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PAEDIATRIC NEW HIV INFECTIONS IN NIGERIA: A BOX-JENKINS ARIMA APPROACH

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ABSTRACT
Using annual time series data on the number of children (ages 0 – 14) newly infected with HIV in Nigeria from 1990 – 2018, the study predicts the annual number of children who will be newly infected with HIV over the period 2019 – 2030. The paper applies the Box-Jenkins ARIMA methodology. The diagnostic ADF tests show that, M, the series under consideration is an I (2) variable. Based on the AIC, the study presents the ARIMA (0, 2, 1) model as the optimal model. The inverse root of the MA polynomial further reveals that the presented model is stable. The residual correlogram indicates that the residuals of the ARIMA (0, 2, 1) model are not serially correlated and furthermore, the normality test of the residuals of the applied model are also normally distributed; thus confirming its adequacy. The results of the study indicate that the number of new HIV infections in children is likely to continue on an upwards trajectory, over the period 2019 – 2030; from the estimated 25735 to approximately 44823 by 2030. The study basically recommends the government of Nigeria to intensively engage on PMTCT programmes amongst other measures.

1.0INTRODUCTION
Human Immunodeficiency Virus (HIV) has remained a global public health challenge since the epidemic began in 1970s (Avert, 2017). HIV is a retrovirus that infects cells of the immune system, destroying their function (Awoleye & Thron, 2015). 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). 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 (NSP, 2010).

There is an increase in the number of children infected with HIV in recent years as the number of HIV-positive women has increased (UNAIDS, 2006). More than 90% of HIV infections in children aged less than 15 years are due to mother-to-child transmission of HIV (Giaquinto et al., 1998; NSP, 2010). The number of children living with HIV in Nigeria increased from 150000 in 2001 to 220000 in 2007 (WHO, 2008). In 2014, approximately, 58000 new HIV infections occurred among children in Nigeria, making the country to be the largest harbourer of new childhood HIV infections among the 22 Global Plan Priority Countries committed to curbing HIV epidemics (UNAIDS, 2014; UNAIDS, 2015). Actually, Nigeria accounts for 30% of the global burden of mother-to-child transmission of HIV and 10% of pediatric HIV/AIDS. HIV accounts for 3% of deaths in under-fives in Nigeria and most deaths are from opportunistic infections (WHO, 2007). In many developed countries, testing, Antiretroviral Therapy (ART) and infant-feeding modifications have been used to eliminate mother-to-child transmission of HIV (Rukujei, 2007). In Nigeria, Prevention of Mother-To-Child Transmission (PMTCT) programme coverage is still very limited. In fact, only 4.7% of Antenatal Clinic (ANC) facilities in the country offer PMTCT services (WHO, 2011). The main goal of this study is to predict the number of children newly infected with HIV in Nigeria over the period 2019 – 2030. This study will go a long way in assisting health policy makers in ending pediatric HIV scourge in the country.

2.0 LITERATURE REVIEW

In an attempt to evaluate the awareness and knowledge of mother-to-child transmission of HIV/AIDS and the methods to prevent mother-to-child transmission of HIV, Adeleke et al. (2009) conducted a descriptive study at the pediatric HIV clinic of Aminu Kano Teaching Hospital. The study established that the level of knowledge and perceptions of mother-to-child transmission of HIV is still inadequate in the country. In another Nigerian study, Ayodele & Ayodele (2016) studied 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 calculated to describe variables of interest and one way ANOVA as employed to examine differences in the HIV/AIDS knowledge means scores. The research showed that there were misconceptions regarding HIV preventive measures, modes of transmission and treatment. More recently, Badru et al. (2020) investigated 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 employed. A multiple logistic regression as used to examine relationships with the study outcomes. Results of the paper showed that there was low comprehensive knowledge among young adolescents. No study has attempted to empirically predict 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 pediatric HIV prevention and control 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, M, the series under consideration.

3.2 The Applied Box – Jenkins ARIMA Model Specification

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

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

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 number of children newly infected with HIV (ages 0 – 14) [denoted as M] in Nigeria. 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 Stationarity Tests: Graphical Analysis

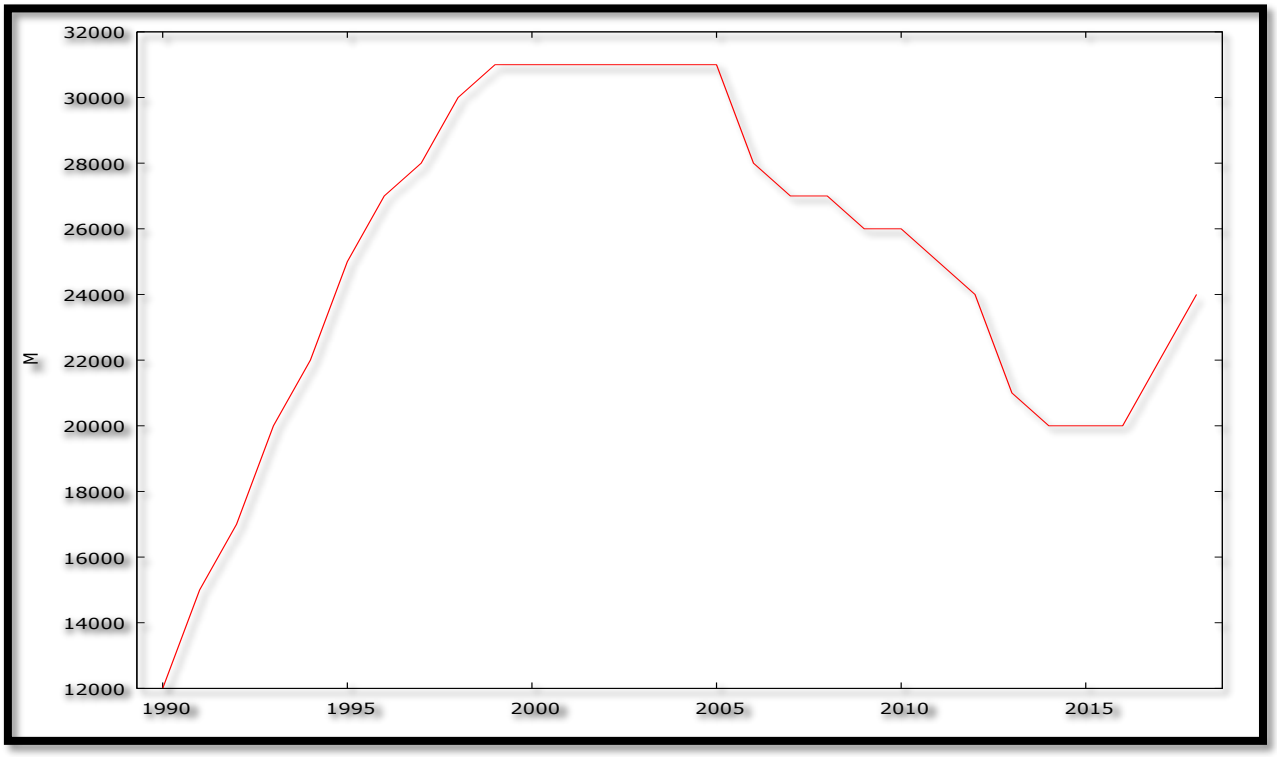

Figure 1

3.4.2 The Correlogram in Levels

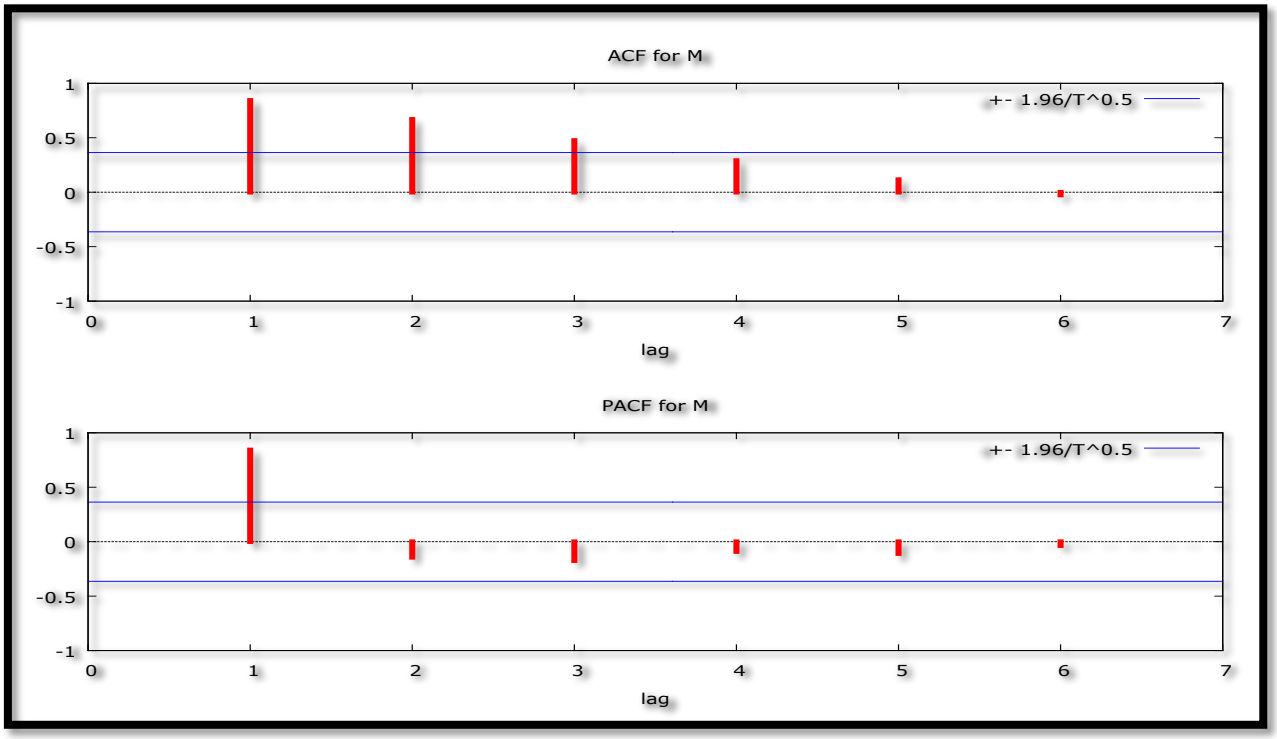

Figure 2: Correlogram in Levels

3.4.3 The ADF Test in Levels

Table 1: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
M	-2.131561	0.2346	-3.699871	@1%	Non-stationary
			-2.976263	@5%	Non-stationary
			-2.627420	@10%	Non-stationary

Table 1 shows that M is not stationary in levels. Figure 1 confirms the same, so do figure 2.

3.4.4 The Correlogram (at First Differences)

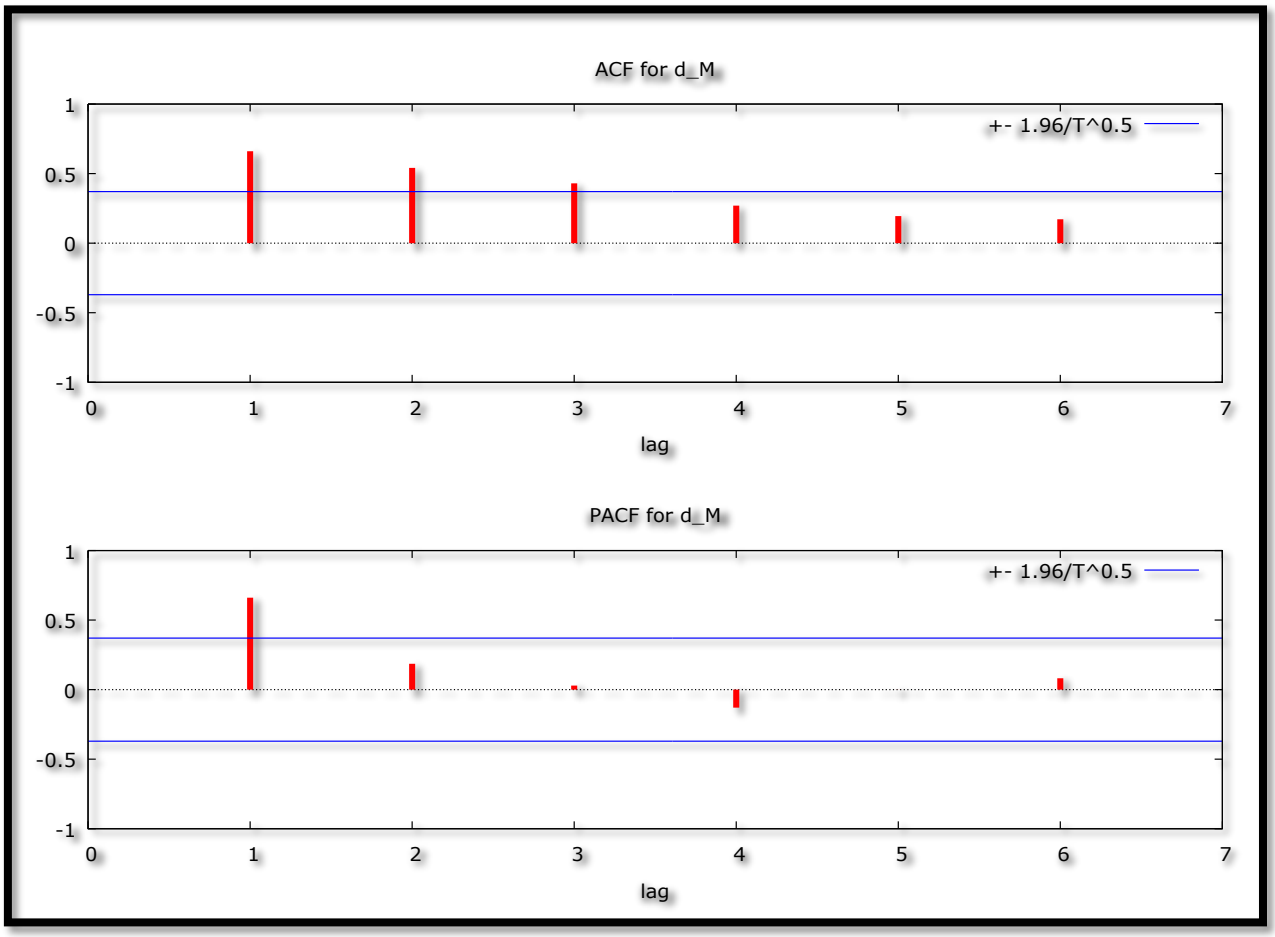

Figure 3: Correlogram (at First Differences)

3.4.5 The ADF Test (at First Differences)

Table 2: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔM	-2.309306	0.1764	-3.699871	@1%	Non-stationary
			-2.976263	@5%	Non-stationary
			-2.627420	@10%	Non-stationary

Figure 3 and table 2 indicate that M is not an I (1) variable. We, therefore, proceed to test for stationarity in second differences.

3.4.6 The Correlogram (at Second Differences)

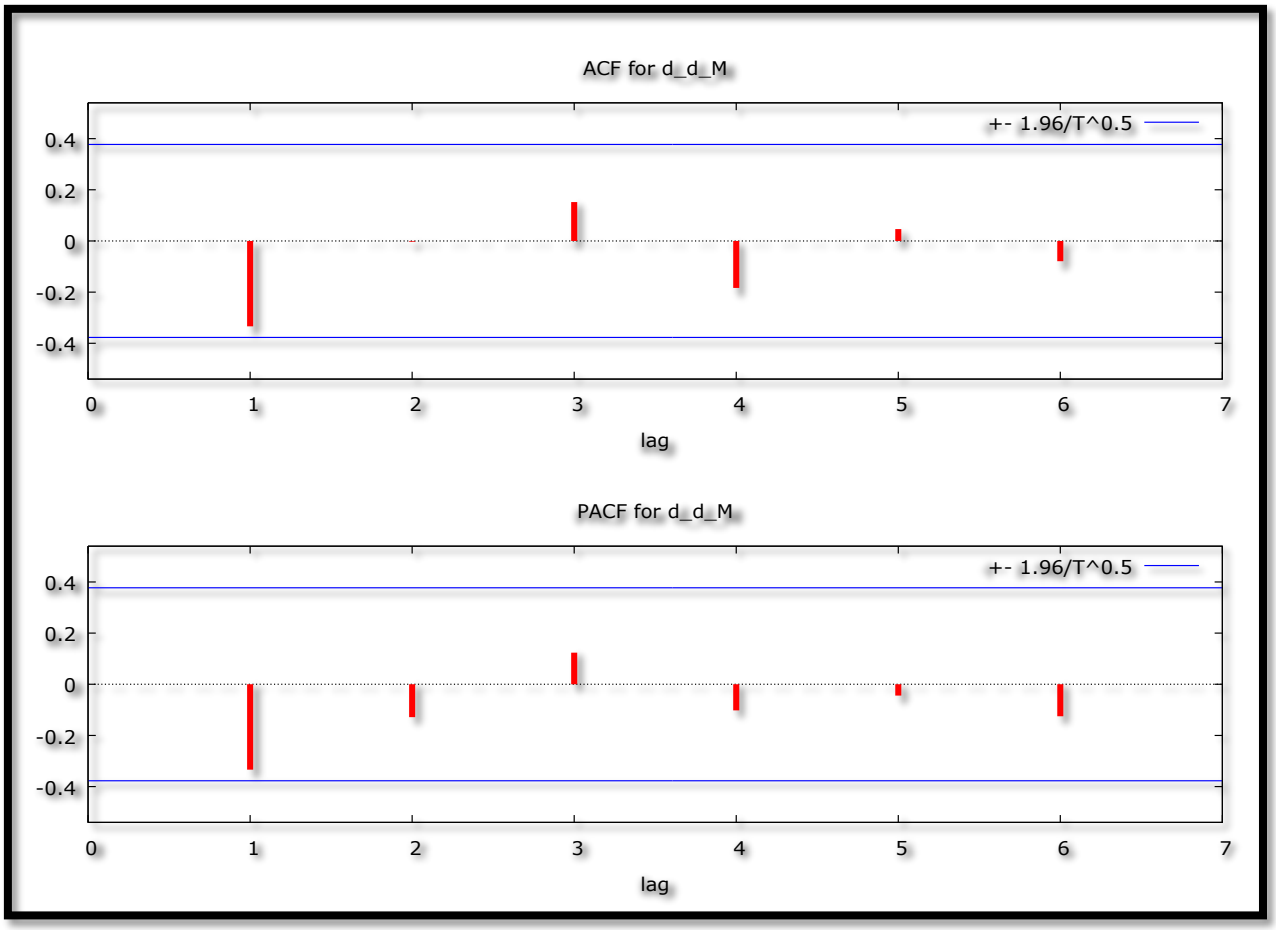

Figure 4: Correlogram (at Second Differences)

3.4.7 The ADF Test (at Second Differences)

Table 3: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
Δ^2M	-7.029058	0.0000	-3.711457	@1%	Stationary
			-2.981038	@5%	Stationary
			-2.629906	@10%	Stationary

Figure 4 and table 3 indicate that M is an I (2) variable.

3.4.8 Evaluation of ARIMA models (with a constant)

Table 4: Evaluation of ARIMA Models (without a constant)

Model	AIC	U	ME	RMSE	MAPE
ARIMA (1, 2, 1)	462.1717	0.66572	-62.167	1127.8	3.7188
ARIMA (1, 2, 0)	460.4206	0.6659	-49.246	1133.1	3.6952
ARIMA (1, 2, 2)	464.1384	0.66517	-54.409	1127.1	3.7059
ARIMA (2, 2, 1)	461.5145	0.6202	-54.201	1067.2	3.4596
ARIMA (0, 2, 1)	**460.2246**	0.66724	-69.942	1128.8	3.7462
ARIMA (2, 2, 0)	462.0014	0.66552	-63.617	1124.1	3.7133

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

3.5 Residual & Stability Tests

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

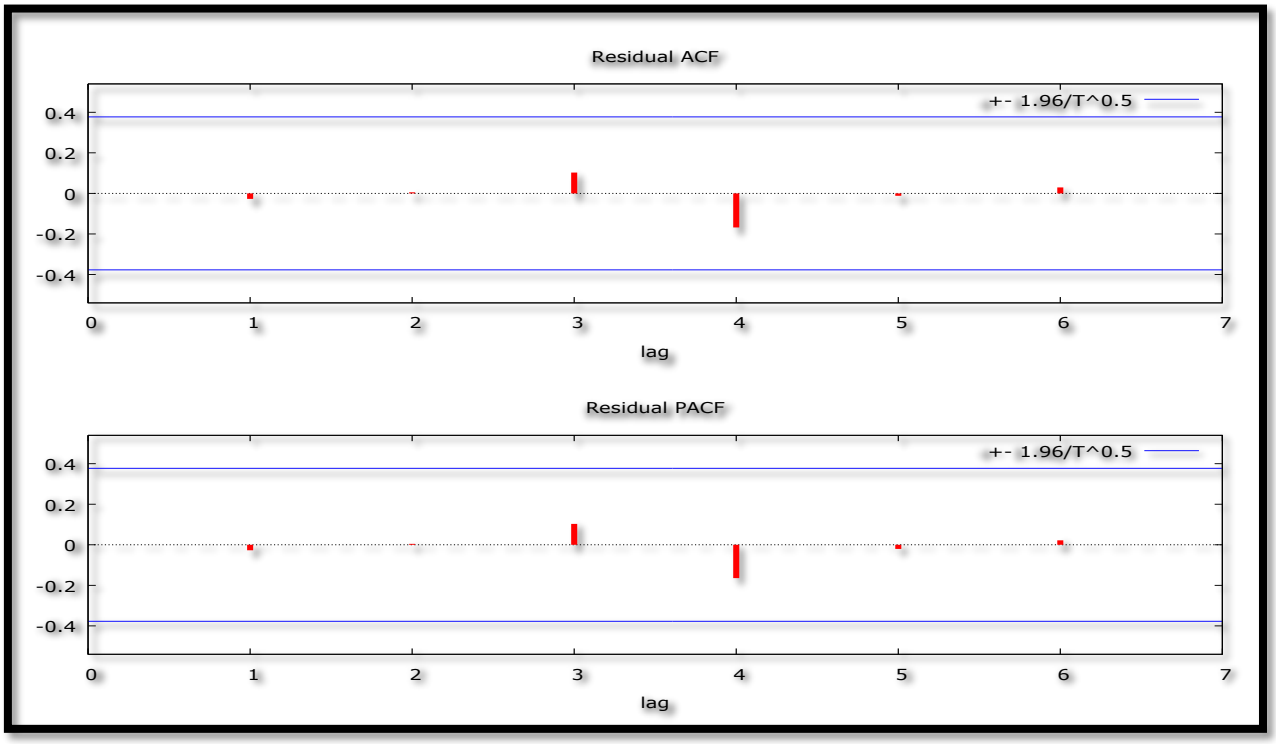

Figure 5: Correlogram of the Residuals

Figure 5 tells us that the estimated optimal model is adequate since ACF and PACF lags are quite short and within the bands.

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

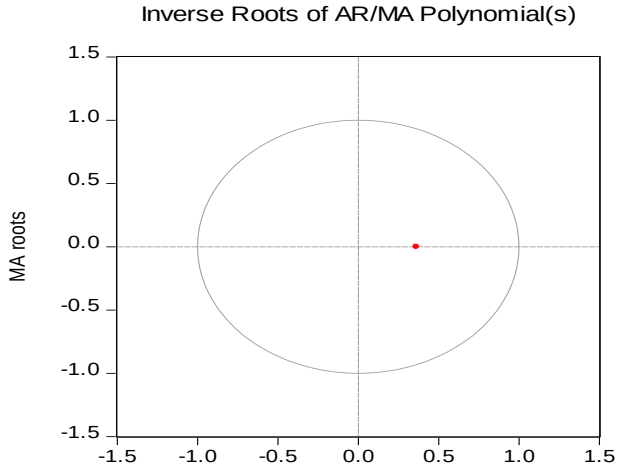

Figure 6: Inverse Roots

Since all the roots lie inside the unit circle, it implies that the estimated ARIMA process is (covariance) stationary; hence confirming that the ARIMA (0, 2, 1) model is stable and suitable for forecasting annual number of new pediatric HIV infections in Nigeria.

3.5.3 Normality Test of the Residuals of the ARIMA (0, 2, 1) Model

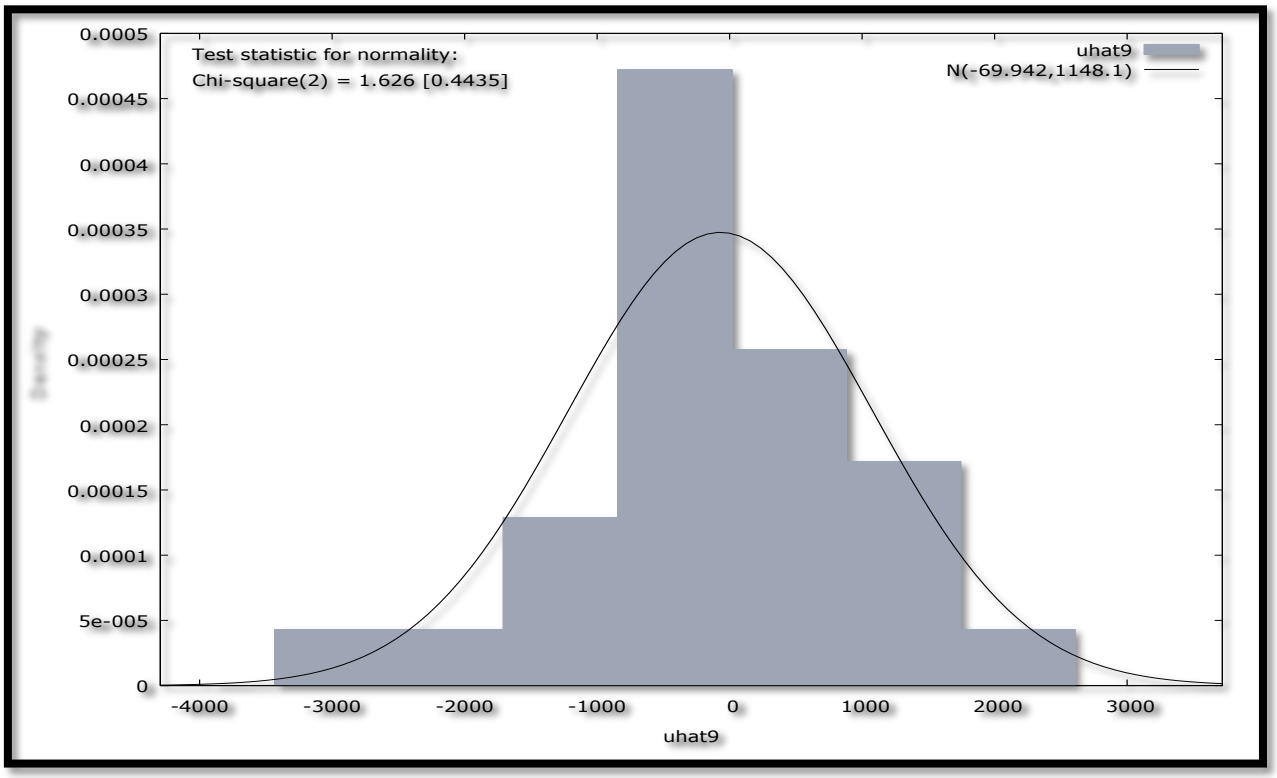

Figure 7: Normality Test

Since the probability value of the chi-square statistic is insignificant, we reject the null hypothesis and conclude that the residuals of the ARIMA (0, 2, 1) model are normally distributed.

4.0 FINDINGS OF THE STUDY

4.1 Descriptive Statistics

Table 5: Descriptive Statistics

Description	Statistic
Mean	24931
Median	26000
Minimum	12000
Maximum	31000

Over the study period, the annual average number of new HIV infections in adults in Nigeria is 24931 new infections. This is a serious warning signal for policy makers in Nigeria with regards to the need to prevent and control pediatric HIV infections. The minimum number of new HIV infections over the period under study is 12000 and as recorded in 1990 while the maximum is 31000 and as recorded over the period 1999 – 2005. Since then, new HIV

infections in Nigerian children has generally started to trend downwards. However, the years 2017 and 2018 saw resurgence in new pediatric HIV infections of 22000 and 24000 respectively.

4.2 Results Presentation

Table 6: Main Results

ARIMA (0, 2, 1) Model:				
The chosen optimal model, the ARIMA (0, 2, 1) model can be expressed as follows: $\Delta^2 M_t = -0.348843\mu_{t-1} \ldots \ldots \ldots$ [2]				
Variable	Coefficient	Standard Error	z	p-value
α_1	-0.348843	0.189693	-1.839	0.0659*

Table 6 shows the main results of the ARIMA (0, 2, 1) model.

Forecast Graph

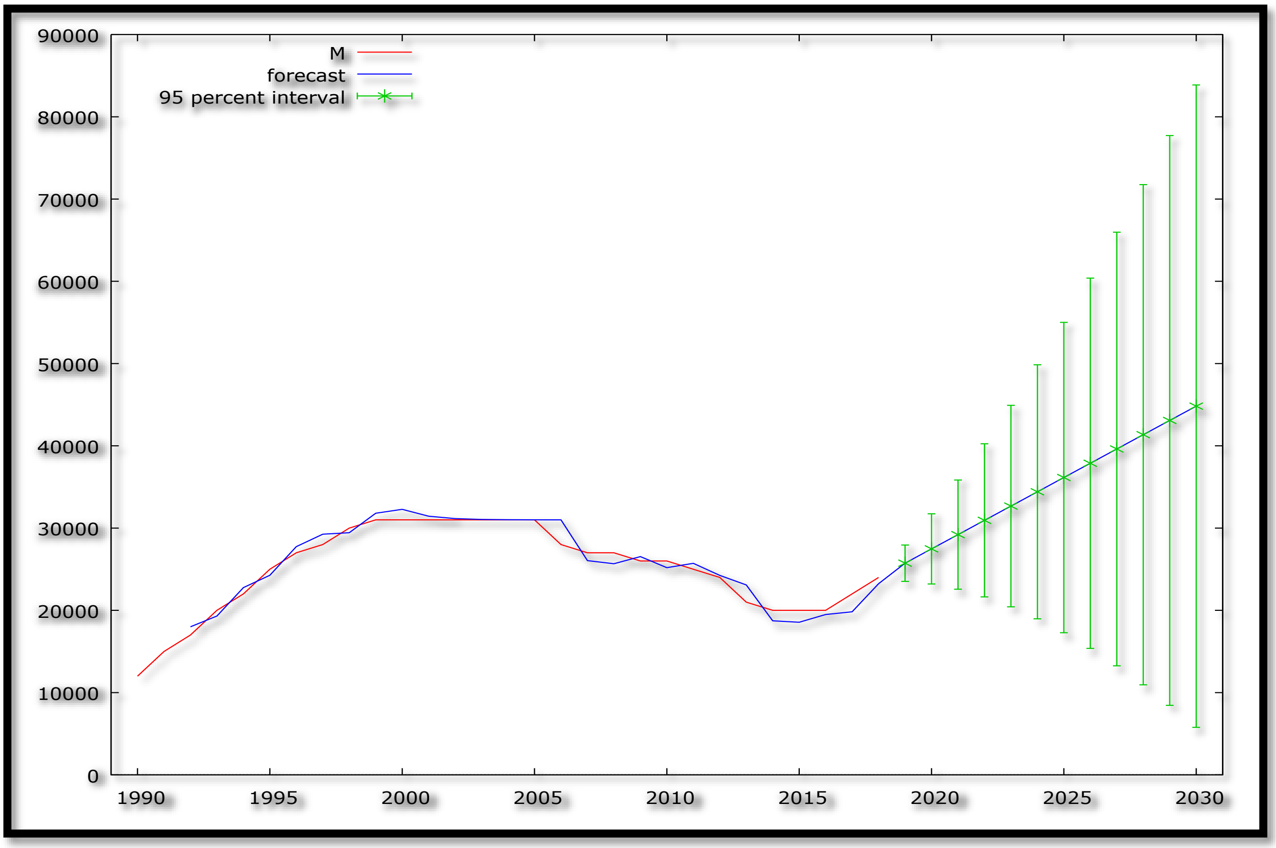

Figure 8: Forecast Graph – In & Out-of-Sample Forecasts

Figure 8 shows the in-and-out-of-sample forecasts of the series, M. The out-of-sample forecasts cover the period 2019 – 2030.

Predicted M– Out-of-Sample Forecasts Only

Table 7: Predicted M

Year	Predicted M	Standard Error	95% Confidence Interval
2019	25735.2	1126.94	(23526.5, 27944.0)
2020	27470.5	2175.41	(23206.8, 31734.2)
2021	29205.7	3385.88	(22569.5, 35841.9)
2022	30940.9	4747.88	(21635.3, 40246.6)
2023	32676.2	6248.51	(20429.3, 44923.0)
2024	34411.4	7876.90	(18973.0, 49849.9)
2025	36146.7	9624.17	(17283.6, 55009.7)
2026	37881.9	11482.9	(15375.8, 60388.0)
2027	39617.1	13447.0	(13261.5, 65972.8)
2028	41352.4	15511.1	(10951.1, 71753.6)
2029	43087.6	17670.7	(8453.72, 77721.5)
2030	44822.8	19921.7	(5777.11, 83868.6)

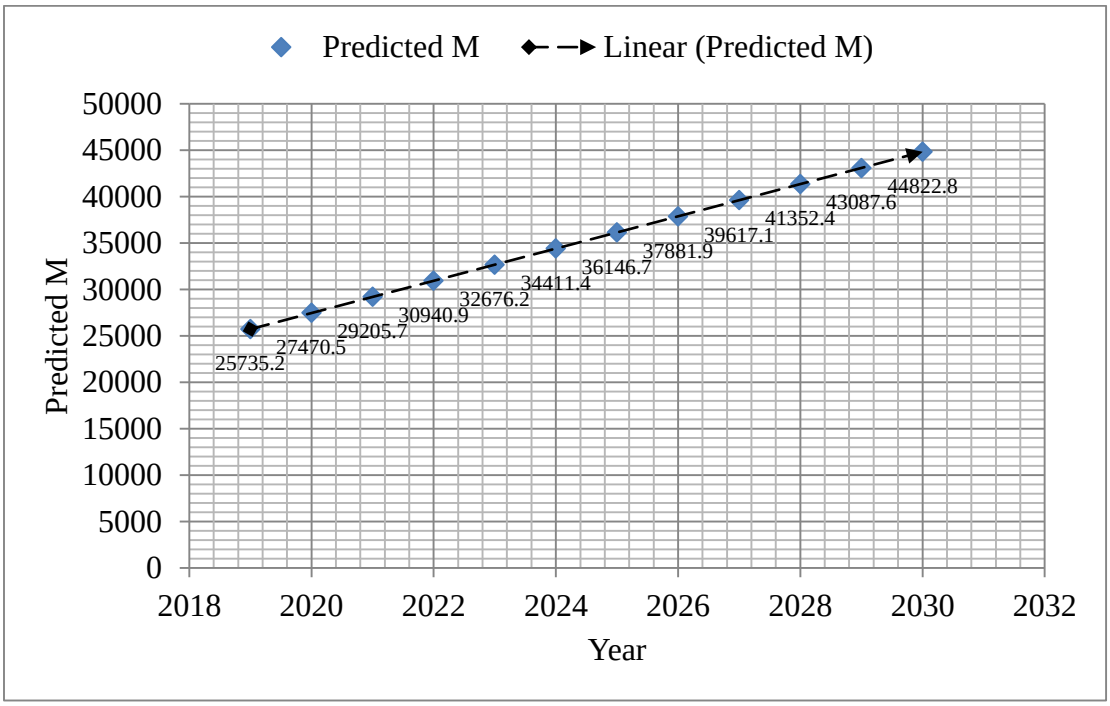

Figure 9: Graphical Analysis of Out-of-Sample Forecasts

Table 7 and figure 9 show the out-of-sample forecasts only. The number of new HIV infections in children in Nigeria is predicted to continue to rise from the estimated 25735 to nearly 44823 new infections by 2030. This could be necessitated and hatched by the fact that the level of knowledge and perceptions of mother-to-child transmission of HIV is still inadequate in the country (Adeleke et al., 2009; Ayodele & Ayodele, 2016; Badru et al., 2020). The results of this study are not surprising: they are in line with the scientific observations made by UNAIDS (2006).

5.0 CONCLUSION

The study shows that the ARIMA (0, 2, 1) model is not only stable but also the most suitable model to forecast the annual number new HIV infections in children in Nigeria over the period 2019 – 2030.We applied a generalized Box-Jenkins ARIMA model. The results show that Nigeria is far away from ending the HIV epidemic. In fact, pediatric HIV is rising at the moment and this has been projected to continue if nothing is done by relevant authorities in the country. The study recommends that the government of Nigeria should intensify pediatric HIV prevention and control programmes in the country, especially the PMTCT programme. Furthermore, there is need to conduct massive educational campaigns on HIV/AIDS, especially on the preventive measures and modes of transmission.

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