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The Causal Relationship between Interest Rates and Foreign Exchange Rates in Kenya

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Abstract
The objective of this research was to investigate the causal relationship between interest rates and foreign exchange rates in Kenya. The data sources were limited to the nominal value of exchange rate represented by the Kenya Shilling price of one US dollar and aggregate interest rate represented by the Treasury bill yield over a 3-month period. The data set consisted of monthly observations of the nominal value of the daily closing exchange rate between January 1993 and June 2006. The monthly closing Treasury bill rates over the same period were used. Testing causal relations between interest rates and foreign exchange rates were based on comparing the results of Granger causality test of Granger (1969) based on error correction modelling (ECM) technique. The series were tested for stationarity, co-integration, autocorrelation, and heteroscedasticity. The main findings were that foreign exchange rates do not Granger-cause interest rates. Moreover, since there was a significant error correction term, it was concluded that causality between interest rates and foreign exchange rates in Kenya is attributable to external factors other than the variables in the model. It was therefore established that interest rates causes foreign exchange. These findings support previous empirical studies by Furman and Stiglitz (1998), Goldfajn and Gupta (1999), Cho and West (2001) that interest rates Granger cause exchange rates.
Keywords: Augmented Dickey-Fuller Test, Autoregressive Distributed Lag, Covered Interest Parity, Dickey Fuller Test, Error Correction Model, Error Correction Terms, Expectations Theory, Fisher Effect, Final Prediction Error, Gross Domestic Product, Uncovered Interest Parity, Vector Auto-regression, Vector Error Correction Model

1. Introduction

At independence, in 1963, Kenya inherited a financial system that lacked monetary and financial independence (Nasibi, 1992). This robbed the authorities the ability to impose and generate inflation tax revenue. In 1966 Central Bank of Kenya was established, allowing the country to formulate and operate an independent monetary policy. The Central Bank was given supervisory powers over commercial banks and financial institutions, while low interest rate policy was adopted where the government set maximum and minimum rates for lending and savings deposit rates. The aim was to encourage investment and protect the small borrowers. Interest rates were, however, too low to attract savings with negative real returns. Low interest rates, however, enabled the government to finance its expenditure cheaply. So the basic constraints in the financial market were laid. The influence on the interest rate structure did not encourage savings but they were meant to encourage capital since the interest structure subsidized capital indirectly. The pattern of investment through the import substitution industrialization strategy was therefore to encourage capital-intensive production (Mwega & Njuguna, 2002).

In 1993 the government of Kenya changed its policy on both interest and foreign exchange rate from a fixed interest and exchange rate regime to a floating rate regime. At that time the government embarked on a mission to develop financial institutions such as the Central Bank of Kenya so as to monitor the economy in line with the liberalized interest and exchange rates. It is therefore important to understand the relationship between interest rate and exchange rates to effectively manage both monetary policy and the exchange rate policy.

Studies elsewhere have established that the levels of relationship between the interest rate and the foreign exchange rate can at times be ambiguous (IMF, 1998). For instance, whether higher interest rates are an essential part of the defence strategy for the currency in times of financial crisis is controversial (Hwee, Kwan and Yoonbai, 2004). Furman and Stiglitz (1998) argued that high interest rate policies destabilize exchange rates by raising corporate bankruptcy levels while accelerating capital outflows. With regard to the volatility relationship, it is conventionally argued that greater exchange rate variability is stabilizing in the sense that it releases the pressure off the economy and promotes stability in such macroeconomic aggregates as interest rates, money supply and output. Indeed, one of the traditional advantages of floating rates is that interest rates are more stable as the monetary authority is free from the burden of maintaining the fixed exchange rate (Reinhart, 2001).

2. Historical Patterns of Interest Rates and Exchange Rates in Kenya

2.1 Historical Patterns of Interest Rates in Kenya

Previous to the implementation of its Structural Adjustment Programme (SAP) in 1983, the financial sector in

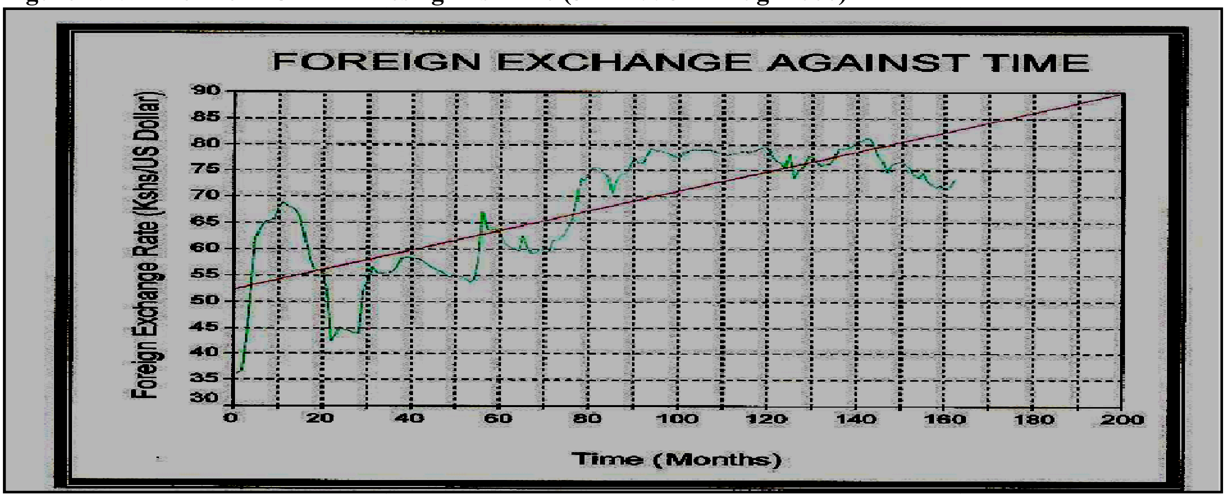
Kenya suffered from severe repression. Interest rates were maintained below market-clearing levels, and direct control of credit was the primary monetary control instrument of the authorities (Willem, 995). Accompanying the SAP, interest rate deregulation took place. In September 1991 the maximum lending rate was increased from 10 to 14 %. The rediscounting rate for crop finance paper was raised to 11.25 %, while the minimum savings deposit rate was raised to 12.5 %.

Between 1983 and 1987, the differentials between the interest rates of banks and non- bank financial institutions were narrowed. This improved the competitiveness of commercial banks. One of the first steps towards freeing interest rates was taken in 1989, when the government started selling Treasury Bonds through an auction. In 1991, interest rates were completely freed. Since then, interest rates have been following a steep upward ascent, with the gap between loan and deposit rates shrinking (Willem, 1995).

In 2001, the nominal interest rates were generally lower compared to the previous year in response to developments in the monetary sector. The Treasury bill rate, which rose to 15 per cent at end of 2000 came down to 10.9 per cent by end-2001 and continued to fall to 8.3 per cent by May 2002. The decline reflected the increased availability of funds in the market as a result of the slow pace of economic recovery and, consequently, subdued demand for private sector credit. Given the low rate of inflation during 2001-2003 all real interest rates remained on a positive trend over the same period (African Development Bank (AfDB) and Organization of Economic Co-operation and Development (OECD, 2003).

In 2005, the short-term interest rates were stable during the first half of the year (Stanbic Bank, 2005). The yield on the 91-day Treasury bill was 8.59% on 30 June from 8.66% in December, with the 12-week moving average rate hovering around 8.64% since the beginning of the year. This stability was attributable to prudent monetary policy, with the central bank ensuring that money supply growth is consistent with economic fundamentals, and restrained domestic short-term borrowing and long-term borrowing by the government. From the month of July to the end of 2006, the maintenance of fiscal prudence and inflation developments were to determine the direction of short-term interest rates (Standard Bank, 2005). This also explained the continued short-term interest rate stability the second half of 2005. Figure 1.1 below shows the pattern of foreign exchange rates in Kenya for the period between January 1993 and June 2006.

Figure 1.1: Pattern of FOREX rates against time (Jan' 1993 — Aug' 2006)



2.2 Historical Patterns of Exchange Rates in Kenya

The exchange rate regime in Kenya has undergone remarkable changes since the colonial regime of the East African Currency Board. As at early 1980, the key problem was how to manage exchange rate movements around the SDR to which the shilling was pegged. The peg was abandoned in 1982, in favour of a composite of currencies representative of Kenya's main trading partners. The effect of the peg was to remove the fluctuations of currencies in the SDR unrelated to Kenya's trade flows, and maintain a measure of competitiveness. However, the peg retained the technical capability of transmitting and maintaining inflation to Kenya at the levels obtaining in the major trading partners. As a first step in engendering flexible exchange rates, Kenya adopted a dual exchange rate in 1990 by operating the official rate alongside the rate available in the market for those who purchased interest-bearing and marketable foreign exchange bearer certificates (the so-called Forex Cs). The monetary authorities were thus able to monitor the market performance of the security and adjust the official rates accordingly.

In 1993, following elimination of controls on imports and most foreign exchange transactions, the exchange rate attained a full float (Wagacha, 2000). According to the Export Processing Zone Authority (EPZAJ, 2005), the Exchange Control Act in Kenya was repealed. The Central Bank became responsible for supervision of the currency market. Residents are now free to hold foreign currency accounts. Foreign exchange for eligible transactions is purchased from the commercial banks or Foreign Exchange Bureaus without any control. Eligible transactions include payments in respect of dividends, capital and interest on loans, current account transactions and proceeds on disposal of investments. There are no controls on foreign exchange rates or interest rates on loans and overdrafts. Exchange rates are driven largely by market supply and demand. Figure 1.2 below shows the patterns of Treasury bill Interest rates in Kenya for the period between January 1993 and June 2006.

Figure 1.2: The Pattern of T-BILL Rates against Time

1.3. Statement of the Problem

The nature of the relationship between interest rates and foreign exchange rates has been subjected to a significant debate among international organizations and researchers (Brailsford, Jack, Penm, and Chin Diew, 2006). For example, the International Monetary Fund argued that sharp rises in interest rates were helpful in stabilizing Asian exchange rates during the Asian financial crisis (IMF, 1998). On the other hand, the World Bank believes that significantly higher interest rates destabilized the Asian currencies by markedly increasing the risks of business bankruptcy and economic contraction (Caporale, Cipollini and Demetriades, 2000).

Numerous studies have employed Granger causality testing to investigate whether sharply higher interest rates supports or weakens foreign exchange rates. The studies above present mixed results about the effectiveness of using higher interest rates to support foreign exchange rates (Brailsford et al, 2006). Based on the full order Vector Auto Regression (VAR) techniques, Goldfajn and Baig (1998) estimated the relationship between interest rate and foreign exchange rate data for a number of Asian countries, and found little evidence supporting the use of higher interest rates. Similarly, Kaminsky and Schmukler (1998) estimated full order VAR models using daily nominal interest and foreign exchange rates to calculate the corresponding impulse response functions. Their results also indicated little interaction between interest rates and foreign exchange rates in either direction. Using full order VARs in levels, Choi and Park (2000) re-examined this issue. They included spot and forward exchange rates and interest rate differentials in their study, and concluded that no causal relationship from interest rate differentials to spot exchange rates existed for the countries they investigated.

Studies Conducted in Kenya have focused on the causal relationship between stock prices and other financial variables like money supply, interest rates, inflation rates arid exchange rates in Kenya (Nyamute, 1998, Kisaka, 1999, Kisaka, 2012); Nyamute established that a positive relationship exists between stock prices and exchange rates. Kisaka (1999; 2012) conducted a study to establish the causal relationship between exchange rates and stock prices. The results indicated a unidirectional causality from foreign exchange rates to stock prices in Kenya. No study has been conducted so far to establish the causality between interest rates and foreign exchange rates. The aim of this research was to fill this gap by investigating the causal relationship between interest rates and foreign exchange rates (represented by the Kenya shilling price of one U.S. dollar).

2. Literature Review

2.1 Efficient Market Hypothesis in the Foreign Exchange Markets

There are three different forms of market efficiency which are described based on how much information is used in forming expectations about the future price. These are the weak form, semi-strong form and strong form efficiency (Fama, 1970). These forms of efficiency are described by the procedures outlined below.

Tests for 'weak form' market efficiency have normally been based on the predictive power of the forward rate for the future spot rate (Swarna, 1994). The test is to determine whether the forward rate is an unbiased predictor of the future spot rate in a foreign exchange market. The procedure is specified as follows:

$$\text{Log } SP_{t+1} = \alpha + \beta LogFW_{t-1} + \mu_t \quad (1)$$

Where SP_{t+1} is the time *t+1* future spot rate; FW_{t-1} is the calculated forward rate at time *t* for delivery at time (t+ 1); β is the relationship between SP_{t+1} and FW_{t-1}.

The test for efficiency in Equation 1 relates to testing the null hypothesis $\alpha = 0$ and β = 1. If the forward market is not very active in the foreign exchange market, then it means that the few agents that undertake these transactions base them on the interest rate differentials between the local and foreign interest rates and those of its foreign partners. The forward rate *FW*, is therefore computed as follows:

$$FW_{t-1} = SP_t^* \frac{1+i_l}{1+i_f} \quad (2)$$

Where i_l is the local interest rate, i_f is the foreign interest rate; SP_t is the spot rate at time t.

Empirical studies have suggested that in the strong form of market efficiency, co-integration between future spot and forward rate series should exist. The Engle-Granger (1987) bivariate two-step co-integration regression procedure is applied in this case. The reverse regression from Equation 1 above is specified as in equation (3) below:

$$\text{Log } FW_{t+1} = \alpha + \beta LogSP_{t+1} + \mu_{It} \quad (3)$$

The direct regression specified in Equation 1 and the reverse regression in Equation 3 are conducted to determine whether the foreign exchange market is characterized by strong form efficiency. Co-integration tests involve establishing whether the stochastic trends in future spot and forward rate series have long-run relationship. This is accomplished by testing whether the residuals of co-integration regressions are stationary by applying the Augmented Dickey-Fuller (ADF) unit root tests (Dickey and Fuller, 1979). The co-integration equations are of the form shown in equations (1) and (3), μ_1 and μ_{1t} are the residuals to be tested for stationarity. If the computed ADF are found to be greater than the critical values (5% and/or 1%), the null hypothesis of existence of co-integration between the future spot and forward rate series will be rejected, and accepted, otherwise.

Semi-strong form of EMH requires that current price incorporates all publicly available information, including its own past prices (Fama, 1970). Geweke and Feige (1979) distinguished two categories within the semi-strong form of market efficiency: (a) single market efficiency where all publicly available information concerning a single exchange rate is contained in the information set; and (b) multi-market efficiency where information on all other exchange rates and all available economic information is included in the information set.

2.2 Covered and Uncovered Interest Rate Parity Conditions

There are two parity conditions, which play a key role in the development of the literature on the efficiency of the foreign exchange markets. These relationships which are simple theoretical concepts have been used as cornerstones for the building of more complex theoretical analyses. These relationships are the Covered interest Parity (CIP) and the Uncovered Interest Parity (UIP). The conditions are thought of as arbitrage relationships which hold continuously.

2.2.1. Covered Interest rates Parity (CIP)

Under the assumption of free capital flow, Covered Interest Parity (CIP) states that the forward premium of a foreign currency should be equal to the interest rate differential between a domestic asset and a substitutable foreign asset. CIP implies the equality of returns on comparable financial assets denominated in different currencies (Chinese University of Hong Kong, 2000). The underlying mechanism for CIP is covered interest arbitrage. Covered interest arbitrage is the transfer of liquid funds from one monetary centre to another to take advantage of higher rates of return or interest, while covering the transaction with a forward currency hedge.

According to the Chinese University of Hong Kong (2000), empirical deviations from CIP are always explained as violations to the assumption of free capital flow and the substitutability of assets from different countries. There are three possible explanations. First, there may be transaction costs, which introduce a "transaction band" into the CIP equation. Secondly, there may be possible capital controls, which actually adds costs to the investment in other countries and creates similar effects of the transaction costs to the CIP equation. Thirdly, there may be differences in tax rates on interest income and foreign exchange losses/gains in different countries. These differences contribute to the non- substitutability of investments in different countries and makes investment in one country more preferable than the other.

In the absence of barriers to international capital mobility, there are theoretical links among spot and forward exchange rates, interest rates and prices (Nikolaos and Dimitrios, 2005). The CIP ensures that profitable opportunities in the foreign exchange and interest rate markets do not last for long and that the tendency in these markets is towards equilibrium (Nikolaos and Dimitrios, 2005). Equation (4) shows the relationship between foreign exchange and interest rate markets under CIP conditions.

$$\frac{i-i^*}{1+i^*}=\frac{f_o-S_0}{S_0} \tag{4}$$

Where i = interest rate in the home country, i^* = interest rate in the foreign country, f_0 = forward rate at time t = 0, S_0 = Spot rate at time t = 0.

2.2.2. Uncovered Interest rates Parity (U1P)

UIP states that if funds flow freely across country boarders and investors are risk-neutral, after the adjustment of expected depreciation, the expected rates of return to substitutable assets denominated in different currencies should be equal. Algebraically, it is expressed as the equality between the expected changes in spot exchange rate and the interest differentials of two countries. Like that of CIP, the underlying mechanism of UIP is interest arbitrage activities. For example, if domestic interest rate is lower than the expected rate of return on an identical foreign asset, investors will borrow from the home country and invest in the foreign country. The borrowing and investing process will cause domestic interest rate to increase and foreign interest rate to decrease until the two kinds of returns reach the same level.

The argument by Nikolaos and Dimitrios (2005) is that rational investors' actions in purchasing one currency and selling another will move exchange rates until excess profits from uncovered interest arbitrage are eliminated, hence bringing interest rate differentials in line with spot exchange rates and expectations of their movement.

2.3 Development of Models for Testing Causality

2.3.1. Regression Models

Regression analysis is based on several assumptions. When those assumptions are satisfied, the estimated values of regression constants can be shown to be accurate in the sense that they are close to the true behavioural parameters. The first assumption of the classical regression model is that all explanatory variables are uncorrelated with unobserved factors, that is, with the error term. Secondly, the basic regression model also assumes that all variables are exogenous, which means that they are determined by factors that are not part of the behaviour under investigation (Margery and Felicity, 1999). Thirdly, the classical regression models assume that the error terms are normally distributed with a means of zero and constant variance. Fourthly, the model assumes that all variables in the model are non-stationary. Finally, the classical regression model assumes that all variables in the model are integrated of the same order.

According to Hallam, Rapsomanikis and Conforti (2004), statistical properties of series can be summarized by the concept of stationarity. A stationary series has a constant mean and a constant finite covariance structure. Such a series does not vary systematically with time, but tends to return frequently to its mean value and to fluctuate around it within a more or less constant range. Thus, the series is said to have a memory. Alternatively, a non-stationary series has time-dependent statistical properties and does not hover around the mean value. Hence such time series are called memoryless. Non-stationary series may contain stochastic or deterministic trends. Variables that contain stochastic trends are called "integrated" and exhibit systematic, but unpredictable variation, as compared to series that contain deterministic trends and display completely predictable variation (Hallam, et al., 2004). A stochastic trend in a series can be removed by differencing. The differenced series has statistical properties which are invariant with respect to time. Inferences about the similarity of the statistical properties of different economic series can be made by comparing the number of times the series has to be differenced in order to achieve stationarity. More formally, a variable is integrated of order d, written $I(d)$, if it must be differenced d times to achieve stationarity.

Before carrying out the estimation of regression coefficients in a time series, the stationarity of the data series is first tested by conducting an Augmented Dickey-Fuller test (Nelson and Plossser, 1982). This involves estimating the following regression and carrying out unit root tests:

$$\Delta X_t=\alpha+\mathrm{P}_tT+\beta X_{t-1}+\sum_{i=1}^{n}\lambda_i\Delta X_{t-i}+\varepsilon_t \tag{5}$$

In this equation, X is the variable under consideration, Δ is the first difference operator, T is a time trend, and ε is a stationary random error term. According to Baltagi (2001), before conducting the unit root test, the time-series trending effects are removed by subtracting the cross-country average from the original data (Heimonen, 1999). If the null hypothesis in the regression model that the regression coefficients β = 0, is not rejected, then the variable series contains a unit root and is non-stationary. The optimal lag length in the above equation has been identified by ensuring a white noise error term (Using the Hsiao (1969) technique).

2.3.2. Vector Autoregressive Models

The hypothesis that Variable p_1 Granger-causes Variable p_2 and vice versa can be assessed within a Vector Auto

Regression (VAR) framework by testing the null hypothesis that the coefficients of a subset of these jointly determined variables, the lagged p_1 terms, are equal to zero. In addition, Granger (1988) proposed a test for long run Granger causality within the context of the error correction representation of a co-integrated system of variables. The error correction representation provides a framework for testing for a systematic and nonlinear adjustment to long run equilibrium.

Granger and Lee (1989) proposed an asymmetric ECM (AECM) where the speed of the adjustment of the endogenous variable depends on whether the deviation from the long run equilibrium is positive or negative. The single asymmetric ECM is specified as follows:

$$\Delta p_{It} = \mu_1 + \alpha_1^+ (P_{1t-1} - \beta P_{2t-1})^+ + \alpha_1^- (P_{1t-1} - \beta P_{2t-1})^- + \sum_{i=0}^{k} \delta_i \Delta P_{2t-i} + \sum_{i=t}^{n} \gamma_i \Delta P_{1t-i} + v_{1t} \tag{6}$$

The errors or divergences from this equilibrium are decomposed in two parts, $(P_{1t-1} - \beta P_{2t-1})^+$ and $(P_{1t-1} - \beta P_{2t-1})^-$ reflecting positive and negative disequilibria respectively. Within this context, asymmetry occurs in the event when positive and negative divergences from the long run equilibrium between P_{it} and P_{2t} result in changes in p_{1t} that have different magnitude. Therefore, asymmetric transmission implies that a_1^+ is not equal to a_1^-. The null of symmetry against the alternative hypothesis that adjustment is asymmetric is tested by imposing the equality restriction $a^+1 = a_1^-$

In addition to the above, short run asymmetric transmission can also be tested by decomposing ΔP_{2t} in two parts reflecting price rises and price falls, and testing for equality of the corresponding short run coefficients. Asymmetric adjustment can be also tested by following Prakash et al. (2001).This method involves the assignment of a dummy variable, *d=0* to all the parameters of the underlying Autoregressive Distributed Lag (ADL) if there is positive disequilibrium and *d=1* if there is negative disequilibrium. Asymmetric adjustment to the long run equilibrium is then tested by imposing and testing zero restrictions on the dummies' parameters.

2.3.3. Co-integration and Error Correction Modelling Techniques

The concept of co-integration (Granger, 1981) and the methods for estimating a co-integrated relation or system (*inter alia* Engle and Granger, 1987; Johansen, 1988, 1991, 1995) provide a framework for estimating and testing for long run equilibrium relationships between non stationary integrated variables. Co-integration and error correction modelling technique involves three main steps. Testing the relevant time series for stationarity (unit roots), testing for co-integration, and finally error-correction modelling.

The standard textbook notation of Maddala (1988) is used to explain briefly the steps involved. A non-stationary time series Y_t is said to be integrated of order $d, [Y_t \sim I(d)]$, if it achieves stationarity after being differenced *d* times (Granger, 1986; Engle and Granger, 1987). To determine the order of integration, unit root tests have been developed. The most common test is known as Dickey-Fuller (DF) or Augmented Dickey-Fuller (ADF) (Dickey and Fuller, 1979).

Engle and Granger (1987) argued that ADF test allows for dynamics in the DF regression and consequently is over-parameterized in the first order case but correctly specified in the higher order cases.

To discuss the DF test, consider the model presented by equations (7) and (8) below.

$$Y_t + \beta_0 + \beta_{1t} + u_t, \tag{7}$$

$$u_t = \alpha u_{t-1} + \varepsilon_t, \tag{8}$$

where ε_t is a covariance stationary process with zero mean. The reduced form for this model is

$$Y_t = \gamma + \delta t + \beta_{1t} + \alpha Y_{t-1} + \varepsilon_t \tag{9}$$

Where $\gamma = \beta_0 (1-\alpha) \beta_{1\alpha}$ and $\delta = \beta_1 (1-\alpha)$. This equation is said to have a unit root if $\alpha = 1$. The DF test is based on testing the hypothesis $\alpha = 1$ in (5) under the assumption that ε_t are white noise errors. The test statistics are:

$$k(1) = T(\alpha' - 1) \qquad t(1) = (\alpha' - 1)/SE(\alpha')$$

Since these statistics do not have a standard t distribution, the critical values for *k* (1) and *t* (l) are tabulated in Fuller (1976).

Suppose that $[Y_t \sim I(d)]$ and $X_t \sim I(d)$ then Y_t, and X_t are said to be co-integrated if there exists a β such that $Y_t \sim \beta X_t \ is \ I(d-b)$ and b > 0. Thus testing for co-integration one must make sure that both series are integrated of the same order in first step. An alternate approach to test for co-integration was developed by Johansen (1988). Johansen method is more appropriate for models with more than two time series. The second step then involves estimating the following co-integration equation by Ordinary Least Squares (OLS):

$$Y_t = a_0 + boX_t + \mu_t \tag{10}$$

$$X_t = a_0 + boY_t + \mu_t \tag{11}$$

Then a test for the stationarity of the residuals from equations (10) & (11) is done to make sure that μ_t and $\mu_t^{'}$ are *I(d-b), b> 0.* If two variables are co-integrated, then the third step involves formulating the error-correction model (ECM) as follows:

$$(I-L)Y_t = C_0 + d_0\mu_{t-1} + \sum_{i=1}^{n} e_{oi}(I-L)Y_{t-i} + \sum_{i=1}^{n} f_{oi}(I-L)X_{t-i} + \varepsilon_t \tag{12}$$

$$(I-L)X_t = C_1 + d_1\mu_{t-1} + \sum_{i=1}^{n} e_{1i}(I-L)X_{t-i} + \sum_{i=1}^{n} f1i(I-L)Y_{t-i} + \varepsilon_t \tag{13}$$

Where *L* is the lag operator and the error correction terms (ECTs) μ_t and μ_t' are the stationary residuals from co-integration equations (10) and (11), respectively.
According to the standard Granger causality test, *X* is said to Granger cause *Y* if f_{oi}'s are jointly significant (1 = 1, 2). The inclusion of ECTs, however, provide additional channel through which the Granger causality could be detected. Thus, *X* is said to Granger cause *Y*, as long as the ECT carries a significant coefficient even if f_{oi}'s are not jointly significant (Granger, 1988). One important implication of co-integration and the error correction representation is that co-integration between two variables implies the existence of causality (in the Granger sense) between them in at least one direction (Granger, 1988).
The definition of causality and its relevance in the context of market integration and price transmission warrants some discussion. Co-integration itself cannot be used to make inferences about the direction of causation between the variables, and thus causality tests are necessary. Granger (1969) proposed an empirical definition of causality based only on its forecasting content: if x_t causes *t* then Y_{t+1} is better forecast if the information in X_t is used, since there will be a smaller variance of forecast error. This definition has caused considerable controversy in the literature (Pagan, 1989) as it really indicates precedence, rather than instantaneous causality that most economists profess. Nevertheless, if two markets are integrated, the price in one market, p_1, would commonly be found to Granger-cause the price in the other market, p_2 and/or vice versa. Therefore, Granger causality provides additional evidence as to whether, and in which direction, price transmission is occurring between two series.

2.4 Empirical Evidence on Causality between Interest Rates and Exchange Rates

Furman and Stiglitz (1998) argued that the high interest rate policy destabilizes exchange rates by raising corporate bankruptcies and accelerating capital outflows. Goldfajn and Gupta (1999) found that high interest rates helped stabilize exchange rates using monthly data for 80 countries for 1980-98. Cho and West (2001) reported similar findings for five East Asian crisis countries.
In their study, Hwee Kwan and Yoonbai (2004) used the call rate to represent interest rates. They employed weekly data obtained from DataStream for the period from January 1993 to July 2002 for Indonesia, Korea, Philippines and Thailand. They established that all the Asian crisis countries appeared to adjust their exchange rate more sensitively in the post-crisis period to changes in the neighbours' exchange rate. The relationship between the interest rate and the exchange rate can at times be ambiguous (Hwee Kwan and Yoonbai, 2004). For instance, whether higher interest rates are an essential part of the defence strategy for the currency in times of financial crisis is controversial. This uncertainty was well borne out in the context of the Asian financial crisis.
In a similar study to establish the empirical relationship between exchange rates and interest rates in post-Crisis Asia, Brailsford et al. (2006) tested for Granger causality between interest and foreign exchange rates in four Asian countries (South Korea, the Philippines, Thailand, and Malaysia). Their study concentrated on testing for Granger causality over the Asian financial crisis period (from 1 July 1997 to 1 July 1998). They adopted a similar model to Dekle et al. (2002), which includes the variables: daily overnight interest rate differential with the United States, exchange rate against the US dollar and producer price differential with the United States (approximated by the monthly index movements). To capture the currency contagion effect during the crisis period, they also included the exchange rate of the Malaysian Ringgit against the US dollar in the models for Thailand, the Philippines and South Korea. In the case of Malaysia, the Thai baht against the US dollar was used as a proxy currency contagion effect. After taking into account the currency contagion effect, their results

indicated that sharply higher interest rates helped to support the exchange rates of South Korea, the Philippines and Thailand. For Malaysia, no significant causal relation was found from the rate of interest to exchange rates, as the authorities in Malaysia did not actively adopt a high interest rate policy to defend the currency (Brailsford, Jack, Penm and Chin, 2006).

In summary, this study sought to predict the causality between interest rates and foreign exchange rates in Kenya. The review has shown that even in developed economies, much empirical research on foreign exchange markets provides evidence that the uncovered interest parity condition (or its equivalent in the forward premium unbiasedness hypothesis) does not hold (Hwee Kwan and Yoonbai, 2004). The controversy between efficient markets proponents and their opponents centres on whether the small measured deviation from efficiency is due to the presence of a time-varying risk premium or such factors as the "peso effect" (where there is a small probability every period of a big regime change affecting the exchange rate), which does not detract from the efficient markets hypothesis; or whether investors, or a subset of investors, make systematic predictive errors (Froot and Thaler, 1990).

Various studies had focused on the causal relationship between stock prices and other financial variables like money supply, interest rates, inflation rates and exchange rates (Nyamute, 1998; Kisaka, 1999; Kisaka and Mwasaru, 2012). Kisaka (1999) conducted a study to establish the causal relationship between exchange rates and stock prices. No study had been conducted so far to establish the causality between interest rates and foreign exchange rates in Kenya. The aim of this research was to fill this gap by investigating the causal relationship between interest rates and foreign exchange rates in Kenya.

3. Research Methodology

3.1 Research Design

This study employed a causal research design. This research design enables the determination of not only the relationship but also the direction of influence between variables. Therefore, causal research design helps to determine the cause and effect among variables. This can be achieved experimentally or quasi-experimentally.

In this study a quasi-experimental approach was adopted to study the relationship between interest rates and foreign exchange rates in Kenya. The objective was to determine whether interest rates can help improve the prediction of exchange rates and vice versa.

3.2 Population

The population of this study consisted of all observations of interest rates of the 91-days Treasury bills and monthly foreign exchange rates of the Kenya shillings per US dollar. The two variables constituted the units of analysis.

3.3 Data, Sample Selection and Sample Period

The data sources were limited to the nominal value of exchange rate represented by the Kenya Shilling price of one US dollar and aggregate interest rate represented by the Treasury bill yield over a 91-days period. The data set consisted of monthly observations of the nominal value of the daily closing exchange rate between January 1993 and June 2006. The monthly closing Treasury bill rates over the same period were used.

The starting date in this case was dictated by the time when the government shifted its foreign exchange policy from fixed exchange rates to independently floating exchange rates. Monthly closing values on the nominal exchange rate (dollar rate) and the closing monthly Treasury bill rates were obtained from the Central Bank of Kenya. The Treasury bill rates were used for this study because according to Ngugi and Kabubo (1998), the 91-days Treasury bills are used as a yardstick for other short-term interest rates.

3.4 Research Model

Studying the causal relationship between interest rates and foreign exchange rates involved establishing whether changes in interest rates affects the foreign exchange rates and vice versa. The Granger's 1969 causality test checks for causality between an explanatory variable and the dependent variable. The nominal exchange rate was treated as the dependent variable to test whether past values of T-bill interest rates predict the current values of the exchange rate, and vice versa. Testing causal relations between two stationary series (in a bivariate case) were based on comparing the results of equations (14) and equation (15) below.

$$E_t = \alpha_0 + \sum_{i=1}^{p} a_k E_{t-k} + \sum_{k=1}^{p} \beta_k I_{t-k} + \mu_t \tag{14}$$

$$I_t = \delta_0 + \sum_{k=1}^{p} \varphi_k E_{t-k} + \sum_{k=1}^{p} \lambda_k I_{t-k} + V_t \tag{15}$$

Where E = Foreign exchange rate; I = Interest rate; p = is a suitably chosen positive integer that defines the lag structure; a_k, β_k = coefficients of the exchange rate equation; φ_k, λ_k = Coefficients of the interest rate

equation; μ_k, v_k = white noise error terms with zero means and finite variances.
Granger-Causality tests can be placed in one of four categories: No causality, ***I*** causes ***E*** only, ***E*** causes ***I*** only, and a bi-directional causality, (i.e., ***I*** causes *E* and *E* causes ***I*** simultaneously).These definitions for causality according to Granger (1969) imply that the null hypothesis that ***I*** does not Granger-Cause ***E*** is rejected if the $\beta_k's, k>0$ in equation (14) are jointly significantly different from zero using a standard joint test (e.g., an ***F*** test). Similarly, ***E*** Granger-causes ***I*** if the $\lambda_k's, k>0$ coefficients in equation (15) are jointly significantly different from zero.
The causality test above is applicable for stationary data. In reality, however, interest rates and foreign exchange rates data are known to be non- stationary. In such cases, one has to transform the original series into stationary series before performing causality tests. A special class of non-stationary process is the *I* (1) process (i.e. the process possessing a unit root). An *I* (1) process may be transformed to a stationary one by taking first order differencing. Thus, while dealing with two *1*(1) processes for causality, equations (14) and (15) must be expressed in terms of differenced-series. However, if the underlying variables have a unit root and are co-integrated, the specifications so obtained must be modified by inserting the error correction term as an additional explanatory variable (Engle and Granger, 1987). In other words, equations (14) and (15) will be modified as shown in equations (16) and (17)

$$\Delta E_t = \alpha_0 + \sum_{k=1}^{p} \alpha_k E_{t-k} + \sum_{k=1}^{p} \beta_k \Delta I_{t-k} + \lambda ECT_{t-1} + \mu_t \tag{16}$$

$$\Delta I_t = \delta_0 + \sum_{k=1}^{p} \varphi_k \Delta E_{t-k} + \sum_{k=1}^{p} \lambda_k \Delta I_{t-k} + \eta ECT_{t-1} + V_t \tag{17}$$

Where Δ is the difference operator and ECT_{t-i} represents an error correction term derived from the long-run co-integrating relationship between the *1*(1) processes E_t and I_t. This term can be estimated by using the residual from a co-integrating regression. Clearly, if E_t and I_t are *1*(1) are not co-integrated, the term ECT_{t-i} would be absent from equations (16) and (17).

3.5 Determination of Optimum Lag using the Hsiao's Procedures

Determining appropriate lag length is important because a small value of optimal lag length would lead to a mis-specified model. On the other hand, a larger value of optimal lag length would waste degrees of freedom (Mohan, 2006). Hsiao (1979) proposed a test procedure that combines Akaike's (1969) final prediction error (FPE) and Granger's (1969) definition of causality to determine the optimum lag for each variable and the causal relationships. Hsiao's method is superior to both ad hoc lag-length selection and several other systematic procedures for determining lag-length. Several recent studies investigating causal relationships between money and income, defence spending and economic growth and investment and economic growth have utilized Hsiao's procedure (Mohan, 2006; Carol and Weil, 1994; and Sinha; 1996).
The first step in Hsiao's procedure is to perform a series of autoregressive regressions on the independent variable, beginning with one lag and adding one more lag in each succeeding regression. Therefore, for the Foreign Exchange rate variable, *P* regressions of the form of equation (18) will be performed; where *p* in this case will vary from 1 to *P*, *P* being the maximum lag length. For each regression, the FPE will be computed using equation (19) as shown below.

$$E_t = \alpha_0 + \sum_{k=1}^{p} \alpha_k E_{t-k} + \mu_t \tag{18}$$

Where E_t = Foreign exchange rate at time *t*; α_k, α_0 = regression constants; μ_t = White noise error terms;

$$FPE(p) = \left[\frac{T+p+1}{T-p-1}\right] x \left[\frac{SSE(p)}{T}\right] \tag{19}$$

Where *T* is the sample size and FPE (*p*) and SSE (*j*) are the final prediction error and the sum of squared errors, respectively. The optimal lag, *p**, is the lag length which produces the lowest FPE. Secondly, the exchange will be treated as the only output of the system and assume interest rates I_t, as the input variable, which controls the output of the foreign exchange variable E_t. With the order of the autoregression of exchange rate determined from the first step, regressions will be estimated with the lags of the interest rates variable added sequentially in the same manner used to determine *p**. Therefore, *q* regressions of the form of equation (20) will be estimated.

$$E_t = \alpha_0 + \sum_{k=1}^{p*} a_k E_{t-k} + \sum_{k=1}^{q} \beta_k I_{t-k} + \mu_t \tag{20}$$

For each regression, the FPE will be computed using equation (21) as shown below.

$$FPE(p*, q) = \left[\frac{T + p * + q + 1}{T - p * - q - 1}\right] x \left[\frac{SSE(p * q)}{T}\right] \tag{21}$$

Where q varies from 1 to q. q is the maximum lag-length. The optimal lag-length for I_t, (denoted $q*$) will be chosen as the lag length which produces the smallest FPE. To test for causality, the FPEs from steps one and two will be compared. If FPE ($p*$) is less than FPE ($p*$, $q*$), a uni-dimensional autoregressive representation for exchange rate will be used, and in this case the conclusion is be that interest rates do not Granger-cause exchange rates. If the converse is true, then the conclusion is interest rates Granger-causes exchange rates. Once the test has been performed with exchange rate as the output variable, a similar test for interest rates, treating exchange rate as the input variable is undertaken.

3.5 Diagnostic Tests

3.5.1. Unit Root Tests

The classical regression model requires that the data series of equations (14) and (15) are stationary; otherwise the inference from the *F*-statistic might be spurious because the test statistics will have non-standard distributions. In reality, however, underlying series may be non-stationary. In such cases, original series are transformed into stationary series and causality tests are performed based on transformed-stationary series. Thus, while dealing with two 1(1) process when testing for causality, equations (14) and (15) must be expressed in terms of differenced-series. The Augmented Dickey-Fuller (ADF) unit root tests (Dickey and Fuller, 1979) are used to check for stationarity of the foreign exchange rate and interest rates data series. The equation used for conducting ADF test has the general structure of equations (22) and (23). The null hypothesis, H_0 is that E_t, and I_t are stationary (i.e., from equations 22 and 23, H_0: $P_1 = P_2 = 0$) while the alternative hypothesis is that both variables are integrated of order one, I(1).

$$\Delta E_t = \alpha_0 + \beta_{1t} + P_1 E_{t-1} + \sum_{k=1}^{n} \delta_k \Delta E_{t-k} + \varepsilon_{1t} \tag{22}$$

$$\Delta I_t = \alpha_0 + \beta_{2t} + P_2 I_{t-1} + \sum_{k=1}^{p} \omega_k \Delta I_{t-k} + \varepsilon_{2t} \tag{23}$$

Where Δ = first difference operator, $\Delta E_t = E_t - E_{t-1}$; $\Delta I_t = I_t - I_{t-1}$; ω_k = coefficients of the differenced lagged variables of the interest rates, α_0 = constant term; δ_k = coefficients of the differenced lagged variables of the foreign exchange rates, β_1, β_2 are coefficients of the time trend for E and I respectively, P_1, P_2 = coefficients of the lagged variables of E and I respectively, t = time trend, and $\varepsilon_{1t}, \varepsilon_{2t}$ = white noise error terms.

In equation (22), if

(i) $\beta_1 = 0$ and $|P_1| < 1$, the series E_t is stationary;

(ii) $\beta_1 = 0$ and $P_1 = 1$ then the series is an $I(1)$ process;

(iii) $\beta_1 \neq 0$ and $|P_1| < 1$ then the series is trend-stationary (i.e. stationary around a deterministic linear time trend).

The same conditions for stationarity test apply to the constants in equation (23).

3.5.2. Co-integration Tests

Co-integration tests involve establishing whether the stochastic trends in E_t and I_t that contained unit roots have long-run relationship. This is accomplished by testing whether the residuals of co-integration regressions are stationary. The co-integration equations are of the form shown in equations (24) and (25).

$$E_t = \pi I_t + \omega_t \tag{24}$$

$$I_t = \theta E_t + \xi_t \tag{25}$$

Where ω_t and ξ_t are the residuals to be tested for stationarity. If the computed ADF will be found to be greater than the critical values (5% and/or 1%), the null hypothesis of existence of co-integration between the foreign exchange rates and interest rates will be rejected, and accepted otherwise.

3.5.3. Auto-correlation tests

Auto-correlation test is a reliable measure for testing of either dependence or independence of random variables in a series. The serial correlation coefficient measures the relationship between the values of a random variable at time *t* and its value in the previous period. Autocorrelation test evidence whether the correlation coefficients for residuals are significantly different from zero. The test is based on the following regression equation (26):

$$\Delta S_t = S_{t-1} + \delta_1 \Delta S_{t-1} + \delta_2 \Delta S_{t-2} + \delta_3 \Delta S_{t-3} + \ldots\ldots\ldots\ldots\delta_n \Delta S_{t-n} + \varepsilon_t \tag{26}$$

Where δ = coefficient of the error term; S_t = residual from the regression; δ_1 = coefficient of the lagged residuals; $\Delta S_t = S_t - S_{t-1}$.

A way to test for the presence of autocorrelation is to carry out a regression analysis using equation (26) and check whether the $\delta_i 's =$ i = 1, 2, 3... *n* have values between [-1, 1]. Values of zero for $\delta_i 's =$ *i* = 1,2, 3... *n,* suggests no autocorrelation. Ljung-Box Q statistics were used to test for autocorrelations between the variables. Ljung-Box Q statistic follows the chi-square distribution with *m* degrees of freedom as shown in equation 27:

$$LB = n(n+2)\sum_{k=1}^{m}\left(\hat{p}^2 k / n - k\right) \cong x^2 \tag{27}$$

Where $\hat{p}^2 k$ autocorrelation coefficients at lag *k*; and *n* = sample size

3.5.4. Test for Heteroscedasticity

In forecasting, normally it is assumed that the variance of disturbance term (σ^2) is constant over time *t*. However, the actual volatility of a time series is not always constant. When the variances of the disturbances tend to increase or decrease with the increasing value of the regressors, the disturbances are said to be heteroscedastic. Engle (1982) introduced a forecasting method by allowing the variances vary over time. This test is based on the regression of equation (26). Engle (1982) test for the null hypothesis that the residuals do not have an ARCH structure will be used. In this case, a *t*-test for coefficients on these terms in the error-correction model is conducted.

4. Data Analysis, Results, Discussion and Conclusion

This section presents the data analysis, interpretation, and discussion of the research findings.

4.2. Results of Unit Root and Co-integration Tests

As a matter of procedure, we first tested the time series properties of the data. In particular, we examined whether interest rates and exchange rates are stationary. We used the Augmented Dickey-Fuller (ADF) unit root tests (Dickey and Fuller, 1979) and the results are reported in Table 1 below. The equation used for conducting ADF test has the general structure of equations (22) and (23). The null hypothesis, H_0 is that E_t and I_t, have unit roots (i.e., from equations 22 and 23, H_o: $P_1 = P_2 = 1$) while the alternative hypothesis is that both variables are integrated of order zero, *I* (0).

Table 1 Results of the Unit Root Test for Foreign Exchange Rates and Interest Rates

Variable	ADF	Critical Values (5%)	Critical values (1%)	Decision
E_t	17.698	-3.45	-3.99	Reject H_0
I_t	32.781	-3.35	-3.99	Reject H_0
1st Difference, E_t	-4.171	-3.45	-3.99	Reject H_0
1st Difference, I_t	-4.525	-3.35	-3.99	Reject H_0
2nd Difference, E_t	-3.114	-3.45	-3.99	Reject H_0
2nd Difference, I_t	-2.69	-3.35	-3.99	Reject H_0

Source: Authors computations

The results of Table 1 were obtained by differencing the series twice. Thus, it was established that both variables are *I* (2) processes and therefore the classical Granger-causality test was found to be appropriate. The results also indicate that both variables were non-stationary in level forms. The decision rule was to reject H_0 if the ADF statistics are greater than the critical values (Dickey and Fuller, 1979).

Co-integration tests were necessary to establish if the stochastic trends in I_t and E_t, that had unit roots have long-run relationship. This involved establishing whether the residuals of the co-integrating relations are stationary. This was based on regressions of equations (24) and (25) and then conducting ADF tests on the residuals based on the null hypothesis that there exists no co-integration between the foreign exchange rates and interest rates. The computed *t*-statistic was -5.57694 which is greater in absolute value than the critical value of -3.45 at 5%

level of significance. On the basis of this, the null hypothesis was rejected and hence the conclusion is that there exists a long-run relationship between the foreign exchange rates and interest rates. This necessitated the use of the error correction model (ECM) instead of the classical Granger-causality test.

4.3. Determination of Lag Length using the Hsiao's Procedure

The first step in Hsiao' s procedure was to perform a series of autoregressive regressions on the independent variable, beginning with one lag and adding one more lag in each succeeding regression. Therefore, for the Foreign Exchange rate variable, *P* regressions of the form of equation (18) were performed; where p in this case varied from 1 to *P*, *P* being the maximum lag length. For each regression, the FPE was computed as illustrated in equation (19). Table 2 shows the results of the first step.

Table 2 Results of the First step of the Hsiao's Procedure

	P=1	P=2*	P=3	P=4	P=5
SSE (p)	742.968	650.372	648.547	646.449	643.490
FPE (p)	4.7008	4.166 14	4.20608	4.24459	4.27771

Source: Authors computations. Dependent variable = Foreign Exchange Rate T (Sample size) 162; p* (lag length which produces the lowest FPE) 2

Secondly, the exchange rate variable was treated as the only output of the system and the interest rate variable I_t was assumed to be the input variable, which controls the output of the foreign exchange rate variable E_t,. With the order of the auto-regression of exchange rate determined from the first step ($p^* = 2$), regressions were estimated with the lags of the interest rates variable added sequentially in the same manner used to determine p*. Therefore, *q* regressions of the form of equation (20) were estimated and the results are as shown in Table 3.

Table 3 Results of the Second step of the Hsiao's Procedure

	P=1	P=2*	P=3	P=4	P=5
SSE (p)	627.132	517.615	517.502	514.516	508.005
FPE (p*,q)	4.06719	3.398670	3.44018	3.46289	3.46163

Dependent variable = Foreign Exchange Rates T (Sample size) = 162; q* [lag length which produces the lowest FPE (p, q)j = 2

Source: Authors computations

The findings of Table 3 therefore indicate that the maximum number of lags required to test for causality is two lags. The procedures were repeated with the interest rates as the dependent variable and the results are presented in Tables 4 and 5 below.

Table 4 Results of the First step of the Hsiao's Procedure

	P=1	P=2	P=3	P=4	P=5*
SSE (p)	2246.62291	1008.03486	916.46724	912.18312	879.69018
FPE (p)	14.2147	6.4572	5.9436	5.9894	5.8479

Dependent variable = Interest Rates T (Sample size) = 162; q* (lag length which produces the lowest FPE) = 5

Source: Authors computations

Table 5 Results of the Second step of the Hsiao's Procedure

	P=1*	P=2	P=3	P=4	P=5
SSE (p*q)	868.09454	858.25303	853.40496	844.90235	834.74781
FPE (p*,q)	5.8426	5.8482	5.8876	5.9017	5.9034

Dependent variable = Interest rates. T (Sample size) = 162; q* [lag length which produces the lowest FPE (p*, q)]= 1

Source: Authors computations

The test results with interest rates as the dependent variable yielded the value for FPE (p^*, q^*) that is less than FPE (p^*).

4.4 Error Correction Model and Granger - Causality

According to Engle and Granger (1987), if E_t and I_t are co-integrated, the Granger representation theorem states that the two time series may be considered to be generated by the error correction models of the form of equations (16) and (17). The error correction coefficients λ and η in equations (16) and (17) were expected to capture the adjustments of ΔE_t, and ΔI_t, towards long-run equilibrium while ΔE_{t-k} and ΔI_{t-k} were expected to capture the short-run dynamics of the model. The error correction models were used to test the causal relationship between interest rates and foreign exchange rates. Table 6 gives the results of the ECM using both the interest rates and the foreign exchange rate equations. Based on the results of section 4.3 above, the residuals were lagged twice. *F*-test was then applied to establish the Granger-causality.

Table 6 Full information estimates of the Error-correction Model

Equation	Interest rates Granger-causes Foreign Exchange Rates	Foreign Exchange Rates Granger-causes Interest rates
Dependent Variable	ΔE_t	ΔI_t
Constant	0.165	-0,079
Error Correction Terms	0.033 (2.03 3) *	0.049 (3.094)*
ΔE_{t-1}	0.231 (2.988)*	0.084 (0.823)
ΔE_{t-2}	0.009 (0.367)	0.009 (0.285)
ΔI_{t-1}	0.257 (4.468) **	0.887 (11.352)**
ΔI_{t-2}	-0.076 (-1.218)	-0.297 (3.429)**

Source: Authors computations. *t*-statistics are in parentheses. *Significance at 5% level. **Significance at 1% level

The findings indicate that both the E_t and I_t equations produced significant error correction estimates when lagged twice. After applying *F*-tests (Table 7), the results led to acceptance of the null hypotheses that foreign exchange rates do not Granger-cause interest rates. According to Miller and Russek (1990), the null hypotheses are not only rejected if the coefficients of E_t and I_t, are jointly significant but also if the error correction coefficients (λ and η) are significant. The results of Table 7 indicate that the error correction terms are jointly significant at 5% level. A significant error- correction term implies that causality is attributable to external factors other than the variables in the model. So the analysis shows that interest rates causes foreign exchange rates but not the vice versa. This is in agreement with the previous findings that FPE (p^*, q^*) is less than FPE (p^*). That is, interest rates improve the prediction of foreign exchange rates.

Table 7 Results for Granger-Causality Tests

Null Hypothesis (Ho)	**F-statistics**	**Critical F values**	**Decision**
E_t does not Granger-cause I_t	5.886	6.63	Accept H_0
I_t does not Granger-cause E_t	11.389	6.63	Reject H_0

Source: Authors computations.

4.5. Diagnostic Tests

The models specified by equations (16) and (17) were subjected to econometric testing procedures of auto-correlation and heteroscedasticity. Auto-correlation test is a reliable measure for testing of either dependence or independence of random variables in a series. The serial correlation coefficient measures the relationship between the values of a random variable at time *t* and its value in the previous period. Autocorrelation test evidence whether the correlation coefficients for residuals are significantly different from zero. The test was based on regression of equation (26) and the results are as reported in Table 8.

Table 8 Results for Heteroscedasticity and Autocorrelation Tests

Diagnostic Test	Test statistic obtained	Critical value for *t*-statistics & Chi-square	*p*- values	Decision
Heteroscedasticity	15.837[a]	1.96	0.079	Accept H_0
Auto-correlation (Equation 11)	1st Order = 71.928[b]	90.53	0.000 0.000	Reject H_0 Reject H_0
Auto-correlation (Equation 12)	2nd Order =76.407[b]	90.53	0.000 0.000	Reject H_0 Reject H_0

Source: Authors computations. [a]H_0: There is no heteroscedasticity. [b]H_0: There is no autocorrelation.

Ljung-Box Q statistics were used to test for autocorrelations. Ljung-Box Q statistic follows the chi-square distribution with *m* degrees of freedom as shown in equation (27). The results from the Table 8 confirmed that there is significant autocorrelation of the two time series for the whole sample period. The first order auto-correlation in first sample period is higher than the second sample period. On the other band, second order auto-correlation and auto-correlation at higher lags is significant in second sub-sample than the first sub-sample period. The nonzero auto-correlation of the series associated with Ljung -Box Q statistics, which are jointly significant at 1% level, suggest that both series do not follow random walk model. The findings also confirmed absence of heteroscedasticity.

5. Conclusions

This study examined the causal relationship between the foreign exchange rates and interest rates in Kenya. The study employed monthly data and applied co-integration, error correction modelling approach and standard Granger causality tests to examine the long run and short-run association. The results showed that there exists a long-run relationship between the foreign exchange rates and interest rates. This necessitated the use of the error correction model (ECM) instead of the classical Granger-causality test. The study established that there is uni-directional causality running from interest rates to foreign exchange rates in Kenya. Since the causation runs from interest rates to foreign exchange rates then authorities in the Kenyan financial markets use interest rates to stabilize the foreign exchange rates. Moreover, the fact that the two markets prices are related implies that the investors can use this information on interest rates to predict exchange rates.

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