NOVATEUR PUBLICATIONS
JournalNX- A Multidisciplinary Peer Reviewed Journal
ISSN No: 2581 - 4230
VOLUME 5, ISSUE 4, Apr. -2019

NEW HIV INFECTIONS IN CHILDREN ON THE RISE IN LESOTHO: PROJECTIONS FROM ARIMA MODELS

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ABSTRACT:

Using annual time series data on the number of children (ages 0 – 14) newly infected with HIV in Lesotho from 1990 – 2018, the study predicts the annual number of children who will be newly infected with HIV over the period 2019 – 2030. The research applies the Box-Jenkins ARIMA methodology. The diagnostic ADF tests show that, X, the series under consideration is an I (0) variable. Based on the AIC, the study presents the ARIMA (3, 0, 1) model as the optimal model. The residual correlogram reveals that the presented model is indeed stable. The results of the study indicate that the number of new pediatric HIV infections in Lesotho is likely to decline, over the period 2019 – 2030, from approximately 1258 to almost 123 new infections by 2030. This is a "green light" towards the achievement of an AIDS free society in Lesotho. The study encourages the government of Lesotho to continue intensifying PMTCT services in the country to ensure victory in the fight against pediatric HIV, at least 10 years from now.

1.0 INTRODUCTION:

Human Immunodeficiency Virus (HIV) remains a global public health challenge since the epidemic began in 1970s (Avert, 2017). HIV is a chronic infection that leads to Acquired Immunodeficiency Syndrome (AIDS)(Lauritano et al., 2020). Worldwide, there are about 3.3 million children under the age of 15 years living with HIV. Of this number 88% live in Sub-Saharan Africa (Gyamfi et al., 2017). In fact, nearly 3.4 million children and adolescents in Sub-Saharan Africa (SSA) are infected with HIV, amounting to an estimated 10% of all persons in the region living with HIV or AIDS (Avert, 2017). Lesotho is one of the countries worst affected by HIV and AIDS worldwide, with 23% of adults now living with HIV. HIV prevalence peaks to almost 42% among some sub-populations in the country. Children continue to be vulnerable to HIV. Due to the uptake of Prevention of Mother-To-Child Transmission (PMTCT) services, annual HIV incidence in children is now as low as 0.17% (Government of Lesotho, 2011). In fact, between 2009 and 2011, Lesotho has seen a 21% decline in the number of new pediatric infections, from 4700 to 3700 (UNAIDS, 2012). The main goal of this research article is to predict the number of children newly infected with HIV in Lesotho over the period 2019 – 2030. This study will help in assessing the possibility of ending the pediatric HIV scourge in Lesotho.

2.0 LITERATURE REVIEW:

Empirical papers on modeling and forecasting new HIV infections are scanty in literature. Here we review closely related researches. In an attempt to assess 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) carried out a descriptive study at the pediatric HIV clinic of Aminu Kano Teaching Hospital in Nigeria. The paper

established that the level of knowledge and perceptions of mother-to-child transmission of HIV is still inadequate in the country. In a Zambian study, Kandala et al. (2011) investigated the effect of geographical location on HIV prevalence based on a Bayesian Geo-additive Mixed Model. The paper indicated that there was an increased HIV prevalence in Western Zambian province. In an effort to assess the determinants of Early Infant Diagnosis (EID) and early treatment initiation among HIV exposed children from informal settlements in Nairobi, Kenya, Makau et al. (2015), carried out a descriptive cross-sectional study, where HIV-infected mother-infant pairs attending healthcare facilities were recruited. The paper showed that knowledge on PMTCT and EID was low. No research has looked at forecasting new pediatric HIV infections in Lesotho and yet such information is important for future planning and effective delivery of HIV preventive and control measures. By filling this research gap, this paper will add value to the existing literature.

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, X, the series under consideration.

3.2 The Applied Box – Jenkins ARIMA Model Specification

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

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

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 X] in Lesotho. 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

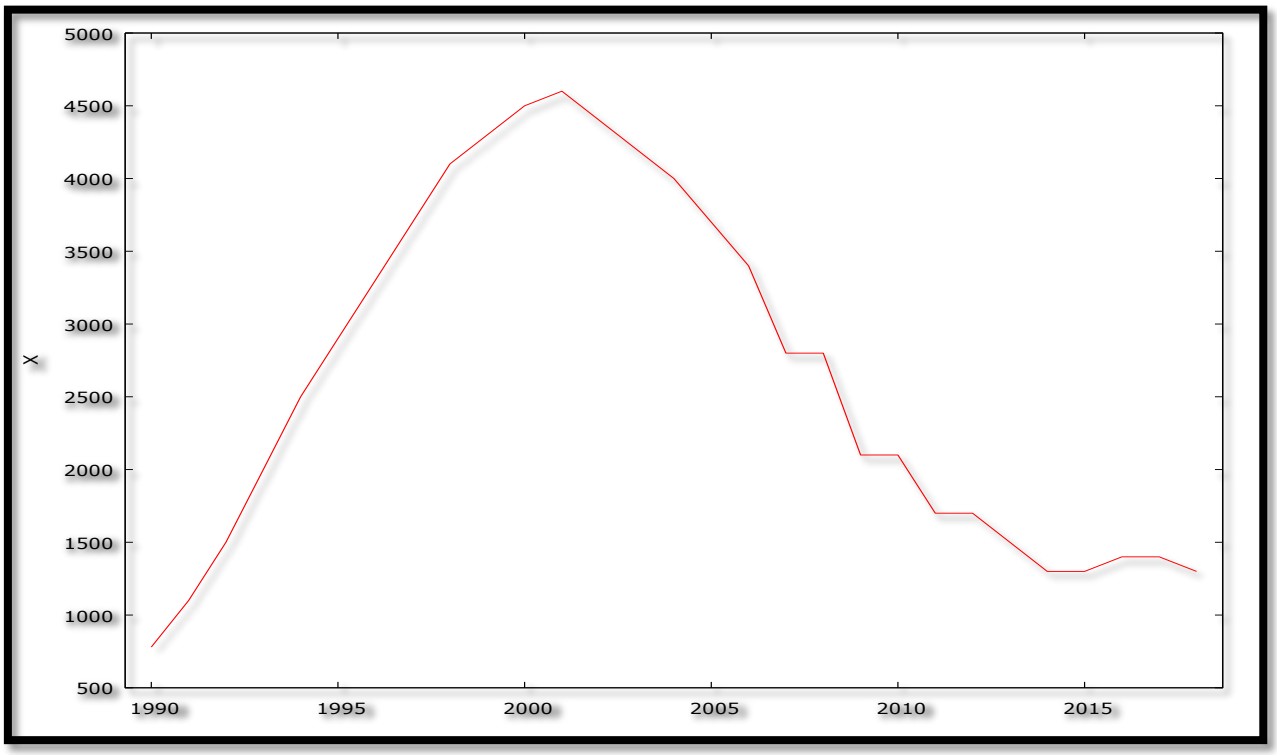

Figure 1

3.4.2 The Correlogram in Levels

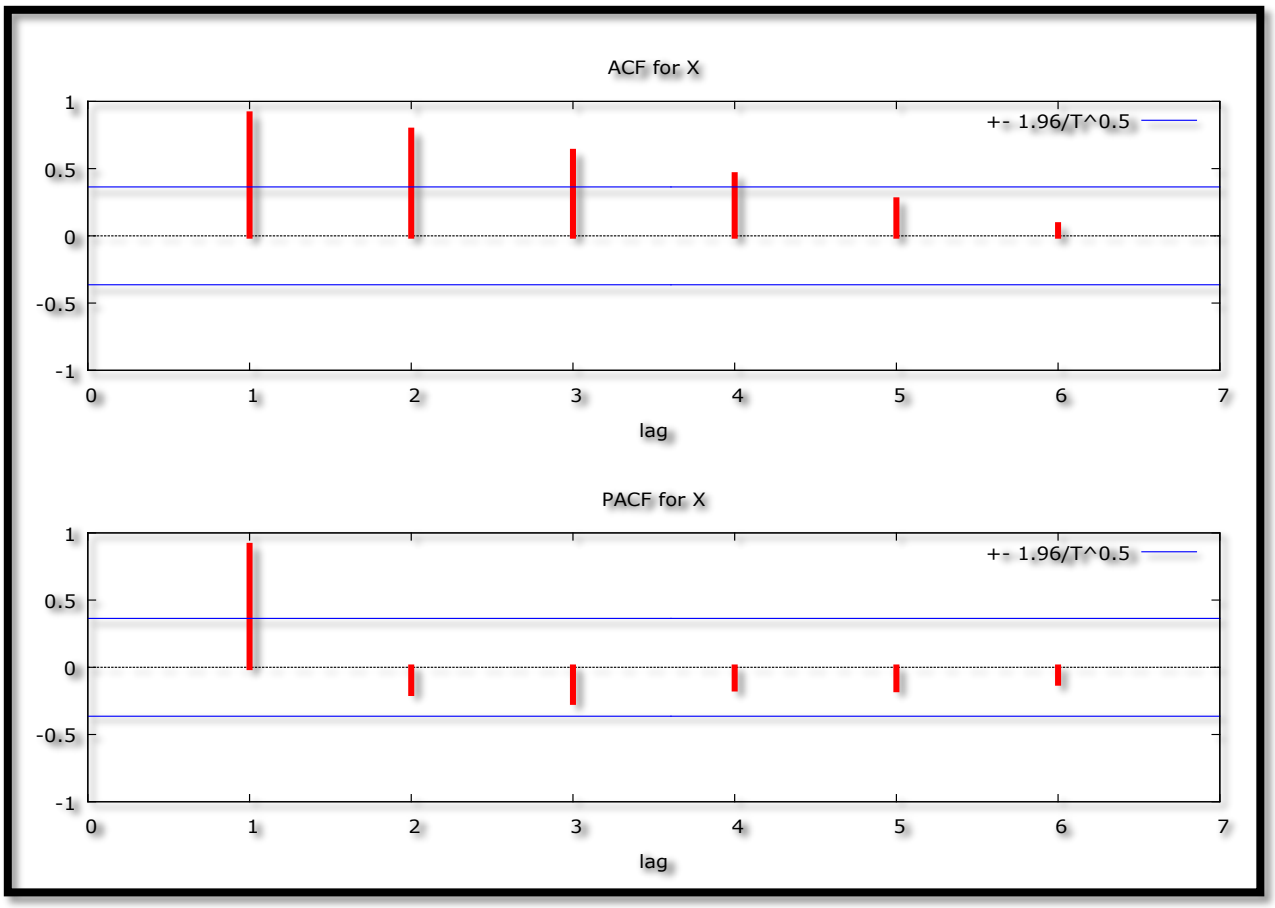

Figure 2: Correlogram in Levels

3.4.3 The ADF Test in Levels

Table 1: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
X	-3.675900	0.0119	-3.752946	@1%	Non-stationary
			-2.998064	@5%	Stationary
			-2.638752	@10%	Stationary

Table 1 shows that X is stationary in levels as suggested by figure 1.

3.4.4 Evaluation of ARIMA models (with a constant)

Table 2: Evaluation of ARIMA Models (without a constant)

Model	AIC	U	ME	RMSE	MAPE
ARIMA (1, 0, 3)	408.2792	0.7566	67.822	260.8	11.322
ARIMA (1, 0, 2)	406.2792	0.7567	67.8	260.8	11.326
ARIMA (1, 0, 1)	420.5212	0.93339	78.022	321.63	13.986
ARIMA (4, 0, 1)	396.07	0.7291	77.4	223.95	10.369
ARIMA (3, 0, 1)	**394.5141**	0.72888	76.796	224.79	10.599
ARIMA (2, 0, 1)	403.6942	0.77561	82.822	251.75	11.079

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 employed to select the optimal model. Therefore, the ARIMA (3, 0, 1) model is finally chosen. It is important at this moment to take note of the fact that the chosen model is indeed an ARMA (3, 1) process. However, for the sake of consistency, throughout the paper, we describe our model as the ARIMA (3, 0, 1) model.

3.5 Residual & Stability Tests

3.5.1 Correlogram of the Residuals of the ARIMA (3, 0, 1) Model

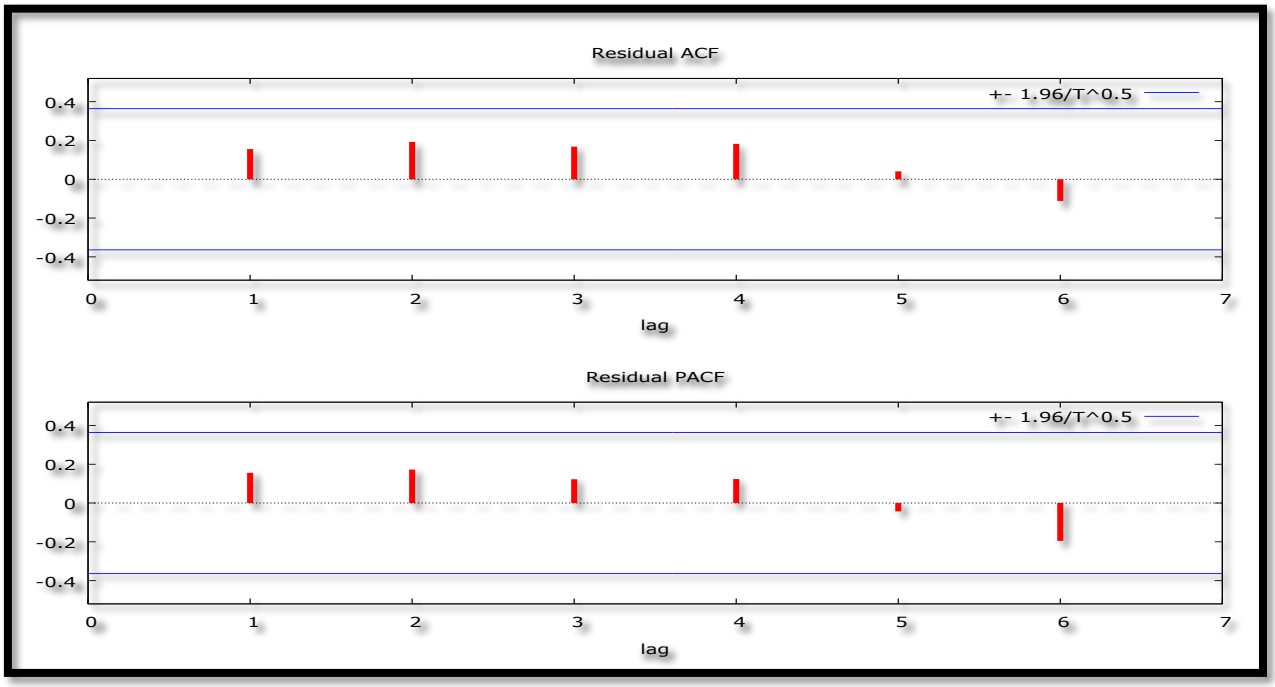

Figure 3: Correlogram of the Residuals

Figure 3 shows that the estimated optimal model is adequate since ACF and PACF lags are quite short and within the bands.

4.0 FINDINGS OF THE STUDY:

4.1 Descriptive Statistics

Table 3: Descriptive Statistics

Description	Statistic
Mean	2633.8
Median	2500
Minimum	780
Maximum	4600

Over the study period, the annual average number of new HIV infections in children is approximately 2634. The minimum number of new HIV infections in children is 780 and this was recorded in 1990, while the maximum is 4600 and has been recorded for the year 2001. Since then, HIV infections in children have followed a downwards trends.

4.2 Results Presentation

Table 4: Main Results

ARIMA (3, 0, 1) Model:

The chosen parsimonious model, the ARIMA (3, 0, 1) model can be expressed as follows:

$$X_t = 1.17289X_{t-1} + 0.506993X_{t-2} - 0.700965X_{t-3} - 0.0368021\mu_{t-1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots [2]$$

Variable	Coefficient	Standard Error	z	p-value
β_1	1.17289	0.172447	6.801	0.0000***
β_2	0.506993	0.307898	1.647	0.0996*
β_3	-0.700965	0.152663	-4.592	0.0000***
α_1	-0.0368021	0.268230	-0.1372	0.8909

Table 4 shows the main results of the ARIMA (3, 0, 1) model.

Forecast Graph

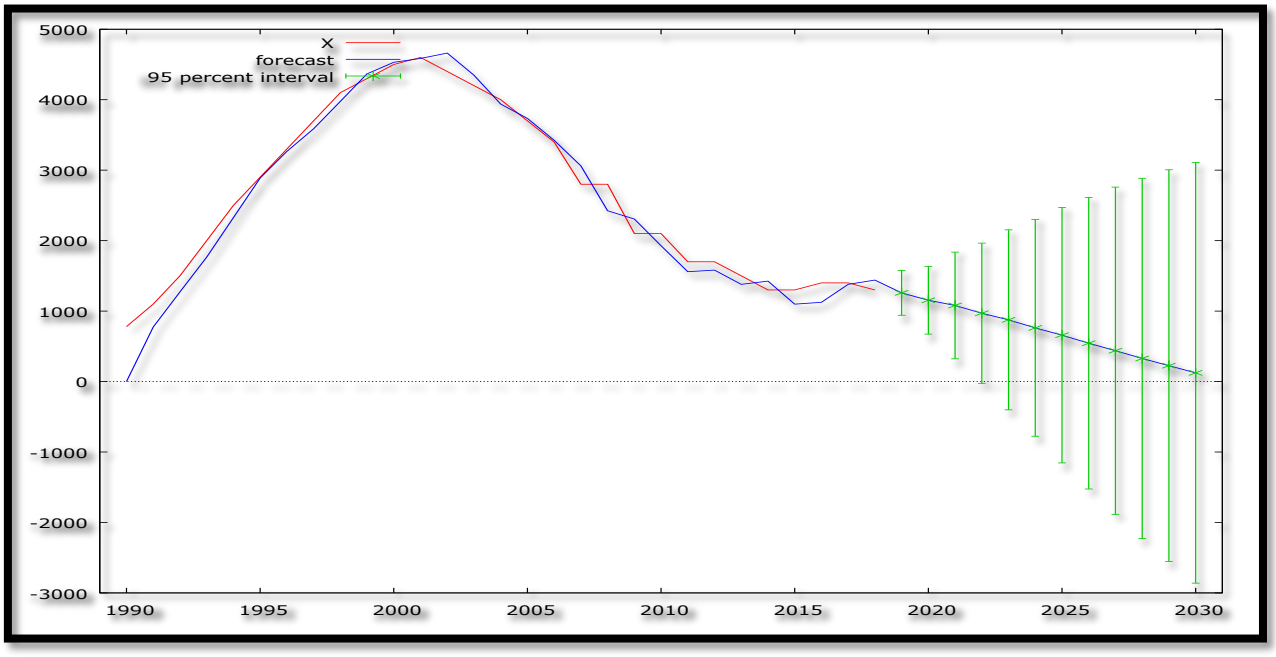

Figure 4: Forecast Graph – In & Out-of-Sample Forecasts

Figure 4 shows the in-and-out-of-sample forecasts of X. The out-of-sample forecasts cover the period 2019 – 2030.

Predicted X– Out-of-Sample Forecasts Only

Table 5: Predicted X

Year	Predicted X	Standard Error	95% Confidence Interval
2019	1258.34	162.121	(940.589, 1576.09)
2020	1153.63	245.371	(672.715, 1634.55)
2021	1079.80	386.190	(322.880, 1836.72)
2022	969.314	507.666	(-25.6933, 1964.32)
2023	875.691	651.660	(-401.539, 2152.92)
2024	761.622	784.753	(-776.465, 2299.71)
2025	657.812	924.637	(-1154.44, 2470.07)
2026	543.849	1055.39	(-1524.68, 2612.37)
2027	437.509	1184.70	(-1884.47, 2759.48)
2028	327.774	1304.66	(-2229.31, 2884.86)
2029	225.038	1418.64	(-2555.45, 3005.53)
2030	123.445	1522.71	(-2861.01, 3107.90)

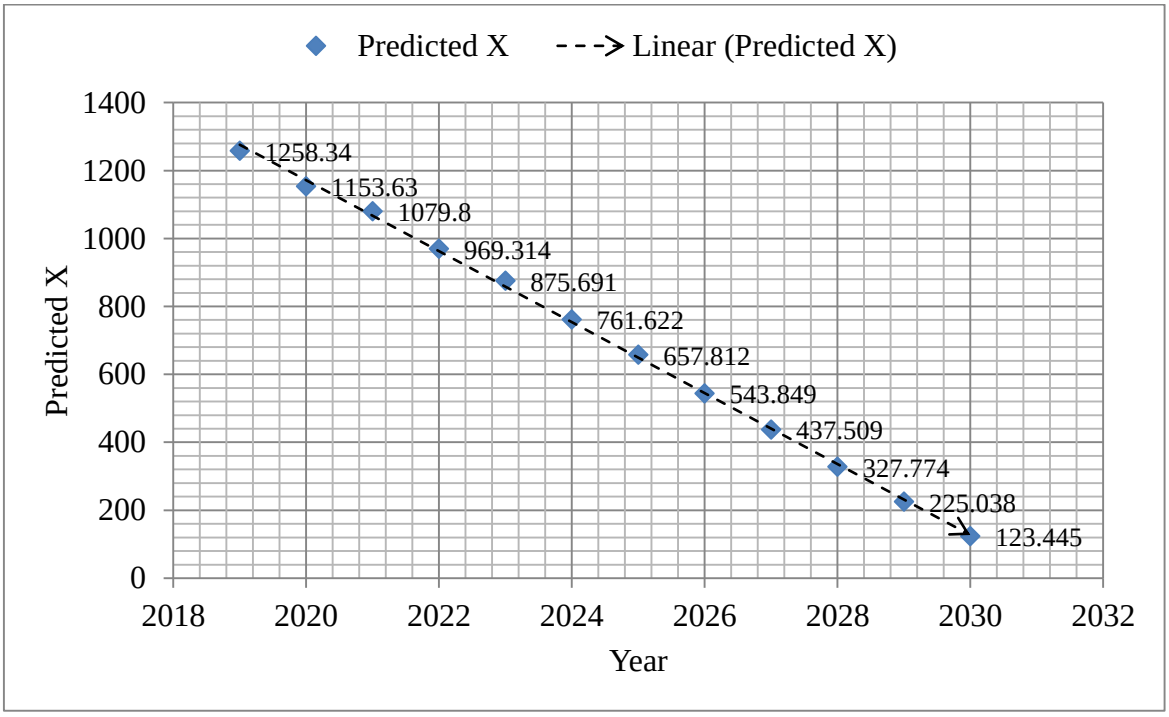

Figure 5: Graphical Analysis of Out-of-Sample Forecasts

Table 5 and figure 5 show the out-of-sample forecasts only. The number of new HIV infections in children in Lesotho is projected to go down significantly from approximately 1258 in 2019 to about 123 new infections by 2030. The predicted decrease in new HIV infections in children in Lesotho is largely attributed to efficacious PMTCT services in the country (WHO, 2011).

5.0 CONCLUSION:

The study shows that the ARIMA (3, 0, 1) model is not only stable but also the most suitable model to forecast the annual number of new pediatric HIV infections over the period 2019 – 2030. The model predicts a commendable decrease in the annual number of new infections in Lesotho. These

results are important for the government of Lesotho, especially for long-term planning with regards to creating an AIDS-free society. The study basically implies that Lesotho is actually in the right direction as far as pediatric HIV prevention and control is concerned. However, we encourage the government of Lesotho to continue scaling up the PMTCT services throughout the country.

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