IS THE SOUTH AFRICAN EXCHANGE RATE VOLATILE? APPLICATION OF THE ARCH FRAMEWORK

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Abstract

This study applies the autoregressive conditional heteroscedasticity (ARCH) model to forecast exchange rate volatility in South Africa for the period 1990Q1 to 2014Q2. The ARCH (1) and ARCH (2) models were constructed using four variables; namely, exchange rate, gross domestic product, inflation and interest rates. Upon addressing the issue of stationarity, the models were fitted and the ARCH (1) model was found to be fit. This model revealed a high volatility of exchange rate compared to the ARCH (2) model. Prior to forecasting, the selected model was subjected to a battery of diagnostics tests and was found to be stable and well specified. The forecasts from the ARCH (1) model proved that in the near future, exchange rate will not be highly volatile though SA will experience depreciation in its currency.

Keywords: Exchange Rate Volatility, ARCH, Macroeconomic Variables, Stationarity

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1. Introduction

In the era of globalization, there is a need for foreign currency in order to manage economic activities such as exports, imports and investments. There are other components that benefit from the exchange of foreign currency such as industrialization and advancement, government departments, industries and organisations (Rishipal and Jain, 2012). The authors emphasise that the availability of various economic resources and means of production in the South African government depends largely on the value of exchange rate. As a result, the resources responsible for evaluation of exchange rate are not stable and fixed. Subsequently, the value of exchange rate fluctuates with respect to its purchasing power in the government and foreign currencies.

Exchange rate volatility has been found to have a significant effect on the overall economy of a country as reported by Rishipal and Jain (2012). The adverse consequences of exchange rate volatility on various parts of the domestic economy have now been well documented in numerous research works as highlighted by Rahmatsyah et al. (2002). Having said that, the Economist Intelligence Unit in 2007 affirmed that the impact of exchange rate on the economy has become an important question for economic policy makers. The former President of South Africa (SA) Thabo Mbeki created the Myburgh Commission to investigate the causes of the acute depreciation of the rand in 2001. The unit reported that the South African rand remains one of the most volatile of emerging market currencies, and is prone to sharp movements. It was then concluded that exchange rate volatility is a problem that affects the country's economy and investments.

Exchange rate across the world has fluctuated widely particularly after collapse of the Bretton Woods system of fixed exchange rate (Srinivasan and Kalaivani, 2012). Excessive fluctuations have been observed in the exchange rate in countries. These fluctuations have been reported to be the major causes of uncertainties worldwide as reported by Chaudhary et al. 2012. SA was one of the countries that experienced this volatility according to Nyahokwe (2013). After the collapse of the Bretton Woods system of fixed exchange rate, majority of the affected countries initiated the flexible/floating exchange rate system (Chaudhary et al., 2012). In their study, Insah and Chiaraah (2013) highlighted that the change in the exchange rate regime from fixed to floating exchange rate system in 1983 caused a spike in exchange rate volatility in SA and this had marked effects on economic growth, capital movements and international trade. Fixed and floating exchange rate systems are identified by literature as the types of exchange rate as highlighted in Mohr et al. (2008). Some countries use the fixed exchange rate while others use the floating exchange rate systems. According to their explanation, Rishipal and Jain (2012) are of the view that fixed exchange rate system does not fluctuate overtime, while floating exchange rate system keeps on changing continuously.

Immediately after the move to a floating exchange rate system, exchange rate became highly volatile in SA, Omojimite and Akpokodje (2010) warned that this had negative repercussions for trade, investment and growth. Volatility in the exchange rate affects the country in such a way that an appreciation in the exchange rate may create current account problems because it leads to overvaluation. This in turn makes imports artificially cheaper for foreign buyers while the volume of exports becomes relatively expensive for foreign buyers. Takaendesa (2006) alluded that exchange rate volatility reduces the international competitiveness of a country. Moreover, volatility in exchange rate hurt producers and investors alike because it affects their projected (planned) revenue and costs, including profits margin (Ben et al., 2010).

Campbell et al. (1997) commented on the statistical inefficiency and inconsistency of the assumption of a constant variance over some time period. He mentioned that in financial data the variance changes with time and defines this phenomenon as heteroscedasticity. It is of utmost importance to study models which accommodate this possible variation in variance. Numerous researches have been conducted in SA where the problem of exchange rate volatility was considered. Unfortunately, none of these researches used mathematical methods on quarterly data to model the conditional variance and performed forecast of exchange rate volatility. Therefore this study applies the autoregressive conditional heteroscedasticity (ARCH) framework to model and accommodate the dynamics of conditional heteroscedasticity in exchange rates. Moreover, the study intendeds to model long term performance of quarterly exchange rates of SA for the period 1990 to 2014.

The rand volatility is regarded as the biggest encounter faced by the South African economy. The Congress of South African Trade Union and other firms in the manufacturing industry had previously made calls to reduce the rand value. However, by far, the steadiness of the South African exchange rate is regarded as the most preferable choice for the financial sector and the industry at large. The inconsistencies in the rand resulted into one of the serious political-economic dilemma for the country. Most studies reported the volatility of the rand as one of the determinants which slows down the economic wellbeing of SA. The stock market is also suffering due to these volatility effects. It is however also necessary to investigate what could be the factors of exchange rate volatility. This information could be useful to policy makers in the country.

The findings of this study may be of help to economic policy makers in the country as they would know what to emphasise on in respect of exchange rate volatility. The findings may also help in bridging a gap in literature on the subject. This study may also give a guide to policy makers in the country to embark on policies that could help with reducing if not stabilising the challenge of exchange rate volatility. SA is a developing country, and other countries benchmark on it. It is therefore important come up with policies that are informative not only to the South African government policy makers but also to other countries who are investors or wish to invest their resources in the country. Good investment is good for the country as it helps in boosting the economy and as a result poverty is alleviated and more jobs are created. Researchers and academicians in the field of finance and economics may also find this study as a useful guide when dealing with the issues of exchange rate. The recommendations made by this study may help prevent further exchange rate volatility in SA. The remainder of this paper is structured as follows; Section 2 provides a brief literature review, Section 3 describes the methodology, followed by results and discussion in Section 4. Section 5 gives concluding remarks.

2. Literature review

This section examines the review of studies on exchange rate volatility with the aim of identifying statistical framework and the variables adopted. Uddin et al. (2013) in their study suggest that, before exploring a new phenomenon, it is necessary for a researcher to look into various aspects already studied. As research is a continuous process and it must have some continuity with earlier facts. In this section, we elaborate on the research problem by looking into studies that already investigated exchange rate volatility. The emphasis is basically on what the theory says about the research problem.

Various studies around the world have investigated the factors affecting exchange rate volatility using different methods. For instance, in Pakistan, Zada (2010) studied the factors affecting exchange rate volatility using annual data for the period 1979 through 2008. The author employed multiple regression technique whereby inflation, interest rate, foreign exchange reserves, trade balance, money supply and gross domestic product were used as independent variables. The findings of the study indicated that inflation rate, interest rate and foreign exchange reserves strongly influence the exchange rate volatility and remained significant at 1% level while other variables such as gross domestic product (GDP), money supply, and trade deficit remained insignificant.

In Nigeria, Mayowa and Olushola (2013) used annual time series data to investigate the determinants of exchange rate volatility for the period 1981 through 2008. Variables used in the study include exchange rate, productivity, trade openness, government expenditure, real interest rate and money supply. The GARCH (1, 1) technique and the error correction model (ECM) were applied to examine the various determinants of exchange rate volatility. The findings of the study indicated that openness of the economy, government expenditure, interest rate movement as well as the lagged exchange rate is among the major significant variables that influence exchange rate volatility.

Umaru et al. (2013) investigated the impact of exchange rate volatility on export in Nigeria. The study used GARCH (p, q) on time series data covering the period 1970 to 2009. The findings of the study indicated that exchange rate volatility impacts exports in Nigeria. The study recommended that, Nigerian government implement a fixed and sustainable exchange rate policy that will promote greater exchange rate stability and improve terms of trade.

Danmola (2013) studied the relationship between exchange rate volatility and GDP, foreign direct investment (FDI) and trade openness. The study used annual data which covered the period 1980 to 2010 in the Nigerian context. For the purpose of analysis, the author employed the correlation matrix, ordinary least square (OLS) and Granger causality test to test the short run dynamics. The findings of the study indicated that GDP, FDI and Trade Openness have a positive influence on exchange rate volatility. The findings further indicated that all variables are stationary at different levels of significance and order of integrations.

The study by Mahmood et al. (2011) looked into the relationship between exchange rate volatility and FDI, GDP and trade openness in Pakistan. The investigation was mainly to check whether fluctuations in exchange rate volatility affect FDI, GDP and trade openness in Pakistan. The study used annual data from 1975 to 2005. GARCH (1, 1) model was applied and the findings of the study indicated the impact of exchange rate volatility on macroeconomic variables in Pakistan. The results further indicated that exchange rate volatility positively affects GDP and trade openness and negatively affects the FDI. From the literature gathered above, it is evident that the subject is of interest and has been investigated in several countries. It is evident that less interest is paid to ARCH as a method of investigation. This is an indication that the application of this model has not been exhausted in the field of econometrics. This study is important since there is no evidence that the same has been done in SA.

3. Data and methodology

3.1 Data

The empirical analysis uses quarterly data that covers the period 1990Q1 to 2014Q2. The sample period is selected because it covers the 2007 and 2008 financial crisis and the period gives a clear trend of what happened prior to and after the apartheid era. Moreover, with a considerable number of observations, the assumption of normality may also not be violated and the effective applications of the methods chosen for data analysis are catered for. Data is mainly sourced from the electronic data delivery system of the South African Reserve Bank (SARB) and Organization for Economic Co-operative and Development (OECD). The econometric views (E-Views) version 8 software package is utilized to analyse data. E-Views helps with data management, perform econometric and statistical analysis, generate forecasts and model simulations, and produce high quality graphs and tables. The variables used in the analysis are exchange rate (ER), gross domestic product (GDP), and inflation rate (INF) and interest rate (INTR). A brief description for each of these variables is given below.

Exchange rate (ER): Todaro and Smith (2011) define the ER as the price of one unit of foreign currency in terms of domestic currency for instance, the exchange of the Rand for the US dollar. This variable is used in this study as a dependent variable ER and is measured in percentages.

Gross Domestic Product (GDP): Mohr et al. (2008) define GDP as the total value of all goods and services produced within the boundaries of a country in a particular period (usually on year). According to Rishipal and Jain (2012), a volatile ER, especially when it depreciates constantly, affects the GDP which will lead to exports becoming cheaper and imports expensive. GDP is an independent variable and is measured in millions.

Inflation rate (INFR): Mohr et al. (2008) define INFR as a continuous and considerable rise in prices in general. According to Chaudhary and Goel (2013), INFR is a determinant of ER whereby a higher INFR in the country will be followed by a depreciation of the currency while a lower INFR in the country will be followed by an appreciation of the currency. INFR as an independent variable in the model is measured in percentages.

Interest rate (INTR): According to Mohr et al. (2008), INTR is the percentage charged by the lender to the borrower for the use of money/assets. A higher INTR in the domestic country attracts foreign investors which in turn increases the value of the domestic currency. INTR as another independent variable in this study is measured in millions.

Exchange rate in this study is modelled as percentage the first difference of the series defined as:

$$\mathrm{r_t} = 100 * \log\left(\frac{\mathrm{E_t}}{\mathrm{E_{t-1}}}\right) \tag{1}$$

where $\mathrm{r_t}$ is the daily percentage return to the exchange rate and $\mathrm{E_t}$ and $\mathrm{E_{t-1}}$is denoted the exchange rate at the current and previous day respectively.

3.2 Methods

Preliminary data analysis is performed before the primary statistical data analysis. Firstly, it is important to explore the behavior of a random variable. Therefore trend analyses are employed for this reason.

3.2.1. Stationarity analysis

Challis and Kitney (1991) define stationarity as a process whereby the statistical parameters, for instance, the mean and standard deviation of the process do not change with time. On the other hand, Aas and Dimakos (2004) clarify that a sequence of random variables X_t is stationary if there is no trend and if the covariance does not change over time, that is:

$$E[X_t] = \mu \text{ for all } t \text{ and } Cov(X_t X_{t-k}) = E[(X_t - \mu)(X_{t-k} - \mu)] = \gamma_k \text{ for all } t \text{ and any } k.$$

Sibanda (2012) asserts that the dependent and independent variables of a classical regression model be stationary and the errors have a zero mean and finite variance. Hill et al. (2008); Bowerman and O'Connell (1979) provide reasons why stationarity of variables needs to be assessed. The first basic reason is to avoid spurious results. Secondly, if a regression model has variables which are non-stationary, then t-ratios do not follow a t-distribution. The sequence for stationarity check is to firstly show time series plots which determine the behaviour of random variables. This further assesses whether or not the properties of time series are violated. The formal tests conducted are the Augmented Dickey-Fuller (ADF) and Phillips Perron (PP) formal tests. These tests are important as they give insight into the structural breaks, trends and stationarity of the data set (Brooks, 2008). Discussed below is the ADF and PP test for stationarity.

Augmented Dickey Fuller (ADF)

A customized version of the Augmented Dickey-Fuller (ADF) was developed by Dickey and Fuller (1979). Phillips Perron (PP) slightly differs from ADF in terms of the heteroscedasticity in the error term and the serial correlation. The PP uses a different approach to approximate the ARMA structure of errors in the test regression and ignores any serial correlation as compared to the ADF that uses a parametric auto regression. The ADF test was recommended by Chun-Leng (2006) as a good measure for assessing stationarity of the series. The following regression equation adopted from Moroke (2014) is used for testing stationarity:

$$\Delta Y_t = \alpha + \beta Y_{t-1} + \sum_{i=1}^{k} \phi_1 \Delta Y_{t-1} + \varepsilon_t, \qquad (2)$$

where Δ represents the first difference operator, t is the time drift, k is the number of lags used and ε_t is the error term, α and β are the model bounds. The ADF test includes a constant and deterministic trend. Assuming that the series $\{Y_t t_{-1}^{T}\}$ follows an AR (p) process, Hamilton (1990) highlights that the rejection or acceptance of the null hypothesis of a unit root is based on running the regression:

$$Z_t = \mu + (\phi_1 - 1)Y_{t-1} + \sum_{j=1}^{p-1} C_j Z_{t-j} + \varepsilon_t \qquad (3)$$

where $Z_{t-j} = Y_{t-j-1}$ for j = 0, 1, 2,…, p -1 and ε_t is a white noise process. The ADF test statistic is given as;

$$\hat{\tau}_{ADF} = \frac{\hat{\phi}_1 - 1}{se(\phi_1)}, \qquad (4)$$

$se(\phi - 1)$ Represents the standard error of $\phi - 1$. The null hypothesis of a unit root $H_0 : \phi_1 = 1$ is rejected if $\hat{\tau}_{ADF}$ is less than the appropriate critical value at some level of significance.

Phillips Perron (PP)

Phillips-Perron (1988) test of stationarity is a more comprehensive theory of unit root non stationarity. The test uses non-parametric statistical methods in order to take care of the serial correlation in the error terms without adding lagged difference terms (Brooks, 2008).The test is similar to the ADF test but it incorporates an automatic correction to the DF procedure to allow for auto correlated residuals. The PP test involves fitting the regression:

$$y_i = \alpha + \rho y_{i-1} + \varepsilon_i \qquad (5)$$

where ε_t is $I(0)$ and may be heteroscedastic. The test statistic is calculated with the equation:

$$\hat{\tau}_{pp} = \left(\frac{t_{\phi-1}}{\xi}\right)\Gamma_0^{\frac{1}{2}} - \frac{N}{2}\left(\frac{\xi^2 - \Gamma_0}{\xi \hat{\sigma}}\right) se(\phi - 1) \qquad (6)$$

where $t_{\phi-1}$ is the test statistic of $\phi - 1$, $se(\phi - 1)$ is the standard error of $\phi - 1$, $\hat{\sigma}$ is the standard error of the test regression and Γ is the truncation lag. The asymptotic distributions of the PP test statistics are the same as those of the ADF test. Here again, the null hypothesis of unit root H_o: ϕ_1 = 1 is rejected if $\hat{\tau}_{ADF}$ or $\hat{\tau}_{pp}$ is less than the appropriate critical value at some level of significance.

3.2.2. ARCH model estimation

The variance of the disturbance term is assumed to be constant in economic modelling. However many economic series do not have a constant variance and a number of these series are exposed to periods of high, others to low period of volatility (variance). Exchange rate has been found to be prone to the volatility. The ARCH model is recommended to capture these effects of conditional heteroscedasticity. This model was first introduced by Robert Engle in 1982. The model could also be applied when the researcher desires to simultaneously model estimates of the mean and the variance of a series. As the name of the model indicates it assumes heteroscedasticity of the residual and takes it into account (Abdalla, 2012). The autoregressive part comes from the fact that it uses realized values of old residuals, which are obtained from the mean equation.

$$r_t = \varepsilon_t,$$

where $\varepsilon_t \sim N(0,\sigma_t^2)$ and $\sigma_t^2 = c.$

The model is mostly used in finance. Engle (2001) supported by Brooks (2008) recommends the ARCH model when the goal of the study is to analyse and forecast volatility. Volatility is referred to as the spread of all likely outcomes of an uncertain variable. Abdalla (2012) cautions that in financial markets, we are often concerned with the spread of asset returns. The statistical definition of volatility is a measure of the sample standard deviation as;

$$\hat{\sigma} = \sqrt{\frac{1}{T-1}\sum_{t=1}^{T}(r_t - \mu)^2} \tag{7}$$

where r_t is the return on the day and t and μ is the average return over the T-day period. Poon (2005) asserts that volatility as a measure strictly for uncertainty could be due to a positive outcome. In the presence of the ARCH effects, the variance will no longer be time independent and the ARCH model that deals with the heteroscedastic variance becomes:

$$\varepsilon_t \mid I_{t-1} \sim N(0,\sigma_t^2) \tag{8}$$

This paper uses the variance as a measured of volatility. Adopting the procedure used by Abdalla (2012), the general form of the ARCH (q) model is

$$\sigma_t^2 = \alpha_0 + \sum_{p}^{q} \alpha_i \varepsilon_{t-1}^2 \tag{9}$$

The residual is conditionally heteroscedastic and depends on all information available at time $t-1, I_{t-1}$. The residual becomes;

$$\varepsilon_t = \upsilon_t \sigma_t \tag{10}$$

And υ_t is a white noise process and is assumed to be normally distributed with mean 0 and variance 1, i.e. $\upsilon_t \sim N(0,1)$ and is independent of σ_t. σ_t is a non-negative stochastic process. The variance of ε_t is no longer a constant and depends on the lagged values of the residual, where $\alpha_0 > 0$ and $\alpha_i \geq 1$ (necessary to restrict the variance to be positive) (Abdalla, 2012). The ARCH model is advantageous to use as the conditional forecasts are vastly superior to unconditional forecasts because they incorporate all information available. The unconditional forecast for the mean and variance of an ARCH (1) model becomes:

$$E(\varepsilon_t) = 0 \tag{11}$$

$$E(\varepsilon_t^2) = \frac{\alpha_0}{1-\alpha_1}. \tag{12}$$

The conditional forecasts of these coefficients would be;

$$E(\varepsilon_t \mid I_{t-1}) = 0 \tag{13}$$

$$E(\varepsilon_t^2 \mid I_{t-1}) = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 \tag{14}$$

In this instance, the conditional mean is still zero due to the white noise process but the conditional variance is different and is dependent on the realized value of ε_{t-1}^2. The unconditional variance only looks at the estimated values of α_0 and α_1. If the realized value of ε_{t-1}^2 is large so will ε_t^2. It is a desirable feature for financial series since most of them display evidence of volatility clustering and the ARCH process takes it into account (Abdalla, 2012).

3.3 Model selection criteria

Model selection criteria provide a basis for model selection (Acquah, 2010). The study uses the Akaike information criterion (AIC) and Schwarz information criterion (SIC) in order to select between candidate models. Discussed below is the procedure for using the AIC and SIC criteria. AIC was developed by Akaike (1973) while SIC was developed by Schwarz (1978). The AIC test is aimed at finding the best approximating model to the unknown data generating process (Acquah, 2010).

Gujarati and Porter (2009) emphasise that the advantage of forecasting performance of a regression model using the AIC is not only in-sample but also out-of-sample. The advantage of using the SIC is to identify the true model (Fox, 2008). Gujarati and Porter (2009) emphasises that the SIC can be used to compare in-sample or out-of-sample forecasting performance of a model. Both models are given in equations 15 and 16 respectively:

$$AIC = -2\log_{\varepsilon} L(\hat{\theta}) + 2s \qquad [15]$$

$$SIC = -2\log_{\varepsilon} L(\theta) + s\log_{e} n \qquad [16]$$

where $L(\hat{\theta})$ is the maximised log likelihood under the model and θ is the parameter vector for the model. The model with the smallest AIC and SIC is chosen and used for further analyses.

3.4 Model diagnostics tests

The model that satisfies the requirements of the AIC and SIC is subjected to a battery of diagnostics tests prior to the forecasting process. This step ensures that the model is adequate enough to be used for further analyses. Tandrayen-Ragoobur and Emandy (2011) emphasise that model diagnostics testing is important as it helps in identifying misspecification of a functional form and the stability of regression coefficients. In light of the above information, the cumulative sum control chart (CUSUM) stability test and Ramsey's (regression error specification test) RESET tests are used to test for stability of the coefficients and misspecification of a functional form. The description of these tests is given below;

Cumulative Sum Control Chart (CUSUM) stability test

Checking model stability is necessary for prediction and econometric inference (Hansen, 1992). The author further cautions that model instability generally makes it difficult to interpret regression results. In the present study, the CUSUM stability test is used to assess stability of the long run dynamics (Tandrayen-Ragoobur and Emandy, 2011). The test is essentially designed to detect instability in the model. This test was developed by Page (1954). It is based on a normalized version of the cumulative sums of the residuals (Brooks, 2008). Tandrayen-Ragoobur and Emandy (ibid) point out that, if a plot of the CUSUM statistics stays within the critical bounds of 5% significance level, it means that all coefficients in the model are stable. Stability of the model implies that the explanatory variables are fit for the selected model.

Ramsey's Regression Error Specification Test (RESET)

The RESET test was developed by Ramsey (1969). This test is a general misspecification test designed to check the inappropriate functional form of the model. It further tests whether a regression model is correctly specified in terms of the regressors that have been included in the model (DeBenedictis and Giles, 1998). The rejection rule is to reject the null hypothesis if the probability value associated with the Ramsey's RESET test is greater than 0.05 or 5%. According to Hill et al. (2008), rejection of H_0 implies that the specification of the equation can be improved.

4. Results and discussion

This section provides and discusses the results based on the objective of the study and the methods employed.

4.1 Stationarity test result

The initial analysis of data involves analysing the time series plots in order to identify the salient features of the data. This further helps in deciding about the properties of the model to fit. Figure 1 is a graphical representation of the four variables used in the study.

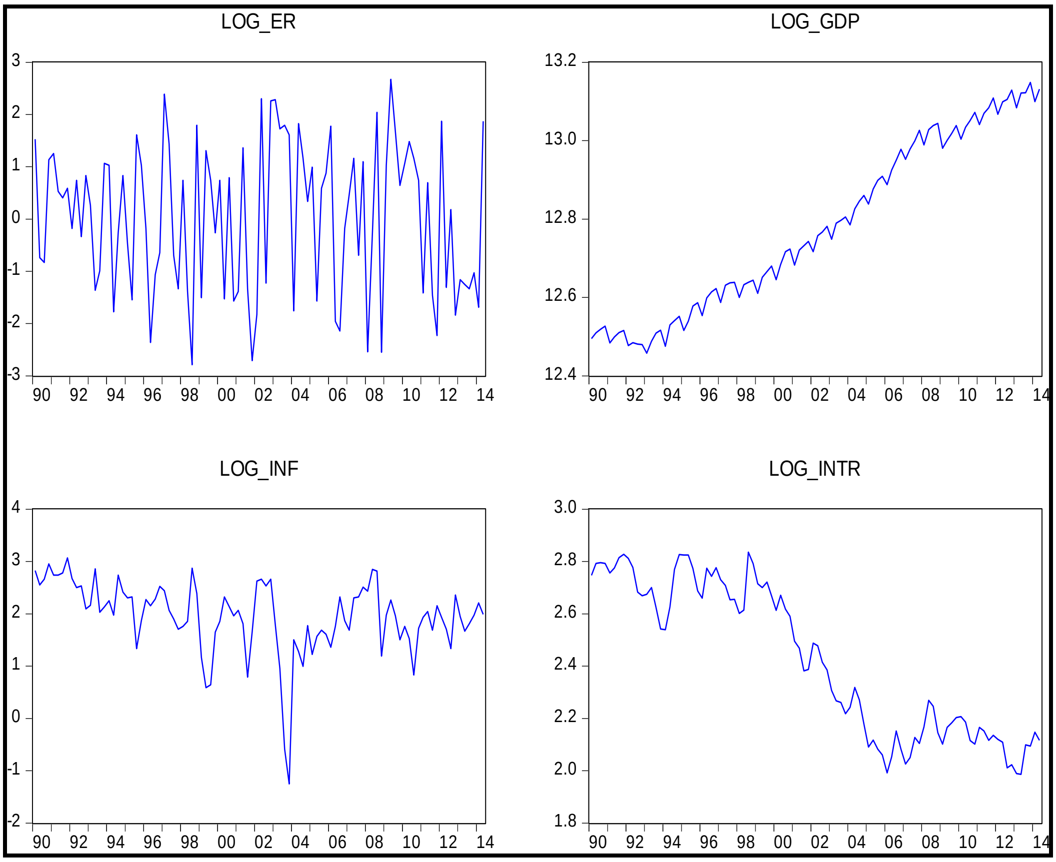

Figure 1. Time series plots

It is evident from figure 1 that exchange rate is explained by irregular components and has disturbance errors between the years 1993 and 1998. The figure shows that the rand experienced a sharp depreciation in the year 2000. This is a period when the inflation targeting-flexible exchange regime was adopted by the country and the currency underwent an era of excessive volatility. Also depicted is an accelerated devaluation which took place from 2000 until 2002. A sharp depreciation of the rand was experienced in 2000 and continued with the weakening trend 2001. This rapid depreciation in 2001 became an enormous concern and forced the government to make a formal inquiry in to the depreciation of the rand by Myburgh Commission. Several of the macroeconomic variables were reported to be the causes of this depreciation. Major reasons to this were among others a slowdown in global economic activity, contagion from events in Argentina, and a worsening in the current account balance in the fourth quarter of 2001 as reported by Bhundia and Gottschalk (2003). According to the Industrial Development Corporation, the South African rand exhibited excessive volatility from the year 1996 to 2001 and the pace of the depreciation was particularly strong but then again the rand strengthened between the years 2003 and 2006.

During the subprime mortgage crisis which took place in 2007 and the financial crisis in 2007 and 2008, the rand embarked on a generally declining trend but increased again in the years 2009 and 2010. A volatile exchange rate cause uncertainties in terms of foreign investment and therefore macroeconomic factors such as gross domestic product, interest rate and inflation rate are affected negatively. The findings of the study by Ozturk (2006) highlighted that changes in exchange rate create uncertainty about the profits to be made and hence, reduces the benefits of international trade.

Other three variables just like the exchange rate are explained by trend and irregular components are said to be non-stationary. This means that the mean and variance of the series are not constant. In addition to the visual representation of the series, the ADF and PP tests are used to confirm the results. The results are summarized in Table 1 and 2.

Table 1. Augmented Dickey Fuller (ADF) results including intercept

Variable	Level of test	Number of lags	T-statistics (ADF test)	Critical value – 5%	Conclusion
LOG_ER	Level	0	-9.544059	-2.89155	Stationary
	1st Difference	1	-12.73441	-2.8922	Stationary
LOG_GDP	Level	4	-0.472878	-2.892879	Non stationary
	1st Difference	3	-2.789771	-2.892879	Non stationary
LOG_INF	Level	0	-4.72665	-2.89155	Stationary
	1st Difference	1	-9.489337	-2.8922	Stationary
LOG_INTR	Level	0	-1.037114	-2.89155	Non stationary
	1st Difference	1	-8.212624	-2.8922	Stationary

The results in Table 1 reveal the presence of stationarity for the exchange and inflation rates at levels. The test indicates stationarity at a 5% significance level with the exception of LOG_GDP and interest rates. Based on these findings, first differencing was applied to the series to render them stationary. However, gross domestic product only became stationary after second differencing.

Table 2. Phillips Perron (PP) results including intercept

Variable	Level of test	Bandwidth	T-statistics (PP test)	Critical value – 5%	Conclusion
LOG_ER	Level	3	-9.551906	-2.89155	Stationary
	1st Difference	29	-48.45519	-2.891871	Stationary
LOG_GDP	Level	15	0.447924	-2.89155	Non stationary
	1st Difference	20	-16.79365	-2.891871	Stationary
LOG_INF	Level	0	-4.72665	-2.89155	Stationary
	1st Difference	11	-13.4538	-2.891871	Stationary
LOG_INTR	Level	10	-0.895208	-2.89155	Non stationary
	1st Difference	15	-8.831559	-2.891871	Stationary

In Table 2, the results of the PP stationarity test including intercept are presented. The results indicated that The PP unit root test proves that gross domestic product and interest rate are non-stationary at levels. However, exchange and inflation rates are stationary at 5% level of significance. For the sake of consistency all the variables were subjected to first differencing to induce stationarity. It is evident from the results that all the variables are stationary according to the ADF and PP tests.

4.3 ARCH (1) and ARCH (2) modeling results

This Section provides the results of the ARCH (1) and ARCH (2) models presented in Tables 3 and 4. In the case were the ARCH (q) model is interpreted, the variance equation coefficients exhibit low volatility when they are less than 1 and high volatility when they are greater than 1.

Table 3. ARCH (1) model

Dependent Variable: Exchange Rate
Method: ML - ARCH (Marquardt) - Normal distribution
Sample: 1990Q1 2014Q2
Pre sample variance: backcast (parameter = 0.7)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
GDP	-2.13E-05	1.48E-05	-1.442250	0.1492
INF	0.013084	0.129442	0.101079	0.9195
INTR	-0.493796	0.359411	-1.373901	0.1695
C	13.29741	8.850257	1.502488	0.1330
	Variance Equation			
C	20.31837	2.862861	7.097226	0.0000
RESID(-1)^2	0.063162	0.164584	0.383769	0.7011

The estimated ARCH (1) model from the results is given as:

$$ER_t^2 = 13.29741 - 0.0000213(GDP) + 0.013084(INF) - 0.4937961(INTR)$$

The results suggest that gross domestic product and interest rates have a negative effect on exchange rate while inflation rate has a positive effect. These findings disagree with those by Khan et al. (2012) who reported a positive relationship between these variables. A 0.00213% decline in exchange rate leads to a situation whereby imports in South Africa become artificially cheaper for foreign buyers while the volume of exports become relatively expensive. This as a result reduces international competitiveness in South Africa.

The results prove that increased inflation rate is influenced by increased interest rate which inflates the government's fiscal burden. This consequently causes the exchange rate to appreciate. These results are not in accordance with those obtained by Chaudhary and Goel (2013) and Mirchandani (2013). Moreover, the results confirm that increases in interest rates lowers the exchange rates with about 49.38% and these findings are not in accordance with Chaudhary and Goel (2013) and Mirchandani (2013). In the variance equation, RESID (-1) indicates that the ARCH (1) model gives a lower measure of volatility of about 0.063162(6.316%). This is an indication that the three determinants contribute to exchange rate volatility. Presented next in Table 4 are the summary results for of the ARCH (2) model.

Table 4. ARCH (2) model

Dependent Variable: Exchange Rate				
Method: ML - ARCH (Marquardt) - Normal distribution				
Sample (adjusted): 1990Q1 2014Q2				
Pre sample variance: backcast (parameter = 0.7)				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
GDP	-1.77E-05	1.36E-05	-1.305563	0.1917
INF	-0.089170	0.135544	-0.657868	0.5106
INTR	-0.310334	0.343453	-0.903568	0.3662
C	10.39456	8.252242	1.259605	0.2078
	Variance Equation			
C	16.24788	2.869194	5.662874	0.0000
RESID(-1)^2	0.140945	0.168579	0.836076	0.4031
RESID(-2)^2	0.130146	0.101505	1.282165	0.1998

The estimated ARCH (2) model given as:

$$ER_t^2 = 10.39456 - 0.0000177(GDP) - 0.089170(INF) - 0.310334(INTR)$$

The results of this model differ from the ARCH (1) model with regard to the inflation rate. However, this model yields volatility measures greater than that of ARCH (1). The three determinants contribute to even higher exchange rate volatility of about 27.1% when represented with ARCH (2) model. The results of this study are in support of those by Mirchandani (2013), Umaru et al. (2013) and Ngailo (2011).

4.4 Model selection results

Table 5. Model selection criterion

Criterion	**ARCH (1) model**	**ARCH (2) model**
SIC	3.777125	3.820431
AIC	3.618861	3.635790

The results provided in Table 5 reveal that the ARCH (1) model prove to be the best model when compared to ARCH (2) model. ARCH (1) has the smallest AIC and SIC. This model is subjected to the diagnostics tests and if found fit will be used for further analyses. Presented next are the diagnostic checking of ARCH (1) in Section 4.5.

4.5 Model diagnostic results

Presented in this section are the results on model specification and stability tests.

CUSUM stability test results

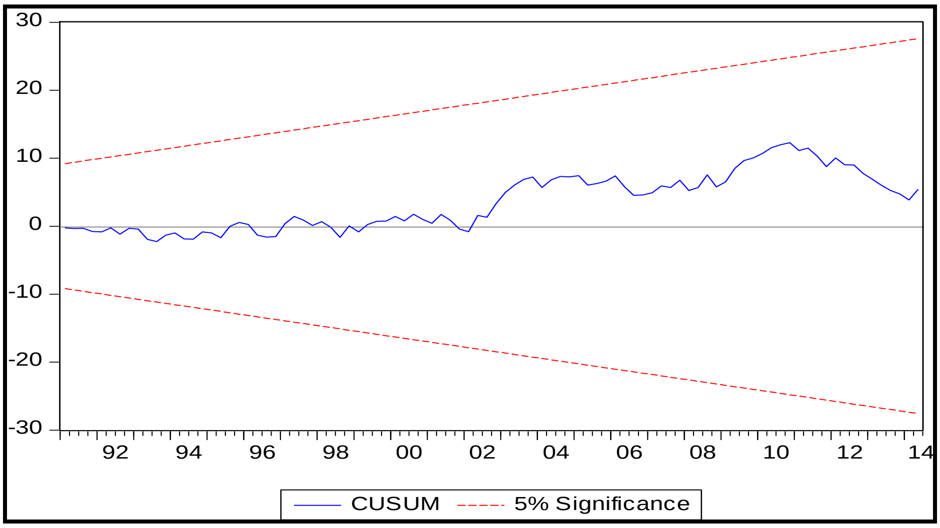

Figure 2. CUSUM stability test

The null hypothesis that all the coefficients in the regression model are correctly specified cannot be rejected at 5% level of significance based on the results in Figure 2. The plot of CUSUM statistic remains within the critical bounds which suggest that the ARCH (1) model is stable. Stability of this model implies that the determinants used are suitable to explain exchange rate volatility. The plot further shows that changes in the exchange rate for the selected period was seen in 2002 onwards but such changes remained within the critical bounds.

Ramsey's REST test

Table 6. Ramsey RESET test statistic

Ramsey RESET test			
	Value	**Df**	**Probability**
F-statistic	1.022155	(1, 93)	0.3146

The observed probability value associated with the Ramsey's RESET testis greater than 0.05 / 5% significance level. This leads to failure to reject the null hypothesis of no misspecification.

4.6 Forecasting results

Forecasting is very crucial as predictions of future events are used for decision making processes in many organisations (Bowerman and O'Connell, 2005). One of the objectives of this study is to compute forecasts for exchange rate volatility. Presented in Figure 3 is the six years in sample forecasts of exchange rate volatility obtained from ARCH (1) model.

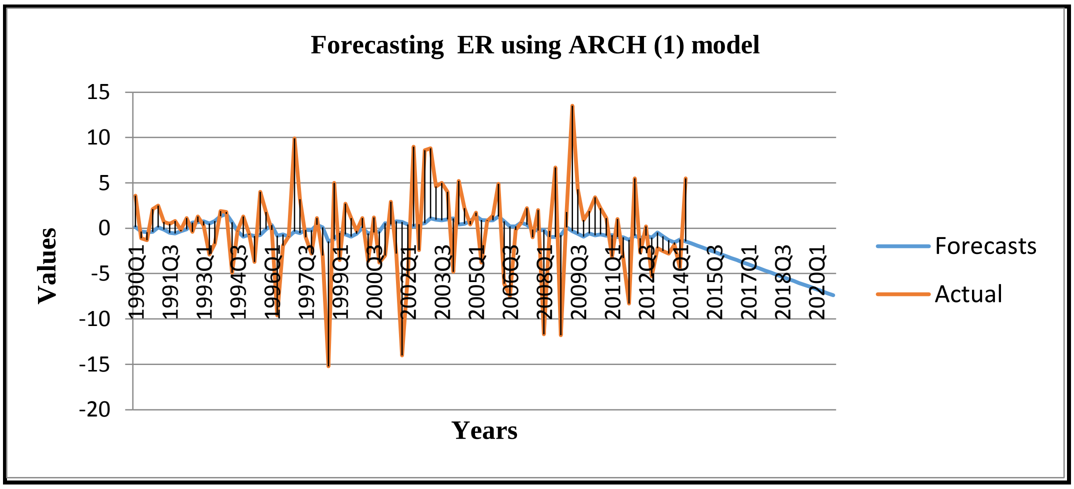

Figure 3. ER volatility forecasts for 2014Q3 – 2020Q4

Figure 3 displays forecasted values of exchange rate volatility for the period 2014Q3 to 2020Q4. A downward trend is seen from the period 2014 Q1. The picture could be appealing to SA since the country depends largely on trade. Mirchandani (2013) advised that weak exchange rate makes currency more attractive which in turn increases the demand for the currency for the domestic country. It is evident that past values of the series (denoted as actual) are equivalent to the forecasted values (shown as forecasts) confirming the validity of the ARCH (1) in forecasting exchange rate volatility. The forecast indicate that in future exchange rate will not be volatile but SA will experience depreciation in its currency. The actual and forecasted values of exchange rate volatility slightly differ due to disturbances which occurred during the periods indicated by long spikes in Figure 3.

5. Concluding remarks

The current investigation evaluated exchange rate volatility in South Africa. The analysis took into consideration the objectives as outlined in section 1. Secondary data covering the period 1990Q1 through 2014Q2 was obtained from the SARB and OECD databases. Gross domestic product, interest rates and inflation rate were used to explain exchange rate volatility in the context of South Africa. Stationarity testing on the series was performed using the ADF and PP tests. The series were found to be non-stationary at their level but stationarity after first differencing was imposed.

For primary analyses, this study applied ARCH (1) and ARCH (2) models to assess exchange rate volatility in SA. This was done to determine the model which reveals high exchange rate volatility and ARCH (1) outperformed the ARCH (2) model also according to the AIC and SIC. The ARCH (1) model was found to be fit and stable for the data according to the diagnostic checking. This model was used for producing forecasts of exchange rate volatility in South Africa for the period 2014Q3 and 2020Q4. Exchange rate volatility forecasts exhibited a downward trend or movement starting after the year 2014Q3. The downward trend of forecasts serves as good news for South Africa because a weak exchange rate makes currency more attractive as a form of investment. Finally, the study concludes that exchange rate volatility can be modelled with the ARCH model.

Based on these findings, the study makes the following recommendations:

- A downward trend starting from 2014Q3 means currency in South Africa becomes weaker which leads to foreign investments favouring South Africa for the next 6 years. Therefore, the South African government should start identifying sectors where possible investments can be made. The exchange rate may be used as a policy tool to attract foreign portfolio investments.
- These forecasts may also be used when embarking on new policies concerning exchange rate in the country.
- Based on the literature reviewed and the results of this study, the study recommends reimplementation of the fixed exchange rate system in SA. A volatile exchange rate has a potential to unsettle foreign investors, and therefore foreign trade and investments are affected negatively.
- A fixed exchange rate would encourage government to implement a policy on import restrictions. A weak exchange rate will enable foreign countries to import more and uncontrolled imports tend to affect domestic industries (markets). Domestic markets will not be able to export mainly because foreign currency will be expensive as compared to the South African Rand. Further research is proposed to improve this study results significance where daily or weekly data is analysed. Studies have shown that using more frequent observations better capture the dynamics of exchange rate and other financial variables. The use of multivariate GARCH family models is also recommended.

References:

1. Aas, K. and Dimakos, K. (2004), "Statistical modelling of financial time series: An introduction to applied research and development", Norwegian Computing Center, Norway.
2. Abdalla, S.B.S. (2012), "Modelling Exchange Rate Volatility using GARCH Models: Empirical Evidence from Arab Countries International", Journal of Economics and Finance, Vol. 4, No. 3, pp. 216-229.
3. Acquah, H. (2010), "Comparison of Akaike information criterion and Bayesian information criterion in selection of an asymmetric price relationship," Journal of Development and Agricultural Economics. Vol. 2, No. 1.
4. Akaike, H. (1973). Information theory as an extension of the maximum likelihood principle. pp. 267-281 in B. N. Petrov, and F. Csaki, (Eds.) Second International Symposium on Information Theory. Akademiai Kiado, Budapest.
5. Bhundia, A. and Gottschalk, J. (2003), "Sources of Nominal Exchange Fluctuations in South Africa," IMF Working Paper No. 03/252, Washington International Monetary Fund.
6. Ben, O., Wafure, Obida, G. and Abu, N. (2010), "Determinants of exchange rate in Nigeria, 1970-2007: an empirical analysis", Indian Journal of Economics and Business, Vol. 9, No. 1, pp. 175-187.
7. Bowerman, B.L. and 'O'Connel, R.T. (2005), "Forecasting, Time series and Regression: An applied approach," 4th Ed., Curt Hinrichs, USA.
8. Brooks, C. (2008), "Introductory econometrics for finance", 2nd Ed. Cambridge University Press, New York.
9. Campbell, J.Y., Lo, A. and MacKinlay, A.C. (1997), The Econometrics of Financial Markets, Princeton University Press, Princeton, N.J.

10. Challis, R. and Kitney, R. (1991), "Biomedical signal processing", Journal of medical and biological engineering and computing, Vol. 28, No, 6, pp. 509-524
11. Chaudharry, G.M and, Goel, D. (2013), "Driving forces which influence exchange rates in the global market." International journal of management and development studies, Vol. 2, No. 3, pp. 67-75.
12. Chaudhary, G. M., Shah, S.Z.A. and Bagram, M.M.M. (2012), "Do Exchange Rate Volatility affect Foreign Direct Investment?", Journal of Basic and Applied Scientific Research, Vol. 2, No. 4, pp. 3670-3681.
13. Chun-Leng, C. (2006), "Stationarity and stability of underwriting profits in property and liability insurance", Journal of Risk Finance, Vol. 7, No. 1, pp. 49-63.
14. Danmola, R. (2013), "The impact of exchange rate volatility on the macro economic variables in Nigeria," European Scientific Journal, Vol. 9, No 7, pp. 152-165.
15. DeBenedictis, L. and Giles, D. (1998), Diagnostics testing in econometrics: variable addition, RESET, and Fourier approximations, Handbook of applied economics statistics, Marcel Dekker, New York.
16. Dickey, D.A. and Fuller, W.A. (1979), "Distribution of the Estimators for Autoregressive Time Series with Unit Root," Journal of American Statistical Association, Vol. 74, pp. 427-431.
17. Economist Intelligence Unit (2007), "South Africa: Country Profile 1992-1993", London.
18. Engle, R. (2001), "The use of ARCH/GARCH models in applied econometric", Journal of economic perspective, Vol. 15, No. 4, 157–168.
19. Fox, J. (2008), Applied regression analysis and generalized linear models. 2nd ed., AGE Publications Ltd., USA.
20. Gujarati, D. and Porter, C. (2009), Basic econometrics. 5th Ed. McGraw – Hill Companies, Inc., Asia.
21. Hamilton, J. D. (1990), "Analysis of time series subject to changes in regime", Journal of Econometrics, Vol. 45, pp. 39-70.
22. Hansen, B. (1992), "Testing for parameter instability in linear models", Journal of policy modelling, Vol. 14, No. 4, pp. 517-533.
23. Hill, R.C. Griffiths, W.E. and Lim, G.C.(2008), Principles of Econometrics, 3rd Ed, Wiley and Sons, Hoboken, New Jersey.
24. Insah, B. and Chiaraah, A. (2013), "Sources of real exchange rate volatility in the Ghanaian economy", Journal of Economics and International Finance, Vol. 5, No. 6, pp. 232-238.
25. Khan, R., Sattar, R. and Rehman, H. (2012), "Effectiveness of Exchange Rate in Pakistan: Causality Analysis", Journal of social science Vol. 6, No. 1, pp. 83-96.
26. Mahmood, I., Ehsanullah, M. and Ahmed, H. (2011), "Exchange rate volatility and macroeconomic variables in Pakistan", Journal of business management dynamics, Vol. 1, No. 2, pp. 11-22.
27. Mayowa, G. and Olushola, E. (2013), "The determinants of real exchange rate volatility in Nigeria", Academic Journal of Interdisciplinary Studies, Vol. 2, No. 1, pp. 459-471.
28. Mirchandani, A. (2013), "Analysis of macroeconomic determinants of exchange rate volatility in India", International Journal of Economics and Financial Issues, Vol. 3, No. 1, pp. 172-179.
29. Mohr, P., Fourie, L and Associates, (2008), Economics for South African students. 4th ed. Van Schaick Publishers, Pretoria.
30. Moroke, N. (2014), "Household Debts and Macroeconomic factors Nexus in the United States: A Cointegration and Vector Error Correction Approach", Journal of Economics and Behavioural Studies, Vol. 6, No. 6, pp. 452-465.
31. Ngailo, E. (2011), "Modelling and forecasting using time series GARCH models: An application of Tanzania inflation rate data", Dissertation submitted to the University of Dar es Salaam., Tanzania
32. Nyahokwe, O. and Ncwadi, R. (2013), "The Impact of Exchange Rate Volatility on South African Exports" Mediterranean Journal of Social Sciences, Vol. 4, No. 3, pp. 507-513.
33. Omojimite, B. and Akpokodje, G. (2010), "A comparative analysis of the effect of exchange rate volatility on exports in the CFA and non-CFA countries of Africa." Journal of social science. Vol. 24, No. 1, pp. 23-31.
34. Ozturk, I. (2006), "Exchange Rate Volatility and Trade: A Literature Survey", International Journal of Applied Econometrics and Quantitative Studies, Vol. 3-1.
35. Page, E. (1954), "Continuous Inspection Schemes", Biometrika, Vol. 41, No. 1-2, pp. 1-11.
36. Phillips, B. and Perron, P. (1988), "Testing for unit root in time series regression", Biometrica, Vol. 75, No. 2, pp. 335-346.
37. Poon, S. (2005), A Practical Guide to Forecasting Financial Market Volatility. New Jersey, John Wiley Sons, Inc.
38. Rahmatsyah, T., Rajaguru, G. and Siregar, R. (2002),"Exchange Rate Volatility, Trade and 'Fixing for Life' in Thailand", Japan and the World Economy, Vol. 14, pp. 445-470.
39. Ramsey, J. (1969), "Test for specification errors in classical linear least squares regression analyses", Journal of royal statistical society, Vol. 31, pp. 350-371.
40. Rishipal, A. and Jain, D. (2012), "Foreign Exchange Management during fluctuating exchange rates: Challenges and Problems", International journal of innovations in engineering and technology. Vol. 1, No. 1, pp. 42-50.
41. Schwarz, G. (1978), "Estimating the Dimension of a Model", Annals of Statistics, Vol. 6, No. 2, pp. 461-464.
42. Sibanda, K. (2012), "The impact of real exchange rates on economic growth: a case study of South Africa", A dissertation submitted to the University of Fort Hare, South Africa.
43. Srinivasan, P. and Kalaivani, M. (2012), "Exchange Rate Volatility and Export Growth in India: An Empirical Investigation", Munich Personal RePEc Archive (MPRA) Working Paper No. 43828.
44. Takaendesa, P. (2006), "The Behaviour and Fundamental Determinants of Real Exchange Rate in South Africa", A dissertation submitted to Rhodes University, South Africa.
45. Tandrayen-Ragoobur, V. and Emandy, N. (2011), "Does exchange rate volatility harm exports? Evidence from Mauritius", Journal of emerging trends in economics and management sciences. Vol. 2, No. 3, pp. 146-155.
46. Todaro, M. and Smith, C.S. (2011), Economic development, 11th Ed., Pearson Education Ltd., New Jersey.
47. Uddin, K.M.K., Quaosar, A.A. and Nandi, D.C. (2013), "Factors affecting the fluctuation in exchange rate of the Bangladesh: A Co-Integration Approach", The

international journal of social sciences, Vol. 18, No, 1, pp. 1-12.
48. Umaru, A., Sa'idu, B.M. and Musa, S. (2013), "An empirical analysis of exchange rate volatility on export trade in a developing economy", Journal of emerging trends in economics and management sciences, Vol. 4, No. 1, pp. 42-53.
49. Zada, B. (2010), "An Analysis of Factors Affecting Exchange Rate of Pakistan 1979 -2008", A dissertation submitted to Hazara University, Pakistan.