t-1}$ … $K_{t-p}$ are previous period values of the K series and $\mu_t$ is as previously defined. Equation [2] is an Autoregressive (AR) process of order p, and is usually denoted as AR (p).

### 3.4 The Autoregressive Moving Average (ARMA) model:

An ARMA (p, q) process is just a mere combination of AR (p) and MA (q) processes. Thus, by combining equations [1] and [2]; an ARMA (p, q) process may be specified as shown below:

$$K_t = \sum_{i=1}^{p} \beta_i K_{t-i} + \sum_{i=1}^{q} \alpha_i \mu_{t-i} + \mu_t \dots\dots\dots\dots [3]$$

### 3.5 The Autoregressive Integrated Moving Average (ARIMA) model:

A stochastic process $K_t$ is referred to as an Autoregressive Integrated Moving Average (ARIMA) [p, d, q] process if it is integrated of order "d" [I (d)] and the "d" times differenced process has an ARMA (p, q) representation. If the sequence $\Delta^d K_t$ satisfies an ARMA (p, q) process; then the sequence of $K_t$ also satisfies the ARIMA (p, d, q) process such that:

$$\Delta^d K_t = \sum_{i=1}^{p} \beta_i \Delta^d K_{t-i} + \sum_{i=1}^{q} \alpha_i \mu_{t-i} + \mu_t \dots\dots\dots [4]$$

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

### 3.6 Data Collection:

This study is based on annual observations (that is, from 1990 – 2018) on the number of new HIV infections in adults (ages 15 years and above) [denoted as K] in Botswana. Out-of-sample forecasts will cover the period 2019 – 2025. All the data was gathered from the World Bank online database.

### 3.7 Diagnostic Tests & Model Evaluation:

#### 3.7.1 Stationarity Tests: Graphical Analysis:

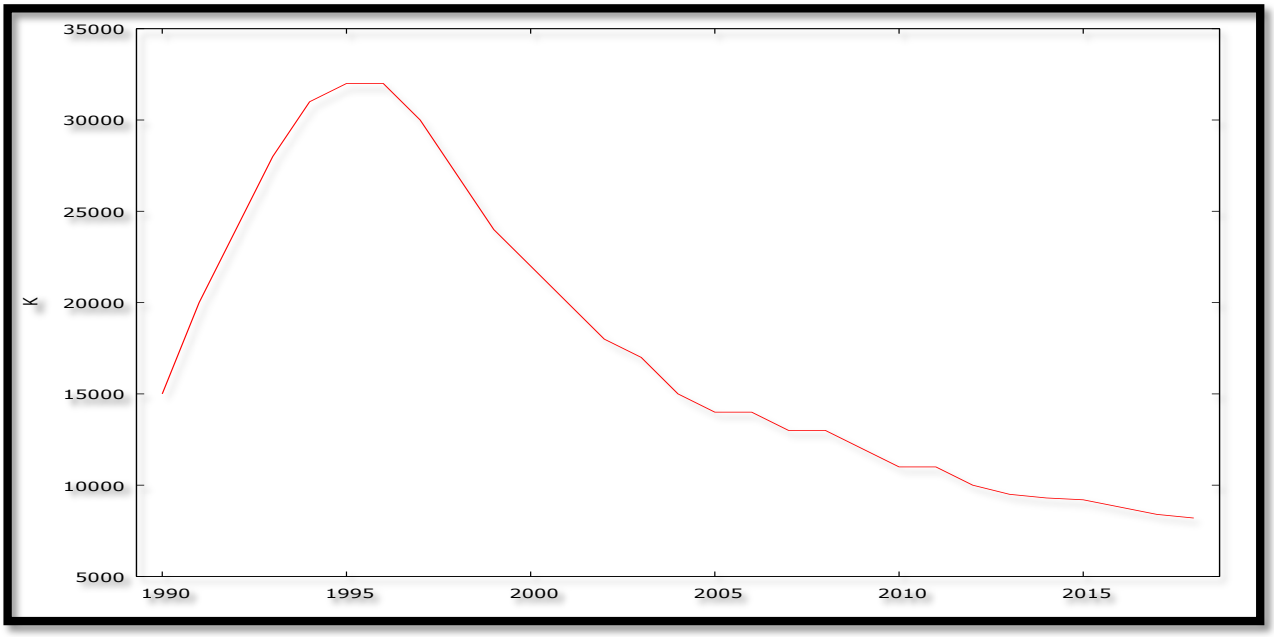


Figure 1

### 3.7.2 The Correlogram in Levels:

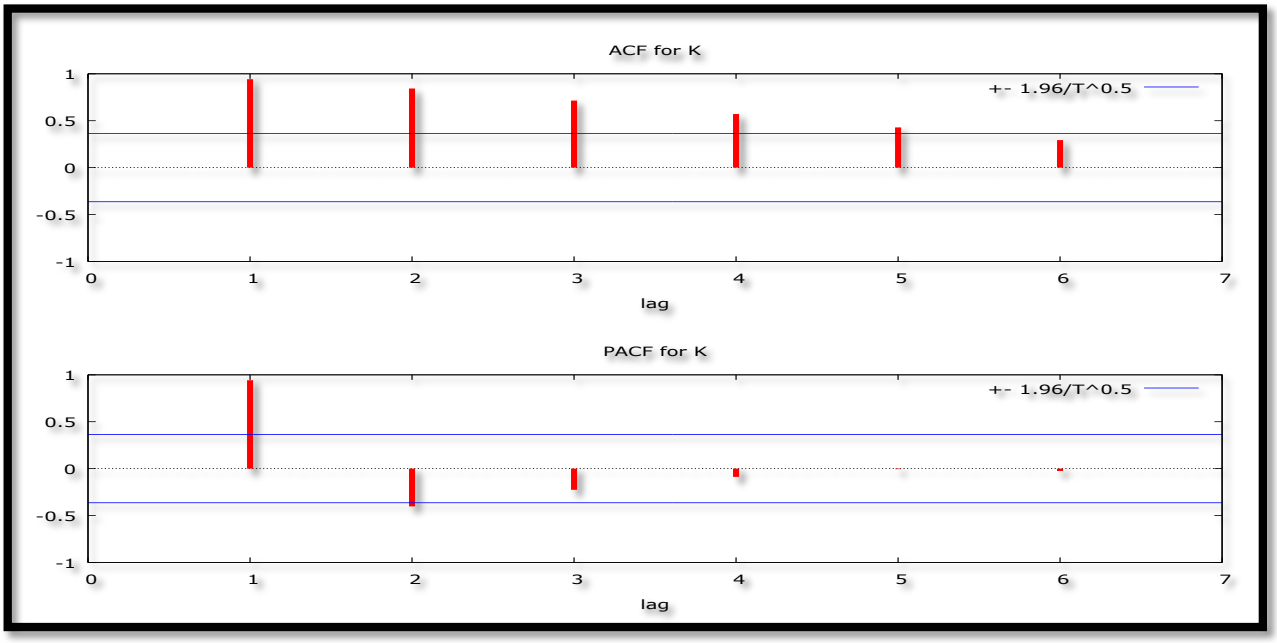


Figure 2: Correlogram in Levels

### 3.7.3 The ADF Test in Levels:

Table 1: with intercept

| Variable | ADF Statistic | Probability | Critical Values | | Conclusion |
|---|---|---|---|---|---|
| K | -0.162702 | 0.9325 | -3.689194 | @1% | Non-stationary |
| | | | -2.971853 | @5% | Non-stationary |
| | | | -2.625121 | @10% | Non-stationary |

Table 1 shows that K is not stationary in levels, in line with implications from figure 1 and 2.

### 3.7.4 The Correlogram (at First Differences):

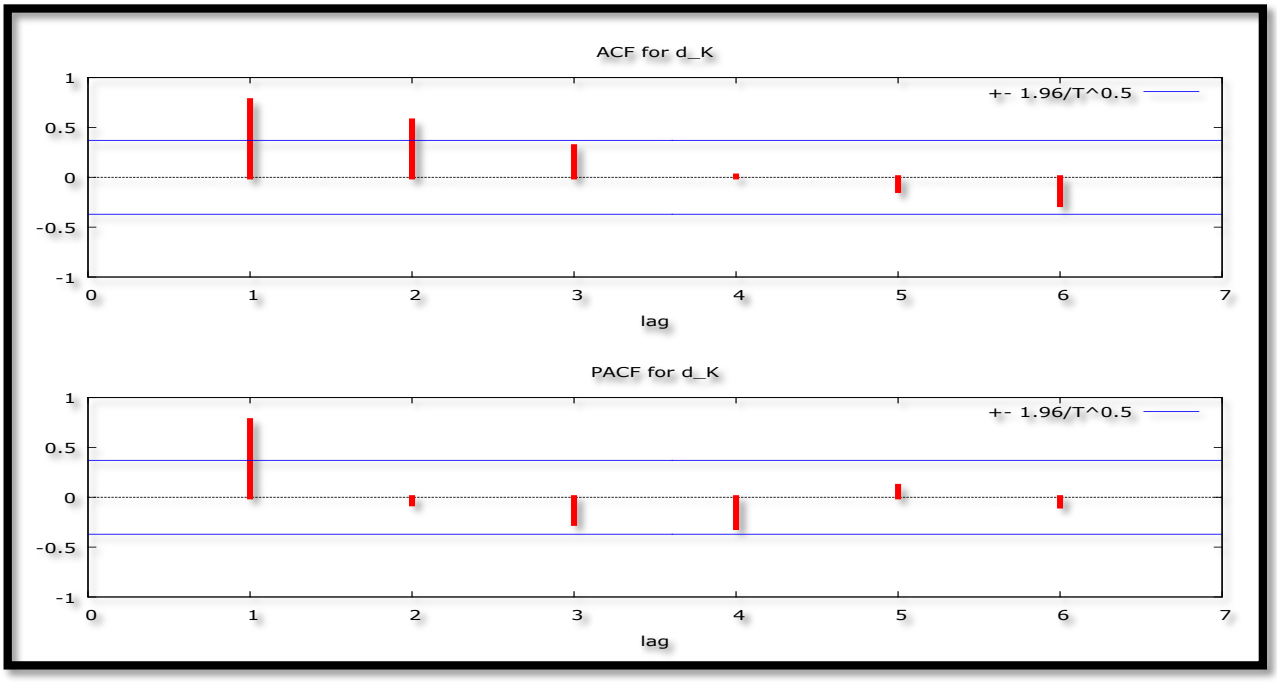


Figure 3: Correlogram (at First Differences)

### 3.7.5 The ADF Test (at First Differences):

Table 2: with intercept

| Variable | ADF Statistic | Probability | Critical Values | | Conclusion |
|---|---|---|---|---|---|
| ΔK | -5.269198 | 0.0003 | -3.737853 | @1% | Stationary |
| | | | -2.991878 | @5% | Stationary |
| | | | -2.635542 | @10% | Stationary |

Figure 3 as well as table 2 indicate that K is an I (1) variable.

### 3.7.6 Evaluation of ARIMA models (without a constant):

Table 3: Evaluation of ARIMA Models (without a constant)

| Model | AIC | U | ME | RMSE | MAPE |
|---|---|---|---|---|---|
| ARIMA (1, 1, 2) | 464.4638 | 0.58565 | 19.813 | 1200.7 | 4.9883 |
| ARIMA (1, 1, 0) | 466.8711 | 0.58203 | -21.455 | 1267.9 | 4.9414 |
| ARIMA (2, 1, 0) | 468.1866 | 0.61663 | 4.1189 | 1257.7 | 5.0742 |
| ARIMA (3, 1, 0) | 467.0542 | 0.61798 | 45.114 | 1218.4 | 5.1212 |
| ARIMA (2, 1, 2) | 464.3771 | 0.54803 | 56.566 | 1174.4 | 4.459 |
| ARIMA (4, 1, 0) | **459.9494** | 0.49402 | 62.281 | 1141.8 | 4.0111 |
| ARIMA (5, 1, 0) | 460.2396 | 0.49354 | 73.541 | 1128.3 | 4.1865 |

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 paper, only the AIC is used to select the optimal model. Therefore, the ARIMA (4, 1, 0) model is finally chosen.

### 3.8 Residual Tests:

### 3.8.1 Correlogram of the Residuals of the ARIMA (4, 1, 0) Model:

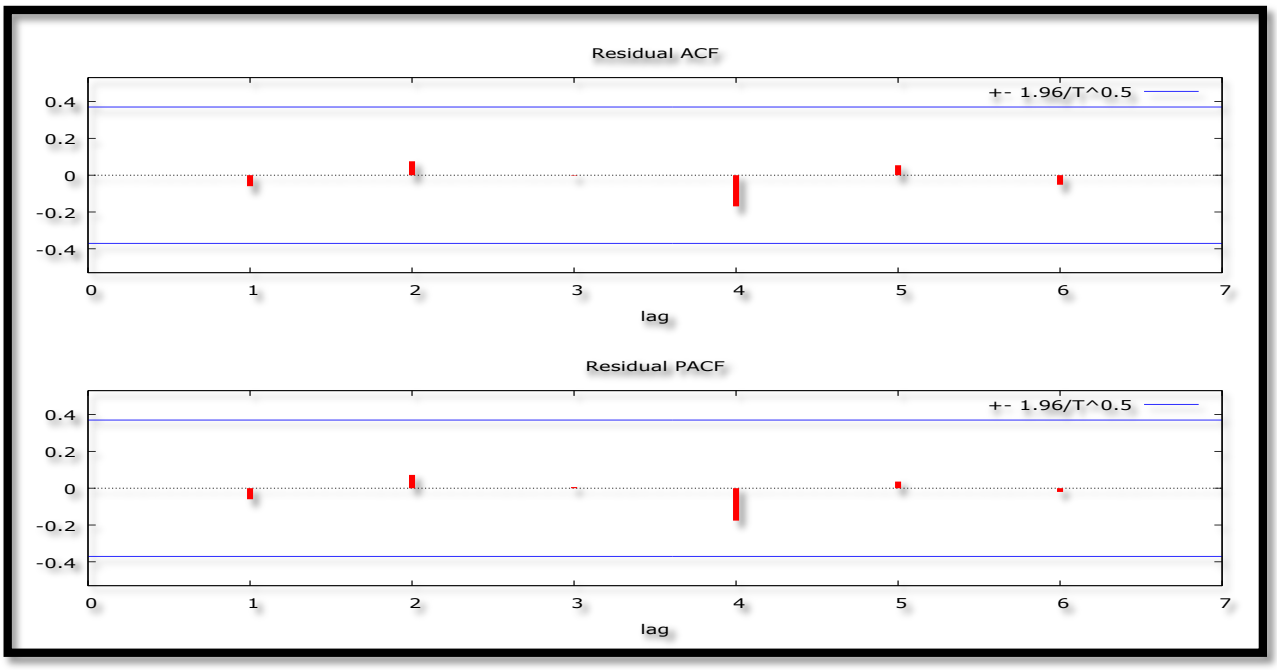


Figure 4: Correlogram of the Residuals

Figure 4 indicates that the estimated optimal model is adequate since ACF and PACF lags are quite short and within the bands. This implies that the "no autocorrelation" assumption is not violated in this paper.

## FINDINGS:

### 4.1 Descriptive Statistics:

Table 4: Descriptive Statistics

| Description | Statistic |
|---|---|
| Mean | 17462 |
| Median | 15000 |
| Minimum | 8200 |
| Maximum | 32000 |

As shown in table 4 above, the mean is positive, that is, 17462. This means that, over the study period, the annual average number of adults newly infected with HIV in Botswana is approximately 17462. The minimum number of adults newly infected with HIV in the country is 8200 while the maximum is 32000.

### 4.2 Results Presentation

Table 5: Main Results

**ARIMA (4, 1, 0) Model:**

Guided by equation [4], the chosen optimal model, the ARIMA (4, 1, 0) model can be expressed as follows:

$$\Delta^2 K_t = 0.821715\Delta^2 K_{t-1} + 0.287281\Delta^2 K_{t-2} + 0.171047\Delta^2 K_{t-3} - 0.549120\Delta^2 K_{t-4} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [5]$$

| Variable | Coefficient | Standard Error | z | p-value |
|---|---|---|---|---|
| $\beta_1$ | 0.821715 | 0.167539 | 4.905 | 0.0000*** |
| $\beta_2$ | 0.287281 | 0.225570 | 1.274 | 0.2028 |
| $\beta_3$ | 0.171047 | 0.218498 | 0.7828 | 0.4337 |
| $\beta_4$ | -0.549120 | 0.157135 | -3.495 | 0.0005*** |

Table 5 shows the main results of the ARIMA (4, 1, 0) model.

**Forecast Graph**

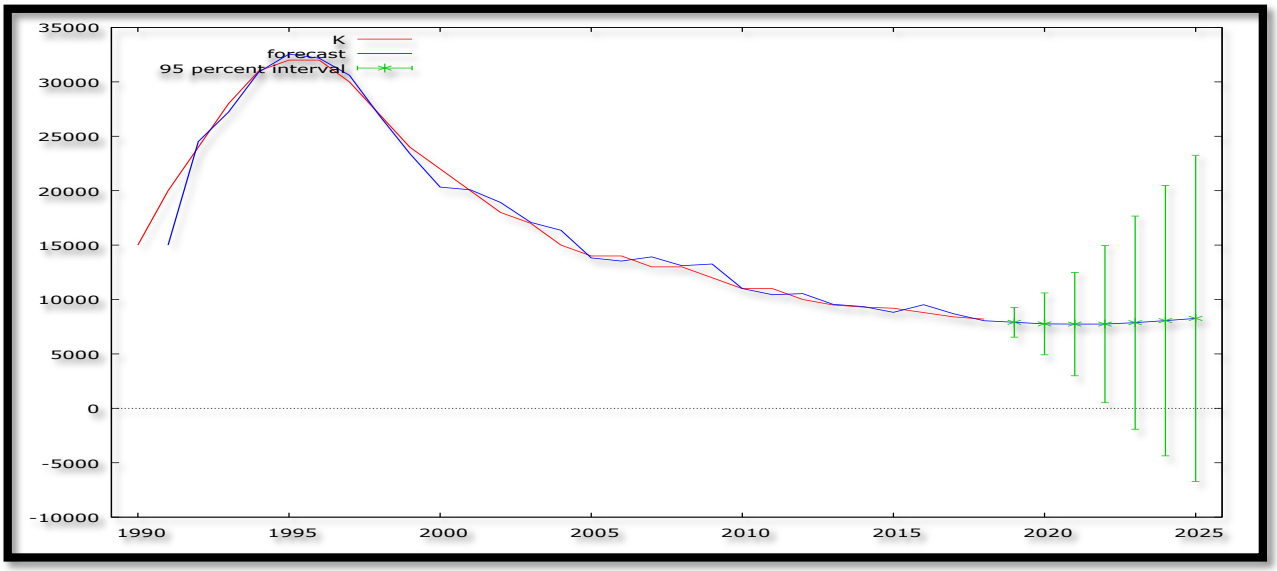


Figure 5: Forecast Graph – In & Out-of-Sample Forecasts

Figure 5 shows the in-and-out-of-sample forecasts of the K series. The out-of-sample forecasts cover the period 2019 – 2025.

**Predicted K– Out-of-Sample Forecasts Only**

Table 6: Predicted

| Year | Prediction | Standard Error | 95% Confidence Interval |
|---|---|---|---|
| 2019 | 7907.24 | 697.727 | (6539.72, 9274.76) |
| 2020 | 7760.44 | 1449.97 | (4918.55, 10602.3) |
| 2021 | 7741.16 | 2424.08 | (2990.04, 12492.3) |
| 2022 | 7742.88 | 3687.31 | (515.887, 14969.9) |
| 2023 | 7874.41 | 4997.48 | (-1920.47, 17669.3) |
| 2024 | 8060.30 | 6340.43 | (-4366.71, 20487.3) |
| 2025 | 8261.72 | 7650.75 | (-6733.48, 23256.9) |

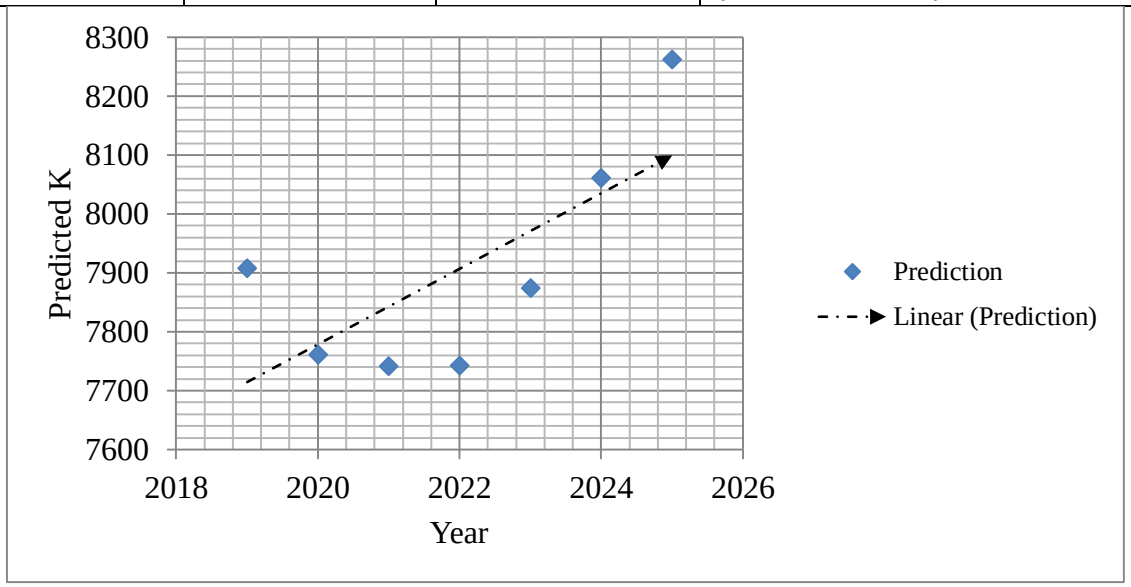


Figure 6: Graphical Analysis of Out-of-Sample Forecasts

Table 6 and figure 6 show the out-of-sample forecasts only. The number of adults newly infected with HIV in Botswana is projected to resurge from approximately 7907 in 2019 to 8262 by the year 2025. New HIV infections in adults in the country remain unacceptably. The results of this study are consistent with previous studies such as Stover et al. (2008), Keetile (2014), Tenforde et al. (2017) and Matlho et al. (2019). Although Botswana was among the first African countries to introduce HIV prevention programs focused on male circumcision, prevention of mother to child transmission, and voluntary counseling and testing, there is need for additional prevention strategies to better control the generalized epidemic in this country (Thigpen et al., 2012). Overall HIV prevalence in the country is not declining (Avila et al., 2014; Siedner et al., 2015; Wang et al., 2016) but rather slowly and progressively going up. However, it is possible to significantly reduce the number of new HIV infections in adults, especially if the current government of Botswana considers the policy directions suggested below.

**CONCLUSION:**

The study shows that the ARIMA (4, 1, 0) model is not only stable but also the most suitable model to forecast the annual number of adults newly infected with HIV in Botswana over the period 2019 – 2025. The model

predicts an increase in the annual number of new HIV infections in adults in the country. These findings are essential for the government of Botswana, especially for long-term public health policy formulation. The study recommends that the government of Botswana should intensify HIV prevention and treatment programs throughout the country; with particular emphasis on behavior change interventions such as increased condom use, reduced/reasonable alcohol consumption and reduction of sexual partners. Public health policy makers in Botswana ought to strengthen HIV, TB, and Sexual & Reproductive Health programme linkages around the country. Although Botswana is not a low-circumcision country, still there is need for up scaling of medical male circumcision as an additional HIV prevention strategy; especially considering the projected increase in new HIV infections in adults.

**REFERENCES**

1) Avert (2017). History of HIV, Avert, Lagos.
2) Avila, D., et al. (2014). Immunodeficiency at the Start of Combination Antiretroviral Therapy in Low, Middle and High Income Countries, Journal of Acquired Immune Deficiency Syndrome, 65: 8 – 16.
3) Awoleye, O. J., & Thron, C. (2015). Determinants of Human Immunodeficiency Virus (HIV) Infection in Nigeria: A Synthesis of the Literature, Journal of AIDS and Research, 7 (9): 117 – 129.
4) Commission on HIV/AIDS and Governance in Africa (2008). Securing our Future, Commission on HIV/AIDS and Governance in Africa, Addis Ababa.
5) Farahani, M., et al. (2014). Outcomes of the Botswana National HIV/AIDS Treatment Programme From 2002 to 2010: A Longitudinal Analysis, Lancet, Global Health, 2: 44 – 50.
6) Karim, S. A. (2016). Is the UNAIDS Target Sufficient for HIV Control in Botswana? Lancet, 3: 195 – 196.
7) Keetile, M. (2014). High-risk Behaviors Among Adults Men and Women in Botswana: Implications for HIV/AIDS Prevention Efforts, Journal of Social Aspects of HIV/AIDS, 11 (1): 158 – 166.
8) Matlho, K., et al. (2019). HIV Prevalence and Related Behaviors of Older People in Botswana – Secondary Analysis of the Botswana AIDS Impact Survey (BAIS) IV, African Journal of AIDS Research, 18 (1): 18 – 26.
9) NACA (2008). 2007 Report, NACA, Gaborone.
10) Nyoni, T (2018b). Modeling and Forecasting Inflation in Kenya: Recent Insights from ARIMA and GARCH analysis, Dimorian Review, 5 (6): 16 – 40.
11) Nyoni, T. (2018a). Modeling and Forecasting Naira/USD Exchange Rate in Nigeria: A Box-Jenkins ARIMA Approach, MPRA Paper No. 88622, University Library of Munich, Munich, Germany.
12) Nyoni, T. (2018c). Box – Jenkins ARIMA Approach to Predicting net FDI inflows in Zimbabwe, MPRA Paper No. 87737, University Library of Munich, Munich, Germany.
13) Siedner, M. J., et al. (2015). Trends in CD4 Count At Presentation to Care and Treatment Initiation in Sub-Saharan Africa, 2002 – 2013: A Meta Analysis, Clinical Infectious Diseases, 60: 1120 – 1127.
14) Statistics Botswana (2013). Botswana AIDS Impact Survey, Statistics Botswana, Gaborone.
15) Stover, J., et al. (2008). Estimated HIV Trends and Program Effects in Botswana, PLoS ONE, 3 (1): 1 – 5.

16) Tenforde, M. W., et al. (2017). Advanced Human Immunodeficiency Virus Disease in Botswana Following Successful Antiretroviral Therapy Rollout: Incidence of and Temporal Trends in Cryptococcal Meningitis, Clinical Infectious Diseases, 65 (1): 779 – 786.
17) Thigpen, M. C., et al. (2012). Antiretroviral Preexposure Prophylaxis for Heterosexual HIV Transmission in Botswana, The New England Journal of Medicine, 367 (5): 423 – 434.
18) UNAIDS (2006). Global AIDS Epidemic, UNAIDS, New York.
19) UNAIDS (2017). HIV and AIDS Estimates in Botswana, UNAIDS, New York.
20) Wang, H., et al. (2016). Estimates of Global, Regional and National Incidence, Prevalence and Mortality of HIV, 1980 – 2015, Lancet, 3: 361 – 387.