Journal of Business and Economic Management 2(5): 074-083, August 2014
DOI: http://dx.doi.org/10.15413/jbem.2013.0154
ISSN: 2315-7755

Research Paper

Time series analysis on monthly average Rwanda currency exchange rate against US dollars

Accepted 28th February, 2014

ABSTRACT

In this work, we broadly describe the exchange rate of Rwandan francs to US dollar on the basis of monthly data from 2003-2012. The Rwandan Franc is the currency of Rwanda. The main objective is to apply appropriate time series model for monthly Rwandan average currency exchange rates against US dollar. The data used were secondary data of mean monthly currency exchange rates in Rwanda from January 2003 to December 2012. Those data are collected from National Bank of Rwanda (NBR) head office from the department of statistics. In this study the result indicates, the appropriate time series model fitted for monthly average exchange rate of RWF against USD is ARIMA (0, 2, 1). The forecasted model and the original data are going in the same pattern; besides the error terms are normally distributed and based on the fitted model the monthly average exchange rate of RWF against USD in the next 5 years especially in December 2017 will be 767.5146 RWF. The result of this research found that the exchange value of Rwanda currency (Rwandan francs) showed a consistent decrease against US dollar. SPSS software was used to capture and analyze the data and to fit appropriate time series model which help to forecast monthly average Rwandan Franc against US dollar. Therefore, it is recommended to the government of Rwanda to change the strategies in order to increase the exchange value of Rwanda currency.

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Key words: Currency exchange rates, time series model, ARIMA.

INTRODUCTION

Exchange rate fluctuation is seen as a general phenomenon around the globe which might have adverse effect on trade. Economists are still very much interested in the operations involved in exchange rate especially in developing countries. Exchange rate uncertainty is said to probably have a negative effect on international trade as bilateral trades are threatened with the risks involved. The economic relationship supporting the negative link is the unwillingness of firms to take on risky activity, namely trade (Anderton and Skudelny, 2001).

In the abundant literature on exchange rates, we can identify two distinct approaches. On the one hand, there is the macroeconomic approach, which seeks to relate exchange rate changes to monetary variables, such as monetary aggregates or indices reflecting national income. Studies adopting this approach use monthly data. For exchange rates, this means the exchange rate value on the last day of the month. And for the fundamentals, monthly figures are extracted from the monetary aggregates and indices of industrial production. These indices are used as substitute for gross domestic product (GDP), which is calculated quarterly.

In this work, we looked at Rwandan francs exchange rate against US dollar from the beginning of 2003, until the end of 2012. The data was obtained from a publication produced by the Board of Governors of National Bank of Rwanda (NBR) (The Rwanda focus, 2012).

The goal of fitting appropriate time series model is the same as that of other predictive models which is to create a model such that the error between the predicted value of the target variable and the actual value is as small as possible.

The main objective in investigating a time series model is forecasting future values from the observed series. This can be done through the model which adequately describes the behavior of the observed variable and the required forecast (Zeleke, 2012).

The general objective of this study is to apply appropriate Time series model for monthly average currency exchange rates of Rwandan Francs against US dollar.

A review based on Sarno suggested that, the studies carried out to date confine themselves to classic econometric forecasting methods, based essentially on linear regression. The other is that they use only publicly available information, while private information, such as information about investor decisions, is a key to explain exchange rate behavior (Sarno, 2005).

Others have studied exchange rate movements from a different angle. Instead of creating a model to predict the value of the exchange rate from other variables, they have chosen a model from among those commonly used in time series analysis.

Exchange rate volatility is a risk associated with unexpected changes in exchange rate, this is caused by some economic factors such as inflation rate, interest rate and balance of payments (Ozturk, 2006).

Williamson concluded that there was no simple answer in determining exchange rate equilibrium, and estimating the equilibrium exchange rate and the proportion of misalignment of the exchange rate remains part of the most defying empirical problems in an open-economy macroeconomics. A country's actual exchange rate deviation in general referred to as an exchange rate misalignment, when an exchange rate depreciates more than the equilibrium it is referred to as undervalued, and an appreciation of an exchange rate more than its equilibrium is referred to as overvalued (Williamson, 1994).

There are unpredictable changes to the exchange rate which ultimately reduces the benefits of international trades, the parties involved are to bear all the risks, countries generally do not hedge because the future market are not susceptible to all traders. Numerous empirical studies have been conducted to investigate whether trade is influenced by exchange rate volatility (Hooper et al., 1978).

METHODOLOGY

The data which have been used were taken from National Bank of Rwanda (NBR), and then analyzed, interpreted and forecasted.

In order to fulfill the objectives of this research project, a series of data were used. Those data are monthly average currency exchange rates of Rwandan franc against USD with sample size of 10 years (from January 2003 to December 2012).

Fitting appropriate time series model

For the main objective which stated as to fit the appropriate Box-Jenkins time series model for Rwandan currency against US dollar, the method used is Box-Jenkins modeling approach. Firstly time plot of series plotted, since the data was neither stationary in mean nor in variance the transformation of the data was made by applying natural log transformation ($\log_e Y_t$) to make the data stationary in variance and difference transformation ($Y_t - Y_{t-1}$)to make data stationary in mean.

Referred to the time sequence plot of this study, we chose the appropriate time series model among Autoregressive model (AR), Moving average model (MA), Autoregressive moving average model (ARMA) and Autoregressive Integrated moving average model (ARIMA).

Model for Autoregressive of order p is:

$$X_t=\varphi_1 X_{t-1}+ \varphi_2 X_{t-2}+\ldots+ \varphi_p X_{t-p}+a_t$$

Model for Moving average of order q is:

$$X_t=a_t-\Theta_1 a_{t-1}-\Theta_2 a_{t-2}- \ldots-\Theta_q a_{t-q}$$

Model for mixed autoregressive moving average of order (p,q) is:

$$X_t=\varphi_1 X_{t-1}+ \varphi_2 X_{t-2}+\ldots+ \varphi_p X_{t-p}+a_t-\Theta_1 a_{t-1}-\Theta_2 a_{t-2}- \ldots-\Theta_q a_{t-q}$$

where the φ's(phis) are the autoregressive parameters to be estimated, the Θ's(thetas) are the moving average parameters to be estimated, the *X's* are the original series, and the *a's* are a series of unknown random errors (or residuals) which are assumed to follow the normal probability distribution (Theresa et al., 2013).

The identification of potential model was done based on patterns of the autocorrelation (ACF) and partial autocorrelation (PACF) functions; to identify the appropriate one, autocorrelation and partial autocorrelation coefficients after transforming the data were calculated and then depending on correlograms of the ACF and PACF the next step was identifying the appropriate model.

Generally, Autocorrelation function at lag k is given by the following formula:

$$r_k = \sum_{t=1}^{N-k} (y_t - \overline{y}_t)(y_{t+k} - \overline{y}_t) \,/\, \sum_{t=1}^{N} (y_t - \overline{y}_t)^2$$

Where Y_t: time series data, $\overline{Y}$: mean of time series data,

Table 1. Monthly average exchange rate of RWF against USD.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
January	512.65	582.57	564.62	554.66	549.40	542.92	566.04	572.98	599.38	604.37
February	512.66	581.79	563.40	554.01	547.74	544.23	567.38	572.39	598.50	605.15
March	516.07	582.93	560.73	552.91	546.47	544.10	569.12	573.57	600.53	606.80
April	522.25	581.02	559.49	552.43	546.10	543.60	568.07	576.38	601.74	608.13
May	528.65	578.71	558.00	551.70	545.14	542.85	567.11	580.77	598.31	609.31
June	544.18	579.45	553.50	552.01	547.87	543.60	568.66	588.58	602.42	612.43
July	544.18	578.49	553.50	552.50	549.06	545.67	569.07	588.83	599.25	613.11
August	552.24	576.98	555.52	551.52	547.86	548.80	568.11	587.19	599.87	614.49
September	556.52	573.22	554.29	549.85	546.76	550.88	568.67	589.95	599.98	622.73
October	561.96	570.26	553.85	550.70	545.86	552.19	569.30	591.31	601.88	627.17
November	568.49	569.39	553.62	550.67	545.29	553.54	569.87	593.02	602.65	629.73
December	580.28	566.86	553.72	548.65	544.22	558.90	571.24	594.45	604.14	631.41

Y_{t+k}: lag values of time series data at k=1,2,3,…

And Partial autocorrelation function at lag m is given by the following formula:

$$\Phi_{m,m} = (r_m - \sum_{j=1}^{m-1} \Phi_{m-1,j} r_{m-1}) / 1 - \sum_{j=1}^{m-1} \Phi_{m-1,j} r_j$$

where r and Φ stands for autocorrelation and partial auto correlation functions.

Looking at ACF and PACF if the autocorrelation function “cuts off” at lag q while partial autocorrelation function dies away through different lags, moving average of order q (MA) must be included in the model. Whereas when partial autocorrelation function “cuts off” at lag p while autocorrelation function dies away through different lags, autoregressive model of order p (AR) must be also included in the model.

But if both ACF and PACF die away through different lags, both auto regressive and moving average (ARMA) models should be included. We have also to take into account the order of differencing both non-seasonal and seasonal differencing, for example if the data was transformed using non-seasonal differencing and both ACF and PACF die away, ARIMA (p,d,q) model must be fitted where p: order of autoregressive; q: order of moving average and d: order of differencing (Mukhopadhyay, 1999).

To choose the order of model the appropriate method is the principle of parsimony. This principle is a rule to seek simplest model as much as possible. For example if the model chosen is ARMA (p,q) using this principle we have to use small values of p and q as much as possible. That is the starting value will be p=q=1 where p is the order of autoregressive and q the order of moving average.

The interpretation based on the output of the time series model chosen was necessary to see if the model is adequate.

To check the adequateness of the model:

(i) Firstly, the residuals should not show any patterns; this can be checked by plotting residuals versus time.
(ii) Secondly, the residuals should not be correlated; this can be checked by examining ACF and PACF of residuals.

Before the analysis, the data of monthly average currency exchange rates was entered in SPSS statistical software. This software was also used in fitting the appropriate Box-Jenkins time series model and forecasting.

RESULTS AND INTERPRETATIONS

Table 1 shows the monthly average currency exchange rates of Rwandan Franc against US dollars from 2003 to 2012 by month.

To fit the appropriate time series model and forecast the future values for monthly average currency exchange rates of Rwandan Franc against US dollars, the following procedure was used. First the time series data was plotted in the form of time plot before any transformation, which helped to check if the data are stationary in mean and variance. Secondly, to see whether it dies down or cuts off after lag p and q, the autocorrelation function (ACF) and partial autocorrelation function (PACF)at different lag values are plotted.

The time plot in Figure 1 shows the original data of monthly average exchange rate of RWF against USD.

Figure 1 shows time plot is neither stationary in mean nor stationary in variance because the time plots in Figure 1 shows systematic change in mean and systematic change in variance. But to fit the Box-Jenkins model the data should be stationary. Therefore the first step is to transform the data in order to make it stationary in variance and mean.

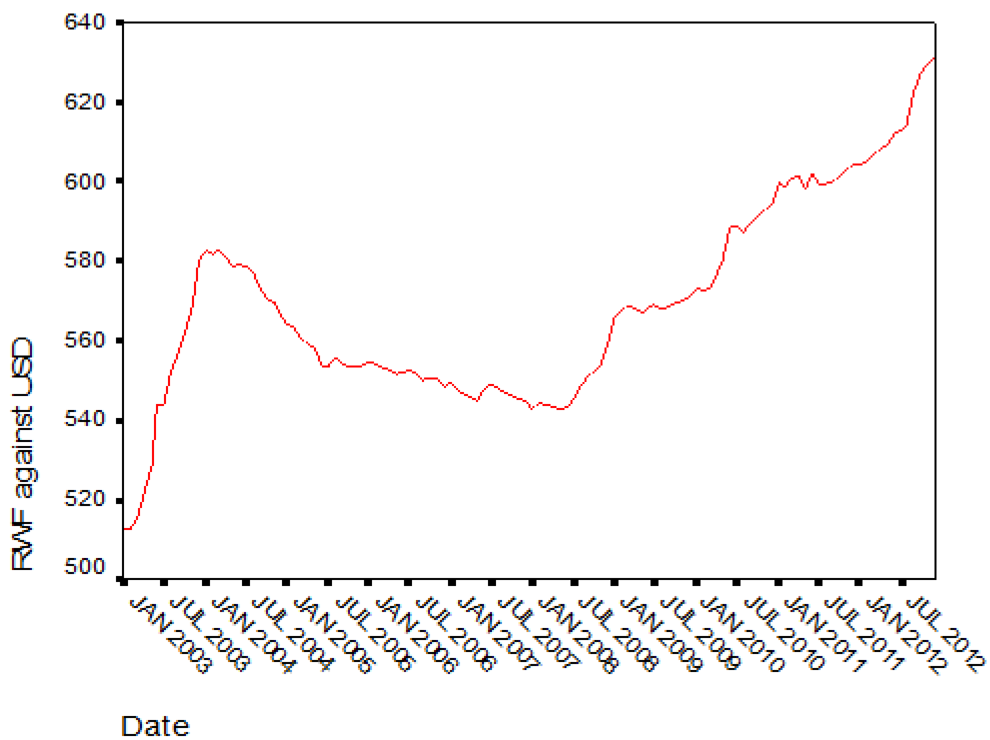

Figure 1. Monthly Average exchange rate of RWF against USD.

This was done by taking log transformation and difference transformation to make the data stationary in variance and in mean, respectively.

The autocorrelation function in Figure 2 shows the original data of monthly average exchange rate of RWF against USD.

According to the ACF figure, it shows pattern, it does not decay to zero which indicates that the original data is neither stationary in mean nor in variance thus the data must be transformed using difference and log transformation to make mean and variance approximately constant.

The Partial autocorrelation function in Figure 3 shows correlation of monthly average exchange rate of RWF against USD.

According to the PACF figure, there is high positive correlation between the current value and their value at lag 1 since the PACF correlogram shows partial autocorrelation coefficient which approaches to 1 at lag 1 (cut-off at lag 1).

The plot in Figure 4 shows the transformed data, and it indicates after log and difference order 2 transformation the data become stationary with respect to mean and variance.

Figure 5 presents the autocorrelation function of monthly average exchange rate of RWF against USD after transformation. It clearly shows that ACF now decay to zero which indicate that the data become stationary with respect to mean and variance; this was done by taking log transformation and difference transformation of order 2.

The Partial autocorrelation function in Figure 6 shows correlation of monthly average exchange rate of RWF against USD after transformation. According to this PACF figure, there is high positive correlation between the current value and their value at lag 1.

FITTING APPROPRIATE TIME SERIES MODEL FOR MONTHLY AVERAGE EXCHANGE RATE OF RWF AGAINST USD

From the autocorrelation and partial autocorrelation, the ACF has a significant cut-off compared to PACF, and ACF shows a large negative value at lag 1, and much smaller values at high lags. This indicates, the appropriate Box Jenkins model to be fitted is ARIMA (0, 2, 1); this is moving average of order 1 and differencing of order 2.

Then the general equation of ARIMA (0, 2, 1) model is as follows:

$$Y_t = \mu + \epsilon_t - \theta_1 \epsilon_{t-1}$$

Where: θ_1: coefficient of MA (1), ϵ_t: error term, μ: constant.

Therefore, fitting ARIMA model for our data using SPSS by

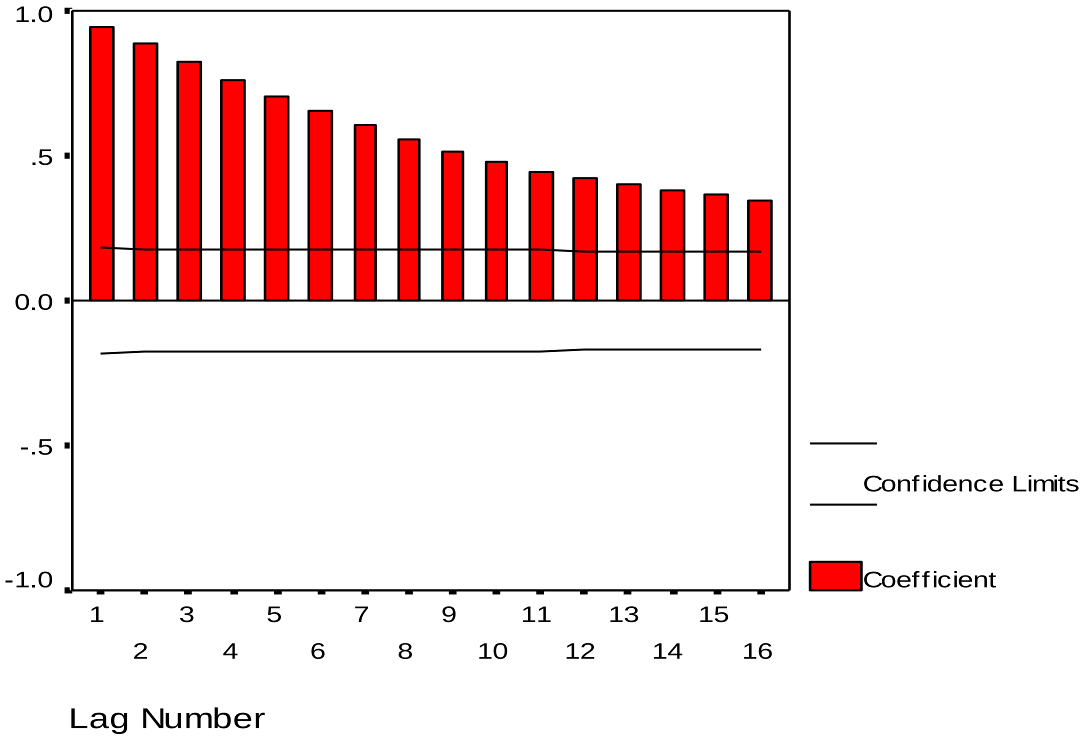

Figure 2. Autocorrelation for RWF against USD

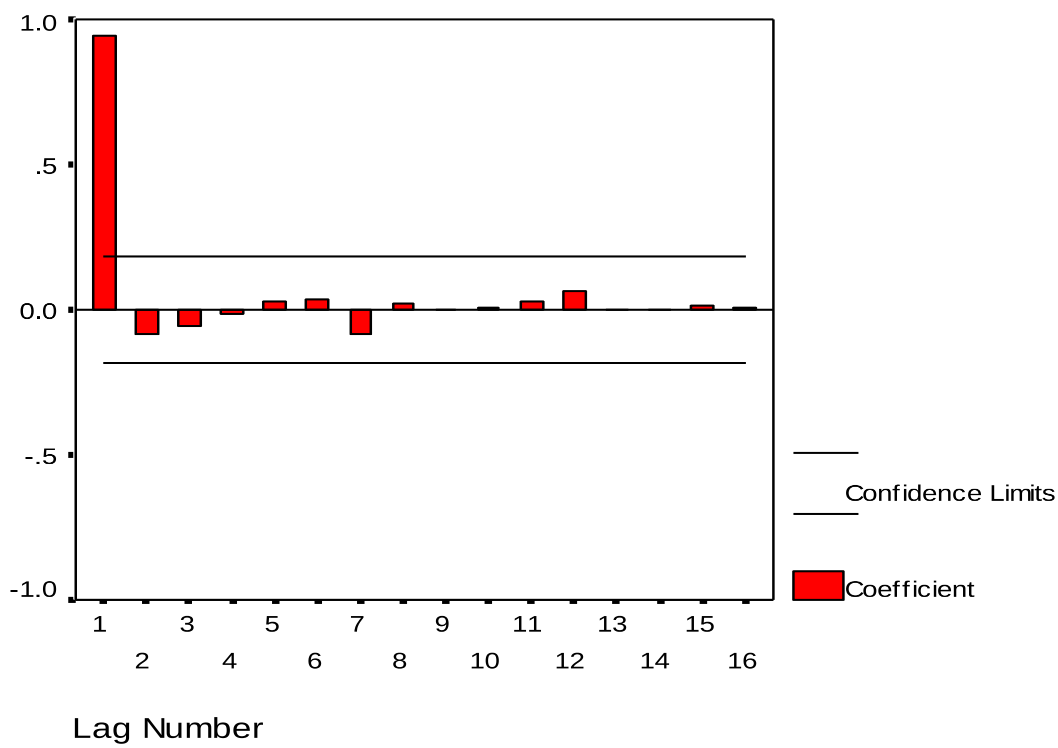

Figure 3. Partial autocorrelation for RWF against USD.

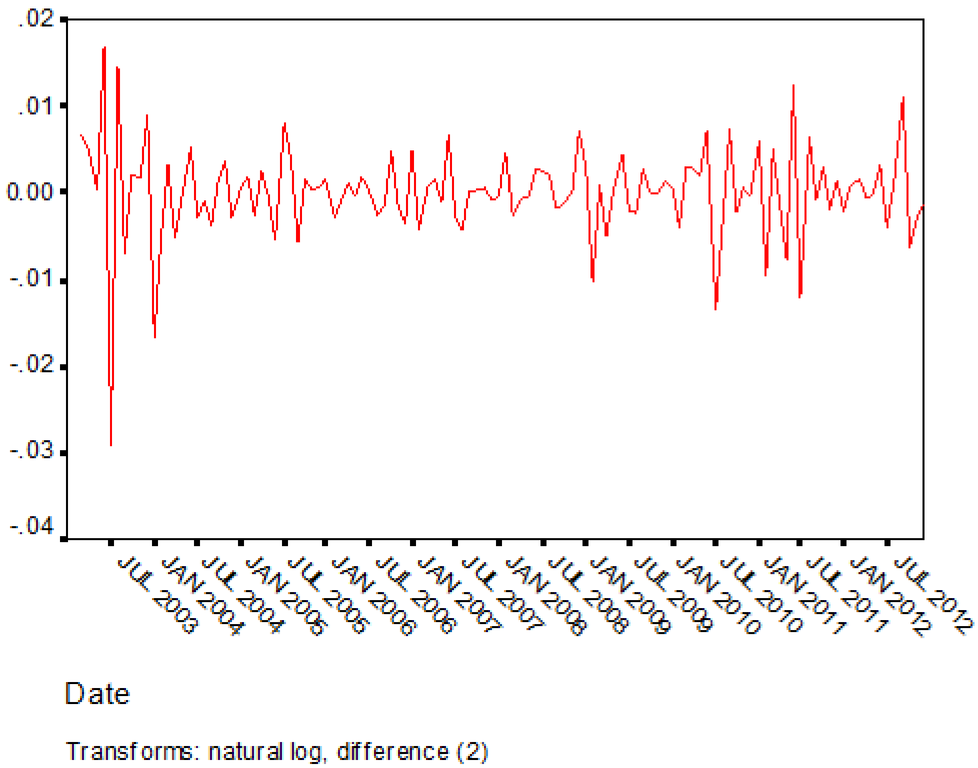

Figure 4. Monthly Average exchange rate of RWF against USD after transformation.

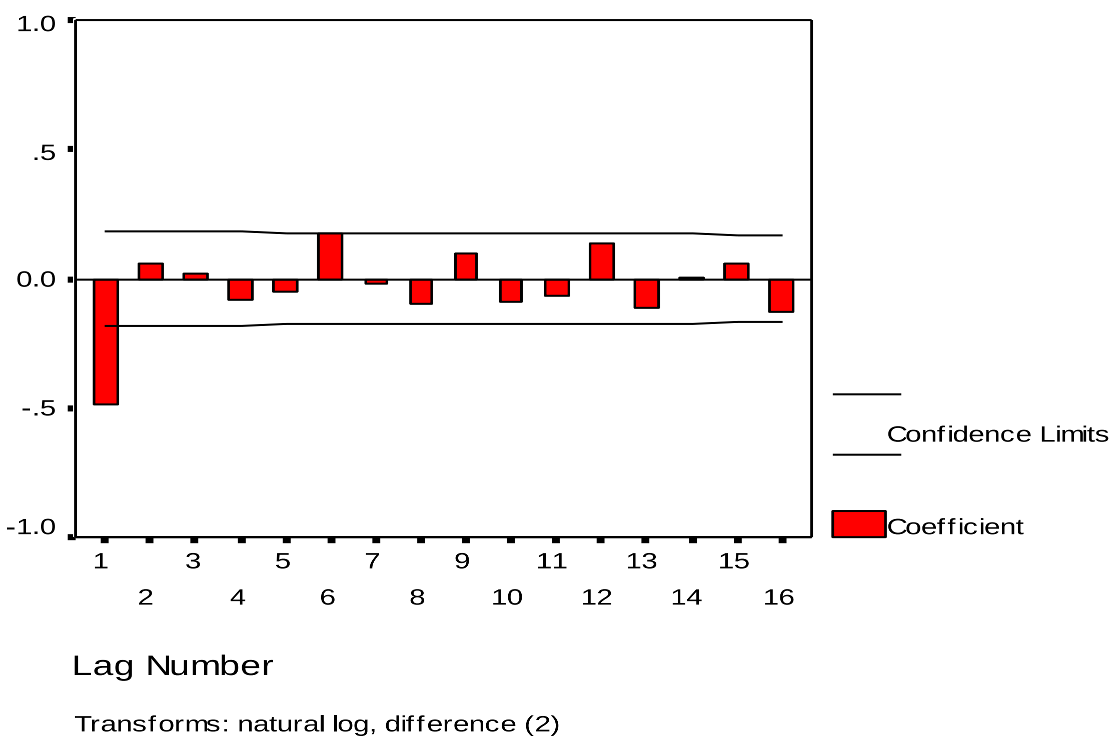

Figure 5. Autocorrelation for RWF against USD after transformation.

Table 2. Coefficient of the model and their corresponding probability.

	B	Probability
MA (1)	0.69507981	0.00000000
Constant	-0.01021832	0.89168959

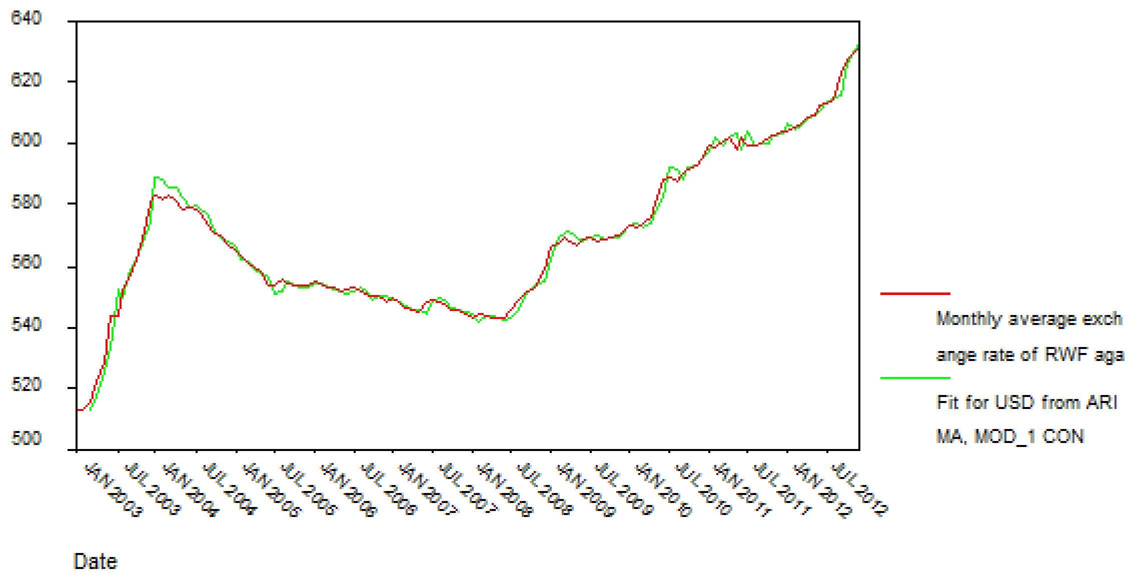

Figure 7. Multiple plot for observed and fitted values.

providing p=0, d=2, q=1 give us the output in Table 2.

The coefficient of MA (1) is 0.69507981 and their corresponding probability is 0.00000000. As it can be seen, coefficient is significant at 99% confidence interval because its corresponding probability is less than level of significance (1%).

Thus the actual fitted model based on the earlier estimated coefficient, is as follow:

$$Y_t=-0.01021832 - 0.69507981\epsilon_{t-1} + \epsilon_t$$

FORECASTING FUTURE VALUES OF MONTHLY AVERAGE EXCHANGE RATE OF RWF AGAINST USDUSING THE FITTED MODEL

Based on the fitted model, we can forecast monthly average currency exchange rates for the coming five years. Before forecasting; the adequate of the model was checked since we cannot forecast without checking if the model fitted is good or not. The model which must be used to predict the future value is an adequate model. The goodness of fit of the fitted model using ACF and Histograms super imposed by normal curve of the error terms are shown.

To check if the fitted values are close to the original data; multiple time plots were used in Figure 7.

Multiple time plots in Figure 7 shows fitted values and monthly average exchange rate of RWF against USD.

As it has seen in Figure 7, multiple time plot; the fitted values and observed values are quietly closing each other. This shows that the model fitted is good.

Figure 8 shows the histogram of forecast error for monthly average exchange rate of RWF against USD, which indicates the error terms from fitted values, is distributed normal.

The auto correlation function plot in Figure 9 shows the forecasting error for monthly average exchange rate of RWF against USD. From ACF of forecasting error plot, it can be seen that the error is uncorrelated because all coefficients are approximately inside boundaries, especially at highest lag.

Multiple time plots in Figure 10, shows original, forecast, upper and lower confidence limits (LCl and UCL) for monthly average exchange rate of RWF against USD. It indicates the original and forecasted data are closing each other but the upper limit is going to increase and lower limit is going to decrease from 2013, this is because we do not have values from 2013 up to 2017, the plot values in this range are the forecasted values. For the period in which data are available (from January 2003 to December 2012)

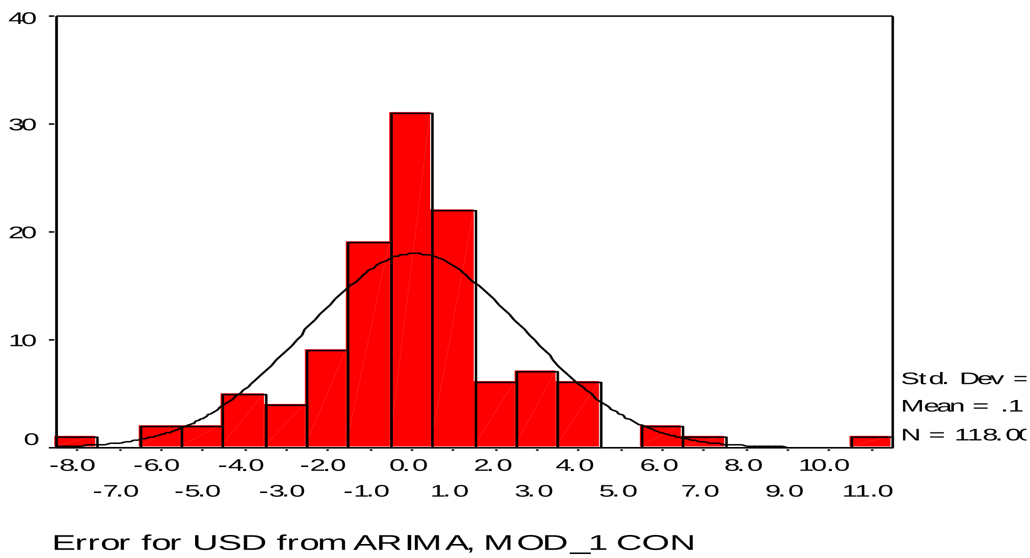

Figure 8. Histogram for forcasted error.

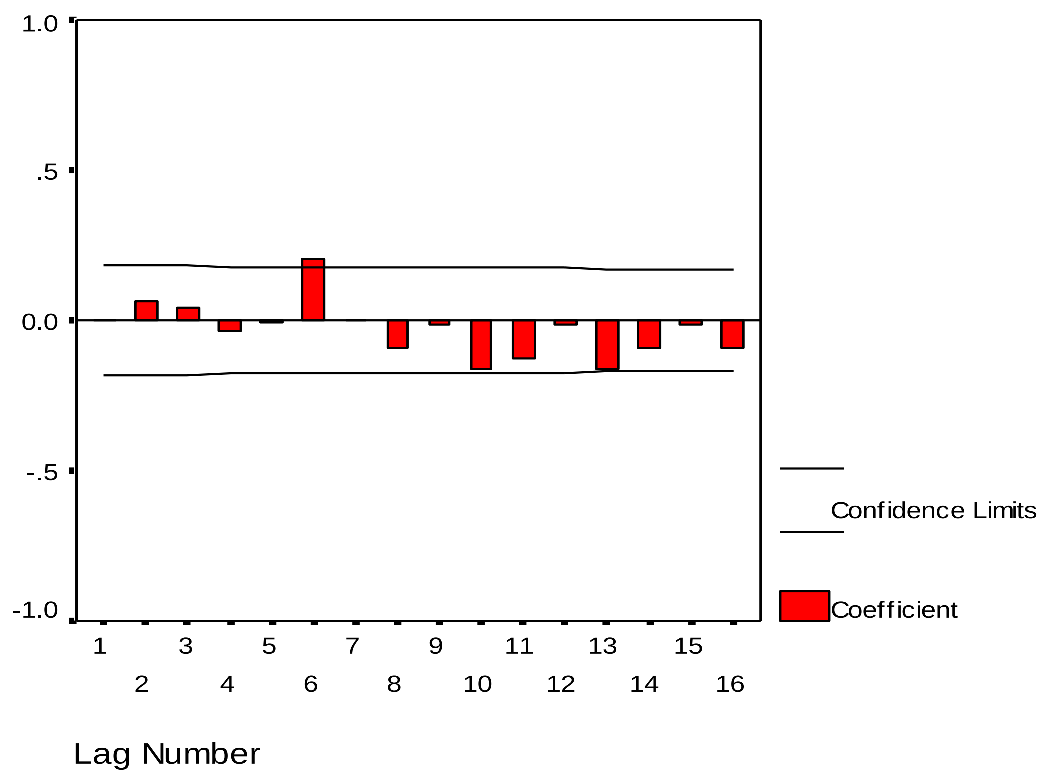

Figure 9. Autocorrelation for forecasted error.

prediction interval for forecasts is narrow.

DISCUSSION

During the analysis, we found that the appropriate time series model fitted for monthly average exchange rate of RWF against USD is ARIMA (0, 2,1).

Based on this model, the results of the prediction are very good, and 95% of the confidence interval for forecasted values is narrower. Therefore, it will help the customers of the bank to understand that the possible interval of

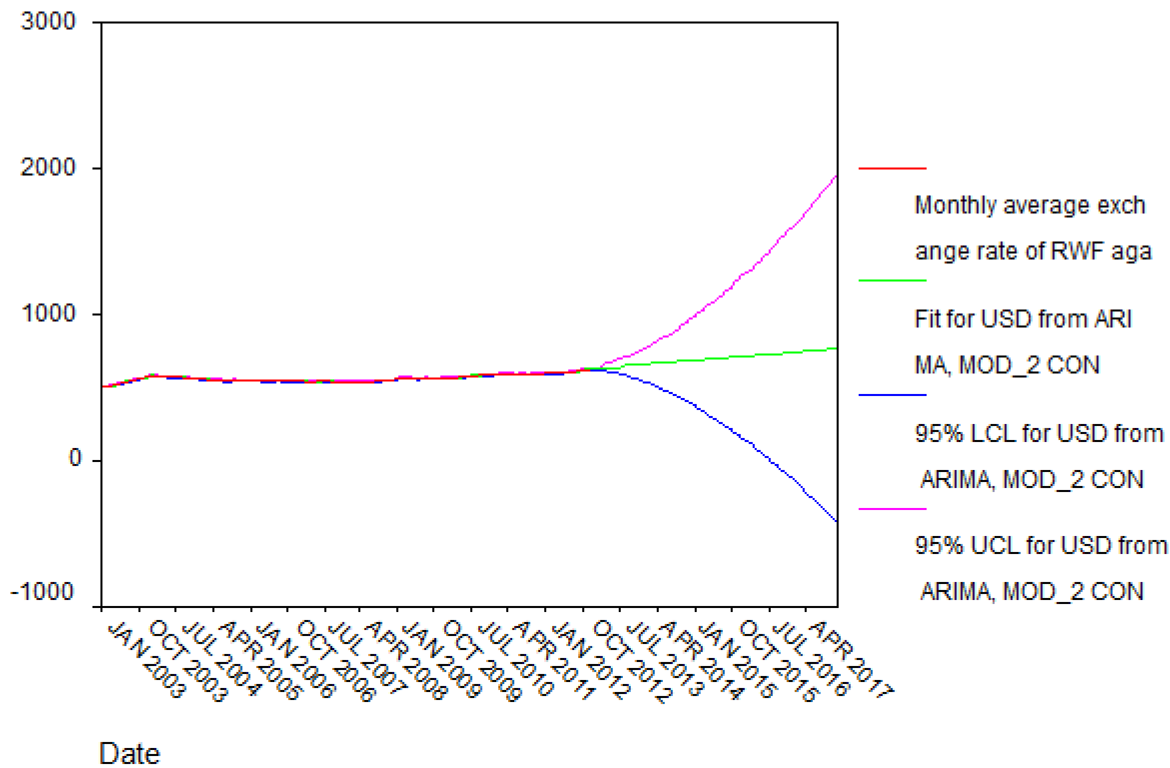

Figure 10. Multiple plot for observed and fittedvalue with boundaries.

Table 3. The fitted model forecasted output for the years 2015, 2016 and 2017.

Month/Years	2015	2016	2017
January	699.44	729.79	758.65
February	702.03	732.26	760.99
March	704.6	734.71	763.32
April	707.17	737.15	765.64
May	709.72	739.58	767.94
June	712.27	742.00	770.24
July	714.80	744.41	772.52
August	717.33	746.81	774.8
September	719.84	749.2	777.06
October	722.35	751.58	779.32
November	724.84	753.95	781.56
December	727.32	756.31	783.80

exchange rate in the macro-economic environment is stable.

According to the fitted model forecasted output as shown in Table 3, the monthly average exchange rate of RWF against USD in December 2017 will be 783.80 RWF.

The appropriate model for monthly average exchange rate of RWF against USD is ARIMA (0, 2, 1), it does not include AR (Autoregressive model) since the order of AR in this study is zero. Which is not the case for monthly average exchange rate of NT dollars (NTD, Taiwan dollars) to US dollars (USD) because it was found that the observation of monthly average exchange rate of NT dollars (NTD, Taiwan dollars) to US dollars (USD) are correlated since all tests showed that the series are autoregressive of second order ARIMA (2, 0, 0) (Gee, 1994).

RECOMMENDATION

One of the factors that cause the depreciation of exchange rate is a decrease in exports and an increase in imports. Rwanda is one of the countries which used large amount and variety of imported goods through the transaction of US dollars, this has an impact on the exchange rate.

As recommendation to Government of Rwanda especially to National Bank of Rwanda (NBR) the following measures better to be taken:

(ii) Appreciation to encourage exports and discourage imports.
(ii) Encourage the five member states of the East African Community to establish a common East Africa Regional currency, as new East African shilling.
(iii) To have short term plan like five years plan to increase the exchange value of Rwanda currency (Rwandan francs) to other strong currencies like the US dollars.

In general, this research gives a recommendation to different researchers especially University of Rwanda, College of Science and Technology students to do further study on monthly average currency exchange rates in Rwanda by considering this as baseline.

REFERENCES

Anderton R, Skudelny F (2001). "Exchange Rate Volatility and Euro Area Imports" European Central Bank (ECB) Working Paper, no. 64.
Hooper P, Kohlhagen SW (1978). "The effect of exchange rate uncertainty on the prices and volume of international trade". J. Int. Econ. 8:483-511.
Mukhopadhyay P (1999). "Applied Statistics", ISBN: 81-87134-38-0. pp.415-455
Ozturk I (2006) "Exchange rate volatility and trade: a literature survey," Int. J. Appl. Econometr. Quant. Stud. pp.3-1.
Gee S (1994). "The effects of NT dollar variations on Taiwan's trade flaws". ISBN: 0-226-38669-4, pp.89-122. University of Chicago press.
Sarno L (2005). "Towards a solution to the puzzles in exchange rate economics: where do we stand?", Warwick Business School, Working paper.
Theresa et al (2013). "The Box-Jenkins methodology for Time series model". SAS global forum on statistics and data analysis.
The Rwanda Focus www.bnr.rw/exchangerates.aspx (Accessed on Nov.5,2012)Dollar scarcity pushes up prices.
Williamson J (1994). "Estimates of FEERs," in Estimating Equilibrium Exchange Rates, ed. by J. Williamson (Washington: Institute for International Economics).
Zeleke GT (2012) Time series analysis and forecasting lecture Notesfrom Kigali Institute of Science and Technology (KIST), Kigali-Rwanda.

Cite this article as:

Girum TZ, Didier D, Ntwali MP (2014). Time series analysis on monthly average Rwanda currency exchange rate against US dollars. 2(5): 074-083.

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