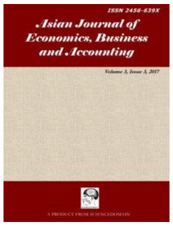

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An Econometric Assessment of the Real Effective Exchange Rate Volatility in Kenya

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Authors' contributions

This work was carried out in collaboration between all authors. Author WSM designed the study, managed the literature searches, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors DN and AO managed the flow and analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

A country's real effective exchange rate (REER) is an important determinant of the growth of cross-border trading and it serves as a measure of its international competitiveness. The REER is an active source of discussions in Kenya where questions have arisen revolving around persistent exchange rate shocks and possible interventions. Kenya's vulnerability to the external shocks has increased and the real effective exchange rate has experienced episodes of appreciations. There is scanty information that has specifically focused on the Kenyan's real effective exchange rate (REER). This study carried out an assessment of the real effective exchange rate (REER) volatility in Kenya. The study was guided by the Dornbusch overshooting model and adopted correlation Research Design. It relied on secondary data for the period 1972 – 2015. To overcome the methodological deficiencies of using the measures of unconditional volatility, this study focused on the conditional volatility employing the GARCH technique that is a superior measure of uncertainty. The Augmented Dickey-Fuller and Phillip-Perron approaches were used to test for the presence of unit roots. It was found that real effective exchange rate in Kenya has been volatile within the period under consideration. These findings will add value to the Dornbusch overshooting model, production

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flexibility and risk aversion theories and partial and general equilibrium theories and will further help in the formulation of fiscal and monetary policies to address macroeconomic shocks associated with REER shocks in the Kenyan economy.

Keywords: Real effective exchange rate; conditional volatility; generalized autoregressive conditional heteroscedasticity; international competitiveness.

1. INTRODUCTION

An exchange rate is a rate at which one currency may be converted into another. Among other things, the exchange rate determines how much the residents of a country pay for imported goods and services, and how much they receive as payments for exported goods and services. The exchange rate can be expressed as nominal exchange rate (NER) when inflation effects are embodied in the rate and as the real exchange rate (RER when inflation influences have been excluded.

The NER can, in turn, be expressed in bilateral or multilateral terms. If expressed in bilateral terms, it is referred to as the nominal exchange rate (NER) and refers to the exchange rate of one currency regarding another [1]. On the other hand, a multilateral nominal effective exchange rate (NEER) is the rate of one currency against a weighted composite basket of the country's trading partner currencies. When NEER is adjusted for inflation, it becomes the real effective exchange rate (REER) which was the focus of this study. Kenya trades with more than one country, hence, the need to focus on the composite basket of trading partner currencies.

Real Effective Exchange Rate (REER) volatility refers to short-term fluctuations of the REER about their longer-term trends [2]. It also entails short-term (monthly, weekly, or even hourly) fluctuations in the exchange rates as measured by their absolute percentage changes during a particular period [3]. Increased, REER volatility may lead to higher prices of internationally traded goods by causing traders to add a risk premium to cover unanticipated exchange rate fluctuations [4,5].

The real exchange rate's level, about an equilibrium real exchange rate level, and its stability have been shown to importantly influence export growth, consumption, resource allocation, employment and private investments [6]. There is need to carry out an assessment of the REER because it plays an important role in an economy. The appropriate real effective exchange rate is one which does not wander too far from its equilibrium value.

Advocates of fixed exchange rate argue that the exchange rate stability enhances cross-border trade and provides an attractive environment for the flow of international capital like a foreign direct investment (FDI), and eventually stimulates economic growth. In their view, volatile and unpredictable fluctuations of the exchange rate may lead to many harmful macroeconomic consequences such as volatility of prices and output, deterioration of total exports as well as worsening the external competitiveness [7,8,9]. On the other hand, proponents of floating exchange rate regime believe that exchange rate flexibility helps the automatic balance of payments adjustments in response to external shocks and positively influence the trade volume and economic growth [10,11].

Measuring exchange rate volatility is one of the controversial issues in the recent economic literature. Several measures of volatility have been employed in the literature, including standard deviations and Autoregressive Conditional Heteroscedasticity (ARCH) techniques. However, methods based on standard deviation suffer from many shortcomings. First, the standard deviation measures of exchange rate volatility ignore relevant information on the random process that generates the exchange rate volatility [12]. Second, this method is arbitrary in choosing the order of the moving average and is noted for underestimating the effects of volatility on decisions [13]. Furthermore, standard deviation measure of volatility is characterized by skewed distribution. Exchange rates are typified by volatility clustering, implying that future exchange rate changes are not independent of the past and current changes. To this extend, the applicability of the findings of the various studies based on standard deviation may be in doubt. To correct for this apparent deficiencies, the ARCH was introduced by [12] and later modified by [14] as the GARCH. Ever since different variants of the ARCH and GARCH models have emerged.

One of the asserted superiority of the ARCH and its variants over the standard deviation measures is their ability to distinguish between predictable and unpredictable elements in the real exchange rate formation process, and are, therefore not prone to overstating volatility [15] This study employed the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model to measure the real effective exchange rate (REER) volatility.

Throughout the economic adjustment agenda, exchange rate and trade reform occupy a core position. The real exchange rate, by its impact on the international competitiveness of an economy, assumes an overriding importance among the cohort of policy variables. The real exchange rate is an active source of discussions in Kenya where questions have arisen both in the policy arena as well as within the public domain revolving around the possible reasons for persistent appreciation of the shilling real exchange rate against key currencies. Also, Kenya's economy is now experiencing a sharp decrease in the foreign exchange reserves. Kenya adopted a unified and flexible exchange rate in the early 1990s, as part of a market-based reform program designed to improve the investment environment and stir up economic growth [16]. Since then, the exchange rate has witnessed continuous shocks and interventions. These changes in the exchange rate have been accompanied by considerable fluctuations in Kenya's economic growth. There is, however, no reliable information yet on whether real effective exchange rate has actually been. This study tried to fill this gap.

The balance of payments deficit has been a common phenomenon in the Kenyan economy from the 1960s. The government has over the years enacted various policy measures aimed at remedying the situation; however, the balance of payments situation does not seem to have improved despite this policy measures [17]. The deficit in the current account widened from a deficit of Ksh. 76.4 billion in the first quarter of 2011 to a deficit of 81.1 billion in the first quarter of 2012. The deterioration in the current account was mainly as a result of 20.8 per cent widening of the merchandise account deficit [17].

Kenya's overall balance of payments positions declined by US$ 220.7 million from a surplus of US$ 360million in May 2011 to a surplus of US$ 139 million in May 2012 [18]. The deterioration was largely due to narrowing of the current account. The current account deficit nearly doubled to 13.1% of GDP. Imports grew by almost 20%, while exports increased by 10%, thus representing a net export of -10%. Import growth was mainly driven by oil imports, which accounted for 27.6% of the total import bill in 2011, jumping from US$ 2.7 billion (8.9% of GDP) in 2010, to USD 4.1 billion (11.6% of GDP) in 2011 [18].

Uncertainty stemming from a previous balance of payments position continues to suppress economic growth prospects. The country has a gaping current account deficit and with only $3.7 billion in foreign exchange reserves – enough to cover a mere 3.44 months of imports – leaving the balance of payments in a shaky position [18]. The latest Central Bank of Kenya (CBK) weekly bulletin shows that the usable official foreign exchange reserves held by the bank marginally increased from $ 3.711 billion, which is equivalent to 3.44 months of imports in the week ending December 2012. CBK is required to maintain foreign exchange reserves equivalent to four months of import cover. For low to medium income oil-importing countries such as Kenya, the current account deficit should be within five to eight percent band that is considered sustainable.

Despite rapid economic growth experienced between 1963 and 1970, the current account balance of payments remained in deficit except in 1963, 1964, 1965, 1977, 1993, 2003, 2009, and 2010 when it recovered a surplus of US$ 10.1 m, US$ 50.6 m, US$ 0.5m, US$ 25.9 m, US$ 124.5 m, US$ 132.4 m, US$ 9908.3 m, and US$ 11404.95 m respectively. The adjustments in balance of payments in Kenya appears to be complicated because the receipts and expenditures are mostly financial and seldom in real assets [19].

Empirical studies on the Kenyan macro economy explaining the impact of shocks to real effective exchange rate movements on some selected macroeconomic indicators are scarce [20,21] called for a reassessment of monetary policy with a view to achieving a more depreciated shilling. The few studies that have been undertaken on the Kenyan economy have mainly concentrated on explaining the determinants of exchange rate behavior but not an econometric assessment of the REER volatility. For instance [22] analyzed the factors that have influenced the exchange rate market since it was liberalized in 1993. A related study by [23] assessed whether the exchange rates in Kenya were affected by monetary policy; and whether these effects were permanent or transitory. The study by [24] focused on the real exchange rate volatility, and misalignment, and its impact on Kenya's international trade and investment. [19] focused on chaos and non-linear dynamic approaches to predicting exchange rates in Kenya. Even then, these studies including [25,26,24] and [19] did not focus on ascertaining the nature of real effective exchange rate in Kenya

A number of researchers have argued that real exchange rates are crucial not only for attaining sustained general economic performance and international competitiveness, but have a strong impact on resource allocation amongst different sectors of the economy, foreign trade flows and balance of payments, employment, structure of production and consumption and external debt crisis [27,28].

Recently, however, volatility increased posing challenges for macroeconomic management in Kenya [20]. Kenya, like other developing countries, has experienced a combination of exogenous shocks such as worsening terms of trade mainly on account of fluctuations in international commodity prices, oil price shocks and volatility in capital flows, which have created macroeconomic management policy challenges. Therefore, understanding the nature of exchange rate volatility would help in guiding appropriate exchange rate policies that foster exports' competitiveness, attract foreign financial sources such as FDI, improving the balance of payments and stimulating economic growth.

1.1 Objective of the Study

The study, in broad terms, assessed empirically the real effective exchange rate (REER) volatility in Kenya.

1.2 Hypothesis of the Study

H_o 1: The real effective exchange rate in Kenya has not been volatile;

1.3 Theoretical Framework

Traditionally two views of exchange rates have been predominant. One regards the exchange rate as the relative price of two monies; in the other, the exchange rate is viewed as the relative price of domestic and foreign goods. These real and monetary aspects of the exchange rate determination are the most extensively modeled.

A third view takes into account portfolio considerations and regards the exchange rate as the relative price of nominal assets [29]. It has been only recently that some interest in the portfolio approach has emerged in the form of exchange rate theory oriented to the current account [29].

An alternative to the simple monetary model is a disequilibrium macroeconomic model that considers the differential speeds of adjustment in asset and goods markets. This leads us to the sticky-price monetary approach to the exchange rate. The most common Sticky-Price Monetary Model (SPMM) is the [30] over- shooting model, which is basically an extension of the Mundell-Fleming model [21,31]. Hence this model is also known as the Mundell-Fleming-Dornbusch model. In it, the nominal output prices are assumed to be sticky - they adjust slowly over time.

On the other hand, asset markets clear continuously in response to new information or changes in expectations [32]. The model thus adopts the principle of the Uncovered Interest Parity (UIP), but the Purchasing Power Parity (PPP) need not hold. A small country with an open economy is faced with a foreign interest, which is assumed to be constant. With open capital markets and perfect foresight, UIP is assumed to hold continuously.

The sluggish adjustment of the national price level, a purely nominal shock or disturbance can cause short-run deviations from PPP and overshooting of the nominal exchange rate [31]. Hence the model is popularly known for its demonstration of overshooting (and undershooting) behavior in exchange rates [30,32] and [33].

The consequences for the short run behavior of the exchange rate, given imperfect price flexibility, are to generate 'over – shooting'. That is, given an initial disturbance, the exchange rate first moves beyond its long run equilibrium level, and then in the longer run moves back. This provides an explanation of an empirical phenomenon which attracted much attention in the late 1970s and early 1980s. In particular, it was the common experience of Switzerland, West Germany and the UK that the adoption of heavily publicized strict monetary targets was followed by a substantial appreciation in the real exchange rate of the respective currencies (J – curve phenomenon).

2. THEORETICAL REVIEW

2.1 Measuring Real Effective Exchange Rate Volatility

The [29] Model with its long run properties are generally in accord with the Monetary Model. In the short run, however, prices are sticky and the impact of a change in the domestic money supply is to change the real exchange rate, with at least the possibility of real consequences for the domestic economy, in the spirit of the Mundel- Fleming Model. In the sense, the Dornbusch Model is an example of a halfway house which is somewhat familiar in modern macroeconomics, where monetary policy has real (Keynesian) effects in the short run and is neutral (in a neoclassical manner) in the long run.

First the long run equilibrium properties of the model are identical to those of the monetary approach (Asset market equilibrium lies at the center of the model) where the asset in question is money and, where the demand for money function is stable and the supply of money is determined by the authorities. The economic interpretation of this is that as the exchange rate rises, aggregate demand rises as net exports respond to increased competitiveness. Thus is offset by a rising price level which reduces aggregate demand via two mechanisms. First, the increased price level reduces competitiveness and therefore net exports. Secondly, the increasing of the price level also has the effect of reducing the real money stock, therefore increasing the domestic interest rate (the 'Keynes effect') which also reduces aggregate demand [29].

The Dornbusch model is interesting for its properties of dynamic adjustment, once the crucial assumption is made that asset markets adjust more quickly than do goods markets and that in the short run, the price level is sticky, while goods prices are fixed in the short run and only adjust gradually in the long run. Thus, an increase in the money stock increases real income in the short run, both because of the fall in the interest rate and because of the (overshooting) the rise in the real exchange rate. In this guise, it is tempting to see the Dornbusch model as reconciliation between Mundel – Fleming as a short run exercise, and the monetary approach as the long run equilibrium to which it tends.

Despite its popularity, the Dornbusch model has methodological limitations when examined from micro-foundation perspective. First, the model lacks explicit choice-theoretical foundations, particularly concerning micro-foundations of aggregate supply [33]. Its specification of the price determination is ad hoc. The model also is ill-equipped to capture current account dynamics or the effects of government spending, since it does not account for private or government inter-temporal budget constraints [33]. In addition, it does not explicitly model the implicit bond market. Nevertheless, the model has played a dominant role in the literature on exchange rate dynamics and remains one of the basic building blocks of open economy macro-models.

3. METHODOLOGY

The study measured the REER volatility using the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) developed by [14]. The GARCH method can discriminate between predictable and unpredictable elements in the exchange rate formation process, and therefore, they serve as accurate measures of volatility [34].

To overcome the methodological deficiencies of standard deviation methods, the study used the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) developed by [14] The advantage of the GARCH method over the standard deviation measures is their ability to discriminate between predictable and unpredictable elements in the exchange rate formation process, and therefore, they serve as accurate measures of volatility [13] and [34].

The proposed study investigated the real effective exchange rate (REER) volatility using the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model. The Vector Error Correction Model was used to establish the impact of exchange rate volatility on those selected macroeconomic indicators.

Therefore, the conditional variance of GARCH model could be specified as follows:

$ln\text{REER}_t = \boldsymbol{\alpha}_o + \boldsymbol{\alpha}_1 ln\ \text{REER}_{t-1} + e_t$; where

$$e_t \sim (0,\ \mathrm{h}_t) \tag{1}$$

$$\mathrm{h}_t = \boldsymbol{\alpha} + \beta e^2_{t-1} + \gamma \mathrm{h}_{t-1} + \mu \tag{2}$$

This equation means that the conditional variance is a function of three terms: the mean, α; information about volatility from the previous period, measured as the lag of the squared residual from the mean equation e^2_{t-1} (the ARCH term), and the variance of previous period's forecast error, h_t (the GARCH term). Accordingly, we will estimate GARCH (1,1) conditional variance on quaterly real effective exchange rate (REER) over the period l972-2015.

3.1 Data Type and Sources

The quarterly data set covering the period 1972-2015 was selected because since 1972 the exchange rate has seen many policy interventions in Kenya. Also, by the end of the 1970s, the country had started to suffer from unfavourable economic situations. Moreover, this period ensures the availability of data on the variables under investigation.

The data on REER included trade volume with major trading partners, real bilateral exchange rate, foreign price index calculated as the weighted Consumer Price Index (CPI) and the domestic CPI.

The quarterly data series was sourced from various issues of the Central Bank of Kenya (CBK), Kenya National Bureau of Statistics, International Monetary Fund (IMF), UNCTAD and World Bank's world development indicators.

3.2 Measurement of Variables

An Exchange Rate: Is the rate at which Kenyan currency may be converted into another currency. Among other things, the exchange rate determines how much the residents of Kenya pay for imported goods and services, and how much they receive as payments for exported goods and services.

Nominal Exchange Rate: refers to the exchange rate of the Kenyan currency regarding another expressed in bilateral terms.

Nominal Effective Exchange Rate is the rate of the Kenyan currency against a weighted composite basket of the Kenya's trading partner currencies.

Real Exchange Rate: is expressed as the Nominal Exchange Rate adjusted for inflation.

Real Exchange Rate Volatility: refers to short term fluctuations of the RER about their longer term trends. It also entails short-term (monthly, weekly, or even hourly) fluctuations in the exchange rates as measured by their absolute percentage changes during a particular period.

Real Effective Exchange Rate is the rate of the Kenyan currency against a weighted composite basket of the Kenya's trading partner currencies adjusted for inflation.

3.3 Integration Properties (Unit Root Test)

The Classical Econometric Theory assumes that observed data are usually stationary in nature, whereby means and variances are constant overtime [35]. However, the estimates of time series econometric models and historical records of economic forecasting invalidate such assumptions. To avoid spurious regression results, stationarity is important for empirical modeling.

A time series variable has the property of stationarity when it possesses a finite mean, variance and autocovariance function that are all independent of time. Analogously, a non-stationary series possesses a time dependent mean or autocovariance function. A stochastic time series is said to be integrated of order d if the series requires differencing d times in order to achieve stationarity [35]. Note that by stationarity we mean covariance or weak stationarity, meaning the property that a time series variable possesses a finite mean, variance, and autocovariance function that are all independent of time [36].

As is common in time series analysis, before estimating our regression models, all series require to be tested for the unit root to avoid the spurious regression. Therefore, the analysis started with identifying the order of integration of the variables, using Augmented Dickey-Fuller (ADF), Philips-Perron (PP) and Kwiatkowski, Phillips, Schmidt and Shin (KPSS) tests for a unit root. Since the unit root tests are sensitive to the lag length, the study uses the Akaike Information Criterion (AIC) to select the optimal lag length. The study utilized the quarterly time series data covering the period 1972-2015.

After establishing the order of integration, the next step was to establish whether the non-stationary variables are co integrated. According to [35] individual time series could be non-stationary, but their linear combinations can be stationary if the variables are integrated of the same order. To test for co integration among the non-stationary series can be carried out using either Engel – Granger two – step procedure or Johansen procedure. A more superior multivariate technique developed by [37] and applied in [38] was used.

3.4 Measuring Real Effective Exchange Rate

The real exchange rate (RER) was obtained by adjusting nominal exchange rate (NER) with inflation differential between domestic economy, and foreign trading partner's economies. The derivation of the RER, therefore, requires that the data of the NER, domestic inflation and foreign inflation be obtained. Since the Kenyan shilling appreciated against some currencies and depreciated against others during the study period, the nominal effective exchange rate (NEER) is constructed. The NEER was delivered by weighting the bilateral shilling exchange rate against its trading partners currencies using the value of Kenya 'trade (imports plus exports) with its respective trading partners. The data required to derive the NEER is the Kenya's bilateral exchange rates with respective trading partners. Since some of the data on bilateral exchange rates are originally expressed regarding United States (US) dollars, cross rates was obtained, so as to have all bilateral exchange rates expressed regarding Kenya shilling per foreign currency. The calculation of NEER was achieved through the arithmetic mean approach that involves summing up the trade weighted bilateral exchange rates as shown in Equation 4 below.

$$NEER = \sum_{it}^{n} ER_{it} * W_{it} \tag{4}$$

Where ER_{it} is Kenya's bilateral exchange rate index with country ***i*** at time ***t*** while W_{it} is the bilateral trade weight for Kenya's i^{th} trading partner at time t. Each bilateral exchange rate index (ER_{it}) in Equation 4 is computed as follows

$$ER_{it} = \left[\frac{NER_C}{NER_{t=0}}\right] * 100 \tag{5}$$

Where, the NERc is an index of Kenya shilling exchange rate per unit of trading partners currency in the base period (2007) while $NER_{t=0}$ is the index of Kenyan shilling exchange rate per unit of trading partner currency in the current period/ year. The choice of 2007 as the base year is rationalized regarding relative stability of the economy and low volatility in the domestic, foreign exchange market during the year. Kenya's Gross Domestic Product (GDP) growth rate during this period was 7.1%, the highest rate ever achieved during the 1972-2015-study period. The year 2007 also enjoyed macroeconomic stability, with an inflation rate that were not only low but also stable while the current account balance, as well as fiscal deficits, were considered to have been at sustainable levels. Each monthly bilateral trade weight in equation (4) was computed as a ratio of total trade (exports plus imports for each trading partner to the ratio of total trade (pus export imports) for all Kenya's trading partners. The formula to be used in deriving the trade weights is:

$$w_{it} = \left[\frac{\sum(X_{it} + m_{it})}{\sum(X_t + m_t)}\right] \tag{6}$$

Where X_{it} is the total value of Kenyan's exports to i^{th} trading partner at time t. m_t is the total value of imports from Kenya's i^{th} trading partner also in time t. X_t are Kenya's total exports to all trading partners at time t, and m_t are total imports to all trading partners at time ***t***. In this study i=1,2……,n. Where n is the total number of Kenyan's trading partners which in this study will be 140. The NEER is obtained by combining equation 5 and equation 6 using the following formula.

$$NEER_t = \sum_{it}^{n} ER_t * W_t \tag{7}$$

Where ER_t is the bilateral exchange rate (equation 5) and W_t is the bilateral trade weight, n is the total number of countries which is 50. Based on (equation 7) a decline in NEER represents an appreciation while an increase represents a depreciation of the NEER. This is because in the calculation of the NEER index, the base year (2007) exchange rate is taken as the denominator while the current exchange rate is taken as the numerator.

In order to obtain the real effective exchange rate (REER), the NEER was adjusted by the relative price indices of Kenya and the weighted average price indices of Kenya's trading partners. In an equation form, this is expressed as:

$$REER_t = NEER_t \left[\frac{P_{wt}}{P_{dt}}\right] \tag{8}$$

Where P_{dt} is the price level in Kenya (domestic price) proxied by consumer price index (CPI) at time ***t*** and P_{wt} is the weighted average price level of Kenya's trading partner countries proxied by weighting CPI at time ***t***. The price level of Kenya's trading partner countries is obtained by adding all the trade weighted price levels proxied by CPI of Kenya trading partners.

This is shown in an equation form as follows:

$$P_{wt} = \sum_{it}^{n} P_{it} * W_t \quad (9)$$

Where P_{it} is the price level of Kenya's i^{th} trading country's partner proxied by CPI at time t. W_{it} is the trade weight of Kenya's i^{th} trading country's partner at time ***t*** .These weights are the same as those in the derivation of REER.

3.5 Generalized Autoregressive Conditional Heteroscedasticity (GARCH)

Since its "discovery" by (Engle, 1982), ARCH modeling has become a growth industry, with all kinds of variations on the original model. One that has become popular is the generalized autoregressive (GARCH) model, originally modified by [14] as the GARCH. The simplest GARCH model is the GARCH (1, 1) model, which can be written as:

$$\delta_t^2 = \alpha_0 + \alpha_1 \mu_{t-1}^2 + \mu_2 \sigma_{t-1}^2 \quad (10)$$

Which says that the conditional variance of μ at time *t* depends not only on the squared error term in the previous time period as in ARCH (1) but also on its conditional variance in the previous time period? This model can be generalized to a GARCH (*p, q*) model in which there are p lagged terms of the squared error term and q terms of the lagged conditional variances. We will not pursue the technical details of these models, as they are involved, except to point out that a GARCH (1,1) model is equivalent to an ARCH (2) model and a GARCH (*p,q*) model is equivalent to an ARCH (*p* + *q*) model.

Financial time series, such as stock prices, exchange rates, inflation rates, etc. often exhibit the phenomenon of volatility clustering, that is, periods in which their prices show wide swings for an extended time period followed by periods in which there is relative calm. As [39] notes:

"Since such (Financial time series) data reflect the result of trading among buyers and sellers at, for example, stock markets, various sources of news and other exogenous economic events may have an impact on the time series pattern of asset prices. Given that news can lead to various interpretations, and also given that specific economic events like an oil crisis can last for some time, we often observe that large positive and large negative observations in financial time series tend to appear in clusters."

Knowledge of volatility is of crucial importance in many areas. For example, considerable macro econometric work has been done in studying the variability of inflation over time. For some decision makers, inflation in itself may not be bad, but its variability is bad because it makes financial planning difficult.

The same is true of importers, exporters, and traders in foreign markets for variability in the exchange rates mean huge losses or profits. Investors in the stock market are obviously interested in the volatility of stock prices, for high volatility could mean huge losses or gains and hence greater uncertainty. In volatile markets it is difficult for companies to raise capital in the capital markets.

4. EMPIRICAL RESULTS

4.1 Descriptive Statistics

The first step of the analysis was to compute the descriptive statistics reported in table 4.1 below. The real effective exchange rate recorded a maximum of -0.2827, a minimum of -4.6584 and an average of -2.0572. Table 1 also presents the results of normality test. REER was also normally distributed with 857.5843 Jarque-Bera statistic and p – value 0.0028 < 0.05 indicating that it follows normally distributed.

4.2 Unit Root Tests without Structural Breaks

4.2.1 Augmented Dickey-Fuller unit root test

Results of Augmented Dickey-Fuller presented in Table 2 showed that real effective exchange rate was integrated of order one (I(1)).

When variables were first differenced results showed that they became stationary. Therefore it was concluded that the study variables were integrated of order one denoted by *I(1)* as per Augmented Dickey-Fuller test.

4.2.2 Results of phillips-perron unit root test

Results of Phillips-Perron are presented in Table 3 showed that unit root was present in real exchange rate volatility. Mackinnon p – value was 0.0720 > 0.05. The critical values for Augmented Dickey-Fuller test were -3.628 at 1%, -2.950 at 5% and -2.608 at 10%.

The Augmented Dickey-Fuller and Phillips-Perron Unit Root Tests, also referred to as the distinguish between unit root and near unit root stationary processes [36]. The power of the tests is low if the process is stationary but with a root close to the non-stationary boundary (1) i.e. $Y_t = 0.95Y_{t-1}+\mu_t$. The tests are poor at deciding, for example, whether φ = 1 or φ = 0.95, especially with small sample sizes. The study therefore also employed the second generation unit root tests, which included Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test of [40] and Elliot-Rothenberg-Stock unit root test.

4.2.3 KPSS and elliot-rothenberg-stock test

Results of KPSS unit root tests are presented in Table 4. Results were estimated with Newey-West Bandwidth automatic selection using Bartlett Kernel. The aim for this test is to remove deterministic trend of the series in order to make it stationary.

Similarly results of Elliot-Rothenberg-Stock that were estimated with Schwarz Information Criteria (SIC) showed that real effective exchange rate was not stationary thereby supporting first generation unit root test. The results of first difference series showed that the variables became stationary. Therefore it was concluded that the study variables were integrated of the order one denoted *I(1).* This supports prior empirical studies [36,41,42,43] among others) and econometrics theory that indicates that macroeconomic variables were not stationary in levels but become stationary on first differencing [44,39,45,46,47].

4.3 Unit Root Tests with Structural Breaks

The next step of the analysis was testing for unit root with structural breaks and results are presented in Table 5.

As shown in Fig. 2, real effective exchange rate had first significant structural break in 1998q2. This structural break was positive and significant (p – value 0.000 < 0.05). So to 2005q2 (p – value 0.000 < 0.05).

4.3.1 Variance decomposition

Variance decomposition shows the contribution of each shock to the n-period-ahead forecast error of the variable. It typically shows the proportion of the forecast error variance which can be attributed to its own shocks and the innovations that emanate from other variables in the model. The results of variance decomposition for real effective exchange rate are reported in Table 6. From the results it is seen that REER is

Table 1. Descriptive statistics

Variable	Mean	Std. Dev	Minimum	Maximum	Skewness	Kurtosis	Jarque-Bera	Probability
REER	-2.0572	1.1350	-4.6584	-0.2827	0.0004	0.2995	857.5843	0.0028

Note: Sample, 1972q1 – 2015q4; N = 176, Source: Author's Research, 2017

Table 2. Results of Augmented-Dickey-Fuller unit root test

Variable	Intercept		Intercept and Trend		None		Remark
	T – Stat	Prob	T – Stat	Prob	T – Stat	Prob	
Level							
REER	-2.6278	0.0893	-2.6230	0.2707	-1.0867	0.2504	
First Difference							
REER	-13.1175	0.0000	-13.1042	0.0000	-13.1530	0.0000	*I(1)*

Source: Author's Survey 2017

Table 3. Results of phillips-perron unit root test

Variable	Intercept		Intercept and Trend		None		Remark
	T - Stat	Prob	T - Stat	Prob	T – Stat	Prob	
Level							
REER	-2.7238	0.0720	-2.7585	0.2149	-1.0867	0.2504	
First Difference							
REER	-13.1175	0.0000	-13.1042	0.0000	-13.1530	0.0000	*I(1)*

Source: Author's Survey 2017

100% explained by its own innovations in the first period, but its explanatory power declines over time to 93.7% during the 10-th period.

4.3.2 Impulse response

These impulses are derived using a recursive VAR model, in which Cholesky one-standard deviation shocks are applied and the response is estimated over a period of ten years following the initial occurrence of the shocks. The impulse response function of VAR is to analyze dynamic effects of the system when the model received the impulse. Results of the impulse response analysis indicate the reaction of REER volatility due to one standard deviation of unanticipated positive shock to itself – a steady decline in Kenya's REER volatility. The dashed line shows that the positive shock to REER volatility is transmitted almost completely to REER itself. There is a revelation of a persistently sharp decline in REER volatility. Asymptotically, it will converge to the equilibrium in the long run.

Table 4. Results of KPSS and Elliot-Rothenberg-stock test

	Kwiatkowiski-Phillips-Schmidt shin test Elliot-Rothenberg-Stock test				
	Intercept	**Intercept with tend**	**Intercept**	**Intercept with trend**	**Remark**
Level					
REER	0.4749	0.1218	4.8292	7.7434	
First Difference					
REER	0.4154	0.0308	0.2784	1.0372	*I(1)*

Source: Author's Survey 2017

Table 5. Unit root test with structural breaks

Variable	Breaks	Coef	T-Stat	P-Value	Year
REER	*D1*	-2.1547	-12.120	0.000	1998q2
	D2	1.9216	9.413	0.000	2005q2

Source; Author's Research, 2017

Table 6. Variance decomposition of REER

Period	S.E.	REER	GDPR	FDIR	CABR
1	0.000418	100.0000	0.000000	0.000000	0.000000
2	0.000574	99.94756	0.000227	0.037482	0.014736
3	0.000678	99.54139	0.053117	0.196251	0.209242
4	0.000756	98.80389	0.180308	0.422707	0.593099
5	0.000817	97.89138	0.339281	0.647568	1.121766
6	0.000866	96.91193	0.497266	0.837670	1.753131
7	0.000907	95.92543	0.637031	0.985802	2.451736
8	0.000940	94.96360	0.751859	1.096083	3.188456
9	0.000968	94.04353	0.840991	1.175852	3.939628
10	0.000991	93.17470	0.906686	1.232304	4.686305

Source: Author's Survey, 2017

Table 7. GARCH results on real effective exchange rate

Sample period		**1973q1 - 2015q4**		
Number of observations		172		
Log likelihood		-92.341568		
R-squared		.8642756		
Adjusted R-squared		.86347722		
Root MSE		41635337		
Variable	**Coef.**	**Std. error**	**t – value**	**P> |t|**
REER L1	0.9255271	0.0281299	32.90	0.000*
Constant	-0.1612711	0.0666751	-2.42	0.017*
AIC	188.6831			
BIC	194.9781			

Source; Author's Research, 2017

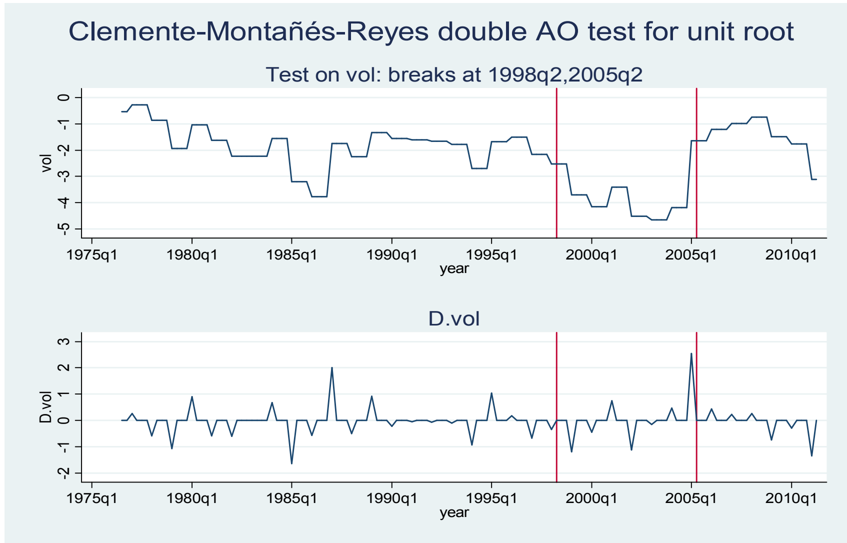

Fig. 1. Plots of structural breaks of REER
Source: Author's Survey, 2017

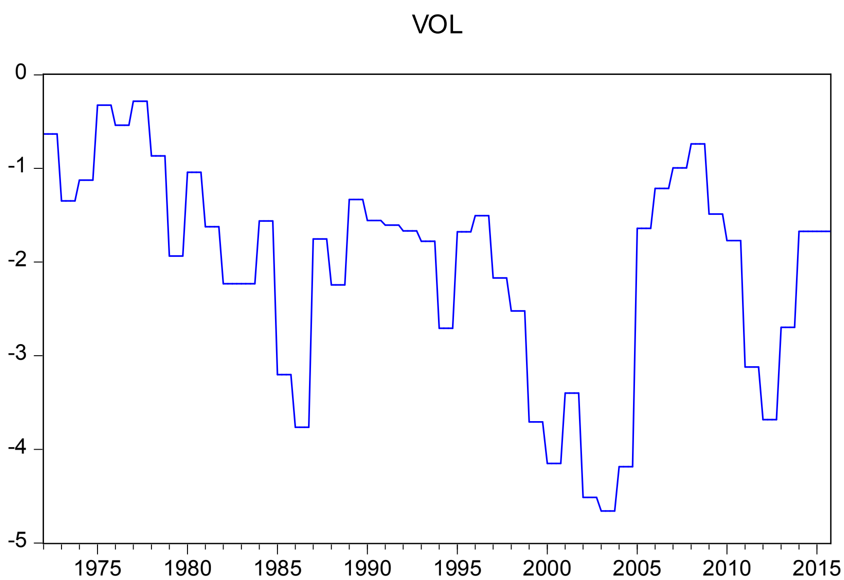

Fig. 2. Plot of REER volatility in Kenya
Source: Author's Survey, 2017

4.4 Nature of Real Effective Exchange Rate

The study sought to determine the nature of real effective exchange rate in Kenya. To achieve this objective the hypothesis stated that real effective exchange rate in Kenya has not been volatile. The GARCH model was estimated since it was feasible and has remained the workhorse for estimation of volatility.

The generalized ARCH (p,q) model – called GARCH(p,,q) – allows for both autoregressive and moving average components in the heteroskedastic variance. If we set p=0 and q=1, it is clear that the first-order ARCH model given by (10) is simply a GARCH (1,1) model. Similarly, if all values of β_1 equal zero, the GARCH (p,q) model is equivalent to an ARCH(q) model. The benefits of the GARCH model should be clear; a high-order ARCH model may have a more parsimonious GARCH representation that is much easier to identify and estimate [43]. This is particularly true since all coefficients in (1) must be positive. Clearly, the more parsimonious model will entail fewer coefficient restrictions. Moreover, to ensure that the variance is finite, all characteristic roots of (1) must lie and imply that the process is stable [43].

The key feature of GARCH models is that the conditional variance of the disturbance of the (y_t) sequence acts like an ARMA process. Hence, it is to be expected that the residuals from a fitted ARMA model should display this characteristic pattern. To explain, suppose you estimate a hypothetical (y_t) as an ARMA process. If the model of (y_t) is adequate, then the ACF and PACF of the residuals should be indicative of a white-noise process. However, the ACF of the squared residuals can help identify the order of the GARCH process. Equation (1) looks very much like a standard ARMA (p,q) process. As much, if there is conditional heteroskedasticity, the correlogram should be suggestive of such a process.

Results of real effective exchange rate are presented in Table 7. Results indicated that the GARCH (1,1,1) selected by AIC and BIC model fitted the data very well R-Square was 0.8642756 indicating that the model explained 86.43 percent, log likelihood was also a large number 92.34 > 30. Based on the results, the first null hypothesis that real effective exchange rate in Kenya has not been volatile is rejected. Results indicated that real effective exchange rate in Kenya was volatile (p – value 0.000 < 0.05) within the period under consideration (1972q1 – 2015q4).

Exchange rate stability is conducive to macroeconomic performance growth through its positive impact on investment and promotion of trade. Stable exchange rate decreases price uncertainty and real interest rate volatility and therefore the efficiency of price system at international level and promotes economic stability and growth. It was therefore concluded that real effective exchange rate in Kenya has been volatile.

5. CONCLUSION AND POLICY RECOMMENDATIONS

The findings of this study exhibit some important implications for policymakers in Kenya and other developing countries of similar characteristics and stage of development. The findings indicate that REER volatility is a persistent feature of the Kenyan economy and that policy interventions are useful in addressing or containing the adverse shocks to the economy from REER volatility. This is in support of the findings of various studies [7,8,48] and [9].

The findings of the volatile REER imply that regular and persistent REER volatility may trigger financial crisis in the long run. In other words, the REER volatility path may be used as an indicator to predict financial crises and international competitiveness. Therefore, the policy implication arising from this analysis is that Kenya should implement policy measures to correct her unsustainable external imbalances in the long run. This was also alluded to by [19].

There is need to apply the appropriate macroeconomic policy mix in the short run to mitigate the cyclical and short-term shocks that arise from REER volatility. However, to ensure that there is external stability in the long run, policies regarding structural improvement, such as export competitiveness enhancement, second stage import substitution and research and development, should be addressed.

The key policy implication of the findings about the REER volatility is that prudent management of the exchange rate stability must be pursued. This will help reduce the exchange rate volatility associated with major trading partners. This conforms to the findings by [49] for the Euro Area Countries. There is need to focus on the terms of trade in order to have a positive impact on the current account balance. On the other hand, inflation should be contained to levels that are productive without affecting the economic growth and current account deficit.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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