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ADULTS NEWLY INFECTED WITH HIV IN ZIMBABWE: 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 Ghana 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 employs the Box-Jenkins ARIMA methodology. The diagnostic ADF tests show that the D series under consideration is an I (1) variable. Using the AIC as the best model evaluation criteria, the study presents the ARIMA (1, 1, 2) model as the optimal model. The diagnostic tests further reveal that the presented model is stable and its residuals are not serially correlated but rather normally distributed. The results of the study indicate that the number of new HIV infections in adults will slightly rise from the estimated 16818 new infections in 2019 to almost 17814 new infections by 2030. On this trajectory, Ghana cannot achieve her ambitious goal of ending the HIV epidemic by 2030. The study generally recommends that the government of Ghana should scale up HIV prevention and treatment access; with special emphasis on behavior change interventions such as increased condom use and reduction of sexual partners.

INTRODUCTION
AIDS, the acquired immunodeficiency syndrome, is a fatal disease caused by HIV, the human immunodeficiency virus. HIV destroys the body's ability to fight off infection and disease, which can ultimately lead to death. 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). The first 42 cases of HIV in Ghana were recorded in 1986, mainly among women who had travelled outside the country (Ghana AIDS Commission, 2000). Today the HIV epidemic in the country is mature (Ghana AIDS Commission, 2016) and mixed (Dutta et al., 2013) and the number of people living with HIV is still very high (Abrefa-Gyan et al., 2015). In fact, the prevalence of HIV in Ghana is approximately 2% and this is quite very high (Ghana AIDS Commission, 2016; Fenny et al., 2017; Agyeman-Duah et al., 2018; Osei-Yeboah et al., 2018; Ali et al., 2019). In Ghana, the dominant mode of HIV transmission is sexual and naturally from mother to child (Agyeman-Duah et al., 2018). HIV prevalence is higher in adults than in children in Ghana (Anokye et al., 2019): in 2013 alone, 189930-206280 adults as compared to 34560-36250 children living with HIV (Dutta et al., 2013). Adults are at high risk of HIV infection precisely due to risky sexual behaviours, attitudes and constraints of the society in which they grew up (Oppong & Oti-Boadi, 2013). The main objective of this study is to predict the number of adults newly infected with HIV in Ghana over the period 2019 – 2030. This study will go a long way in assessing the possibility of ending the HIV scourge in the country.

LITERATURE REVIEW
Oppong & Oti-Boadi (2013) evaluated HIV/AIDS knowledge among undergraduate students and how it can be used in HIV prevention strategies in Ghana. A cross-sectional study was conducted using structured questionnaires among 324 conveniently selected students enrolled at a tertiary institution in Accra, Ghana. The study results indicated that students were less knowledgeable about the causative agent of AIDS and that the majority of students had not received any information about HIV/AIDS from their parents. Consistently, Fenny et al (2017) examined the trends and distribution in comprehensive knowledge of HIV/AIDS and determined the factors associated with comprehensive awareness of HIV/AIDS among adult women and men. A logistic regression model was applied for multivariate analysis. The study showed that there was a significant decrease in comprehensive HIV knowledge from 72% in 2008 to 59% in 2013.

Oppong & Oti-Boadi (2013) and Fenny et al. (2017) ironically tell us that Ghana HIV infections could increase in future given the lack of adequate knowledge on the disease. However, these studies did not project the trends of new HIV infections in the country. Recently, Agyeman-Duah et al. (2018) carried out a 5-year retrospective study in order to examine the socio-demographic and economic characteristics of people living with HIV/AIDS. The study results showed that HIV/AIDS is still on a sharp increase in Ghana with HIV type 1 expressing a high incidence of 84% with the least prevalence being HIV type 2 (6%). Just like other previous studies, Agyeman-Duah (2018) did not project future trends in new HIV infections in the country. This paper is the first of its kind in Ghana and is expected to assist public health policy makers in ending the HIV epidemic in Ghana.

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 D series under consideration.

3.2 The Moving Average (MA) model

Given:

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

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). D is the annual number of adults newly infected with HIV in Ghana 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:

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

Where $\beta_1 \ldots \beta_p$ are estimation parameters, $D_{t-1} \ldots D_{t-p}$ are previous period values of the D 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:

$$D_t = \sum_{i=1}^{p} \beta_i D_{t-i} + \sum_{i=1}^{q} \alpha_i \mu_{t-i} + \mu_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [3]$$

3.5 The Autoregressive Integrated Moving Average (ARIMA) model

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

$$\Delta^d D_t = \sum_{i=1}^{p} \beta_i \Delta^d D_{t-i} + \sum_{i=1}^{q} \alpha_i \mu_{t-i} + \mu_t \quad [4]$$

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 D] in Ghana. 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

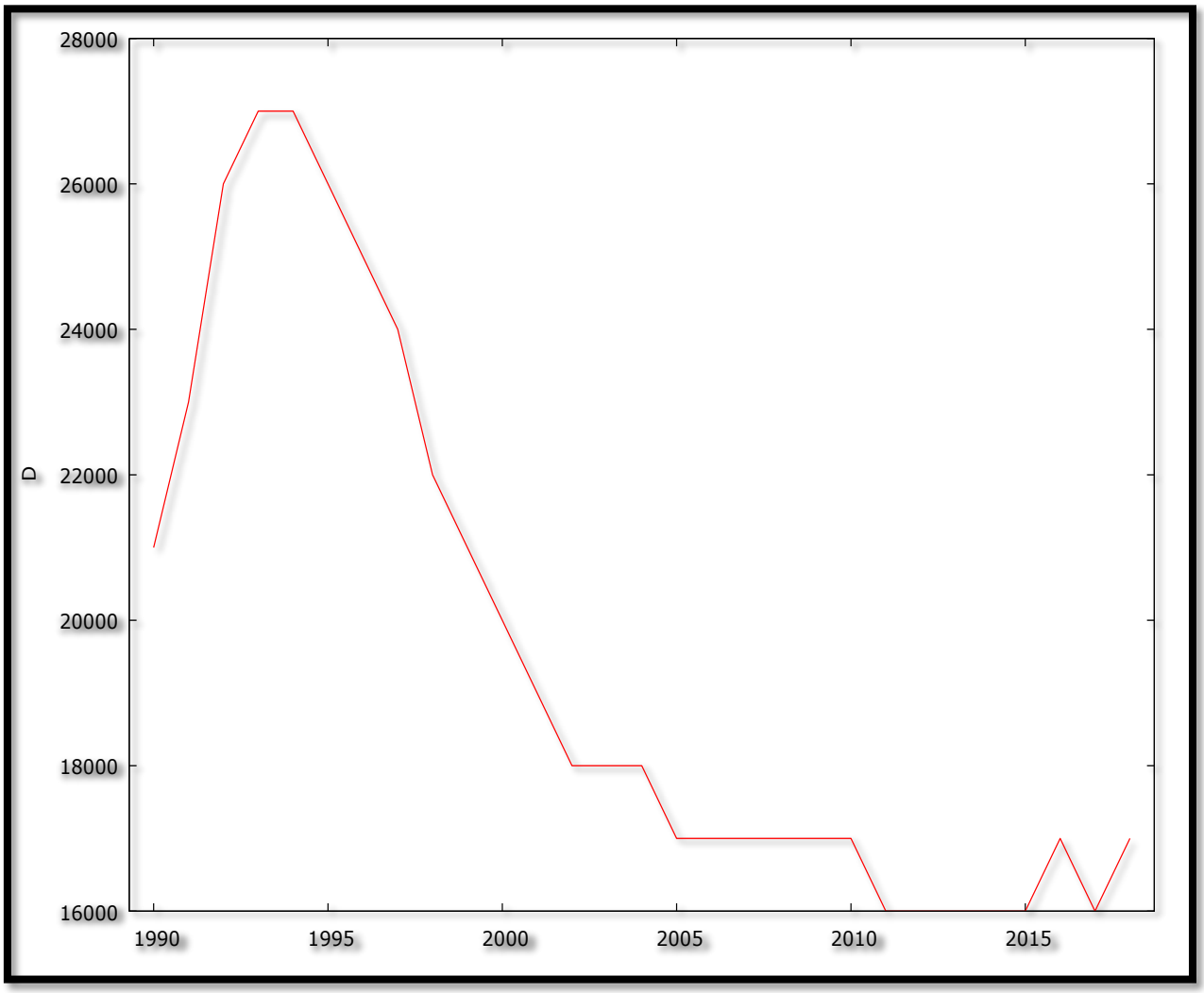

Figure 1

3.7.2 The Correlogram in Levels

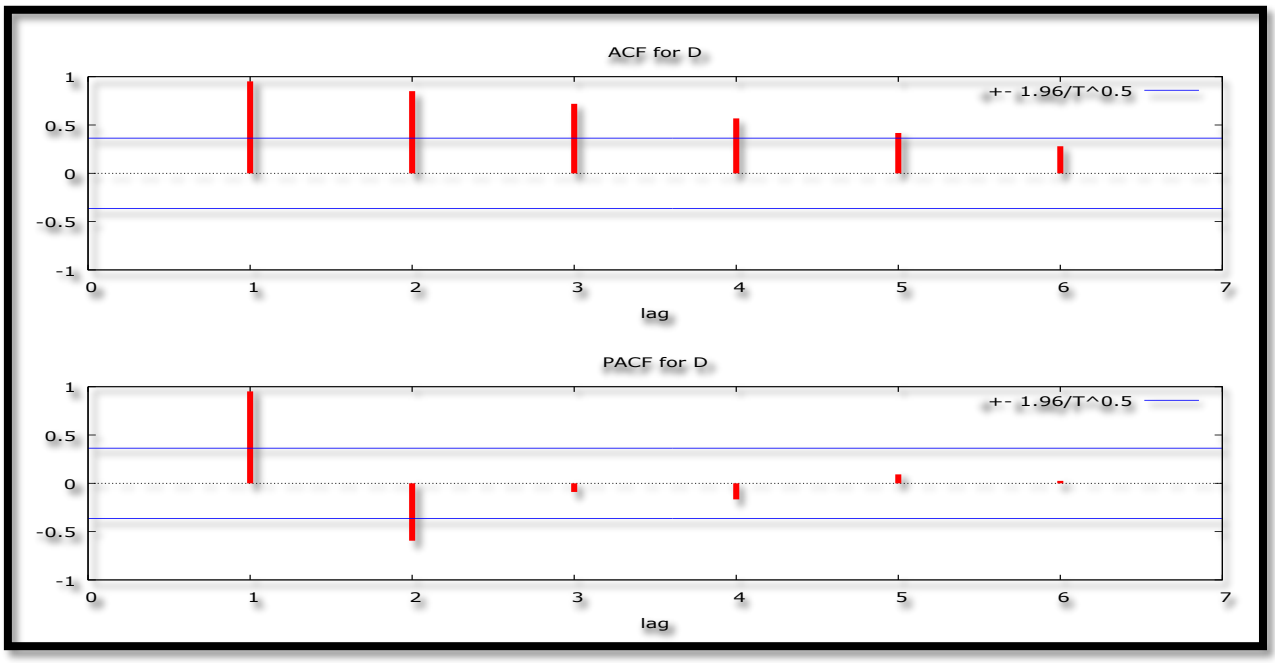

Figure 2: Correlogram in Levels

3.7.3 The ADF Test in Levels

Table 1: without trend and intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
D	-0.826061	0.3491	-2.650145	@1%	Non-stationary
			-1.953381	@5%	Non-stationary
			-1.609798	@10%	Non-stationary

Table 1 shows that D is not stationary in levels; as already indicated in figures 1 and 2.

3.7.4 The Correlogram (at First Differences)

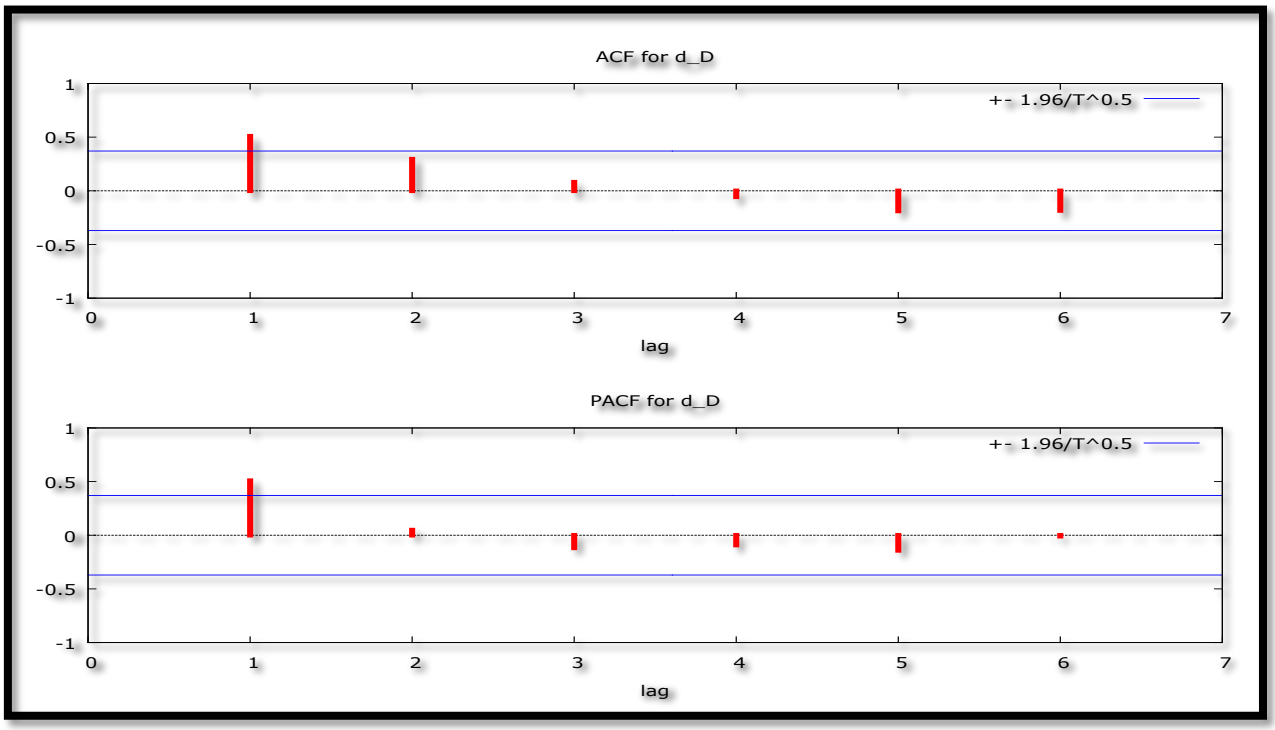

Figure 3: Correlogram (at First Differences)

3.7.5 The ADF Test (at First Differences)

Table 2: without trend and intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔD	-2.239284	0.0271	-2.669359	@1%	Non-stationary
			-1.956406	@5%	Stationary
			-1.608495	@10%	Stationary

Figure 3 and table 2 indicate that D 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, 1)	462.5016	0.88635	-30.659	867.23	3.2342
ARIMA (0, 1, 1)	465.0100	0.95066	-76.074	922.53	3.4136
ARIMA (1, 1, 2)	**462.3662**	0.84275	-21.205	860.79	3.3792
ARIMA (2, 1, 1)	463.5209	0.86689	-30.873	861.66	3.3575
ARIMA (0, 1, 2)	463.9176	0.9071	-64.057	879.47	3.3923

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

3.8 Residual & Stability Tests

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

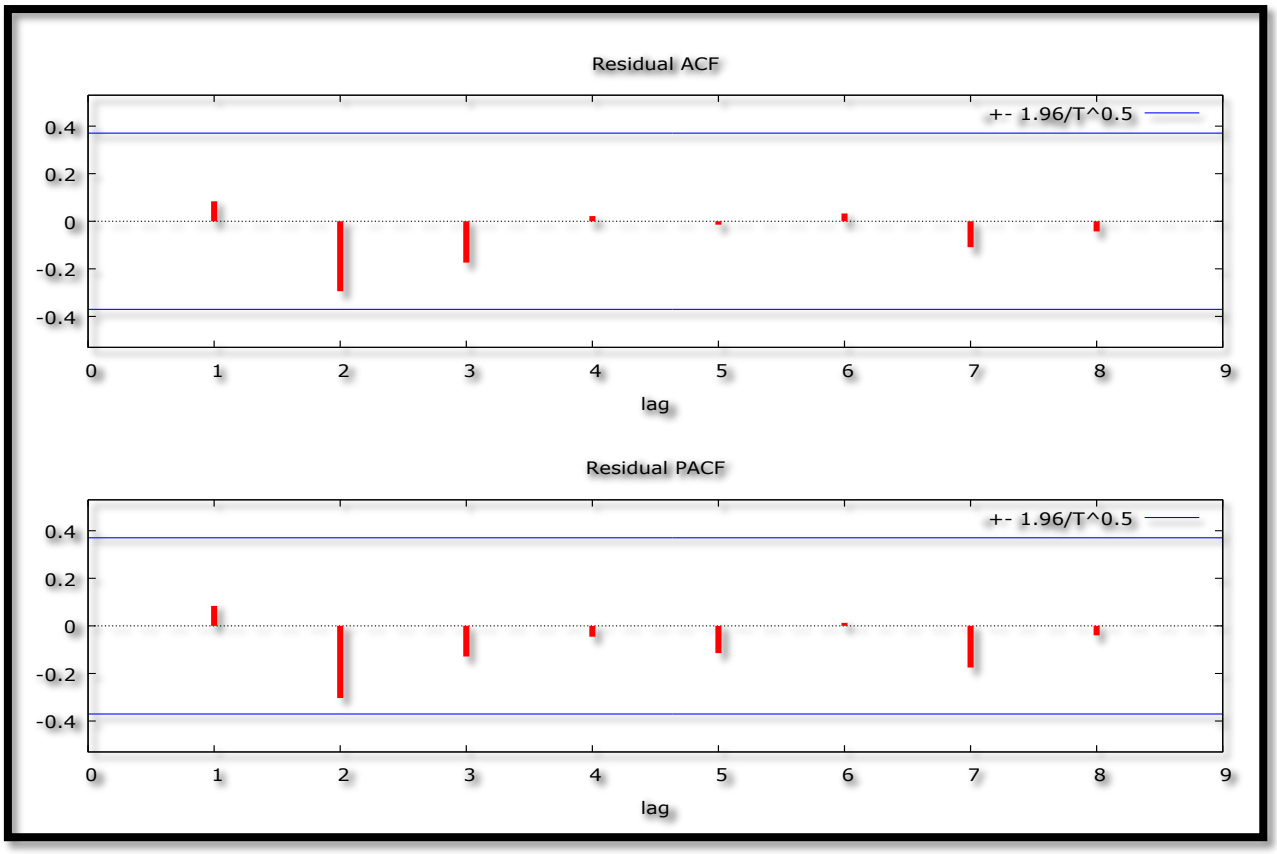

Figure 4: Correlogram of the Residuals

Figure 4 indicates that the estimated optimal ARIMA (1, 1, 2) 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 Normality Test of the Residuals of the ARIMA (1, 1, 2) Model

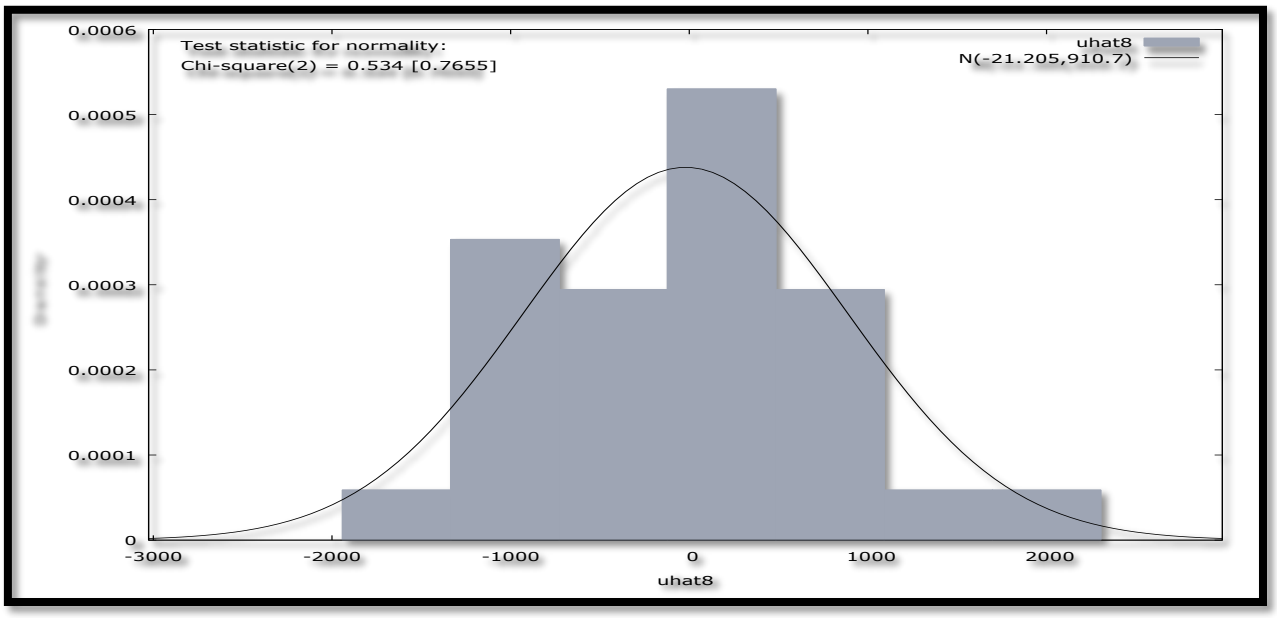

Figure 5: Normality Test

Since the probability value of the chi-square statistic is insignificant, we reject the null hypothesis and conclude that the residuals of the ARIMA (1, 1, 2) model are normally distributed.

FINDINGS

4.1 Descriptive Statistics

Table 4: Descriptive Statistics

Description	Statistic
Mean	19552
Median	18000
Minimum	16000
Maximum	27000

Over the study period, the annual average number of new infections in adults in the country is 19552 new infections. This is a serious warning signal for policy makers in Ghana with regards to the fight against HIV/AIDS. The minimum number of new HIV infections in adults was 16000 while the maximum was 27000. These huge numbers of new HIV infections are a wake up call for public health researchers in the country.

4.2 Results Presentation

Table 5: Main Results

ARIMA (1, 1, 2) Model:

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

$$\Delta D_t = 0.724050\Delta D_{t-1} - 0.340923\mu_{t-1} + 0.487110\mu_{t-2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [5]$$

Variable	Coefficient	Standard Error	z	p-value
β_1	0.724050	0.191682	3.777	0.0002***
α_1	-0.340923	0.199749	-1.707	0.0879*
α_2	0.487110	0.197247	2.470	0.0135**

Table 9 shows the main results of the ARIMA (1, 1, 2) model.

Forecast Graph

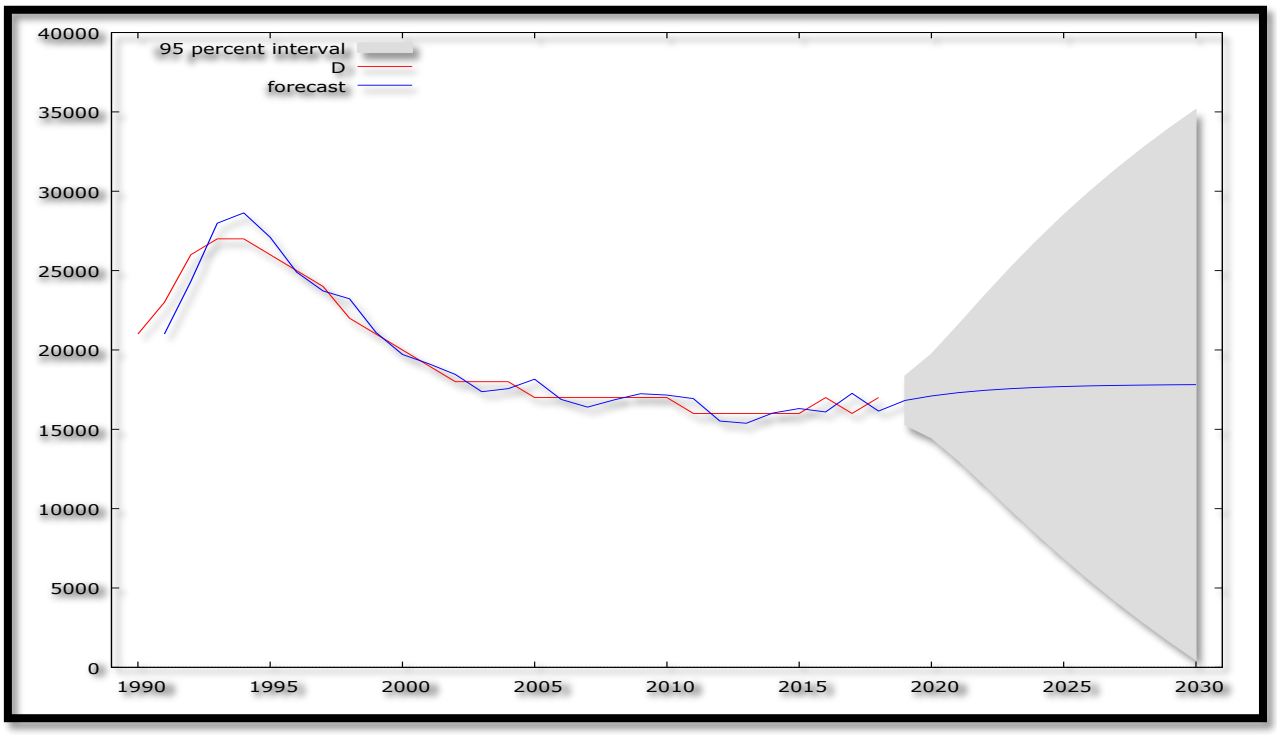

Figure 6: Forecast Graph – In & Out-of-Sample Forecasts

Figure 6 shows the in-and-out-of-sample forecasts of the D series. The out-of-sample forecasts cover the period 2018 – 2030.

Predicted D– Out-of-Sample Forecasts Only

Table 6: Predicted

Year	Prediction	Standard Error	95% Confidence Interval
2019	16817.7	788.820	(15271.7, 18363.8)
2020	17100.7	1346.33	(14461.9, 19739.4)
2021	17305.5	2163.93	(13064.3, 21546.8)
2022	17453.9	3036.88	(11501.7, 23406.1)
2023	17561.3	3900.00	(9917.41, 25205.1)
2024	17639.0	4729.69	(8369.01, 26909.1)
2025	17695.3	5517.65	(6880.95, 28509.7)
2026	17736.1	6262.21	(5462.39, 30009.8)
2027	17765.6	6964.80	(4114.87, 31416.4)
2028	17787.0	7628.17	(2836.05, 32737.9)
2029	17802.5	8255.61	(1621.76, 33983.2)
2030	17813.7	8850.46	(467.090, 35160.3)

Table 6 shows the out-of-sample forecasts only. The number of new HIV infections in adults in Ghana is projected to be around 17000 new infections per year over the period 2019 – 2030. The predicted increase in new HIV infections in adults in Ghana is not surprising but rather consistent with other previous studies such as Agyeman-Duah et al. (2018). This resurge in new HIV infections in adults in the country is being fueled by lack of comprehensive knowledge on HIV/AIDS (Oppong & Oti-Boadi, 2013; Fenny et al., 2017; Anokye et al., 2019). Therefore, there is need for intensified HIV/AIDS control and preventive measures in the country.

CONCLUSION

The study shows that the ARIMA (1, 1, 2) model is stable and suitable model to forecast the annual number of new HIV infections in adults in Ghana over the period 2019 – 2030. These findings are essential for the government of Ghana, especially for long-term strategic planning. The study recommends that the government of Ghana ought to intensify HIV prevention and treatment access; with special emphasis on behavior change interventions such as increased condom use and reduction of sexual partners. There is need for educational campaigns on HIV knowledge throughout the country. Ghana, being a low-circumcision country, should also scale up voluntary medical male circumcision as an additional HIV prevention strategy.

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