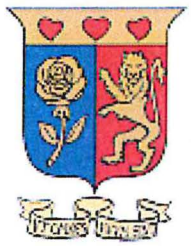

Modeling Nominal Exchange Rates in Uganda.
A Comparison Between Traditional Unit Root Tests and Fractional Integration

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4th December 2019

This Research Project has been submitted for examination with my approval as the Supervisor.

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ABSTRACT

This paper analyzes six major nominal exchange rates in Uganda, determining whether shocks in each series are transitory or permanent in the long run. We obtain results from traditional unit root tests and compare these to the results from newer fractional integration techniques that have been shown to have higher power in establishing stationarity or mean-reversion. The results show evidence of mean reversion in the cases of Euro and Kenya shilling, but not for the US dollar, Japanese Yen, the Pound and the Canadian dollar. This means that the shocks affecting the latter currencies do not dissipate in the long run.

Chapter 1: INTRODUCTION

1.1 Background to the study.

In line with the liberalization of the foreign exchange markets in Uganda and other sub-Saharan countries in 1990, the central bank (Bank of Uganda) pursues a managed exchange rate system. In this regime, the price of the Uganda shilling versus the US dollar and other foreign currencies in the foreign exchange markets is determined by the forces of demand and supply, with the Central Bank's involvement being limited to occasional interventions that include the purchase or sale of the respective foreign currency to check excessive volatility in the exchange rate. Exchange rate is therefore one of the major variables used by the Bank of Uganda to manage the monetary policy in Uganda, as well as interest rates and inflation.

During the 1980s a parallel exchange rate system was used. This was a system in which a market-determined exchange rate co-existed with one or more pegged exchange rates at any given time. But since the liberalization of the foreign exchange market, heavy focus was put on exchange rate policy as crucial for maintenance of macroeconomic stability. "It was suggested that the exchange rate policy tool be used together with appropriate monetary and fiscal instruments so as to enable domestic and external stability of the Ugandan economy." (Mbire, 1997)

Among the main objectives of the exchange system liberalization, Kasekende and Ssemogerere (1994) portray the use of exchange and trade policies to reestablish confidence in the currency, reduce distortion of prices and shift resources from theoretical to productive activities. The main focus then was the prevention of the over-valuation of the shilling, and this has remained the case to date. This mis-valuation is mainly measured by the gradual elimination and eventual convergence of the two-tier foreign exchange markets in recognition of the fact that the price for foreign exchange, on the one hand, affects the domestic price of imports and with it the cost of imported inputs and subsequently the domestic price of consumer goods. On the other hand, it affects the domestic price of exports and hence profitability of exporters. All other things kept constant, depreciation of the exchange rate would likely raise the costs of imported products, leading to increased use of local products and would simultaneously increase savings on imports. This would raise the relative profitability of exports and import substitution industries. On the

other hand, an appreciation of the exchange rate would increase the demand for imports and reduce the profitability of exports and import substitution industries.

Determining the convergence of nominal exchange rates to the long-run mean is therefore critical for developing countries, Uganda in particular, because of the vulnerability of the Ugandan economy to exchange rate shocks. An example of such vulnerability was witnessed in October 2011, when the East African region saw a significant surge in inflation reaching an average of 20% for the entire region. This rise in price was an issue of concern for policymakers and the general public and the crisis had Uganda record the second highest level of inflation in the region hitting 30.5% during this period. Global investors pulled their money out of any asset that they deemed risky, causing the economy to fall even further. This crisis was likely a long term result of the global financial crisis just three years earlier which threw economies worldwide into turmoil. With a fall in demand for Uganda's agricultural produce like flowers, coffee and tea, as well as the increased fuel prices, the Uganda shilling suffered a dramatic fall in value against all major currencies, especially the dollar. The Central bank then intervened in the currency market and increased interest rates to 23% at the beginning of November that year. "This was intended to discourage borrowing and simultaneously encourage saving so as to reduce the amount of Uganda shillings in circulation." (Young, 2011) As a result, there was a partial reversal of the falls in the dollar-shilling exchange rate.

Earlier than this, though, the effects of delayed policy action by authorities in the country was seen in the mid-1980s when the delay resulted in massive distortions in the fiscal, monetary and real sectors of the economy. The economy suffered from high inflation rates, a high budget deficit to GDP ratio, a high debt/GDP ratio, and over-valued exchange rates. All of these combined to complicate macroeconomic management. With the above lessons in mind, the exchange rate policy in Uganda has been closely related to policies involving exchange rate management and trade arrangements.

1.2 Statement of the research problem

While most foreign exchange rates do indeed follow a mean-reverting process, some may not have the tendency to revert to their mean over time and hence beg the need for government intervention in the case of shocks in these specific exchange rates. Failure of a government to make timely intervention into the foreign exchange market in the event of a shock can lead to sharp depreciation or appreciation of currency which in turn can lead to rapid inflation and deflation levels respectively, both of which are usually undesired. Without empirical analysis, however, it is difficult to know which exchange rates to focus government intervention on and whether such intervention should be strong or mild given the degree of the shock as well as the mean reversion properties of the series in question. Therefore, this study, analyzes six major exchange rates in Uganda (including exchange rates of one country in the East African region, Kenya) with the aim of determining which currencies experience persistent shocks in the Ugandan foreign exchange market.

1.2 Research Objectives

i) To introduce fractional integration in analyzing the degree of persistence of shocks in nominal exchange rates in Uganda.

ii) To compare the results from traditional unit root tests with the results from fractional integration.

1.4 Research questions

i) Are nominal exchange rate shocks permanent or transitory?

ii) Do traditional unit root tests give the same results as fractional integration?

The structure of the paper is as follows; Chapter 2 presents a literature review on empirical and theoretical issues to do with exchange rate dynamics. Chapter 3 describes the research methods used for this study, and Chapter 4 contains the data analysis and results obtained. The fifth and final chapter then summarizes the conclusions made.

Chapter 2: Literature Review

This chapter covers a study of past literature on the topics of mean reversion, exchange rate dynamics and other relevant topics within the scope of this research paper. The first part deals with the theoretical literature, followed by a review of past empirical work and conceptual framework.

2.1 Review of theoretical literature.

The theory of mean reversion used in finance suggests that asset prices and historical returns eventually revert to the long run average or mean level of the entire dataset over time. For the case of this paper, it simply implies that exchange rate series tend to revert to their usual patterns after an economic shock. Figure 1 below shows an example of a mean reverting series with the mean being the straight line in the middle of the graph.

Figure 1 : A mean reverting series

This theory of mean reversion is closely linked to another significant theory in economics, that is the theory of Purchasing Power Parity. African policy makers have been implementing exchange rate policy reforms based on the assumption that long-run PPP holds in Africa. This concept of Purchasing Power Parity, henceforth PPP, and discussions concerning the relationship between the exchange rate and prices have a long history in economics, dating all the way back to the sixteenth century.

Taylor 2006 states that "a major building block of PPP is the law of one price (LOP) which states that when converted to a common currency, the same good should be bought at the same price in different countries. This law assumes that there is perfect competition in all markets, meaning that under PPP, the logarithm of the real exchange rate should be zero. As such, movements in

exchange rate are synonymous with deviations from PPP. For the real exchange rate to settle down at any level whatsoever (including the level consistent with PPP,) it must display reversion towards its own mean. Hence a necessary condition for long-run PPP to hold is that real exchange rates must be mean-reverting also meaning that they should follow a stationary process. However, in reality, real exchange rates tend toward PPP only in the very long run. In addition to this, the speed of convergence to parity is awfully slow, and deviations from PPP are large and very volatile. These observations give rise to the purchasing power puzzle which is as follows:

How can one reconcile the enormous short-term volatility of real exchange rates with the extremely slow rate at which shocks appear to dampen out?

Rogoff (1996) gives more insight on the Power Parity Puzzle mentioned above, and according to him, "the markable failure of the law of one price in microeconomic data and the consequential failure of the short-run PPP can be attributed in part to stickiness in nominal exchange rates, and the fact that real exchange rates also change in the short-run. Most explanations of short-term exchange rate volatility point to financial factors such as changes in portfolio preferences, short-term asset price bubbles, and monetary shocks. Such shocks can have substantial effects on the real economy in the presence of sticky nominal wages and prices. It is not difficult to rationalize slow adjustment if real shocks are predominant. But existing models based on real shocks cannot account for short-term exchange rate volatility. The PPP puzzle referred to above has challenged the common practice of using the PPP concept in exchange rate benchmarking and has gained further attention recently because of the problem of exchange rate misalignment throughout the 1990s, a decade of financial turmoil and currency crises." (Rogoff, 1996)

Also, in contrast, an alternative theory, sometimes referred to as the ex-ante PPP theory, suggests that real exchange rates may follow a martingale process with no mean reversion. Adler and Lehmann (1983), for example, note that the real exchange rate can or should follow a random walk, theoretically. "The random walk proposition is based on a number of assumptions, namely that interest rate parity holds, the forward rate is an unbiased predictor of the future spot rate, the Fisher relationship holds, and real interest rates are constant. The proposition seems difficult to prove. The real exchange rate follows closely a random walk, suggesting little tendency for deviations from PPP to reverse." (Adler & Lehmann, 1983)

Another issue in recent literature has been the linearity and nonlinearity of real exchange rates. In recent times, there has been much interest in the area of non-linear times series modelling. "Non-linear models are often found to provide rather better descriptions of the behavior of actual data than do their linear I(0) ARMA or I(1) ARIMA counterparts, particularly so where macroeconomic and financial variables are involved. Since efficient prediction of such variables relies on being able to model them appropriately, it is therefore of fundamental concern that non-linearity, where it exists, should be detectable." (Harvey & Leybourne, 2007)

Theoretical models also exist which suggest non-linearity in the time series processes characterizing spot ex- change rates under floating and managed floating regimes. For example, Hseigh (1989) considers a monetary model of exchange rate extended to incorporate a stochastic intervention rule operated by the central bank, which gives rise to stochastic switching in the exchange rate and non-linear dependence in both the conditional mean and conditional variance of changes in the spot rate. A second model which can motivate non-linear behavior of the exchange rates was developed by De Grauwe & Dewatcher (1990.) In their model there are two classes of speculators, namely "chartists" and "fundamentalists". Chartists base their expectations on extrapolations of past movements in observed exchange rates, whilst fundamentalists compute the long-run value of the ex- change rate using the steady state purchasing power parity value, to which they expect the exchange rate to return. The market expectation of the future exchange rate is then a weighted average of the expectations of the two classes of speculators, where the weights given to chartists and fundamentalists in the market expectation is endogenous, depending on the deviation of the observed rate from the equilibrium rate. A third model of non-linearity in the conditional mean of changes in the spot rate is given by a discrete time approximation to the Sargent and Wallace [1973] model of hyperinflation occurring under money financing of a perpetual government deficit. Given purchasing power parity, the non-linear dynamics implied for the inflation rate in this model are automatically transmitted to the exchange rate. Empirically, it is now well established that short-term changes in the logarithms of spot exchange rates approximately follow a random walk, the innovations of which are non-linearly dependent and can be described at daily and weekly frequencies by the auto- regressive conditional heteroscedasticity (ARCH) model developed by Engle (1982).

2.2 Review of empirical literature.

There have been a number of empirical studies on the dynamics of short and long run nominal and real exchange rates, though on the whole, more emphasis seems to be made on real as opposed to nominal exchange rates. This section is split into three parts, beginning with global literature that is mainly focused on developed countries, followed by literature on developing countries both within and outside Africa. Finally, we review literature on the dynamics of exchange rates in Uganda.

Early analyses of the mean-reversion hypothesis were based on augmented Dickey-Fuller tests, and generally failed to find strong evidence against the unit root null-hypothesis, that is; of mean reversion. Sollis et al (2002), through analysis of individual series of post-1972 data, were able to uncover strong evidence of mean reversion in real exchange rates through two extensions of the standard Dickey-Fuller test, allowing for non-linearity under the alternative hypothesis. In comparison to the usual unit root tests, one of their tests imposed symmetry, so that the impacts of positive and negative discrepancies of the same amount from the mean were identical, and the other test permits asymmetry. These new tests revealed stronger evidence against the unit root null hypothesis than the usual Dickey-Fuller test did.

Anthony and MacDonald (1999) studied the prediction of the target zone (the ideal range of exchange rates of a currency that a government seeks to maintain with a managed float), the key prediction being that the exchange rate should be mean reverting within the band. They investigated this prediction by examining the time series characteristics of seven currencies participating in the Exchange Rate Mechanism (ERM) of the European Monetary System, both immediately before and after the introduction of wide exchange rate bands in 1993. Using standard univariate unit root tests, they found some evidence of mean reversion through establishing stationarity.

Similarly, Bleaney et al (1999) tested for mean reversion in real exchange rates using monthly data from 5 high-inflation countries, and found that stochastic unit root models are a more appropriate way to model mean reversion in real exchange rates for countries with high inflation as compared to models with fixed rates of mean reversion. They argue that mean-reverting tendencies in real exchange rates are likely to be more evident at higher inflation rates.

The above literature is focused on integer degrees of differentiation for the time series of interest. A slightly newer approach to the problem is the use of fractional integration. Booth et al (1982) did a study in which they explored the possibility that long-term dependence was present in the exchange rate series for the British pound, French Franc and the German mark in terms of the US dollar using long-range dependence techniques. The applied R/S analysis and found evidence for long-run dependence for each exchange rate during a flexible regime but negative dependence in the fixed exchange rate regime.

More work was done in the line of long-run dependence by Cheung Yin-Wong in 1993 who also found evidence of long-memory behavior in foreign exchange markets during the managed floating rate regime. This implied that the empirical evidence of unit roots in exchange rates may not be robust to long memory alternatives.

It should also be noted that the literature mentioned thus far focuses mainly on developed countries. Far less work has been published on exchange rate dynamics in developing countries, and that which has been done is mainly centered around integer degrees of freedom. However, several themes have been studied in the recent literature on exchange rates in developing countries.

The issue of flexible versus fixed exchange rates seems to dominate the literature on exchange rates in developing countries. Hoffman (2007) for example studies the hypothesis that for small open economies flexible exchange rates act to lessen effects of external shocks more effectively than fixed exchange rates. He used a sample of forty-two developing countries and showed that there are noteworthy differences in the variability of macroeconomic aggregates under fixed and flexible regimes.

Another issue that is prevalent in the literature is the issue of exchange rate crises. Since the 1980s, but especially in the 1990s, the spread of currency and financial crises was singled out as the most important source of instability across emerging markets. (Schamis, 2003) Schamis also notes that the adoption of fixed exchange rate regimes is at the root of many of those crises and fixing the exchange rate as an alternative approach to stabilization policy in high-inflation economies can lead to undesirable outcomes in the medium to long term.

A theme that also emerges is the impact of exchange rate volatility on macroeconomic variables. Choong & Hooy (2010) generate an exponential generalized autoregressive conditional

heteroscedasticity (EGARCH) model based on conditional exchange rate volatility and their results reveal that exchange rate volatility has a significant positive effect on real exports in most South-Asian countries. The study supports the hypothesis that exchange rate volatility imposes costs on risk-averse market participants.

Mean reversion of exchange rates has, however, only just begun to receive attention in the literature. Arize (2011) studies mean reversion in real exchange rates in developing countries and his results reveal strong evidence in favor of both linear and non-linear mean reversion.

Bahmani-Oskooee, Kutan and Zhou (2008) also do an analysis using monthly real effective exchange rate data from 88 developing countries. In their study, they test the null of non-stationarity versus the alternative of linear stationarity by the means of a conventional unit root test and compare their results to those obtained from a new test in which the null is the same, but the alternative hypothesis is non-linear stationarity. The latter test supports the Purchasing Power Parity (PPP) theory in twice as many developing countries as the former test, suggesting that nonlinear adjustment towards PPP in developing countries is an important phenomenon.

The theory of Purchasing Power Parity as mentioned earlier states that there is an equilibrium level to which exchange rates converge, so that foreign currencies should have the same purchasing power. In light of this, Cashin & McDermott (2006) test for PPP using real exchange rate data for developed and developing countries, with the aim of answering the question "Do real exchange rates really display parity-reverting behavior?" among other questions.

From the assumptions of PPP theory, it can then be posed that long-run PPP is inconsistent with the unit-root in real exchange rates because a shock to a unit-root process (nonstationary) has permanent effects on all future values of the series, potentially with no bound. However, formal statistical tests that compare the unit-root model against the alternative of a stationary autoregressive (AR) model typically lead to failure to reject the unit-root hypothesis. (Cashin & McDermott, 2006).

Cashin & McDermott thus bring to our attention a number of econometric problems concerned with using the UR/AR model to test for PPP, one of them being near-unit-root bias which is likely to be particularly relevant for real exchange rates, as they are often found to be stationary yet exhibit shocks that are highly persistent. This leads to problems with interpreting results, and often

yields conclusions that are dependent on the predisposition of the researcher. They make several contributions to the literature, one of which is the use of Andrews' unbiased rule (Andrews, 1993) to draw conclusions about the presence of parity reversion. They find that the majority of countries sampled have finite half-life estimates, which showed evidence of real exchange rate reversion to parity. With their study, they find that the speed of parity reversion is faster for developed countries than for developing countries and is also faster for countries with flexible nominal exchange rates compared to countries with fixed exchange rate regimes.

Despite all this, there arises the issue of the adequacy of fixed or floating rate regimes during shocks. Calvo & Mishkin (2003) argue that much of the debate on choosing exchange rate regimes misses the point and they conclude that choice of regime is of second-order importance to the development of good fiscal, financial and monetary institutions. They maintain that focus should be put on institutional reforms rather than on exchange rate regime, as the former may encourage emerging market countries to be less prone to crises. Mudida (2011) reinforces the significance of good institutions, arguing that these provide a firm foundation for macroeconomic stability and economic policy in developing economies.

Kan (2007) builds on the work of Calvo & Mishkin above. For emerging markets with global financial markets, neither of the two regimes is desirable. His results show that these extremes cause grave problems for countries with less developed financial markets and supervisory systems, even though they seem to work well for developed countries.

As mentioned earlier in this paper, African policy makers have been implementing exchange rate policy reforms based on the assumption that long-run PPP holds in Africa. Kargbo (2006) conducts a detailed empirical investigation to ascertain whether there is emprical support for long-run PPP in African countries, and his research shows overwhelmig support for long-run PPP in Africa, and he concludes that PPP is a reliable guide for exchange raate determination and exchange rate policy reform in African countries.

In Uganda, not much empirical work has been done on mean reversion of exchange rates. However, the literature seems to be geared around exchange rate regimes and the effect of exchange rate volatility on inflation.

Lubinga & Kiiza (2013) study the effect of real exchange rate volatility on the level of Uganda's bilateral trade flows with the country's major trade partners. Using panel data methods and the US dollar/ Uganda shilling exchange rate, they apply a GARCH (1,1) model to develop volatility measures for the real exchange rate and two-way trade flows. Their results show that real exchange rate volatility has a significant negative effect on volatility of trade flows. Their study shows that prudential management of the real exchange rate is very crucial for trade promotion and macroeconomic stability, and thus the issue of permanence of exchange rate shocks is a vital one for developing countries.

Muwonge & Obwona (2003) apply a vector autoregressive (VaR) methodology to establish how the exchange rate, foreign price, money supply, output and interest changes cause inflation in Uganda. They estimate an exchange rate pass-through equation and an extended model using ordinary least squares, recursive least squares and maximum likelihood techniques. Their results indicate that variations in money suppl, output and exchange rate are vital in explaining Uganda's inflation episodes, and they note that achieving low and stable inflation in the country can only be due to government commitment to policy.

In Uganda, none of the literature around exchange rates takes on a fractional integration approach with regards to mean reversion of exchange rates. However, Mudida & Gil-Alana (2018) analyze several nominal exchange rates in Kenya, an economy that is very similar to that of Uganda, examining if shocks are transitory or permanent by means of fractional integration. Their results reveal evidence of mean reversion for the cases of the Canadian dollar, the Euro and the British Pound but not for the US dollar and the Chinese Yuan. Their study proves to be critical for the Kenya shilling US dollar rate which they discovered to be mean-reverting and this discovery provided great insight into the Kenyan exchange rate crisis of 2011 and gives reasons as to why the Kenya shilling remained on a depreciating trend even after 2011. During this crisis, the monetary policy tools implemented by the Central Bank of Kenya, despite generally being able to smooth out exchange rate volatility in earlier years, seemed to have limited effectiveness against the depreciation of the Kenya shilling against major international currencies, especially the US dollar. This increased the significance of mean reversion in nominal exchange rates, which has continued to be an important factor when coming up with monetary policy in Kenya even after 2011.

Their research objective was to extend the empirical research by introducing fractional integration to analyze the degree of dependence in Kenyan nominal exchange rates. In case of high level of persistence in the event of external shocks, strong policy measures are required to recover from these shocks and on the other hand, with currencies that are less persistent, there is no need for these strong policy measures since the series will return to original trends on their own.

Other work done on exchange rates in Uganda is based on the effects of exchange rate behavior on inflation and macroeconomic performance on the whole.

Yiheyis & Musila (2017) examine the temporal relationship between inflation and exchange rate changes and their implications for the trade balance in Uganda. The country has seen persistent trade deficits, rising inflation and disinflation episodes, as well as significant exchange rate realignments in the past. Their study revealed that in the long run, a real deprecition leads to an increase in inflation, and that both real depreciation and inflation have no significant effect on the trade balance. This study sheds light on the relationship between real exchange rates, inflation and trade balances for a small economy.

Opolot & Thomas (2018) note that "over the last two decades, many developing countries have shifted away from fixed exchange rate regimes towards more flexible ones, but that this, despite the fact that it has worked for some countries, has created exchange rate volatility and uncertainty of movements which have led policy makers to investigate the extent of the impact of such movements in exchange rates on key macroeconomic variables that are influential for sustained growth across many developing countries." They investigate the impact of innovations in the exchange rate on macroeconomic performance in Uganda, using a structural vector autoregressive model and they also use a non-linear size-dependent effect specification to identify the non-linearity and threshold impact of exchange rate volatility on Ugandan macroeconomic aggregates, estimated over a nineteen-year period. Their results suggest that variations in nominal exchange rates have significant implications for domestic prices, private sector credit, domestic interest rates, imports, exports and that high exchange rate depreciations result in exchange rate volatility and are thus disruptive to the economy.

Despite the significance of exchange rate fluctuations to long-run growth and economic stability, the existing theoretical and empirical literature gives little guidance on the impact of exchange rate volatility on key macroeconomic variables (Opolot & Thomas, 2018). The theoretical literature is

mainly focused on richer countries with highly developed markets. In addition to this, most of the literature on exchange rates in Uganda and Africa on the whole focuses on real exchange rates. Therefore, there is a lack of literature on nominal exchange rates. This is interesting because earlier in this paper, we see that Cashin & McDermott bring to our attention a number of econometric problems concerned with using real exchange rates, as they are often found to be stationary yet exhibit shocks that are highly persistent. This usually leads to problems with interpreting results, and often yields conclusions that are dependent on the predisposition of the researcher.

There is thus a need to investigate whether shocks to nominal exchange rates in Uganda are transient or permanent. So far, in the African setting, this question has been addressed using fractional integration only by Mudida & Gil-Alana (2018) for the case of Kenyan nominal exchange rates.

2.3 Conceptual framework

This study examines the nominal exchange rates in Uganda, a developing country. The main assumption that has been implied by past studies is that exchange rates generally follow a mean-reverting process, with the exception of a few. It should also be noted that exchange rate movements are dependent on several other economic variables such as inflation, interest rates and money supply in the economy.

The primary study of this paper is to determine if individual cross exchange rate series are stationary (revert to their mean over time after a shock) or whether shocks are permanent (exchange rate series follow a trend and do not return to their usual patterns after a shock.) This is all with the aim of determining how strong government intervention should be to bring back these rates into a manageable bracket so as to reduce adverse effects to the economy.

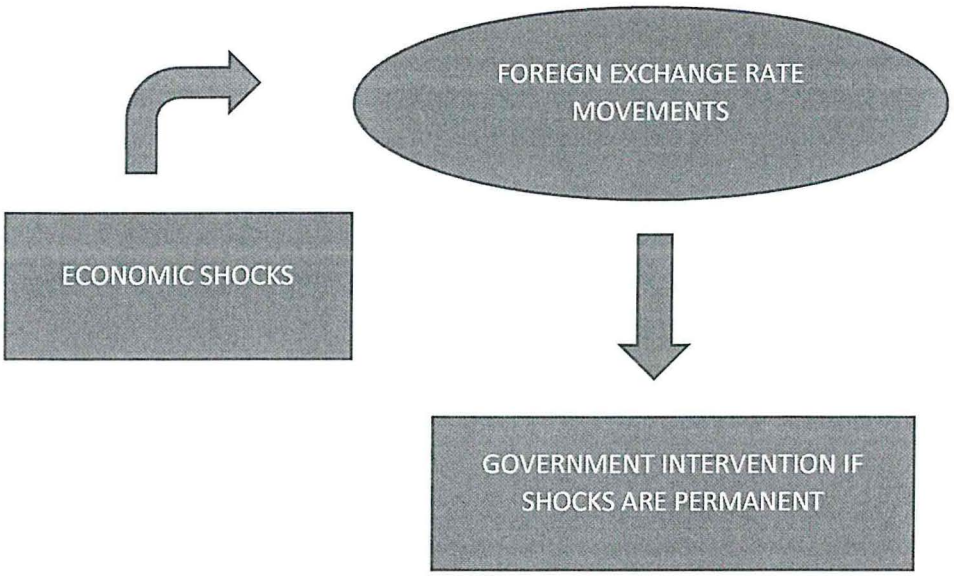

Figure 2: Conceptual Framework

From this framework, we derive the following null hypothesis;

That nominal exchange rates in Uganda are non-mean-reverting series and shocks are therefore permanent and do not dissipate over time. We test this against the alternative hypothesis that exchange rates in Uganda do indeed follow a mean reverting process and shocks are transient.

In the case of permanent shocks, it is the duty of the central bank to step in and implement suitable policies to reduce the unfavorable effects of economic shocks on the exchange rates.

Chapter 3: Methodology

This chapter gives an outline of the research methods that are used to conduct this study. It describes how the data needed to address research objectives and questions was collected, and is arranged in the following way; research design, data collection, and finally economic procedures.

3.1 Research Design

The design used in this study is an exploratory one where we generate hypotheses by examining a secondary data set of monthly nominal exchange rates in Uganda for the period 2000 to 2018 using time series analysis. In total, this gives us 216 observations of cross exchange rates for each currency with respect to the Uganda shilling.

3.2 Data Collection

The data set used is from the Thomson Reuters Eikon system and includes time series data on monthly exchange rates for six currencies with respect to the Uganda shilling. These currencies are as follows: The US dollar (USD), Euro, Great Britain Pound (GBP), Canadian dollar (CAD), Japanese Yen (JPY) and the Kenyan shilling (KES). Two other major currencies, that is the Chinese Yuan and the Tanzanian shilling, were left out due to lack of data for the years preceding 2011.

3.3 Econometric Procedure

The purpose of this study is to determine whether nominal exchange rates in Uganda are permanent or transitory, given the volatile nature of the Uganda shilling against major currencies, especially the US dollar.

To answer the first research question, we focus on fractional integration and how the results from fractional methods differs from the traditional unit root tests, i.e. The Augmented Dickey Fuller (ADF) test, the Phillips-Perron test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test.

Therefore, first, we need to define an I(0) process (integrated of order zero). A series is I(0) if it is stationary, i.e. does not accumulate past errors (Hendry, 1995). An example of an I(0) series is the white-noise process. The mean, variance and autocorrelation are all constant over time, and the

series displays no systematic patterns like trends or cycles. The order of integration tells us the minimum number of differences needed to get a stationary series.

Unit root tests often lack the power to properly distinguish between a truly nonstationary (I(1)) process and a stationary (I(0)) process. However, many times, series exhibit too much long-range dependence to be classified as I(0) but are not I(1) either. The ARFIMA (Autoregressive Fractionally Integrated Moving Average) model is designed to represent such series. This model allows for a series to be fractionally integrated, generalizing the ARIMA model's integer order of integration to allow the d to take on fractional values, $-0.5 < d < 0.5$

With this in mind, we say that a process integrated of order d is denoted by $y_t \approx I(d)$ and can be represented as;

$$(1-L)^d \, y_t = x_t, \qquad for \ t = 1,2, \ldots\ldots \tag{1}$$

With $y_t = 0$ for $t \leq 0$, and where x_t is I(0) and L is the backshift operator.

The polynomial on the left in equation (1) can be expanded to give;

$$(1-L)^d = \sum_{j=0}^{\infty} \binom{d}{j} (-1)^j L^j = 1 - dL + \frac{d(d-1)}{2} L^2 - \ldots \tag{2}$$

The equation above implies that as d gets higher, the dependence level between observations gets higher as well.

If $d > 0$ in equation (1), then that process displays 'long memory' also called 'long-range dependence.' This property relates to the rate of decay of statistical dependence between two points in a series as we increase the distance between them. The autocorrelations decay slowly and hyperbolically, and the spectral density function is unbounded at the origin.

Findings on persistence and long memory can vary greatly depending on the method used. Therefore, we need to conduct a robustness check that uses different approaches.

For our fractional integration analysis, we apply the Bloomfield (1973) exponential spectral model which is a credible and useful alternative when testing I(d) statistical models with weakly autocorrelated (AR) disturbances. (Gil-Alana L. A., 2008) This model is explained further in Chapter 4.

Chapter 4: Data analysis and results

This chapter presents results attained from an analysis of each of the exchange rate series, both graphically and using traditional unit root tests. We then run tests for stationarity using a fractional integration technique. First, we analyze the time series graphs for each exchange rate based on graphical observation, and then we go ahead to conduct three types of traditional unit root tests, that is the Augmented Dickey Fuller test, Phillips-Perron test and the KPSS (Kwiatkowski-Phillips-Schmidt-Shin) test, all of which give us insightful results.

We conclude this chapter by comparing the results above with those from our fractional integrational tests.

4.1 Time series plots

The six exchange rates are discussed below in order of value with respect to the Uganda shilling. However, we begin with the US dollar despite it being less valuable than both the Euro and the GBP because of its importance for trade for the country.

Figure 3: USD/UGX rate

The US dollar.

We can see that the USD/ UGX exchange rate was more or less stable below UGX 2000 within the period 2000 to 2008. Major shifts began to happen in the last decade, probably as an aftermath of the global financial crisis of 2007-2008. A fall in exports in Uganda due to the decreased international demand (especially for agricultural products) after the crisis led to a fall in the value of the Uganda shilling, and from then on, the shilling continued on a downward trend against the US dollar, with the price of dollars increasing steadily up to 2016. In general, the currencies of many sub-Saharan African countries, like those of many emerging and developing economies, suffered large depreciations with the onset of the global financial crisis. Collapsing trade and financial flows led to substantial balance of payments gaps, triggering fast depreciations and higher exchange rate volatility, beginning in mid-2008. (Ltaifa, Dixit, & Kaendera, 2009)

The shock experienced at the end of 2015 was as a result of turmoil in the economy due to the upcoming Ugandan presidential and parliamentary elections in 2016 which led to increased government borrowing and expenditure on non-productive activities. This is in fact a very common phenomenon in many developing countries and is discussed by many authors including Terra and Bonomo (2005) who present a theoretical model based on the distributive effects of real exchange rate changes in Latin American countries in relation to electoral cycles.

Figure 4: Euro/UGX rate

The Euro

Similar to the US dollar, we observe a Euro rate that was relatively stable between 2000 and 2008, only rising in 2002 due to poor export performance brought about by deteriorations in terms of trade in the Ugandan economy. We then observe a period of high volatility between 2009 to 2018 which was consistent with the high volatility of the Euro against all currencies in the aftermath of the Global Financial Crisis (GFC) of 2008.

Around 2008-2012, the Eurozone also faced the 'European Sovereign Debt Crisis' which was the cause of the high volatility seen in the time series plot above since the euro exchange rate is closely tied to market confidence in Europe. (Castleberry, Maniam, & Subramaniam, 2014)

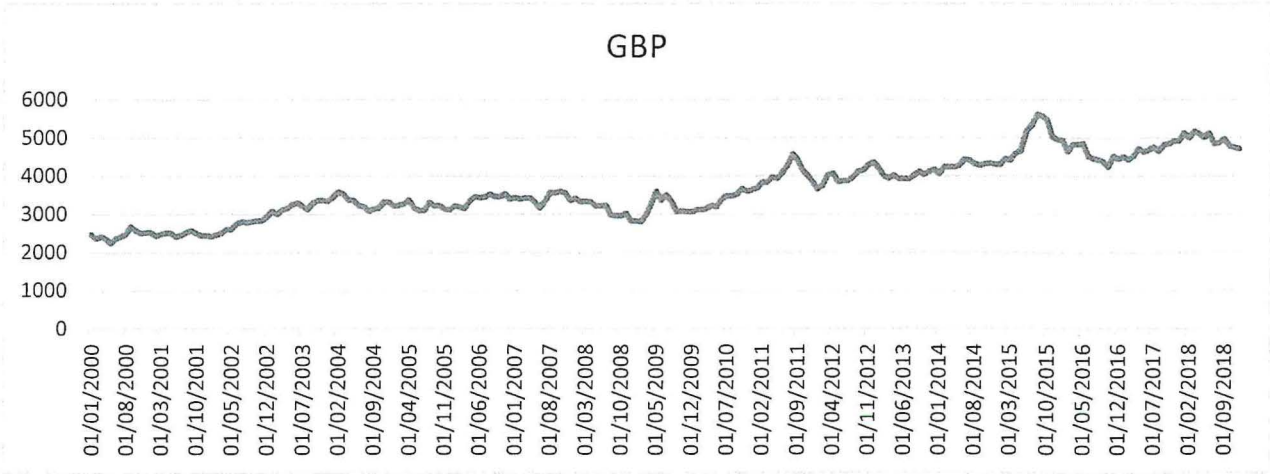

Figure 5: GBP/UGX rate

The GBP

The Pound seems to have remained relatively stable over the past 18 years with very few shocks. It appears that the GBP/UGX rate was also not significantly affected by the GFC and even then, it recovered quickly from the aftermath in 2009. The significant shock in 2011 was due to the bout of high inflation in Uganda as mentioned earlier in the paper, when the entire East Africa saw major declines in the value of currencies, with Kenya taking the worst hit. In 2015, the onset of the parliamentary and presidential elections that were held in Uganda in 2016 also led to a disruption in the exchange rate but the pound quickly returned to its stable state.

The onset of Brexit in 2016 appears to have had little effect on the exchange rate.

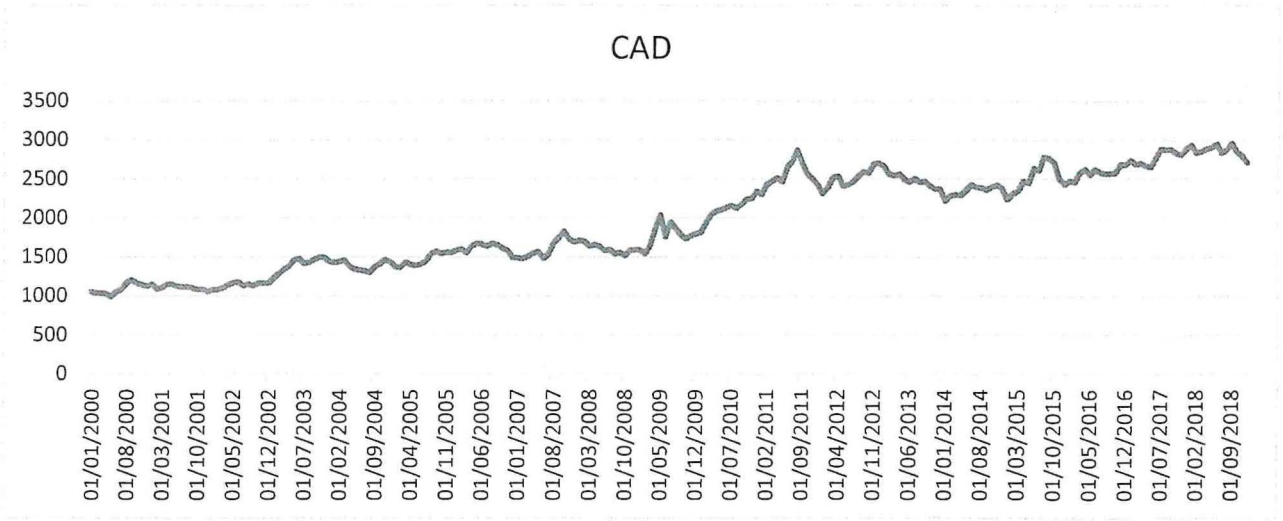

Figure 6: CAD/UGX rate

The Canadian Dollar

The Canadian dollar, like the Euro remained mostly stable before 2007 when we begin to see high volatility due to the GFC, with the largest shock happening in 2011. This specific year saw a dramatic fall in value of the Uganda shilling across all major currencies, including the Canadian dollar as global investors pulled their money out of any asset they deemed risky.

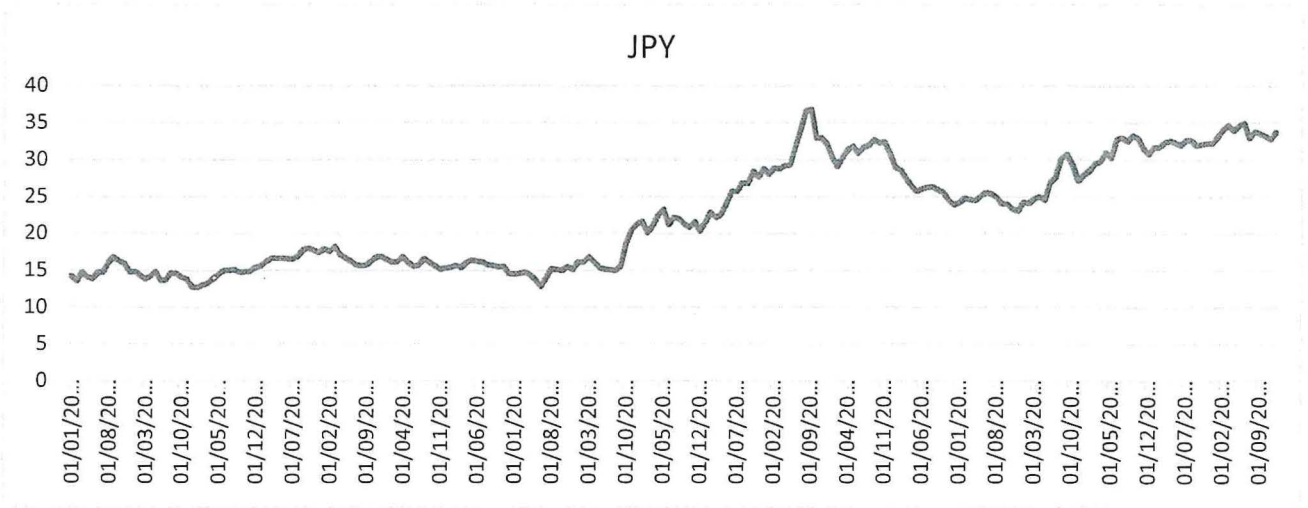

Figure 7: JPY/UGX rate

The Japanese Yen

Like most of the currencies above, the JPY/UGX rate remained relatively stable for the period before 2008. In the aftermath of the Global Financial Crisis, however, the series enters into a period of high volatility with the peak being in 2011, which as we have already seen was a bad year for, Uganda shilling and the entire East Africa as well. Around 2012, the Uganda shilling appreciated sharply against the Japanese Yen due to a severe domestic crisis brought on by excessive debt accumulation.

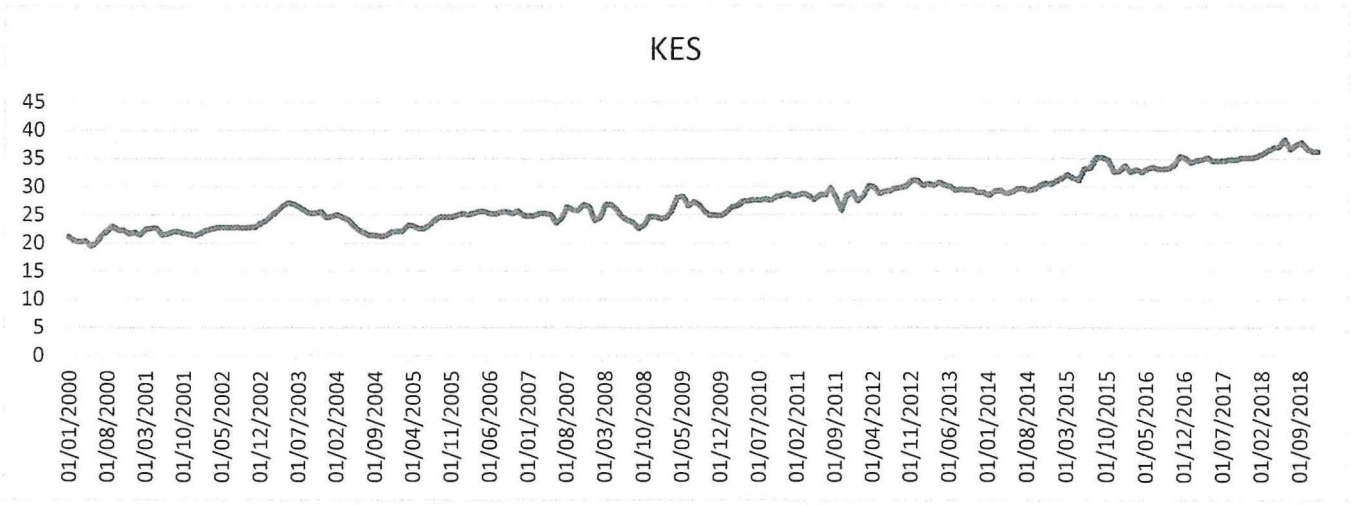

Figure 8: KES/UGX rate

The Kenya Shilling

Compared to all the currencies above, the KES/UGX rate appears to have been the most stable over the years with only mild shocks that quickly dissipate over time. This could be because the two economies (Kenya and Uganda) are largely co-dependent, and a shock in one inevitably leads to a shock in the other, hence the tendency of the two currencies to move together over time. An example is the Global financial crisis in 2007-2008 as well as the inflation crisis in 2011. We can see here that the Kenya shilling did not move much against the Uganda shilling in both scenarios, probably because both economies were affected in the same way.

4.2 Descriptive Statistics

Mean- The descriptive statistics for the six exchange rate series reveal non-zero means as shown in the tables below. This alerts us to the fact that our regressions will include constant terms. From this, we can also infer that the series do not follow a white noise process.

Standard Deviation- This measure shows the average distance between the values of the data in the set and the mean. The relatively low standard deviations in the tables below show that the data points tend to be very close to the mean.

Skewness- Is the measure of symmetry in a distribution and a normal distribution/ a symmetrical distribution should have a skewness of zero. As a rule of thumb, if skewness is greater than 1.0 or less than -1.0 for a particular variable, then the skewness is substantial, and the distribution is far from symmetrical. From the statistics below, however, our six exchange rate series all have skewness values much less than 1.0, which means that the series are not far from symmetrical. It should be noted, though, that the USD skewness value comes quite close to 1 at 0.854.

Kurtosis- Distributions with large kurtosis exhibit tail data exceeding the tails of a symmetric distribution and those with low kurtosis exhibit tail data that is less extreme than the tails of a normal distribution. We know that kurtosis for a normal distribution is always 3. From the tables below, we observe that each of our series has kurtosis less than 3, which implies platykurtic curves.

It's important to note that empirical research in financial econometrics, some of the important characteristics of a financial time series are their high variability, heavy tails and negative skewness. (Cont, 2001) Our series however, seem to differ from normal stylized facts of other financial assets, as they exhibit positive skewness, low kurtosis values and low variability. The reason for this could be because in this paper, we use level data as opposed to returns.

Another fact to note is that the logarithm of a nominal exchange rate is non-stationary, while the first difference is stationary. We explore this further in this paper diving deeper into each exchange rate series. (De Vries & Leuven, 1994)

USD		*EURO*		*GBP*	
Mean	2334.665	Mean	2803.286	Mean	3657.183
Standard Error	45.88384	Standard Error	57.22615	Standard Error	52.33618
Median	1994.5	Median	2753.153	Median	3459.485
Mode	2575	Mode	2264	Mode	4415.17
Standard Deviation	692.8309	Standard Deviation	864.0959	Standard Deviation	790.259
Sample Variance	480014.6	Sample Variance	746661.8	Sample Variance	624509.3
Kurtosis	-0.6184	Kurtosis	-1.04862	Kurtosis	-0.73653
Skewness	0.853945	Skewness	0.187109	Skewness	0.315349
Range	2387.14	Range	3162.29	Range	3375.61
Minimum	1490	Minimum	1378	Minimum	2236.49
Maximum	3877.14	Maximum	4540.29	Maximum	5612.1
Sum	532303.6	Sum	639149.1	Sum	833837.7
Count	228	Count	228	Count	228

CAD		*JPY*		*KES*	
Mean	1948.355129	Mean	22.38908114	Mean	27.49481
Standard Error	40.05225359	Standard Error	0.478671637	Standard Error	0.302185
Median	1796.791192	Median	21.4485	Median	26.6926
Mode	#N/A	Mode	#N/A	Mode	#N/A
Standard Deviation	604.7757668	Standard Deviation	7.227783211	Standard Deviation	4.562889
Sample Variance	365753.7281	Sample Variance	52.24085014	Sample Variance	20.81996
Kurtosis	-1.473067674	Kurtosis	-1.44344786	Kurtosis	-0.72002
Skewness	0.062828309	Skewness	0.31454671	Skewness	0.479799
Range	1964.280442	Range	24.1052	Range	18.9865
Minimum	995.124558	Minimum	12.7348	Minimum	19.401
Maximum	2959.405	Maximum	36.84	Maximum	38.3875
Sum	444224.9695	Sum	5104.7105	Sum	6268.817
Count	228	Count	228	Count	228

4.3 Traditional unit root tests

The unit root problem is a feature of stochastic processes that arises when a series shows a systematic pattern that is unpredictable. Unit root tests can be used to determine if trending data should be first differenced on deterministic functions of time to render the data stationary. Thus, these tests can be used to determine which series exhibit mean-reverting behavior.

For the purpose of this study, we run the unit root tests on the level series and also the differenced versions of each exchange rate series. However, we are more concerned with the level series since differenced exchange rate series are usually expected to be stationary. This happens especially if the series is trend-stationary, i.e. can be made stationary by subtracting a deterministic trend function which could be linear. (Lutkepohl & Kratzig, 2004)

4.3.1 Augmented Dickey Fuller test.

First, we run the normal Augmented Dickey Fuller (ADF) test on each of the series to determine if there is a unit root i.e. if stationarity is present. This test handles bigger, more complex models than the original Dickey Fuller test which was based on linear regression and thus had issues with serial correlation. However, it should be noted that the ADF test does have a downside of having a fairly high type 1 error rate (a type 1 error occurs when we reject a true null hypothesis.) For this reason, we do not rely on this test alone but on a number of traditional unit root tests.

The null hypothesis for the ADF test is that there is a unit root (non-stationarity), and the alternative hypothesis is that there is no unit root, hence the series is stationary.

Already, from the descriptive statistics, the non-zero means indicate that the regressions will have constant terms. (ADF- Augmented Dickey Fuller Test, 2016) Therefore this leaves room for only two regression model types, i.e.

- Constant, no trend: $\Delta yt = \alpha + \gamma yt\text{-}1 + vt$
- Constant and trend: $\Delta yt = \alpha + \gamma yt\text{-}1 + \lambda t + vt$

However, from the graphs above, we see that indeed all our series follow a visually linear upward trend, as indeed we expect exchange rates in developing countries to behave. For this reason, we use the second regression model when running our stationarity test.

Exchange rate series	P values (Augmented Dickey Fuller test)			
	With 1intercept	With intercept and linear time trend	First difference (with intercept only)	First difference (with intercept and trend)
USD	0.9411	0.6523	0.0000	0.0000
EURO	0.8288	0.0294	0.0000	0.0000
GBP	0.6360	0.1091	0.0000	0.0000
CAD	0.7458	0.1415	0.0000	0.0000
JPY	0.8655	0.3933	0.0000	0.0000
KES	0.8627	0.1645	0.0000	0.0000

The ADF test returned p values greater than 0.05 for all series when we accounted for the linear trend in the series, with the exception of the Euro whose p-value is very close to zero at 0.0294, giving us the result that except for the Euro, all five series are nonstationary.

4.3.2 Kwiatkowski-Phillips-Schmidt-Shin test (KPSS)

The KPSS test tells us if a time series is stationary around a linear trend, or if it is non-stationary due to a unit root. Unlike the above unit root tests, in the KPSS test, the null hypothesis is that the specific series is stationary, and the alternative hypothesis is that of non-stationarity. (Kwiatkowski, Phillips, Schmidt, & Shin, 1992). For this reason, based on the above two tests, we expect to get p values close to zero, failing to reject the null hypothesis of non-stationarity for most or at least all of the series.

A major disadvantage of the test, however, is that it has a low power to reject the null hypothesis. A way to deal with this is to combine the KPSS with an ADF test. It has been shown that one

may use the ADF and KPSS tests together to get better results in identifying stationarity and non-stationarity. (Marques, 2016)

Exchange rate series	P values (KPSS test)	
	With intercept and linear time trend	First difference (with intercept and trend)
USD	0.0000	0.8048
EURO	0.0000	0.4592
GBP	0.0000	0.4894
CAD	0.0000	0.3277
JPY	0.0000	0.7184
KES	0.0000	0.7237

With this KPSS test, we get a result similar to the ADF test, revealing p-values of zero for all six series, leading us to reject the null hypothesis of stationarity. This means that all six exchange rate series are indeed nonstationary.

4.3.3 Phillips-Perron test.

The Phillips-Perron (PP) test is also a unit root test that is used to test the null hypothesis that a time series is integrated of order 1. It builds on the Dickey–Fuller test in that PP statistics can be viewed as Dickey-Fuller statistics that have been made robust to serial correlation. The test makes a non-parametric correction to the t-statistic. It is more robust with respect to unspecified autocorrelation and heteroscedasticity in the disturbance process of the test equation.

Exchange rate series	P values (Phillips-Perron test)	
	With intercept and linear time trend	First difference (with intercept and trend)
USD	0.7425	0.0000
EURO	0.0194	0.0000
GBP	0.0483	0.0000
CAD	0.1156	0.0000
JPY	0.4291	0.0000
KES	0.0277	0.0000

The Phillips-Perron test seems to yield very different results from the two tests above. Like the ADF, we get a p-value less than 0.05 for the Euro. However, we also get relatively low p-values for the Japanese Yen (JPY) and the Kenya Shilling (KES), with the GBP p-value being only slightly less than 0.05. This causes us to reject the null hypothesis for four series out of six.

The reason for the differences between this and the ADF test could be because the PP test ignores any serial correlation in the test regression. In other words, the PP test corrects the Dickey Fuller for autocorrelation amongst the error terms outside of a regression framework, even if the critical values have the same distribution.

Comparison of results with earlier work done.

Early analyses of the mean reversion hypothesis, including Meese & Rogoff (1988) and Taylor & McMahon (1988), were based on augmented Dickey-Fuller tests, and generally failed to find strong evidence against the unit root null hypothesis-that is, of non-mean reversion. We see that these are the same results we have gotten by running our ADF tests. Our results are also in line with work done by Bleaney, Leybourne & Mizen (1999) who establish non-stationarity through the use of stochastic unit root processes since tests of mean reversion based on these simple models are very liable to induce incorrect inferences about purchasing power parity in high inflation countries.

On the other hand, Anthony and MacDonald (1999) predict that the exchange rate should be mean reverting within the band, both immediately before and after the introduction of wide exchange rate bands in 1993. Using standard univariate unit root tests, they found some evidence of mean reversion through establishing stationarity.

Arize (2011) also studies mean reversion in real exchange rates in developing countries and his results reveal strong evidence in favor of both linear and non-linear mean reversion.

Bahmani-Oskooee, Kutan and Zhou (2008) also do an analysis using monthly real effective exchange rate data from 88 developing countries. In their study, they test the null of non-stationarity versus the alternative of linear stationarity by the means of a conventional unit root test and compare their results to those obtained from a new test in which the null is the same, but the alternative hypothesis is non-linear stationarity. The latter test supports the Purchasing Power Parity (PPP) theory in twice as many developing countries as the former test, suggesting that nonlinear adjustment towards PPP in developing countries is an important phenomenon.

Cashin & McDermott in their test for PPP using real exchange rate data for developed and developing countries reach the result that formal statistical tests that compare the unit-root model against the alternative of a stationary autoregressive (AR) model typically lead to failure to reject the unit-root hypothesis. (Cashin & McDermott, 2006). Our results from the ADF and KPSS test appear to be in agreement with this.

Cashin & McDermott also bring to our attention a number of econometric problems concerned with using the UR/AR model to test for PPP, one of them being near-unit-root bias which is likely to be particularly relevant for real exchange rates, as they are often found to be stationary yet exhibit shocks that are highly persistent. This leads to problems with interpreting results, and often yields conclusions that are dependent on the predisposition of the researcher. They find that the majority of countries sampled have finite half-life estimates, which showed evidence of real exchange rate reversion to parity. With their study, they find that the speed of parity reversion is faster for developed countries than for developing countries and is also faster for countries with flexible nominal exchange rates compared to countries with fixed exchange rate regimes.

This could be part of the reason that our results do not imply stationarity like is the case for most of the papers mentioned above on mean-reversion of exchange rates. Since our analysis is for Uganda, a developing country, our results, then, are not very surprising.

4.4 Justification for using Fractional Integration techniques

Despite the fact that they are highly informative and have been used extensively, the ADF and PP tests have very low power against I(0) alternatives that are close to being I(1). Traditional unit root tests therefore cannot properly distinguish highly persistent stationary processes from nonstationary ones. Their power also diminishes as deterministic terms are added to the test regressions. For our case, since our exchange rate series all include both a constant and a trend, the tests have even less power than if the series had only included a constant term.

Additionally, fractional processes with the order $d > 0.5$ are non-stationary as well. Standard unit root tests often reject the null hypothesis when the true process is fractionally integrated with $d \in (0.5, 1)$ This can lead to the misleading conclusion that the process of interest is stationary. Hence the need for tests with stronger power. (Perron & Chang, 2016)

It should also be noted that the ADF and PP unit root tests are known (from simulations) to suffer potentially severe finite sample power and size problems that include;

1. **Power** – Both tests are known to have low power against the alternative hypothesis that the series is stationary (or TS) with a large autoregressive root. (See, DeJong, et al, J. of Econometrics, 1992.)

2. **Size** – Both tests are known to have severe size distortion (in the direction of over-rejecting H_0) when the series has a large negative Moving Average (MA) root.

A stationary time series may also look like a non-stationary one when there are structural breaks in the intercept or trend. Traditional unit root tests may therefore lead to false non-rejection of the null when we do not consider the structural breaks, which is also a problem of low power. Fractional integration, being a more general test, overcomes the problem of excluding a structural break representing a major policy change in foreign exchange markets in Uganda.

A number of unit root tests have emerged from the research surrounding structural breaks and unit roots. These tests vary depending on the number of breaks in the data, whether a trend is present or not, and the null hypothesis that's being tested. An important point to note is that testing for structural breaks when the series is otherwise non-stationary will affect whether there is evidence of a structural break. (Glynn, Perera, & Verma, 2007)

4.5 Fractional integration analysis

For our fractional integration analysis, we apply the Bloomfield (1973) exponential spectral model which is a credible and useful alternative when testing I(d) statistical models with weakly autocorrelated (AR) disturbances. (Gil-Alana L. A., 2008)

The examined model is

$$y_t = \alpha + \beta t + x_t, \quad (1 - B)^d x_t = u_t, \quad t = 1, 2, ..., \qquad (1)$$

where α and β are unknown coefficients referring respectively to the intercept and a linear time trend; x_t is integrated of order d, i.e., I(d), and u_t is an error term that we assume to be first uncorrelated (i.e., white noise) in Tables 1 and 2, and then weakly autocorrelated, in the latter case using a non-parametric method proposed in Bloomfield (1973) in Tables 3 and 4. We report the results, in Tables 1 and 3, in terms of the estimated values of d for the three cases of no deterministic terms, i.e., with $\alpha = \beta = 0$ in (1), with a constant ($\beta = 0$) and with a linear time trend (both α and β unknown), marking in these two tables in bold the selected specification in relation with these deterministic components. Tables 2 and 4 report the estimated coefficients for each specific model based on white noise and Bloomfield disturbances respectively.

We start presenting the results for the case of white noise ut. We see that the time trend is required in the cases of the CAD, EURO and KES, but it is not for the remaining three cases. Focusing on the estimated values, all the estimated values of d are around 1, ranging from 0.97 (CAD and KES) to 1.12 (USD) but the unit root null hypothesis ($d = 1$) cannot be rejected in any single case (the intervals include the value 1 in all cases). In the three cases where the time trend coefficient is found to be statistically significant, we found a positive value. (see Table 2).

Table 1: Estimates of d under the assumption of white noise u_t

Series	No terms	With an intercept	With a time trend
CAD	0.97 (0.89, 1.08)	0.97 (0.87, 1.11)	**0.97 (0.86, 1.01)**
EURO	0.98 (0.90, 1.08)	1.00 (0.88, 1.14)	**1.00 (0.88, 1.14)**
GBP	0.98 (0.90, 1.08)	**0.99 (0.88, 1.13)**	0.99 (0.88, 1.13)
JPY	0.98 (0.90, 1.09)	**1.06 (0.96, 1.19)**	1.06 (0.96, 1.19)
KES	0.97 (0.89, 1.07)	0.91 (0.79, 1.06)	**0.90 (0.78, 1.06)**
USD	0.98 (0.90, 1.08)	**1.12 (1.00, 1.27)**	1.12 (1.00, 1.27)

In bold, the specific selected models according to the deterministic components.

Table 2: Estimated coefficients in the selected models in Table 1

Series	d	Intercept (t-val.)	Time trend (t-val.)
CAD	0.97 (0.86, 1.01)	6.9593 (203.75)	0.0042 (2.16)
EURO	1.00 (0.88, 1.14)	7.3052 (211.94)	0.0046 (2.01)
GBP	0.99 (0.88, 1.13)	7.8124 (236.71)	---
JPY	1.06 (0.96, 1.19)	2.6565 (68.17)	---
KES	0.97 (0.89, 1.07)	3.0434 (112.35)	0.0024 (2.20)
USD	1.12 (1.00, 1.27)	7.3329 (283.84)	---

Allowing for autocorrelation, the values are reported in Tables 3 and 4. The time trend is now required in the six series, and the time trend coefficients are all significantly positive (Table 4). Focusing on d, is the evidence of mean reversion ($d < 1$) obtained in the case of the EURO data and KES. In the remaining four cases, the unit root null cannot be rejected.

Table 3: Estimates of d under the assumption of autocorrelated u_t

Series	No terms	With an intercept	With a time trend
CAD	0.95 (0.81, 1.11)	0.80 (0.69, 1.03)	**0.80 (0.63, 1.02)**
EURO	0.95 (0.83, 1.13)	0.77 (0.65, 0.97)	**0.74 (0.58, 0.96)**
GBP	0.95 (0.83, 1.13)	0.79 (0.65, 1.04)	**0.80 (0.62, 1.06)**
JPY	0.96 (0.83, 1.14)	0.90 (0.77, 1.08)	**0.90 (0.77, 1.09)**
KES	0.95 (0.82, 1.14)	0.61 (0.53, 0.72)	**0.48 (0.33, 0.68)**
USD	0.96 (0.82, 1.14)	0.86 (0.76, 1.04)	**0.84 (0.70, 1.04)**

In bold, the specific selected models according to the deterministic components

Table 4: Estimated coefficients in the selected models in Table 1

Series	d	Intercept (t-val.)	Time trend (t-val.)
CAD	0.80 (0.63, 1.02)	6.9593 (213.27)	0.0044 (5.34)
EURO	0.74 (0.58, 0.96)	7.2940 (229.76)	0.0048 (7.71)
GBP	0.80 (0.62, 1.06)	7.8015 (247.56)	0.0030 (3.79)
JPY	0.90 (0.77, 1.09)	2.6496 (68.80)	0.0038 (2.48)
KES	0.48 (0.33, 0.68)	3.0327 (159.63)	0.0024 (14.36)
USD	0.84 (0.70, 1.04)	7.3282 (292.48)	0.0039 (5.09)

In bold, the specific selected models according to the deterministic components

With these Fractional Integration techniques, our results show evidence of mean reversion just in the case of the EURO and Kenya shilling with autocorrelated errors. In all the other cases, we see lack of mean reversion and thus evidence of permanent shocks.

Chapter 5: Conclusion and Recommendations

While the ADF test revealed stationarity of only one series (the Euro), the PP test reveals stationarity for four series i.e. the Euro, the Yen, GBP and the Kenya shilling. The KPSS test however reveals that all the exchange rate series are nonstationary, which we find to be very divergent from the other tests.

To answer our research questions, fractional integration does not in fact give the same results as the traditional unit root tests.

With Fractional Integration, which has higher power than the traditional tests, our results show evidence of mean reversion just in the case of the EURO and Kenya shilling with autocorrelated errors. In all the other cases, we see lack of mean reversion and thus evidence of permanent shocks. This implies that for the other currencies, government intervention is highly recommended to minimize the long-run effects of a negative shock.

These findings are very informative for the Ugandan policy response in the light of the recent exchange rate crisis that occurred in East Africa in 2011, and also for subsequent monetary policy. In the case of Kenya, in the same year, had a study been done earlier to establish mean-reversion of the USD/KES nominal exchange rate, then it would have been known that this series was indeed non-mean-reverting, and more drastic action would have been taken by the monetary authorities to stabilize the exchange rate instead of leaving the market to correct itself. (Mudida & Gil-Alana 2018)

For future policy response to shocks in the above non-mean-reverting series, it is therefore vital that the government consider intervention through monetary policy tools before the Uganda shilling depreciates too much. On the other hand, for the two exchange rates that are found to be mean-reverting, i.e. the Euro and the Kenya shilling, since shocks dissipate over time, the government need not intervene much, or even at all.

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