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

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ABSTRACT:

Employing annual time series data on the number of children (ages 0 – 14) newly infected with HIV in Kenya from 1990 – 2018, the study predicts the annual number of children who will be newly infected with HIV over the period 2019 – 2030. This piece of work applies the Box-Jenkins ARIMA methodology. The diagnostic ADF tests show that, V, the series under consideration is an I (1) variable. Based on the AIC, the study presents the ARIMA (1, 1, 4) model as the optimal model. The residual correlogram further shows that the residuals are not serially correlated and thus indicating that our model is stable and suitable for forecasting new HIV infections in children in Kenya. The results of the study indicate that the number of new pediatric HIV infections will increase from the estimated 8958 in 2019 to approximately 13591 new infections by 2030. A lot needs to be done in Kenya in order to save the lives of children from the HIV/AIDS epidemic. The study basically encourages the government of Kenya to intensively expand PMTCT coverage throughout the country.

1.0 INTRODUCTION:

The HIV epidemic in Kenya has evolved, since the first case was diagnosed in 1984 (KNACC, 2014), and has remained a major cause of preventable morbidity and mortality in Kenya (Braithwaite et al., 2014). HIV is thought to cause 9% of all child mortality in Kenya (WHO, 2011). The first case of HIV in Kenya was reported in 1984. Almost 10 years later, HIV was one of the main causes of illness in the country, putting huge demands on the healthcare system as well as the economy. By 1996, 10.5% Kenyans were already living with HIV. Due to the national HIV programmes, prevalence has nearly halved since then, standing at 5.9% by 2015 (KNACC, 2014). In 2016 alone, 64% of people living with HIV were on treatment, 51% of who were virally suppressed (UNAIDS, 2017). Pediatric HIV infection is a worldwide public health challenge (Ng'eno et al., 2016), with at least 2 million children infected by 2010 (UNAIDS, 2011). Sub-Saharan Africa (SSA) is home to 68% of all people living with HIV. The region accounts for more than 70% of new HIV infections globally, 90% of who are children (WHO, 2011). Most of the pediatric HIV infections are perinatally transmitted (Makau et al., 2015). In Kenya, at least 220000 children less than 15 years of age were living with HIV in 2012 (UNAIDS, 2013). The main aim of this study is to forecast the number of children newly infected with HIV in Kenya over the period 2019 – 2030. This study will go a long way in assessing the possibility of ending the HIV epidemic in the country.

2.0 LITERATURE REVIEW:

In a local study, Braithwaite et al. (2014) estimated the portion of HIV infections attributable to unhealthy alcohol use and also evaluated the impact of hypothetical

interventions and directed at unhealthy alcohol use on HIV infections and deaths. The study was based on a transmission and progression simulation model. The study indicated that the effects of behaviors accompanying unhealthy alcohol consumption are responsible for 13% of new HIV infections in the country. In an effort to evaluate 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), conducted a descriptive cross-sectional study, where HIV-infected mother-infant pairs attending healthcare facilities were recruited. The study indicated that knowledge on Prevention of Mother-To-Child Transmission (PMTCT) and EID was low. Ng'eno et al. (2016) estimated the prevalence of HIV infection among children aged 18 months to 14 years. Data was analyzed from the second Kenya AIDS Indicator Survey (KAIS – 2012). Furthermore, blood specimens were collected for HIV serology and viral load measurement. The paper showed that pediatric HIV care and treatment is still lagging behind in Kenya as than 50% of HIV infected children are still not getting proper care and treatment. Not even a single study has attempted to model and forecast new pediatric HIV infections in Kenya and yet it is from such analysis that public health policy makers are able to formulate health policies that translate into the future in a more desirable manner. Hence, the current research is an attempt to fill-up this information gap.

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, V, the series under consideration.

3.2 The Applied Box – Jenkins ARIMA Model Specification:

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

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

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 V] in Kenya. 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

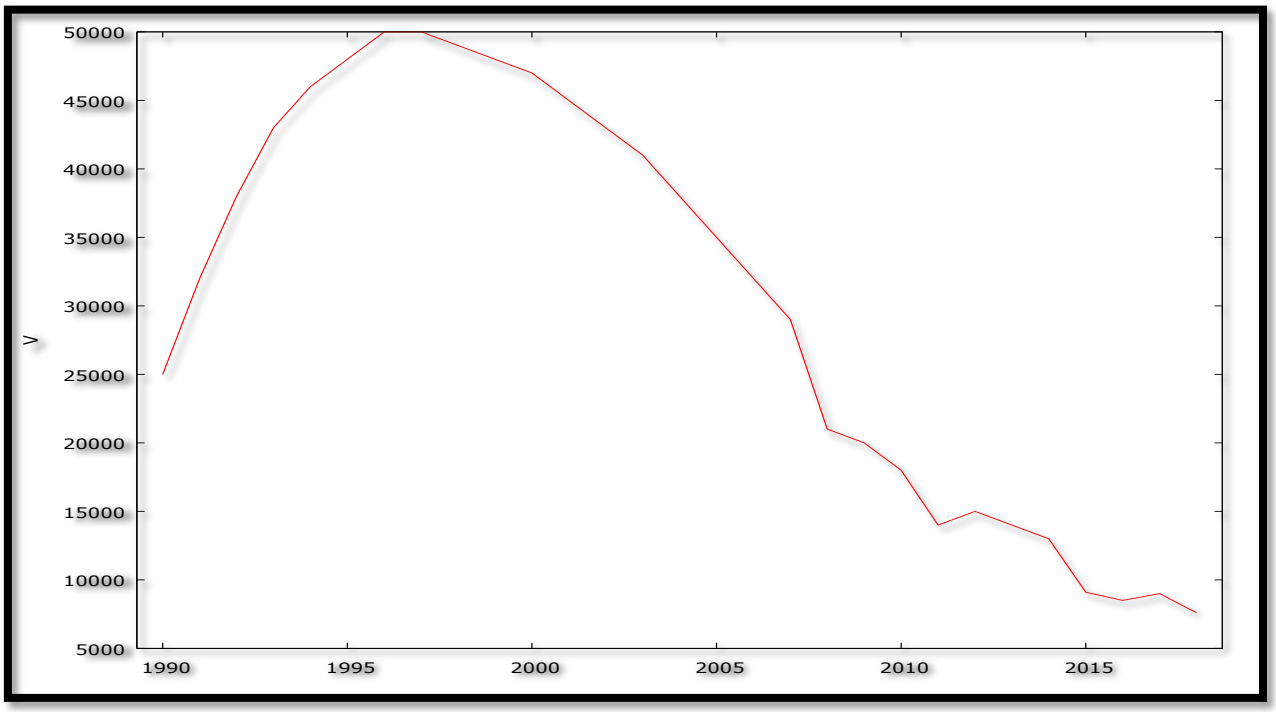

Figure 1

3.4.2 The Correlogram in Levels

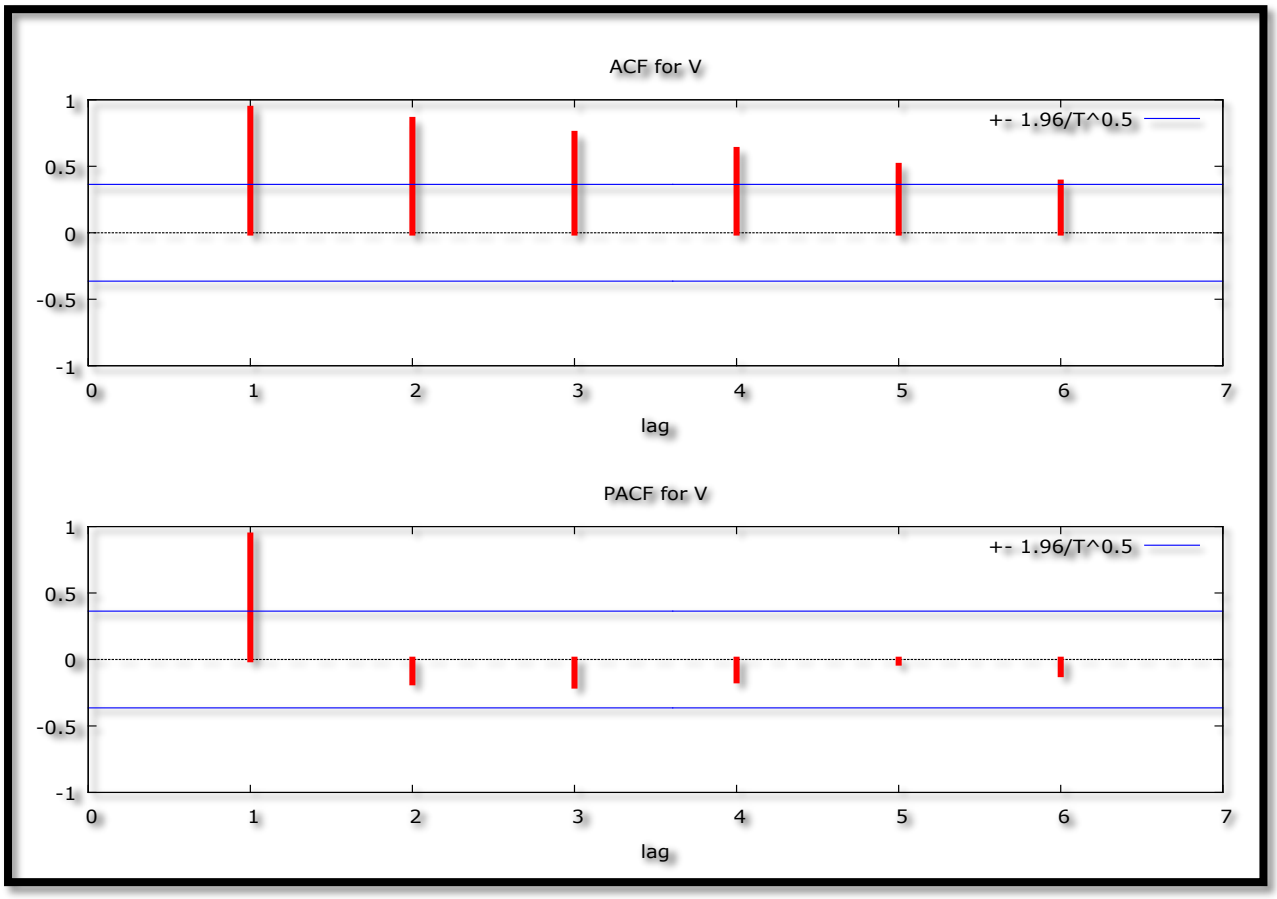

Figure 2: Correlogram in Levels

3.4.3 The ADF Test in Levels

Table 1: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
V	0.493140	0.9834	-3.689194	@1%	Non-stationary
			-2.971853	@5%	Non-stationary
			-2.625121	@10%	Non-stationary

Figures 1 and 2 indicate that V could be non-stationary in levels. Table 1 formally confirms that V is not stationary in levels.

3.4.4 The Correlogram (at First Differences)

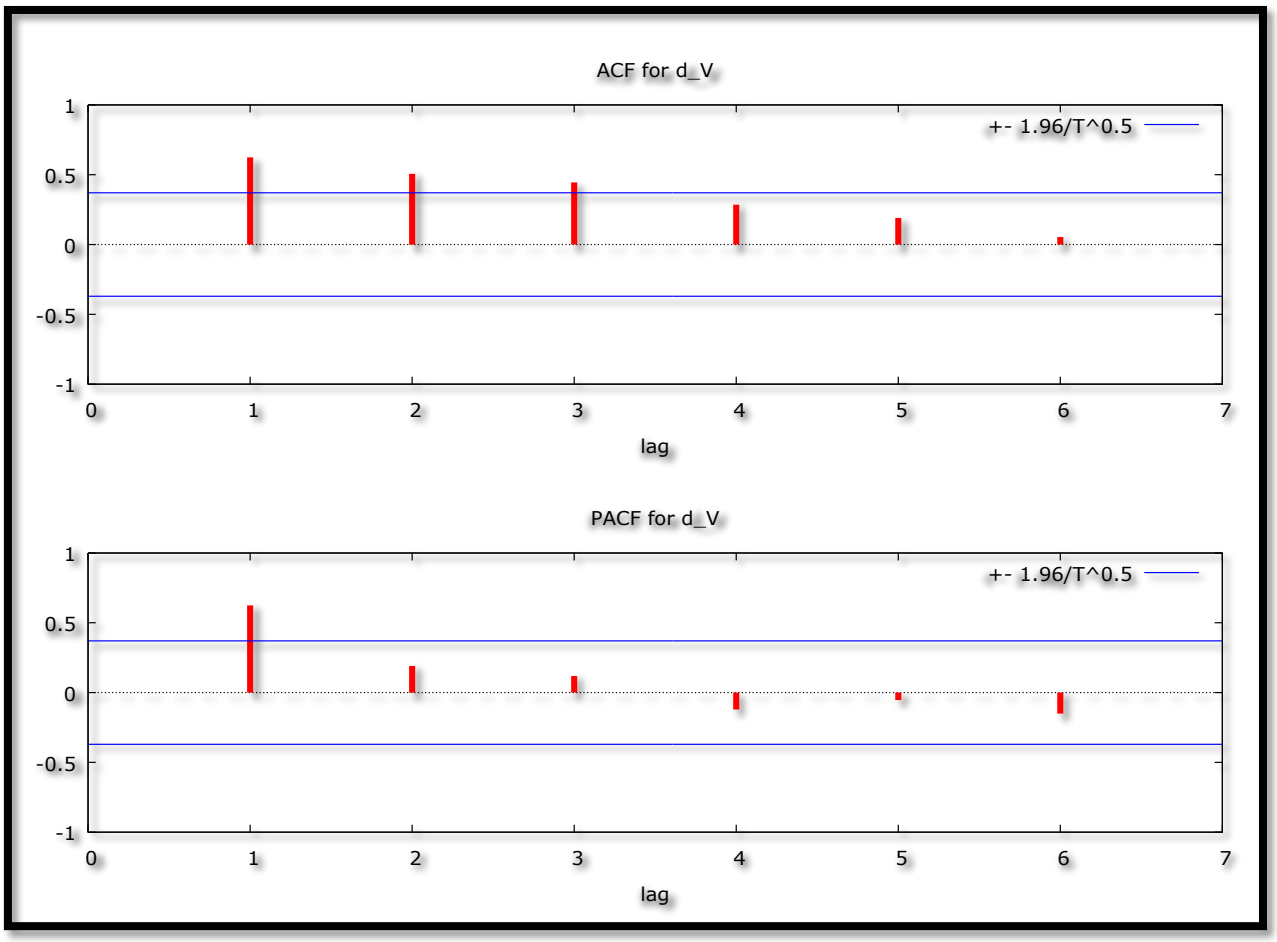

Figure 3: Correlogram (at First Differences)

3.4.5 The ADF Test (at First Differences)

Table 2: with intercept

Variable	ADF Statistic	Probability	Critical Values		Conclusion
ΔV	-2.993817	0.0482	-3.699871	@1%	Non-stationary
			-2.976263	@5%	Stationary
			-2.627420	@10%	Stationary

Figure 3 and table 2 reveal that V is an I (1) variable.

3.4.6 Evaluation of ARIMA models (with a constant)

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

Model	AIC	U	ME	RMSE	MAPE
ARIMA (1, 1, 1)	514.1136	0.95258	-233.23	2336.9	8.5931
ARIMA (1, 1, 0)	515.5512	1.0397	-188.16	2426.7	9.4541
ARIMA (0, 1, 1)	523.9927	0.98644	-372.16	2683.6	10.122
ARIMA (2, 1, 0)	514.4142	0.99537	-188.9	2342.7	9.0722
ARIMA (0, 1, 2)	523.5548	1.002	-346.85	2581.5	10.208
ARIMA (3, 1, 0)	514.6938	0.89978	-244.96	2298.1	8.0158
ARIMA (4, 1, 0)	515.751	0.94373	-147.05	2267.2	8.0283
ARIMA (0, 1, 3)	514.4367	0.66767	-146.98	2211.4	6.385
ARIMA (0, 1, 4)	515.6812	0.70546	-122.55	2186.3	6.678
ARIMA (1, 1, 2)	514.3621	0.98532	-131.68	2286.8	8.503
ARIMA (1, 1, 3)	514.2039	0.90392	-42.748	2173.4	7.473
ARIMA (1, 1, 4)	**514.0355**	0.83679	-60.383	2146	6.9494
ARIMA (1, 1, 5)	515.3106	0.82157	-44.367	2137.1	7.0187
ARIMA (2, 1, 1)	515.7276	0.952293	-224.74	2326.3	8.6747
ARIMA (3, 1, 1)	514.2034	0.82446	-176.82	2217.5	7.5846

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, 4) model is finally chosen.

3.5 Residual Test:

3.5.1 Correlogram of the Residuals of the ARIMA (1, 1, 4) Model

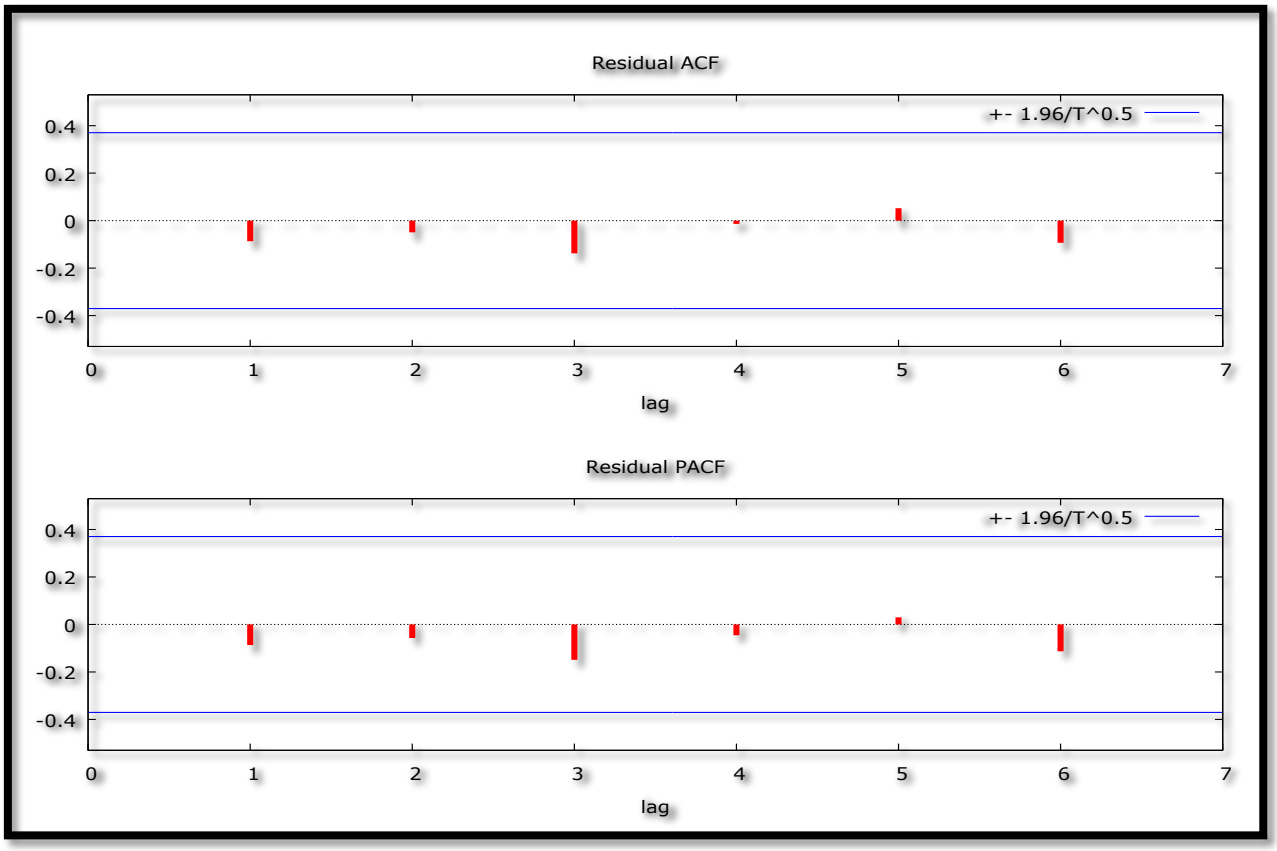

Figure 4: Correlogram of the Residuals

Figure 4 indicates that the estimated optimal model is adequate since ACF and PACF lags are quite short and within the bands. Therefore, the estimated model is stable.

4.0 FINDINGS OF THE STUDY:

4.1 Descriptive Statistics

Table 4: Descriptive Statistics

Description	Statistic
Mean	30628
Median	32000
Minimum	7600
Maximum	50000

Over the study period, the annual average number of new HIV infections in children in Kenya was 30628. The minimum number of new HIV infections in children in the country was 7600 and was recorded in 2018 while the maximum was 50000 and was realized in 1997. Since then, new infections have continued on a downwards spiral.

4.2 Results Presentation

Table 5: Main Results

ARIMA (1, 1, 4) Model:

The applied optimal model, the ARIMA (1, 1, 4) model can be expressed as follows:

$$\Delta V_t = 0.892238\Delta V_{t-1} - 0.308201\mu_{t-1} + 0.0437291\mu_{t-2} + 0.599651\mu_{t-3} - 0.417688\mu_{t-4} \dots\dots\dots [2]$$

Variable	Coefficient	Standard Error	z	p-value
β_1	0.892238	0.131526	6.784	0.0000***
α_1	-0.308201	0.238097	-1.294	0.1955
α_2	0.0437291	0.211376	0.2069	0.8361
α_3	0.599651	0.217625	2.755	0.0059***
α_4	-0.417688	0.260117	-1.606	0.1083

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

Forecast Graph

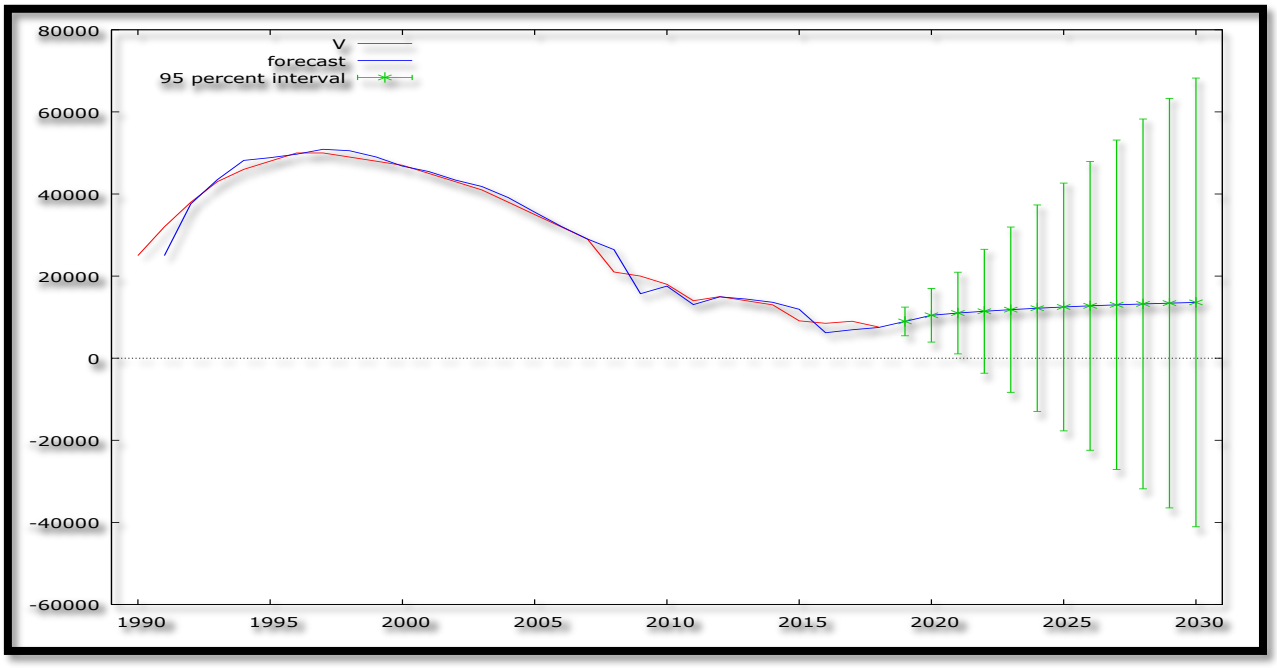

Figure 5: Forecast Graph – In & Out-of-Sample Forecasts

Figure 5 shows the in-and-out-of-sample forecasts of the series, V. The out-of-sample forecasts cover the period 2019 – 2030.

Predicted V– Out-of-Sample Forecasts Only

Table 6: Predicted V

Year	Predicted V	Standard Error	95% Confidence Interval
2019	8957.61	1780.08	(5468.71, 12446.5)
2020	10457.2	3334.59	(3921.54, 16992.9)
2021	10999.5	5074.57	(1053.47, 20945.4)
2022	11434.8	7698.81	(-3654.62, 26524.2)
2023	11823.2	10271.2	(-8308.02, 31954.4)
2024	12169.7	12836.7	(-12989.7, 37329.1)
2025	12478.9	15397.4	(-17699.5, 42657.4)
2026	12754.8	17946.8	(-22420.3, 47929.9)
2027	13001.0	20476.8	(-27132.8, 53134.7)
2028	13220.6	22980.2	(-31819.8, 58260.9)
2029	13416.5	25451.2	(-36466.8, 63299.9)
2030	13591.4	27885.1	(-41062.5, 68245.3)

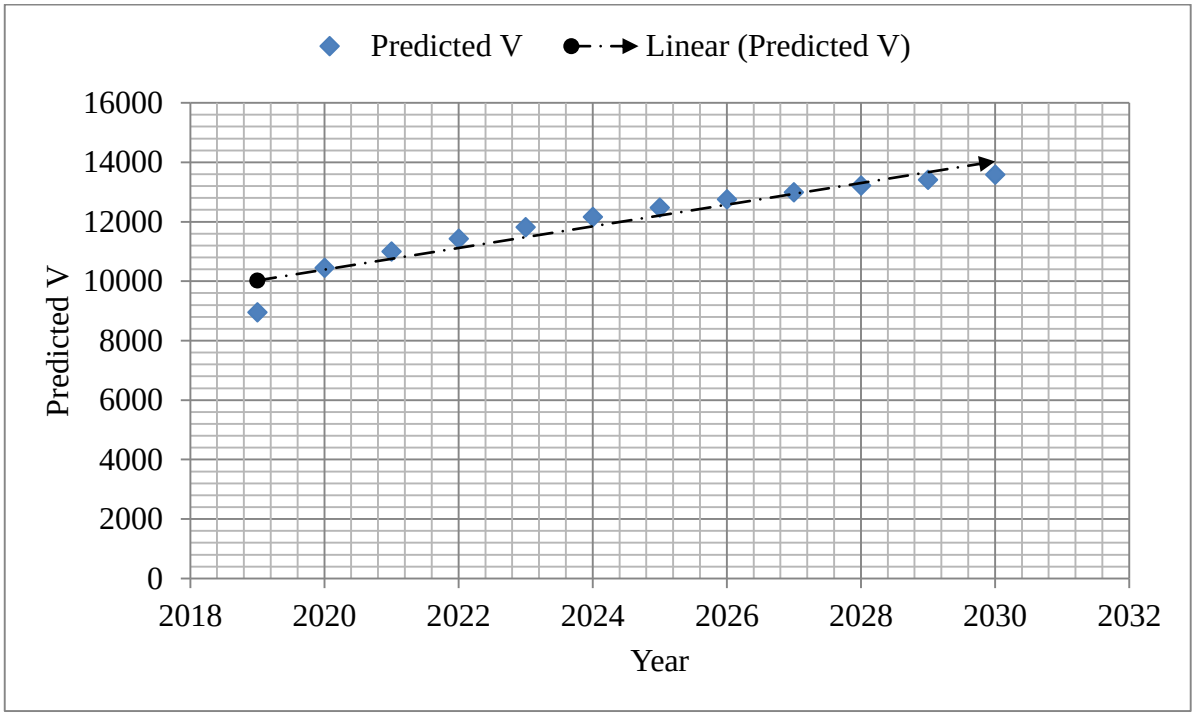

Figure 6: Graphical Analysis of Out-of-Sample Forecasts

Table 6 and figure 6 show the out-of-sample forecasts only. The number of new HIV infections in children in Kenya is projected to increase over the out-of-sample period. This could be attributed to the fact that in Kenya, knowledge on PMTCT and EID is relatively low (Makau et al., 2015).

5.0 CONCLUSION:

The study shows that the ARIMA (1, 1, 4) model is not only stable but also the most suitable model to forecast the annual number of new HIV infections in children in Kenya over the period 2019 – 2030. Post-estimation

diagnostic tests endorse the stability and suitability of the applied predictive model. The model predicted a possible increase in new HIV infections in children in Kenya. The study recommends that the government of Kenya should intensify HIV prevention and control programmes in the country, especially the PMTCT programme. In this regard, the government of Kenya should also make sure that they expand on PMTCT coverage throughout the country.

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