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

Dr. Smartson. P. Nyoni
ZICHIRe Project, University of Zimbabwe, Harare, Zimbabwe
Mr. Thabani Nyoni
Department of Economics, University of Zimbabwe, Harare, Zimbabwe

ABSTRACT

Employing annual time series data on the number of adults (ages 15 and above) newly infected with HIV in Nigeria from 1990 – 2018, the study predicts the annual number of adults who will be newly infected with HIV over the period 2019 – 2030. The study applied the Box-Jenkins ARIMA technique. The diagnostic ADF tests show that the C series under consideration is an I (1) variable. Based on the AIC, the study presents the ARIMA (2, 1, 0) model as the optimal model. The residual correlogram of the model and the inverse roots of the AR/MA polynomials further reveal that the presented ARIMA (2, 1, 0) model is stable and its residuals are not serially correlated. The results of the study indicate that the number of new HIV infections in adults in Nigeria will go up from the estimated 101754 new infections in 2019 to approximately 114883 by 2030. The results of this study indicate that Nigeria is lagging far behind in terms of "wiping out the virus". Indeed, the country's achievable vision of ending HIV by 2030 will no longer be achieved.

INTRODUCTION

The Human Immunodeficiency Virus (HIV) is a retrovirus that infects cells of the immune system, destroying their function (Awoleye & Thron, 2015). HIV has remained a global public health challenge since the epidemic began in 1970s (Avert, 2017). Of all the people living with HIV globally – over 70 million as of 2015 (WHO, 2017), approximately 9% of them live in Nigeria (UNAIDS, 2014a). The first 2 cases of HIV in Nigeria were diagnosed in 1985 and reported in 1986 in Lagos, one of which was a young female sex worker aged 13 (Nasidi & Harry, 2006). Afterward, HIV infection was identified among commercial sex workers in Lagos and Enugu (Federal Ministry of Health, 2004). Because of the widespread patronage of this group of people, cases of HIV infection were occasionally reported from various parts of the country (Federal Ministry of Health, 2004), and have been growing steadily (Entonu & Agwale, 2007).

The news of these first 2 AIDS cases sent panic, doubt and disbelief across Nigeria because AIDS was perceived as the disease of the American homosexuals. Some people saw the story about AIDS as a ploy by Americans to discourage sex and many acronyms, one of which was 'American Idea for Discouraging Sex' emerged at the time (Eze, 2009). Today Nigerians know that HIV/AIDS is real and that the scourge has devastating effects on people

and the economy (Awofala & Ogundele, 2018). In fact, Nigeria now has the second largest HIV epidemic globally with an estimated 60% new HIV infections in West and Central Africa occuring in Nigeria (UNAIDS, 2016). Nigeria, alongside South Africa and Uganda accounts for approximately 50% of the new HIV infection in Sub-Saharan Africa annually (Avert, 2018). The leading route of HIV transmission in Nigeria is heterosexual intercourse (accounting for over 80% of new infections), followed by mother to child transmission. Of new adult infections, 38% is due to female sex workers, injecting drug users and men having sex with men which constitute 3.5% of the adult population (NSP, 2010).

Most HIV infections in Nigeria occur in adults aged 15 years and above (Awofala & Ogundele, 2018) in line with the global HIV epidemic (UNAIDS, 2013). While studies on HIV in Nigeria have been flogged, researches particularly to do with forecasting new HIV infections are relatively dearth. It is against this milieu that this research is being carried out. Therefore, the main aim of this study is to predict the number of adults newly infected with HIV in Nigeria over the period 2019 – 2030. This study will go a long way in assessing the possibility of ending the HIV/AIDS epidemic in the country.

LITERATURE REVIEW

Fagbamigbe et al. (2016) assessed the influence of marital status and other correlates on HIV infection among women in Nigeria. Data were weighted and analyzed using descriptive statistics and logistic regression at the 5% significance level. The results of the study indicated that being formerly married, under 15 years of age at first sex and having engaged in transactional sex are the strongest HIV risk factors among women. In another Nigerian study, Ayodele & Ayodele (2016) assessed urban-rural differences in HIV/AIDS knowledge of senior secondary school students in Ekiti State. A cross-sectional study of 372 students was conducted. Descriptive statistics were used to describe variables of interest and one way ANOVA as employed to examine differences in the HIV/AIDS knowledge means scores. The study showed that there were misconceptions regarding HIV preventive measures, modes of transmission and treatment. In yet another Nigeria study, Chukwujekwu et al. (2017) investigated the sexual behavior and practices of people living with HIV. A cross-sectional study of HIV infected adults receiving care, treatment and support services at a large HIV treatment center in Lagos. The results of the study revealed a low condom use rate and high multiple sexual partnership levels driven by the desire for childbearing. More recently, Badru et al. (2020) examined the factors associated with comprehensive HIV knowledge, stigma and HIV risk perceptions among youth adolescents aged 10-14 years in Akwa Ibom State, Nigeria. Cross-sectional data from the 2017 Akwa Ibom AIDS Indicator Survey was used. A multiple logistic regression as employed to determine associations with the study outcomes. Results of the study indicated that there was low comprehensive knowledge among young adolescents. Many studies indicate lack of adequate knowledge on

HIV. This could be the reason why the HIV epidemic is not easy to control in Nigeria. No study has attempted to empirically forecast the trend of new HIV infections in the country. This paper will be the first of its kind in the country and is expected to go a long way in sensitizing the need to intensify HIV prevention and control in the country.

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 C series under consideration.

3.2 The Moving Average (MA) model

Given:

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

where μ_t is a purely random process with mean zero and varience σ^2. Equation [1] is reffered to as a Moving Average (MA) process of order q, commonly denoted as MA (q). C is the annual number of adults newly infected with HIV in Nigeria at time t, $\alpha_0 \ldots \alpha_q$ are estimation parameters, μ_t is the current error term while $\mu_{t-1} \ldots \mu_{t-q}$ are previous error terms.

3.3 The Autoregressive (AR) model

Given:

$$C_t = \sum_{i=1}^{p} \beta_i C_{t-i} + \mu_t \ldots \ldots \ldots \ldots \ldots \ldots \ldots [2]$$

Where $\beta_1 \ldots \beta_p$ are estimation parameters, $C_{t-1} \ldots C_{t-p}$ are previous period values of the C series and μ_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:

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

3.5 The Autoregressive Integrated Moving Average (ARIMA) model

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

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

where Δ 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 C] in Nigeria. Out-of-sample forecasts will cover the period 2019 – 2030. All the data was gathered from the World Bank online database.

3.7 Diagnostic Tests & Model Evaluation

3.7.1 Stationarity Tests: Graphical Analysis

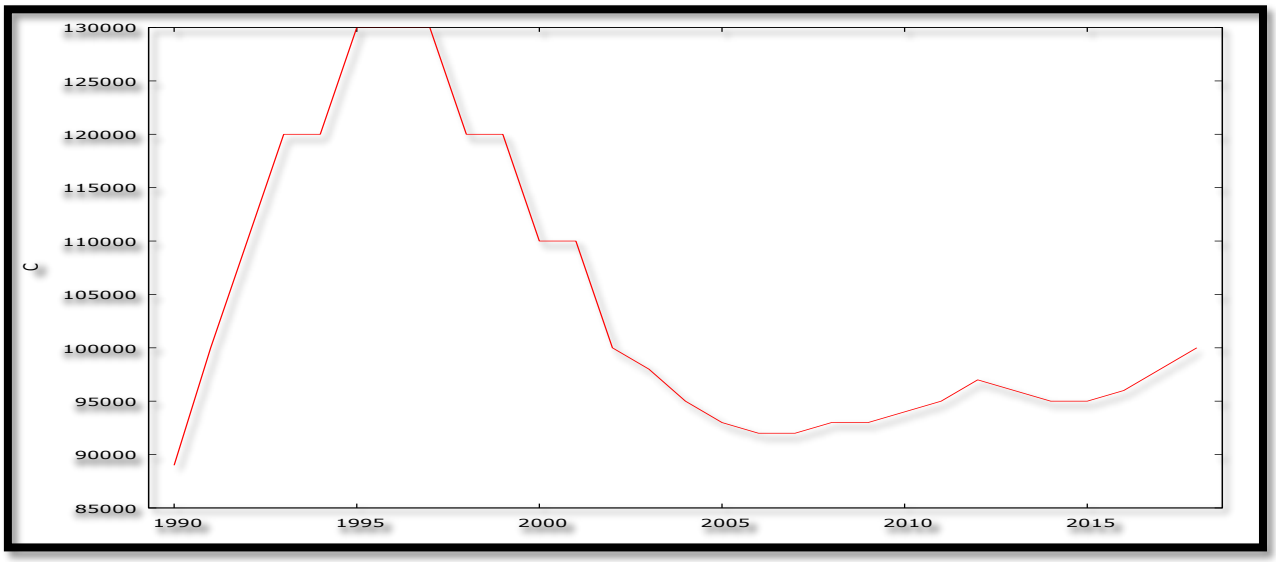

Figure 1

3.7.2 The Correlogram in Levels

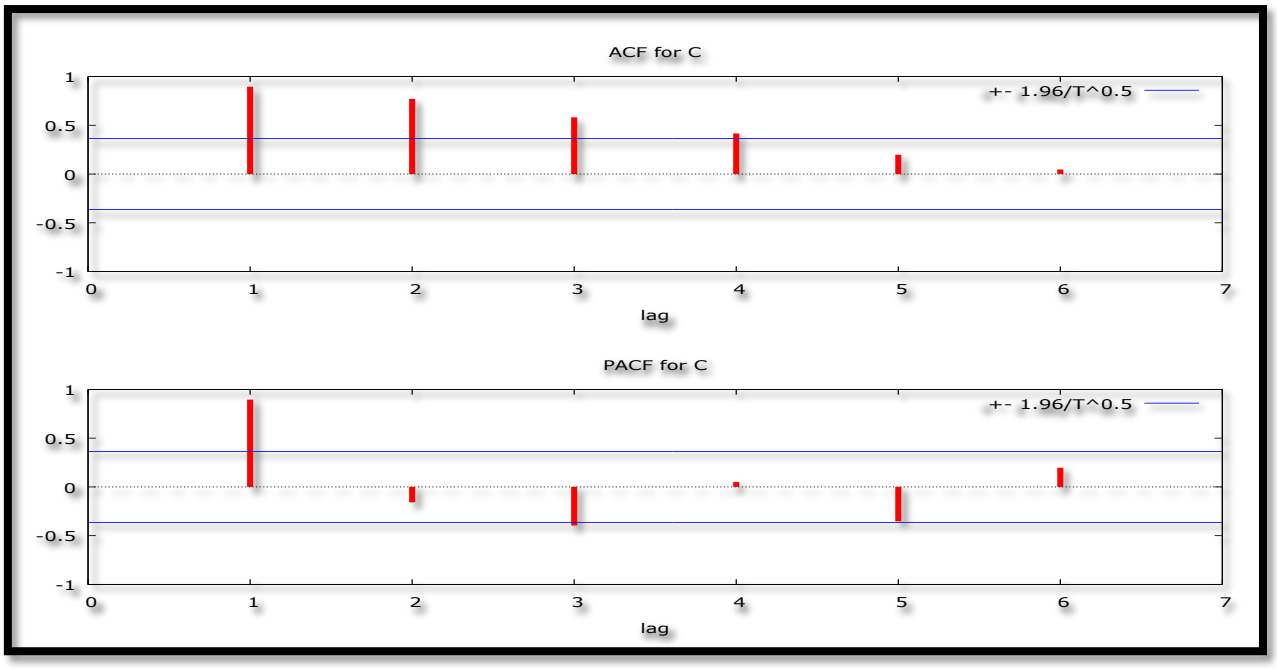

Figure 2: Correlogram in Levels

3.7.3 The ADF Test in Levels

Table 1: without trend and intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
C	-1.124305	0.2288	-2.674290	@1%	Non-stationary
			-1.957204	@5%	Non-stationary
			-1.608175	@10%	Non-stationary

Table 1 shows that C is not stationary in levels as suggested by figures 1 and 2.

3.7.4 The Correlogram (at First Differences)

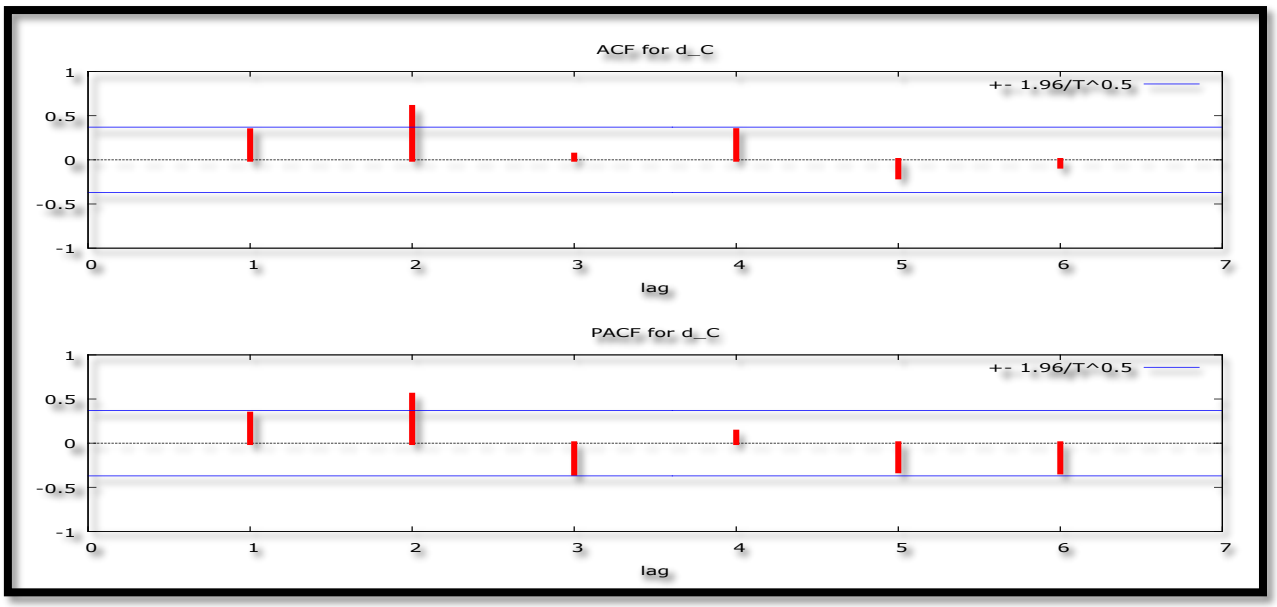

Figure 3: Correlogram (at First Differences)

3.7.5 The ADF Test (at First Differences)

Table 2: without trend and intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔC	-2.942550	0.0050	-2.660720	@1%	Stationary
			-1.955020	@5%	Stationary
			-1.609070	@10%	Stationary

Figure 3 and table 2 indicate that C is an I (1) variable.

3.7.6 Evaluation of ARIMA models (without a constant)

Table 7: Evaluation of ARIMA Models (without a constant)

Model	AIC	U	ME	RMSE	MAPE
ARIMA (2, 1, 2)	547.2474	0.66365	135.29	3852.3	2.6285
ARIMA (2, 1, 0)	**545.1566**	0.67583	-3.1659	3968.9	2.5255
ARIMA (2, 1, 1)	545.2691	0.66443	122.85	3854.9	2.6322
ARIMA (0, 1, 1)	561.0487	0.95705	348.11	5064.8	3.041
ARIMA (0, 1, 2)	549.4155	0.75538	315.2	4311.8	2.617
ARIMA (1, 1, 1)	556.2444	0.82412	47.351	4614.8	3.0369
ARIMA (1, 1, 0)	558.7931	0.9056	270.03	4907.6	3.1002

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 (2, 1, 0) model is finally chosen.

3.8 Residual & Stability Tests

3.8.1 Correlogram of the Residuals of the ARIMA (2, 1, 0) Model

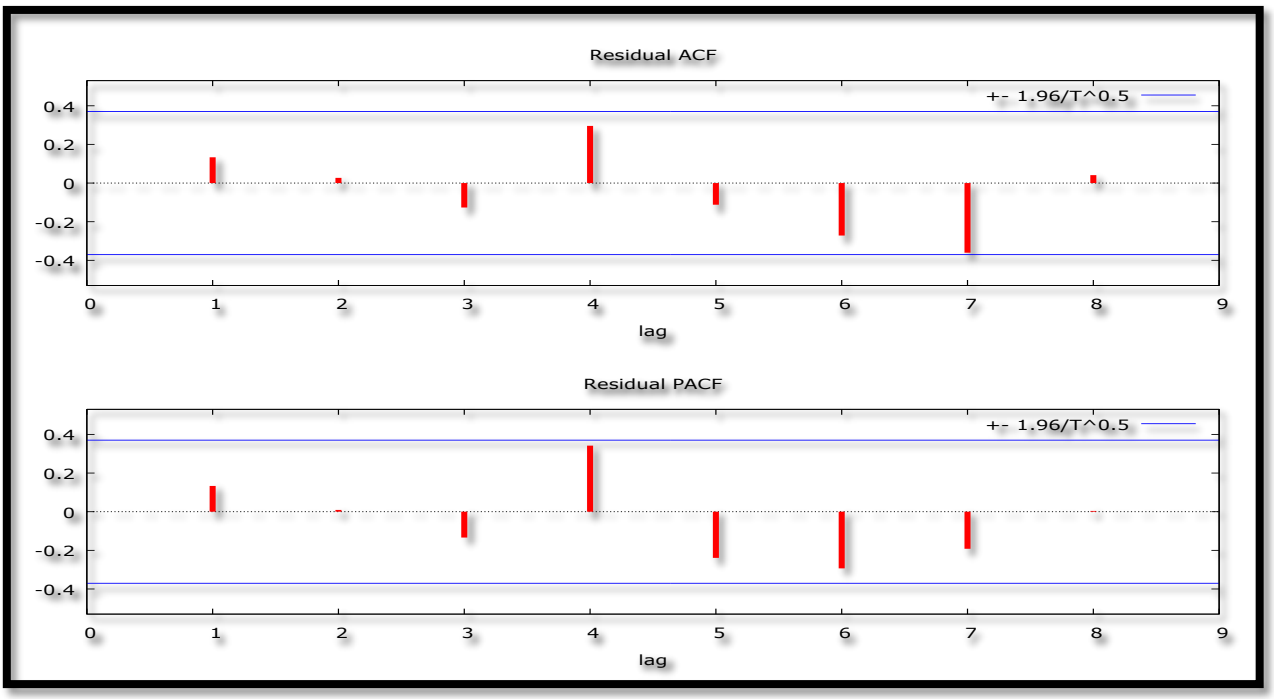

Figure 4: Correlogram of the Residuals

Figure 4 indicates that the estimated optimal ARIMA (2, 1, 0) 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 study.

3.8.2 Stability Test of the ARIMA (2, 1, 0) Model

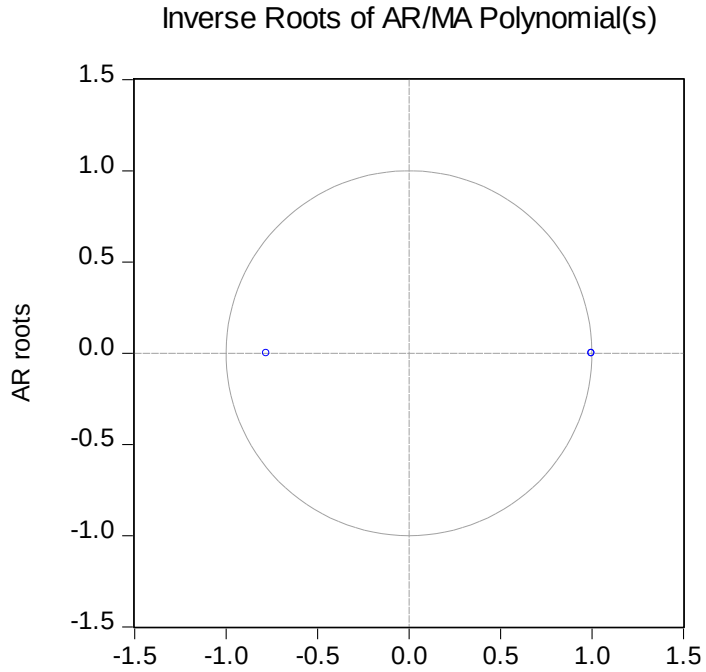

Figure 5: Inverse Roots

Since all the AR roots basically lie inside the unit circle, it implies that the estimated ARIMA process is (covariance) stationary; thus confirming that the ARIMA (2, 1, 0) model is stable.

FINDINGS

4.1 Descriptive Statistics

Table 3: Descriptive Statistics

Description	Statistic
Mean	103830
Median	98000
Minimum	89000
Maximum	130000

Over the study period, the annual average number of new HIV infections in adults in Nigeria is 103830 new infections. The minimum number of new infections is 89000 and that was observed in 1990 while the maximum number of new infections is 130000 new infections and has been observed for 3 consecutive years; that is 1995 – 1997.

4.2 Results Presentation

Table 4: Main Results

ARIMA (2, 1, 0) Model:

Guided by equation [4], the chosen optimal model, the ARIMA (2, 1, 0) model can be expressed as follows:

$$\Delta C_t = 0.186705\Delta C_{t-1} + 0.690247\Delta C_{t-2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [5]$$

Variable	Coefficient	Standard Error	z	p-value
β_1	0.186705	0.126887	1.471	0.1412
β_2	0.690247	0.133923	5.154	0.0000***

Table 4 shows the main results of the ARIMA (2, 1, 0) model.

Forecast Graph

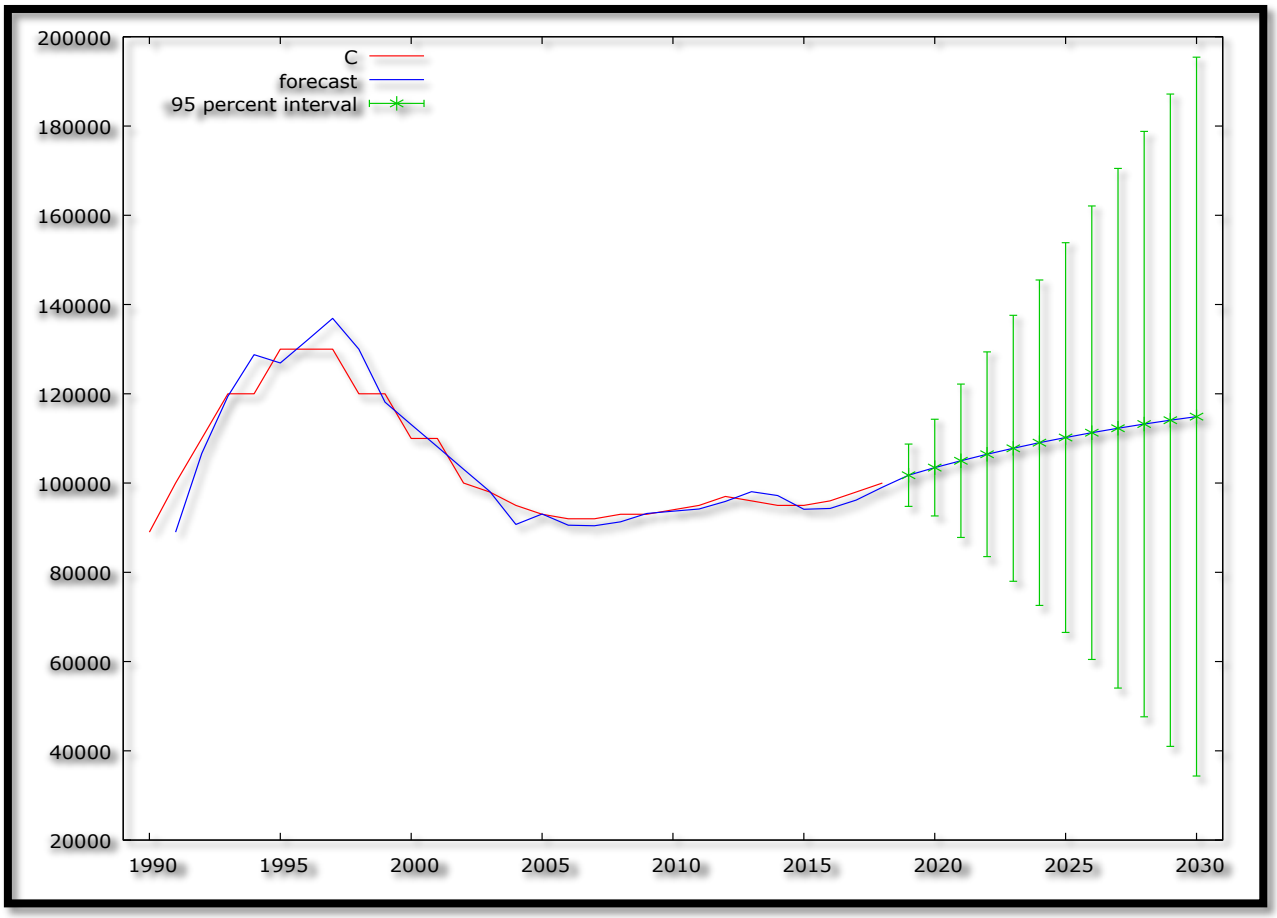

Figure 6: Forecast Graph – In & Out-of-Sample Forecasts

Figure 6 shows the in-and-out-of-sample forecasts of the C series. The out-of-sample forecasts cover the period 2019 – 2030.

Predicted C– Out-of-Sample Forecasts Only

Table 5: Predicted

Year	Prediction	Standard Error	95% Confidence Interval
2019	101754.	3560.60	(94775.3, 108733.)
2020	103462.	5525.55	(92632.0, 114292.)
2021	104991.	8767.53	(87807.3, 122175.)
2022	106456.	11700.5	(83523.2, 129388.)
2023	107785.	15202.2	(77989.3, 137581.)
2024	109044.	18602.2	(72584.4, 145504.)
2025	110197.	22279.8	(66528.9, 153864.)
2026	111281.	25922.1	(60474.5, 162087.)
2027	112279.	29700.9	(54066.0, 170492.)
2028	113213.	33462.1	(47628.9, 178798.)
2029	114077.	37285.0	(40999.6, 187154.)
2030	114883.	41090.4	(34347.4, 195419.)

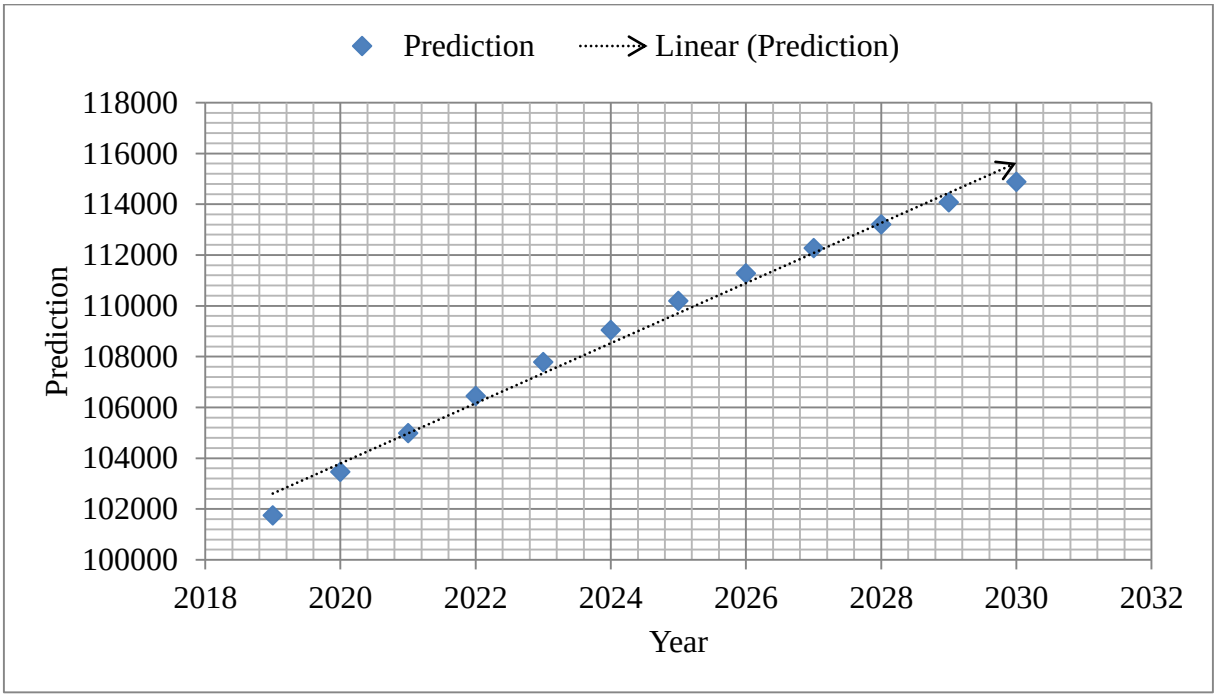

Figure 7: Graphical Analysis of Out-of-Sample Forecasts

Table 5 and figure 7 show the out-of-sample forecasts only. The number of new HIV infections in Nigeria is projected to rise from 101754 in 2019 to about 114883 new infections by 2030. This is attributed to the fact that knowledge on HIV prevention has not resulted into appreciable attitudinal change and behavior modification among Nigerians (Onah et al., 2004; Ogbuji, 2005; Ayodele & Ayodele, 2016; Chukwujekwu et al., 2017; Badru et al., 2020). The findings of this study are in line with the NACA (2014) which has

noted that in Nigeria, the HIV epidemic is spreading at a disturbing rate with sero-prevalence of approximately 3% per year. According to Odutolu et al. (2006), the HIV epidemic in Nigeria has remained unabated.

CONCLUSION

The study shows that the ARIMA (2, 1, 0) model is not only stable but also the most suitable model to forecast the annual number of new HIV infections in Nigeria over the period 2019 – 2030. The model predicts a possible increase in the annual number of new HIV infections in adults in the country. These findings are essential for the government of Nigeria, especially for long-term planning with regards to HIV/AIDS interventions. The study recommends that the federal government of Nigeria ought to seriously intensify HIV prevention and treatment activities throughout the country. Special emphasis on behavior change interventions such as increased condom use and reduction of sexual partners ought to be made as well. There is need for massive country-wide educational campaigns on HIV knowledge. Public health policy makers ought to strengthen HIV, TB, and Sexual & Reproductive Health programme linkages around the country. It is also advisable for the federal government of Nigeria to scale up voluntary medical male circumcision as an additional HIV prevention strategy. This will go a long way in reducing new HIV infections in the country.

REFERENCES

[1] Avert (2017). History of HIV, Avert, Lagos.
[2] Avert (2018). HIV Around the World, Avert, New York.
[3] Awofala, A. A., & Ogundele, O. E. (2018). HIV Epidemiology in Nigeria, Saudi Journal of Biological Sciences, 25: 697 – 703.
[4] 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.
[5] Ayodele, O., & Ayodele, O. M. (2016). Urban-Rural Differentials in HIV/AIDS Knowledge of Nigerian Senior Secondary School Students, International Journal of Health Sciences, 4 (3): 35 – 41.
[6] Badru, T., et al. (2020). HIV Comprehensive Knowledge and Prevalence Among Young Adolescents in Nigeria: Evidence From Akwa Ibom AIDS Indicator Survey, 2017, BMC Public Health, 20 (45): 1 – 10.
[7] Chukwujekwu, E. O., et al. (2017). Behavioural and Sexual Practices of HIV Infected Southwestern Nigerians: Implications for HIV Prevention and Control in the Country, Journal of Prevention & Treatment of HIV/AIDS, 2 (1): 1 – 5.

[8] Entonu, P. E., & Agwale, S. M. (2007). A Review of the Epidemiology, Prevention and Treatment of Human Immunodeficiency Virus Infection in Nigeria, The Brazilian Journal of Infectious Diseases, 11 (6): 579 – 590.

[9] Eze, J. I. (2009). Modeling HIV/AIDS Epidemic in Nigeria, PhD Thesis, University of Glasgow.

[10] Fagbamigbe, A. F., et al. (2016). Marital Status and HIV Prevalence Among Women in Nigeria: Ingredients for Evidence-based Programming, International Journal of Infectious Diseases, 48: 57 – 63.

[11] Federal Ministry of Health (2004). National Seroprevalence Sentinel Survey, Federal Ministry of Health, Lagos.

[12] NACA (2014). Nigeria Prevalence Rate, NACA, Lagos.

[13] Nasidi, A., & Harry, T. O. (2006). The Epidemiology of HIV/AIDS in Nigeria, Harvard Center for Population and Development Studies, Cambridge.

[14] NSP (2010). National AIDS Strategic Plan (2010-2015), ILO, Geneva.

[15] Nyoni, T (2018b). Modeling and Forecasting Inflation in Kenya: Recent Insights from ARIMA and GARCH analysis, Dimorian Review, 5 (6): 16 – 40.

[16] 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.

[17] Nyoni, T. (2018c). Box – Jenkins ARIMA Approach to Predicting net FDI inflows in Zimbabwe, MPRA Paper No. 87737, University Library of Munich, Munich, Germany.

[18] Odutolu, O., et al. (2006). The National Response to HIV/AIDS, Harvard University Press, Boston.

[19] Ogbuji, C. O. (2005). Knowledge About HIV/AIDS and Sexual Practice Among University of Ibadan Students, African Journal of Medical Sciences, 34 (1): 25 – 31.

[20] Ogbuji, C. O. (2005). Knowledge About HIV/AIDS and Sexual Practice Among University of

[21] Onah, H. E., et al. (2004). HIV/AIDS Awareness and Sexual Practice Among Undergraduates in Enugu Nigeria, Nigeria Postgraduate Medical Journal, 11 (2): 121 – 125.

[22] UNAIDS (2013). HIV and Aging, UNAIDS, Geneva.

[23] UNAIDS (2014a). Orphans and Vulnerable Children Affected by HIV and AIDS, UNAIDS, New York.

[24] UNAIDS (2016). Prevention Gap Report, UNAIDS, New York.

[25] WHO (2017). HIV/AIDS in Nigeria, WHO, Geneva.