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Research Article

Time series analysis of consumption and short term forecasting of female contraceptives in the Kenyan public health sector

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Background: Contraceptive security is crucial in ensuring access to family planning services and improving the contraceptive prevalence rate. This requires proper forecasting and procurement of contraceptives. It is therefore important to study consumption patterns and apply forecasting techniques so as to adjust for any changes in the choice of contraceptives over a given time period.

Objectives: The objectives of this study were to analyze trends, identify any seasonal or cyclic patterns in consumption of contraceptives, compare service point and consumption data, forecast consumption for six months and determine optimal models for forecasting contraceptives.

Methods: Data on consumption of implants, injectables, pills, and Intrauterine Contraceptive Devices (IUCDs) were extracted from the Kenya District Health Information System for the years 2014-2018. An exploratory analysis was done and the data decomposed to evaluate the trends and seasonal components. Service point and consumption data of contraceptives were compared. Short-term forecasting using the Autoregressive Integrated Moving Average (ARIMA) and the Exponential Smoothing (ES) models was done. The optimal model for forecasting was determined and the models validated using actual facility consumption data for 2018.

Results: The consumption of pills, injectables, and IUCDs declined while that of implants increased significantly across the 4 years. There were differences in the data reported for consumption and service point data for injectables, implants, and IUCDs. The ES models recorded the least error when forecasting consumption of all contraceptives except for one-rod implants in which the ARIMA model had the least errors.

Conclusion: There was a general shift towards the use of long-acting reversible methods especially implants in Kenya. The difference in the reporting of consumption and service point data for injectables, implant, and IUCDs showed gaps in the documentation and reporting of contraceptives. The ETS models were generally superior to the ARIMA models for predicting consumption of contraceptives.

Keywords: Contraceptives, consumption, forecasting, time series, trends

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1. Introduction

Family planning (FP) is the practice of regulating the number of children born and the spacing interval between them by use of modern or traditional methods. Promotion of FP practices, the supply of preferred contraceptives and services for women and couples is essential in improving the wellbeing and freedom of women (World Health Organization, 2016). In Kenya, the most commonly used modern contraceptive methods are Combined Oral Contraceptives (COCs), Progestin-Only Pills (POPs), injectables, one and two-rod implants and Intrauterine Contraceptive Devices (IUCDs) (Kenya National Bureau of Statistics, 2014).

Kenya, like many developing countries in sub-Saharan Africa, faces various challenges that hinder proper quantification and procurement of contraceptives. This includes inaccurate data on consumption, lack of technical know-how, improper method mix, inadequate financing, and over-dependence on donor funding. Some of the consequences of improper quantification are stock-outs, expiries, unsatisfied clients, reduced Contraceptive Prevalence Rate (CPR) and increased unmet FP needs. Shortages of contraceptives are seen as one of the leading causes of discontinuation of contraceptives and a reason for turning away clients by health care providers (Douglas-Durham et al, 2015).

Lack of contraceptives in health facilities can result from expiries or stock-outs. Stock-outs are experienced commonly in health facilities providing FP services from time to time and at varying levels (Ministry of Health Kenya, 2018). Lack of these contraceptives limits accessibility to the desired choice of contraceptives by women and contributes to the unmet need for contraception (Sedgh and Hussain, 2014). Studying trends in consumption of contraceptives lead to the procurement of appropriate quantities that minimizes waste due to expiries, stocks outs as well as drops in consumption. Comparison of service statistics and consumption levels is key in ensuring proper management of the contraceptives and the quality of reporting.

The aim of the study was to analyze the consumption of contraceptives (pills, injectables, IUCDs, and implants) in the public sector from the year 2014 to 2017 to identify trends and seasonal patterns. Data collected at the service point and consumption levels of the contraceptives were compared to check for similarities. The study also forecasted consumption for six months and actual data from January to June 2018 was used to validate the forecasts. The optimal models for forecasting the contraceptives were also determined.

2. Methods

2.1 Study design

The study design was a time series analysis of contraceptive consumption. The study applied time series forecasting techniques on monthly consumption of pills, implants, IUCDs, and injectables in Kenya. The study population was women of reproductive age (15-49 years) using contraceptives in the public sector and faith-based organizations whose consumption was reported through the District Health Information System (DHIS2) database.

2.2 Data retrieval

Aggregate data on the use of female contraceptives (implants, IUCDs, pills, and injectables) in Kenya public Sector was collected from DHIS2 for the years 2014, 2015, 2016, 2017 and 2018 The study utilized data on dispensed products from the Facility Contraceptive Consumption Report and Request (FCCRR) form and MOH 711 Integrated Summary Report (Reproductive and Child Health, Medical and Rehabilitation services) for number of clients receiving each type of contraceptive (service point data). To improve forecasting, data cleaning was done to mitigate incomplete data sets.

The reporting rates for contraceptives consumption varied from month to month during the study period. The average reporting rate for contraceptive consumption was 63.1 % representing 4795 health facilities reports out of 7882 expected reports. The data was transformed to reflect a 100% reporting rate. Data accuracy could not be verified from the primary facility hence a study limitation.

2.3 Exploratory analysis

Visual inspection of the time series graphs for each contraceptive was done to check for trend, stationarity, and seasonality. An augmented Dickey-Fuller test was also conducted to test for stationarity. For non-stationary series, differencing was done to transform it to stationarity. The Auto-Correlation Function (ACF) and the partial ACF graphs were plotted as well as the Ljung-Box test to test for the presence of autocorrelation. The data were log-transformed to remove any autocorrelation and to ensure the consumption data fitted with an additive model. Each of the contraceptives trend and seasonal components were plotted separately and described.

2.4 Forecasting of consumption data

A short-term forecast for demand for contraceptives was done using Exponential Smoothing (ES) and Autoregressive Integrated Moving Average (ARIMA) methodologies and their predictive accuracies were compared. The forecast was done for six months (h =6). The 95% prediction interval for the forecast was computed and plotted for each of the ES and ARIMA methods. The forecast errors for the consumption data (training data) and validation data (test data) were also determined.

Cross-validation and comparison of the models

The reported data for all contraceptives from January to June 2018 (test data) was compared with the point forecasts for the same period to determine how well the models forecasted the family planning consumption data.

The Ljung-Box test and Shapiro Wilk test were used to check for autocorrelations and normality in forecast errors respectively. To come up with the most parsimonious fit, Root Mean Squared Errors (RMSE),

Mean Absolute Scale Errors (MASE), and Mean Absolute Percentage Errors (MAPE) were used.

2.5 Ethical approval

Approval to use the DHIS2 data for contraceptives was sought from the Ministry of Health, Department of Health Care Financing, Policy and Planning and Health Information Systems Unit. The study utilized aggregate data with no unique identifiers for clients; therefore, it was a minimal risk study. However, approval to carry out the study was sought from the Kenyatta National Hospital/University of Nairobi Ethics and Research Committee (KNH-UON-ERC). The ethics approval was given on 5th March 2018 and the reference number was **P714/12/2017**.

3. Results

The yearly proportion of women who received COCs and injectables declined from 2014 to 2017 while those on implants and IUCDs increased. Most women seeking FP services used injectables (66.5%) followed by COCs (12.7%), implants (12.2%), IUCDs (4.5%) and lastly progestin-only pills (4.1%). This is presented in **Table 1**.

Table 1: The Yearly Proportion of Women Using Various Contraceptives from 2014 to 2017

Year	The proportion of women who received each family planning commodity (%)				
	Combined oral contraceptives	Progestin-only pills	Injectables	Implants	Intrauterine contraceptive devices
2014	14.7	3.5	69.9	9.1	2.8
2015	14.1	3.9	67.3	11.7	2.9
2016	12.7	4.6	64.8	12.4	5.5
2017	9.1	4.4	64.1	15.5	6.9
Average	12.7	4.1	66.5	12.2	4.5

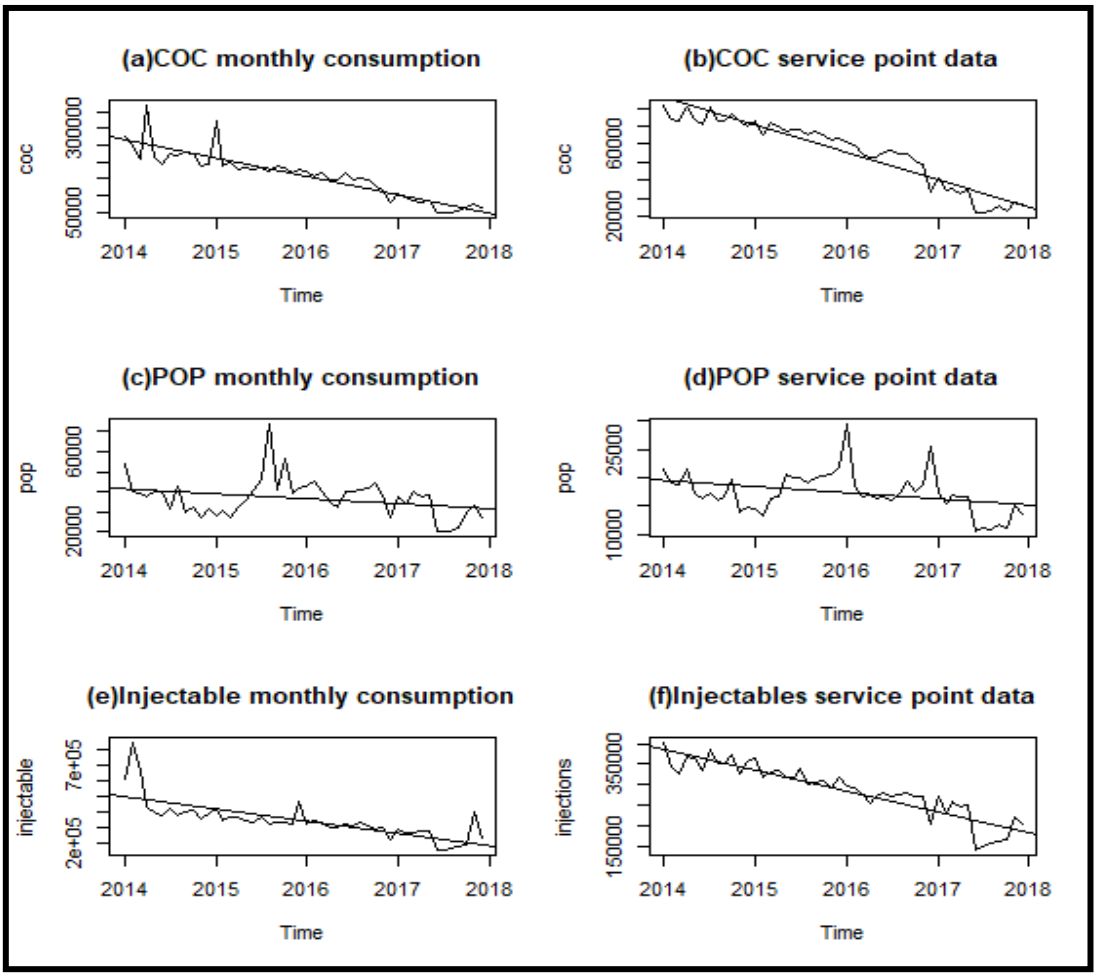


Figure 1: Time plots for consumption and service point data for combined oral contraceptives, progestin-only pills, and Injectables

Exploratory analysis of the contraceptive consumption and service point data

The time series plots of COC's, POPs, injectables consumption (**Figure 1** a, c, and e) showed a decline in consumption from 2014 to 2017. The lowest consumption of these contraceptives was in July and August 2017. The consumption of COCs (**Figure1** a) had high consumption in April 2014 and January 2015. The highest consumption of POPs (**Figure 1** c) was in August and October 2015. The highest consumption for injectables was in February 2014, towards the end of 2016 and 2017 as seen in **Figure 1** (e). The service point consumption for COCs, POPs and injectables also decreased from 2014 to 2017 (**Figure 1** b, d, and f) respectively.

There was increased consumption of IUCDs from mid to the end of 2014 and a slight increase at the beginning of 2017 (**Figure 2**a) and the lowest consumption was towards the end of 2017. One and two-rod implants had an increasing trend in consumption from 2014 to 2017 (**Figure 2**c). The lowest consumption for implants was in June 2017. The service point consumption data for IUCDs decreased from 2014 to 2017 while that of implants was erratic and showed a slight increase.

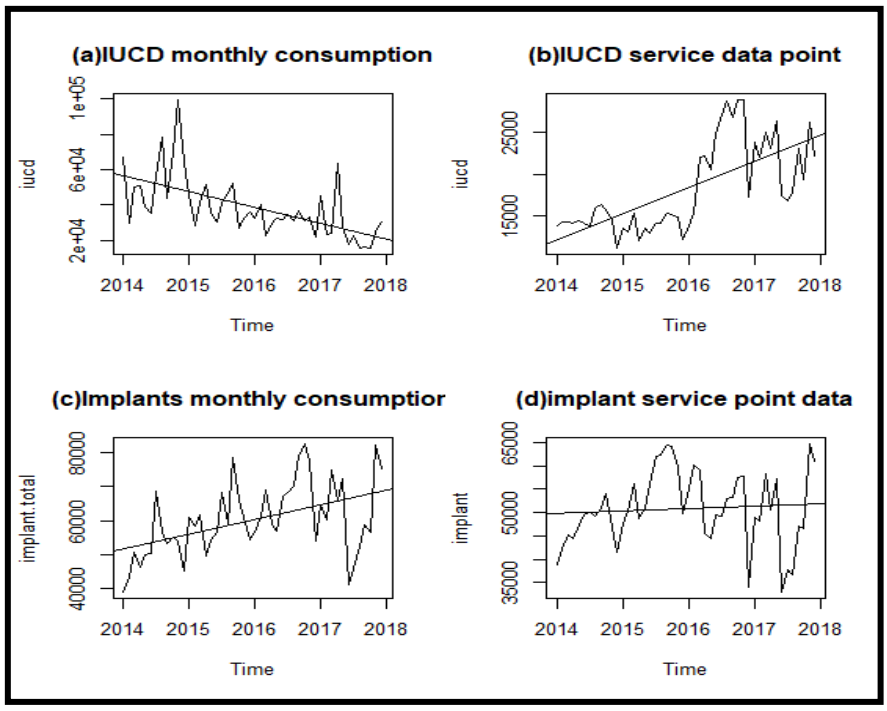


Figure 2: Time Plots for Consumption and Service Point Data for Intrauterine Contraceptives Devices and Implants

Evaluation of the trends in consumption of contraceptives

The consumption of IUCDs, injectables and combined oral contraceptives has been on the decline since 2014 as presented in **Figure 3**. For implants and POPs, there was an increase in consumption followed by a decline from 2014 to 2017.

Evaluation of seasonal patterns in the consumption of contraceptives

The consumption of contraceptives had periods of high and low consumption as presented in **Figure 4**. The consumption for COCs was the highest in January; other high periods were in September and October while the lowest periods of consumption were in April, November, and December. The POPs had the highest periods of consumption in August and October while the lowest consumption was in December. The one-rod implants had the highest consumption in July and the lowest consumption was in June and December. The two-rod implants had the highest consumption in March and September while the lowest consumption was in June and December. The injectables had the highest consumption in January and December while the lowest was in June and August. For IUCDs, the highest consumption was in April, August, and November while the lowest was in February and June.

Comparison of service point data and consumption data of contraceptives

The reported consumption and service data for injectables were relatively similar while that of implants and IUCDs differed significantly as presented in **Figure 5**.

Forecasting consumption of contraceptives

The training and test data fit parameters were examined to compare forecast accuracies of different models as presented in **Table 2**. The Mean Absolute Error (MAE), the Root Mean Squared Error (RMSE) and the Mean Absolute Percentage Error (MAPE) were used to compare the forecast errors of the forecasting models for each of the contraceptives.

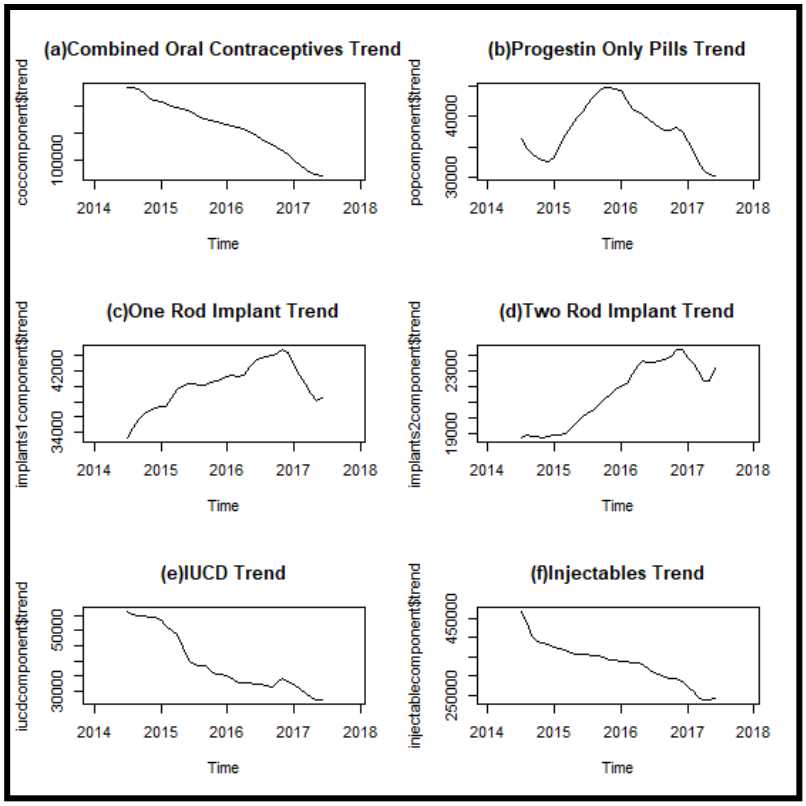


Figure 3: The trend components from 2014 to 2017 for each contraceptive

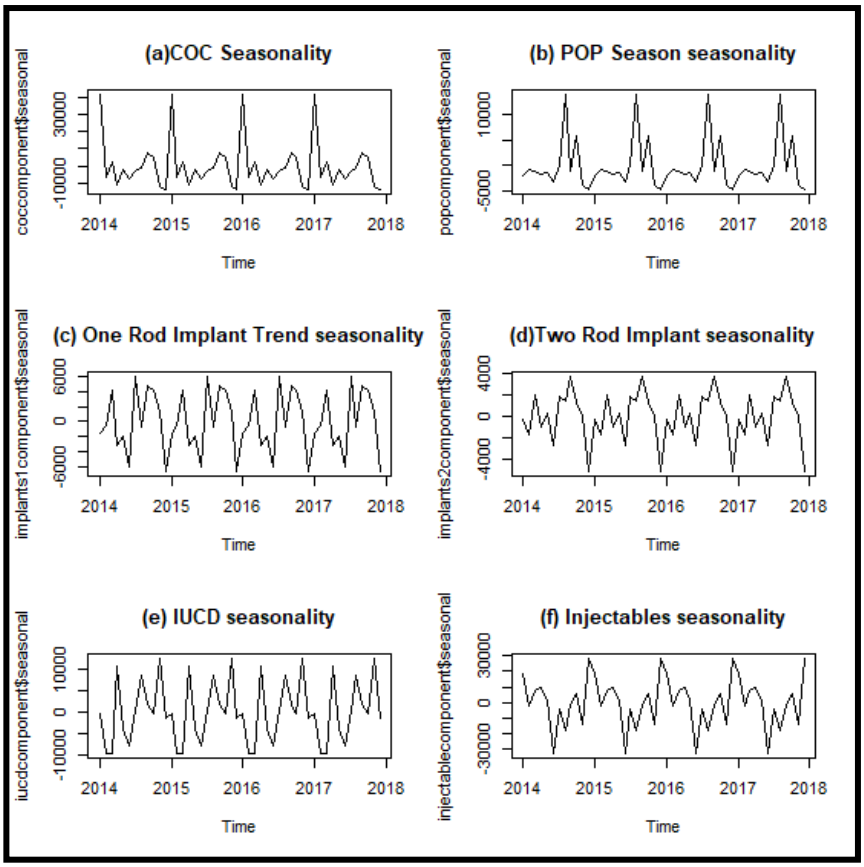
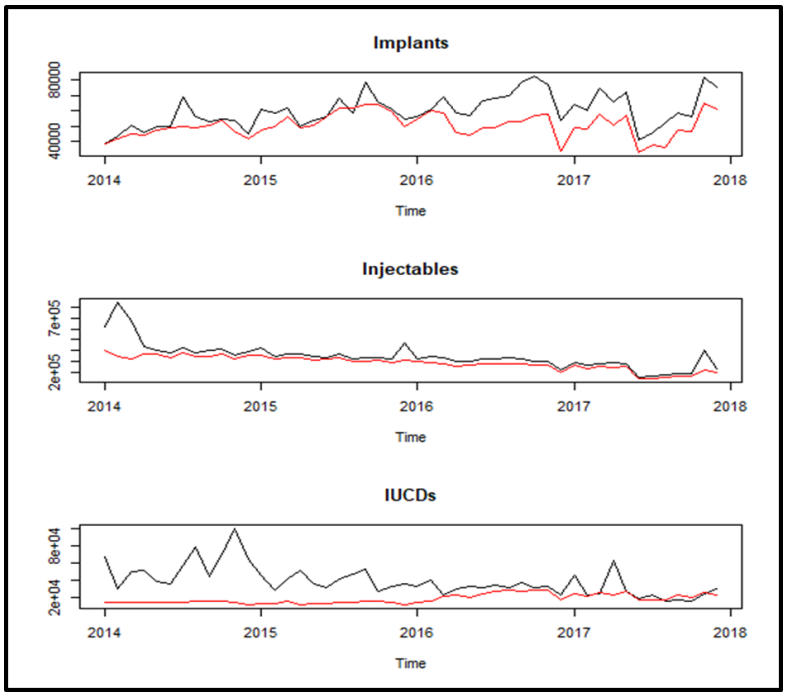


Figure 4: The Seasonal components for contraceptives consumption from 2014 to 2017



Key- Black represents consumption data while red represents the service point data

Figure 5: Comparison of the Consumption and Service Point Data for Implants, Intrauterine Contraceptive Devices, and Injectables.

Table 2: Forecast Errors for the ARIMA and Exponential Smoothing Models for Each Contraceptive

	MODEL	ME	RMSE	MAE	MPE	MAPE	ACF1	Theil's U
POP	ARIMA(0,1,1)	-0.109	0.115	0.109	-1.073	1.073	0.265	3.073
	ETS (M,N,N)	-0.092	0.099	0.092	-0.902	0.902	0.230	2.739
COC	ARIMA(1,1,0) with drift	0.305	0.370	0.305	2.696	2.696	0.581	2.617
	ETS (A,N,N)	0.136	0.212	0.157	1.191	1.387	0.536	1.511
IUCD	ARIMA(0,1,1)	-0.054	0.288	0.249	-0.621	2.495	0.267	0.911
	ETS(M,N,N	-0.054	0.288	0.249	-0.625	2.495	0.267	0.912
Injectables	ARIMA(5,1,0) with drift	0.238	0.289	0.238	1.928	1.928	0.125	3.662
	ETS(A,N,N)	-0.117	0.128	0.117	-0.949	0.949	-0.300	1.555
One rod Implants	ARIMA(1,1,3)	0.048	0.066	0.059	0.447	0.553	-0.354	0.702
	ETS M,N,N	-0.065	0.090	0.072	-0.611	0.676	-0.375	1.021
Two-rod Implants	ARIMA(0,1,1)	0.093	0.103	0.093	0.910	0.910	-0.061	1.392
	ETS(A,A,N)	0.052	0.068	0.052	0.502	0.502	-0.236	0.802

Key: ME-Mean Error, RMSE-Root Mean Squared Error, MAE-Mean Absolute Error, MPE-Mean Percentage Error, MAPE- Mean Absolute Percentage Error and ACF-Autocorrelation coefficient, ETS –Error, Trend, and Seasonality for exponential smoothing models.

The most optimal model for POPs was the ETS (M, N, N) because it reported the lowest value for MAE, RMSE and the MAPE. This model tended to underestimate consumption because the mean error (-0.092) and mean percentage error (-0.902) were negative (**Figure 6**).

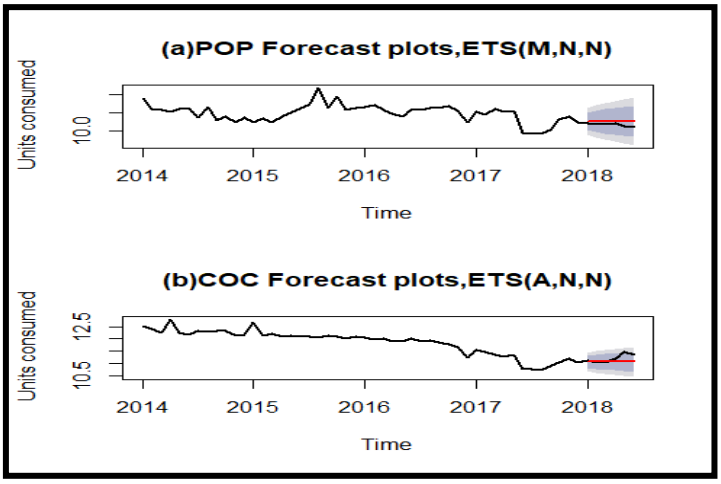


Figure 6: Comparison between actual consumption (black) and forecasted consumption (red) for POPs and COCs using exponential smoothing method

For COCs, the ETS (A, N, N) model was the most optimal and performed better than ARIMA (0,1,1) model because the RMSE, MAE, and MPE for the ETS model were about half those of ARIMA model (**Figure 6**). For the ES model, the mean error and mean percentage error were positive indicating that the forecasts were overestimates of actual consumption in 2018.

The most optimal model for intrauterine contraceptive devices was ETS (M, N, N), however, with regards to the measures of accuracy, the ARIMA model (0,1,1) performed similarly to the ETS model and had similar RMSE and MAE values. Both models also underestimated the consumption because the mean error was -0.054 (**Figure 7**).

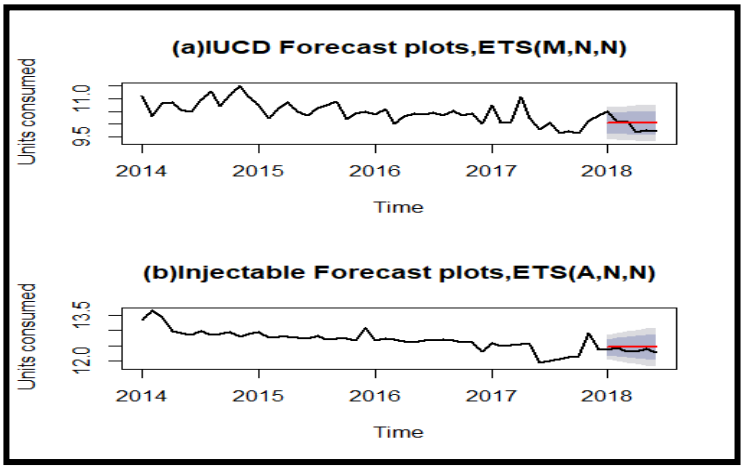


Figure 7: Comparison between actual consumption (black) and forecasted consumption (red) for IUCDs and injectables using the exponential smoothing method.

The best model for injectables was ETS (A, N, N) whereby the forecast error statistics were far less than those for ARIMA (5,0,1) model. The forecasts for injectables were less than the actual values of validation data because the mean error was -0.117 (**Figure 7**).

For two-rod implants, the optimal model was ETS (A, A, N) and the forecasts were overestimated with a mean error of 0.052. The only contraceptive for which the ARIMA model was better than the ES model was the one-rod implants. The ARIMA (1,1,3) model had a mean error of 0.048, which was the smallest indicating that it gave a very good forecast even though the forecasts tended to overestimate the actual consumption (**Figure 8**).

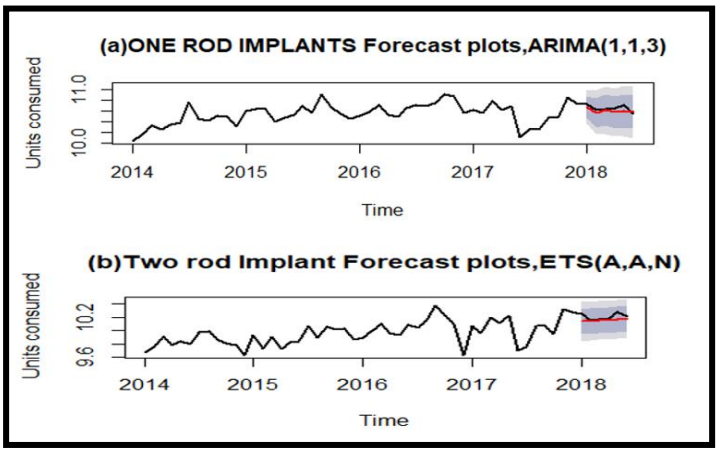


Figure 8: Comparison between actual consumption (black) and forecasted consumption (red) for one rod implants using ARIMA and two rod implants using exponential smoothing methods.

Model diagnostics

Model diagnostics were done for each of the forecasting models. The residuals for all contraceptives were not auto-correlated with either model. The residuals of the selected models for POPs, IUCDs, and one-rod implants were normally distributed except for COC, injectables, and two-rod implants. Lack of normal distribution of residuals was an indication that the model could be improved. The models were acceptable because the residuals were not autocorrelated.

4.0 Discussion

The use of COCs, injectables, and IUCDs steadily declined while that of implants increased from 2014 to 2017. The use of progestin-only pills increased up to 2015 then declined in 2016 and 2017. The decline could have been attributed to a shift towards the use of long-term reversible methods especially implants. There were advocacy programs run by various organizations prior to the review period. The Kenya Urban Reproductive Health Initiative (Tupange program), an initiative by the government and various organizations ended in 2014 and resulted in the rise of the use of long-term methods especially implants in 2014 and a reduction in the use of injectables and pills as compared to the baseline (2010). The Tupange program targeted the urban poor areas in Nairobi, Kakamega, Mombasa, Kisumu and Machakos counties for women of 15 to 49

years of age so as to increase modern contraceptives use (Kenya Urban Reproductive Health Initiative et al, 2014a, 2014b, 2015).

The rise in the use of implants could also be associated to the launch of the Implant Access Program in 2013 where a group of private and public organizations collaborated with manufacturers, Bayer and Merck, to ensure access to implants such as Jadelle®, Implanon® and Implanon NXT® to poor countries through reduced prices of up to 50%. Kenya was a beneficiary of Implant Access Program and was among the countries with the highest procurement of implants in 2015 (Sergison et al., 2017). As part of the Implant Access program, the best practice training and implementation were conducted in Kilifi and Migori counties (Sergison *et al.*, 2017). An easier to insert and remove one-rod implant (Implanon NXT®) was piloted in Kenya in 2015 and rolled out in 2016 (MSD, 2018; United Nation Foundation, 2018).

The proportion of women seeking family planning services declined from 29.7 to 18.5% over the four years. This was consistent with the Performance, Monitoring, and Accountability Survey (PMA 2020), which was done in 2016 (round five) by the Ministry of Health, Kenya in collaboration with various organizations in eleven counties. The survey showed a reduction in the modern methods contraceptive prevalence rate from 46.0 in 2015 to 44.2% in 2016 (Ministry of Health Kenya, 2017).

The PMA 2020 survey in 2016 showed similar trends in the utilization of contraceptives (Ministry of Health Kenya, 2017). There was an increase in the consumption of implants from 23.4 to 25.5% and then to 30.2% from round three, four and five respectively among married women. The injectables reduced from 50.1 to 46.2% then to 46.0% over the same period. The pills (COCs and POPs) use among married women also reduced from 12.3 to 11.9% then to 8.5 % from round three, four to five respectively (Ministry of Health Kenya, 2017).

There were notable peaks in the consumption of COCs, POPs IUCDs and implants. These periods of high consumption were associated with low stock out levels in the providing facilities (Ministry of Health Kenya, 2018). The erratic pattern in consumption of POP's could be explained by frequent stock-outs and erratic supply of the contraceptives. The percentage of women in Kenya using IUCDs was relatively low at 3.4 % in 2014 (Kenya National Bureau of Statistics, 2014). A study done in two Nairobi public hospitals showed that myths and misconceptions about IUCDs were the main barriers to their uptake (Mbuthia, 2014).

The highest proportion of women who sought FP services from 2014 to 2017 used injectables and the proportion was above 60% in the review period. However, the use of injectables had a declining trend from 2014 to 2017 despite the number of facilities having stock-outs being below 7.7% in the review period (Ministry of Health Kenya, 2018). This could be attributed to the shift to long-term contraceptive methods.

There was a general decline in the number of all contraceptives consumed in July and August 2017. This could be attributed to the national wide nurse's strike that affected the public sector health facilities service delivery. The Kenya public sector experienced several industrial strikes by health workers since devolution in 2013. The nurse's strike had a major impact on the provision of family planning services in the health facilities, as they are the primary service providers. There were several strikes by nurses in the country and various counties during the period of evaluation. In 2014 and 2015, several counties experienced industrial disputes by nurses such as Nandi, Mombasa, Homabay, Kilifi, Kericho, Vihiga, Siaya and Kakamega.

The concurrent strike by doctors in December 2016 for three months affected the supply of contraceptives as pharmacists are tasked with reporting and ordering of contraceptives at the sub-county and county levels. A study that was done in 2015 to review the effect of industrial actions by nurses at Rift Valley Provincial General Hospital- Nakuru showed that strikes greatly affected service delivery in the hospital. Strikes led to shutting down of hospitals and turning away of clients at the hospital (Shitsinzi, 2015).

Correlation between consumption data and service data for injectables, IUCDs, and implants revealed discrepancies in the quantities reported. The difference could be partially accounted for by losses and expiries but they were minimal. This could also be attributed to errors in reporting the service data or consumption data. Ideally, the consumption data and service data should be the same for contraceptives issued per piece or unit, which is the case for injectables, implants and intrauterine contraceptives devices after accounting for losses. This showed that there was a gap in the reporting of contraceptives in the facilities hence need for capacity building to bridge the gap.

The exponential smoothing model was the best suited for forecasting consumption of injectables, COCs, IUCDs, POPs, and two-rod implants. The ARIMA models were suitable for forecasting one-rod implants. The models chosen had the lowest mean absolute percentage error, root means squared error and mean absolute scale error for all the contraceptives evaluated for the six months forecasting interval (Hyndman and Athanasopoulos, 2018).

The exponential smoothing model is therefore applicable in short term forecasting of contraceptives consumption for public sector in Kenya. The time series method can be used to study patterns of contraceptive use hence informing the method mix during forecasting and procurement.

5.0 Conclusion

There was a general shift in the use of modern contraceptives from short term to long term acting reversible methods. This was shown by the decline in the use of pills and injectables and the increase in the use of implants. The consumption was greatly affected by the availability of methods and services at the providing facilities. It is therefore important to ensure constant and timely supply of contraceptives in the facilities. There was a significant difference between the

reported consumption data and service point data for injectables, implants and more so the intrauterine contraceptive devices. The exponential smoothing model was the most suitable for forecasting consumption of contraceptives.

Conflict of Interest declaration

The authors declare no conflict of interest.

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