



**University of  
Zululand**

# Predictability of the Dollar- Rand Exchange Rate using Taylor Rule Fundamentals and Commodity Prices.

By

**Ayodele Rita Olowe**  
Student Number: 201200162

A dissertation Submitted to the Faculty of Commerce, Administration and Law in  
Fulfilment of the Requirement for the Master of Commerce (Economics) Degree.

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Supervisor: Prof I. Kaseeram

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## DECLARATION

I, the undersigned, hereby declare that this dissertation, save for supervisory guidance received, is the product of my own work and effort. I have, to the best of my knowledge and belief, acknowledged all the resources of information in line with normal academic conventions. I further certify that the dissertation is original, and has not been submitted before at this or any other university for the award of any degree.

.....  
Ayodele Rita Olowe

Date: 10<sup>th</sup> April 2018

## ABSTRACT

International trade is strongly hinged on the exchange rates of participating nations. The financial crisis of 2008/2009 amongst other things, brought to light the strong interdependence of nations and their currencies. It is therefore of paramount importance for South Africa to be able to effectively predict its long and short term exchange rates especially vis-à-vis its major trading currency, the US dollar. South Africa being a small open commodity exporting economy with inflation targeting as a monetary policy framework is quite vulnerable to international shocks.

This paper is an attempt to forecast the US/ R exchange rate using time series data for the period 1980-2016. The paper estimated three forecasting models, namely, the augmented Taylor rule specification, a Johansen Vector Error Correction Model (VECM) and a Random walk approach. The results from the Root Mean Squared Error (RMSE) show that the Random walk model outperforms both the Taylor rule and VECM models. This brings us to the conclusion that although commodity prices and interest rates may influence short term international trade flows, they are not strong enough to influence exchange rate in the long term. Future researchers should attempt to use other variables, such as socio-political instability and downward economic ratings, in explaining exchange rate movements and forecasting using more sophisticated techniques like neural networks or dynamic stochastic general equilibrium modelling.

Keywords: exchange rate, forecasting, Taylor rule, commodity price, VAR/VECM, random walk model.

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## **DEDICATION**

Dedicated to all students of economics and economic researchers, the hard work  
pays off...eventually.

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## CHAPTER ONE

### OVERVIEW OF STUDY

#### 1.0. Introduction

International trade is strongly hinged on the exchange rates of participating nations. The financial crisis of 2008/2009 amongst other things, brought to light the strong interdependence of nations and their currencies. It is therefore paramount for South Africa to be able to effectively predict its long and short term exchange rates, especially in respect of its major trading currency, the US dollar.

Over the past two decades, South Africa has experienced fundamental changes with regard to the monetary policy setting. These reforms include central bank independence, and the introduction of inflation targeting of 3% - 6% since February 2000, having moved from targeting a constant money supply growth rate rule which was first set in 1986 (Naraidoo and Paya, 2012). This has overall been effective in keeping inflation fairly stable despite the Asian financial crisis of 1997/1998 and the global financial meltdown of 2008/2009 which threatened the stability of the South African Rand (Woglom, 2003, Mminele, 2009, Naraidoo and Paya, 2012). The value of the rand has however continued to depreciate against the US dollar in response to other issues such as inflationary pressure, socio-political instability and downward economic ratings.

Inflation, interest rates and exchange rates are all highly correlated (Meese and Rogoff, 1983, Asari et al., 2011, Frenkel, 2013). The simple efficient markets model implies that exchange rate changes are predicted by interest rate differentials and any variables correlated with interest rate differentials. By manipulating the interest rate, the central bank can influence both inflation and exchange rates. Changing interest rates impact inflation and currency values. Lenders in an economy receive higher return relative to other countries as a result of higher interest rates which may attract foreign capital inflow. This causes the domestic exchange rate to rise. The impact of higher interest rates is diminished, however, if inflation in the country is much higher

than in others, or if additional factors serve to drive the currency down. The opposite relationship exists for decreasing interest rates - that is, lower interest rates tend to decrease exchange rates.

There is also wide-ranging literature analysing the impact of commodity prices on exchange rate forecasting. According to Amano and Van Norden (1995), among other factors, through their impact on the terms of trade, variations in commodity prices are suspected of affecting the exchange rate. Lafrance and Van Norden (1995) also stated that factors that influence exchange rate developments are multifaceted. They show that the broad movements of the Canada-U.S. real exchange rate since the early 1970s can be captured by a simple equation that highlights the role of commodity prices and Canada-U.S. interest rate differentials. The equation has been used to interpret the evolution of the real exchange rate over the last two decades. At times, the real exchange rate deviates significantly from what the equation would predict. An explanation for the deviation could be that the equation omits certain factors that can influence the exchange rate, particularly in the short run. These may include fiscal policy variables, international indebtedness, political uncertainty, and investor sentiments. These have been significant in recent years but are difficult to quantify.

Chen and Rogoff (2003) explain that standard exchange rate models are unable to explain the high volatility and persistence observed in the Organisation for Economic Cooperation and Development (OECD) countries' floating real exchange rates. They investigated the determinants of real exchange rate movements by focusing on three OECD economies (Australia, Canada, and New Zealand) where primary commodities constitute a significant share of their exports. Because commodity products are transacted in highly centralised global markets, an exogenous source of terms of trade fluctuations can be identified for these major commodity exporters. For Australia and New Zealand especially, and Canada to a lesser extent, it was found that the US dollar price of their commodity exports has a strong and stable influence on their floating real rates, with the magnitude of the effects consistent with predictions of standard theoretical models. However, after controlling for commodity price shocks, there is still a purchasing power parity puzzle in the residual. According to Chen and Rogoff (2003), the exchange rate forecasting model that incorporates commodity prices is useful for developing countries who are heavily dependent on income from exporting commodities as they move towards floating exchange rates.

Building on previous research, Chen (2004) investigated the empirical disconnect between exchange rates and economic fundamentals which is the core of several exchange rate puzzles. The research incorporated commodity prices into the classical exchange rate forecasting models for Australia, New Zealand and Canada. The result was that commodity prices improved not only the out-of-sample forecasting performance but also the in-sample fit of the classical models. However, no single specification was found to provide a consistent forecast improvement over a random walk at all horizons and across all currency pairs.

This research intended to draw its major inspiration from the work of Molodtsova and Papell (2009) which uses the Taylor rule in an econometric model to forecast one month ahead nominal exchange rates for twelve OECD countries. The aim was to go a step further to improve the Taylor rule model given, by incorporating commodity prices in the econometric model and assess if indeed the exchange rate forecast can be improved upon through conducting rigorous forecasting tests developed by Clark and West (2006). This aim was however changed when it was discovered that the Taylor Rule applied directly to the South African economy was unable to forecast the exchange rates as the variables were statistically insignificant. This led to the use of a Vector autoregressive model (VAR) and ultimately, a Vector error correction model (VECM) model as for estimation and forecasting. These two models were then compared to a random walk model in order to assess their respective ability to predict the rand-dollar exchange rate movement.

## **1.1. Problem Statement**

Understanding the factors that drive exchange rate dynamics is a crucial question for several reasons. These include predicting the transmission effects of policies in open economies, and assessing the benefits and risks faced by international businesses and short-term financial investors (Mussa, 1982). Recent research has suggested that Taylor rules may be potentially important predictors of future exchange rate fluctuations (Molodtsova and Papell, 2009, Ince et al., 2016). Although much work has been done to examine the relationship between the US dollar and other OECD countries, not much work has been done within the South African context using the

Taylor rule. Moreover, in recent times the dollar-rand exchange rate has experienced a tremendous amount of volatility due to quantitative easing, the subsequent tapering policies of the Federal Reserve (USA), and decreasing commodity prices, all of which has created much uncertainty about the movement of the exchange rates, hence the findings of this study might expound on the future movement of the exchange rate (SARB, 2011, Ncube, 2014).

## **1.2. Aim and Objectives of the study**

Given the importance of a strong exchange rate in international trade, the main aim of this research was to forecast using econometric models the exchange rate between the South African Rand (R) and its major trading currency - United States Dollar. In order to achieve this, we examined previous years using time series data in forecasting and estimating future exchange rates between the two currencies.

The study estimated three forecasting models, namely, the augmented Taylor rule specification as proposed by Molodtsova and Papell (2009), a Johansen Vector Error Correction Model (VECM), and a Random walk approach, in an attempt to address the following objectives:

Objective 1: To assess whether the Taylor rule model proposed by Molodtsova and Papell (2009) with commodity prices included performs better than the Random walk model in forecasting US\$/Rand exchange rate.

Objective 2: To establish whether the VAR/VECM model performs better than the augmented Taylor rule model (commodity prices included) in forecasting \$/R exchange rate.

Objective 3: To test if the Random Walk model outperforms both the augmented Taylor rule model and the VAR/VECM models.

Objective 4: To provide strong policy recommendations with regards to exchange rate movement which directly affect relevant stakeholders in the South African economy.

### **1.3. Hypotheses**

To achieve the mentioned objectives, the study tested the following hypotheses:

Hypothesis 1: The Taylor rule model proposed by Molodtsova and Papell (2009) with commodity prices included performs better than the Random walk model in forecasting US Dollar - Rand exchange rate.

Hypothesis 2: The VAR/VECM model performs better than the augmented Taylor rule model (commodity prices included) in forecasting US\$/Rand exchange rate.

Hypothesis 3: The Random walk model outperforms both the augmented Taylor rule model and the VAR/VECM models.

Note that in order to test the relative performance of the three models in predicting the rand-dollar exchange rate, the root mean square errors (RMSEs) generated from their respective out of sample forecasts were compared. The model with the lowest RMSE was judged as being the best. These issues, as well as data considerations and the statistical models are discussed in greater detail in the methodology chapter (chapter four) of this study.

### **1.4. Intended contribution to body of knowledge**

Using out-of-sample data and econometric modeling, this research is aimed at improving on the research done in forecasting the exchange rate using Taylor rules in the South African context (Woglom, 2003, Saville, 2004, Kaseeram, 2010, Naraidoo and Paya, 2012, de Jager, 2012). In addition, this research aims to highlight the impact of commodity prices on exchange rate movement which will ensure better forecasts.

### **1.5. Organisation of Study**

The dissertation consists of six chapters. This chapter gives an overview of the entire research study. Chapter two presents relevant theories dedicated to exploring

determinants of exchange rates. The chapter streamlines the theoretical literature to those within the asset approach to exchange rate determination. Later in the chapter light is shed on other theories that are not mainstream asset approaches but have an inclination to this research through the efficient market hypothesis. In order to locate this study within its appropriate theoretical context, the theory also serves to identify the relevant variables used in the empirical literature and this study.

Chapter three covers empirical considerations in exchange determination/ forecasting. Empirical studies in South Africa and a selection of international studies are reviewed in an attempt to identify general findings on the subject matter and gaps that this study addressed. Additionally, the empirical review is used to identify appropriate variables and models to estimate in order to quantify the impact the selected variables, especially commodity prices, have on the US/South Africa exchange rate.

Chapter four discusses relevant statistical estimation concepts, techniques and the econometric specification of the models estimated in chapter five. The chapter is divided into two sections that cover time series statistical estimation methodology, and model specification respectively. Under the first section, the concepts of stationarity, cointegration and their designated tests are presented, followed by VAR and VECM modelling frameworks and functionalities. Lastly, the method of forecasting used is discussed. The second section covers the theoretical model estimated and a description of the chosen variables that pertain to the study's econometric model.

Chapter five covers the empirical analysis, gives detailed explanations of the various stages of estimation procedure and discusses the results of this study. The analysis begins with preliminary examinations to determine the basic properties of the data used for econometric analysis and which guided the researcher in the selection of appropriate estimation techniques to employ.

Chapter six concludes the study by summarising the empirical findings and outlining their relevance to macroeconomic policy prescriptions. Accordingly, policy recommendations and strengths and weaknesses of the study are provided.

## CHAPTER TWO

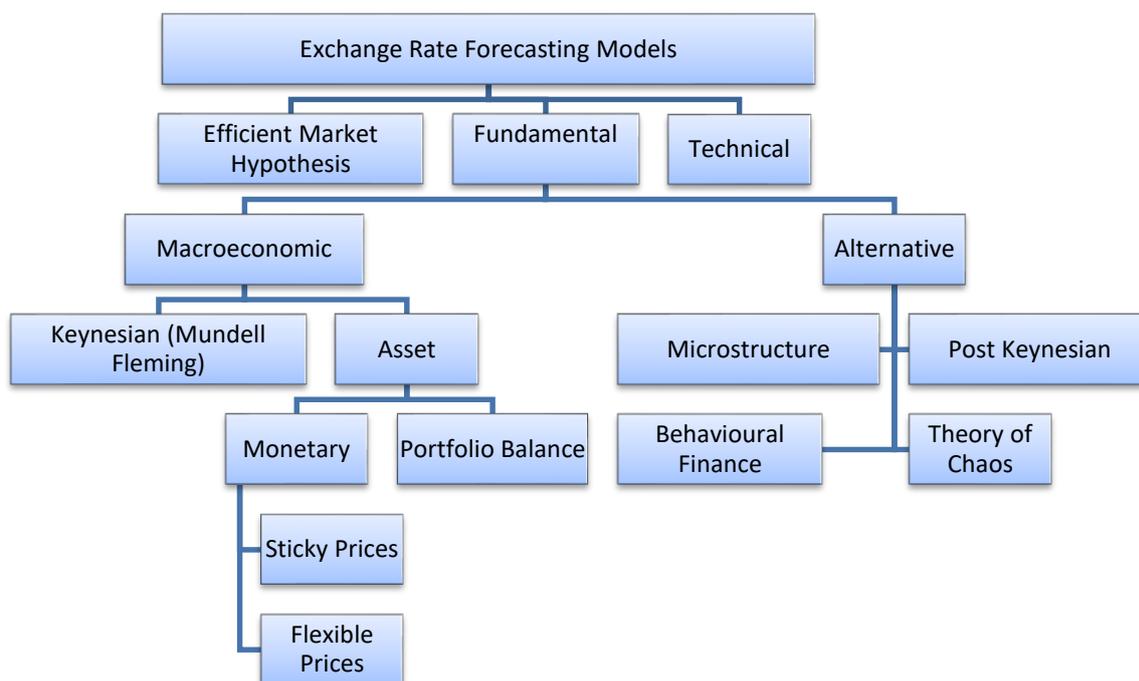
### THEORETICAL FRAMEWORK

#### 2.0. Introduction

Economists have at various times and through the use of economic theories and mathematical-statistical models, tried to explain the movement of, and forecast the exchange rates for trade, financial investment and policy reasons. The 1970s brought about a trend in economic models which put emphasis on the role of exchange rates as asset prices (Engel et al., 2006). Monetary models have also been developed to show that they perform better than the random walk in predicting exchange rates. Meese and Rogoff (1983) provided a new chart to follow in the field of exchange rate determination. This has given rise to models that use better econometric tools, amongst other tools, in ensuring lower mean squared errors and also models that perform better than the random model.

This chapter highlights and explains a few major models of and approaches to exchange rate determination. The focus moves to the asset approach in section 2.1 which views currency as assets and exchange rate is determined by the value placed on it by foreign investors. The two models under the asset approach, the portfolio balance approach (section 2.1.1) and the monetary approach (section 2.1.2), are explored, but with more emphasis on the monetary approach. The study goes further in section 2.2 to briefly explain other related but different approaches to exchange rate movement such as the fisher effect, balance of trade, balance of payments, the relative economic strength approach, and the Efficient Market Hypothesis. Lastly, in section 2.3., the focus is the Taylor Rule based exchange rate model and the theoretical backing for explaining exchange rates.

**Figure 2.0: Classification of exchange rate forecasting models**



Source:(Macerinskiene and Balciunas, 2013)

As illustrated in Fig. 2.0 above, there are several theories and models that try to describe the exchange rate movement. This research focuses basically on the asset approach.

## 2.1. Asset Approach to exchange rate determination

This approach makes use of currency as the asset in question because desirable currencies offer a percentage increase in value over a particular time period, which is in line with the main objective of savings and investment, which is to provide future consumption. The asset market approach suggests that currency holdings by foreign investors are chosen based on factors such as interest rates and real rate of return, as compared to other currencies (Frenkel and Mussa, 1985).

A model of exchange rate determination can be developed using the interest parity condition. That is, rise and fall of exchange rates in response to market changes can be attributed to interest parity from investor behaviour in asset markets. According to Krugman and Obstfeld (2009) the foreign exchange market is in equilibrium when all

deposits of all currencies offer the expected rate of return. Using two major currencies such as the Euro and the US Dollar, the expected rates of return are equal when:

$$R_{\$} = R_{\text{€}} + (E_{\$/\text{€}}^e - E_{\$/\text{€}}) / E_{\$/\text{€}} \quad (2.1)$$

Where

$R_{\$}$  = today's interest rate on one-year dollar deposits

$R_{\text{€}}$  = today's interest rate on one-year euro deposits

$E_{\$/\text{€}}^e$  = dollar/euro exchange rate expected to prevail a year from today

$E_{\$/\text{€}}$  = today's dollar/euro exchange rate

Therefore, when dollar deposits offer a higher return than euro deposits, the dollar will appreciate against the euro as investors all try to shift their funds into dollars. Conversely, the dollar depreciates against the euro when it has a lower return than the euro deposits.

The difficulty with this approach is that exchange rate is determined by expectations about the future not current trade flows. In addition, this approach requires that news that should affect exchange rate be specified and its influence quantified a priori. Lastly, it has a short term view and cannot be used for long time horizons.

### **2.1.1. Portfolio Balance approach**

The Portfolio Balance approach model makes use of three financial assets - domestic money, domestic bonds and foreign bonds. The model also considers two countries - domestic and foreign. The approach has the assumption that there is constant availability of foreign bonds and lack of uncovered interest parity. That is, domestic and foreign bonds have different risk characteristics and both, along with money, are part of a portfolio diversified to balance risk and expected return. In addition, the home country is assumed to be small relative to the foreign country (which is the rest of the world). In addition, purchasing power parity does not hold; home and foreign goods are not perfect substitutes either, contrary to the monetary approach. According to

Frankel (1993), the exchange rate function, and assuming static expectations, is given as:

$$e = -\alpha_H - \beta_H(i - i^*) + b - f_H \quad (2.2)$$

Where

$\beta_H$  = asset demand function shared by all home residents

$i$  = interest rate

$i^*$  = foreign interest rate

$b = \log B$  = log of sum of all domestic bonds held by home residents

$f_H = \log F_H$  = log of sum of foreign bonds held by home residents

In the case of a small foreign country,

$$e = -\alpha_F - \beta_F(i - i^*) + b_f - f \quad (2.3)$$

Where  $b_f$  = log of domestic bonds held by foreign residents

Exchange rate establishes equilibrium in investor portfolios of domestic money and domestic and foreign bonds. Balance between domestic and foreign bonds in a portfolio is positively related to expected excess return on domestic bonds over foreign bonds. Investors' asset preferences may be similar across countries, which is described in the Uniform Preference model (Dornbusch, 1980), or investors may prefer assets of their home country, which is explained in the Preferred Local Habitat model (Dooley and Isard, 1979, Kouri and De Macedo, 1978)

The monetary approaches to exchange rate determination, which are explored in the next section, assume that Uncovered Interest Rate Parity (UIRP) and Purchasing Power Parity (PPP) hold. This assumption implies that domestic and foreign assets are perfect substitutes, which the portfolio balance approach clearly deviates from. The deviation arises from different risk attitudes towards foreign financial assets in relation to domestic financial assets, meaning that there exists a risk premium on holding foreign financial assets relative to holding domestic financial assets. Such risks include, but are not limited to liquidity, default risk, political risk, tax treatment, and

exchange risk. Moreover, and in contrast to the monetary models, foreign exchange rate expectations are static with the portfolio balance approach, that is, they are not expected to change (Wang, 2009, Frankel, 1993).

### 2.1.2. Monetary Approach

In the monetary approach, the theory of aggregate money demand and supply is used to explain that the exchange rate of any two currencies is determined by the relative money demand and money supply between the two countries. According to Krugman and Obstfeld (2009), in the short run, given that price level and exchange rate expectations are given, an increase in a country's money supply causes its currency to depreciate in the foreign exchange market, while a reduction in the money supply causes its currency to appreciate. In the long run, the effects are similar only just more prominent. Shifts in interest rates and output levels affect exchange rate only through their influence on money demand.

Assuming purchasing power parity, uncovered interest rate parity (UIRP), and no rational speculative bubbles, the fundamental value of the exchange rate can be derived by:

$$f_t = (m_t - m_t^*) - k(y_t - y_t^*) \quad (2.4)$$

Where

$m$  = log of money supply

$y$  = log of income

$t$  = time period

\* = foreign country variables.

We construct the monetary fundamentals with a fixed value of the income elasticity,  $k$ , which is equal to either 0 or 1 (Ince and Molodtsova, 2015).

We substitute the monetary fundamentals (2.3) into (2.4), and use the resultant equation for forecasting

$$s_{t+h} - s_t = \alpha + \beta(f_t - s_t) + v_{t+h} \quad (2.5)$$

Where

$t$  = time

$h$  = period ahead.

$f_t$  = long-run equilibrium level of the nominal exchange rate determined by macroeconomic fundamentals,

$v_{t+h}$  = the projection error.

$s_t$  = log of the U.S. dollar nominal exchange rate determined as the domestic price of foreign currency, so that an increase in  $s_t$  is a depreciation of the dollar.

In a case where the foreign currency is appreciating sharply against the domestic currency, the process of sterilisation will involve increasing domestic credit in order to purchase foreign-denominated bonds by the domestic central bank. The concept of sterilisation is such that central banks offset international reserve flows to follow an independent monetary policy. In effect, a sterilisation process, which is a foreign exchange market intervention that leaves the domestic money supply unchanged is put into place in a monetary approach setting (Husted and Melvin, 2010). The demand increase for foreign bonds will mean an increase in the demand for foreign currency in the foreign exchange market, resulting in the higher foreign exchange value of the foreign currency. In addition, suppose the domestic central bank has a target level of the domestic money supply that requires the increase in domestic credit to be offset. The central bank will sell domestic-denominated bonds within the country to reduce the domestic money supply which was originally increased by the increase in domestic credit used to buy foreign bonds. The money supply ultimately returns to its initial level as the domestic central bank uses a domestic open-market operation to reduce domestic credit. In this case of managed floating exchange rates, the domestic central bank uses sterilised intervention to achieve its goal of slowing the appreciation of the local currency with no effect on the money supply. Sterilised intervention is ultimately an exchange of domestic bonds for foreign bonds. This intervention activity could alter expectations of the private market. If the intervention changes expectations in a manner that changes money demand, then the spot exchange rate could change.

However, Mussa (1984), using empirical data, observed that movements in nominal and real exchange rates are not closely related to differential rates of monetary expansion, except possibly for some highly inflationary economies.

### 2.1.2.1. Major themes in the monetary approach

The major themes highlighted in the monetary approach to exchange rate which are used in the course of discussion are explained as follows:

#### 2.1.2.1.1. The Law of One Price

The law of one price states that in competitive markets free of transportation costs and official barriers to trade (e.g. tariffs), identical goods sold in different countries must sell for the same price when prices are expressed in terms of the same currency. That is, when trade is open and costless, identical goods must trade at the same relative price regardless of where they are sold. (Obstfeld and Rogoff, 1996).

It is described as  $P_{US}^i = (E_{\$/\epsilon}) \times (P_E^i)$  (2.6)

Where

$P_{US}^i$  = dollar pricing of good  $i$  when sold in the United States

$P_E^i$  = the corresponding euro price in Europe

The exchange rate therefore becomes the ratio of good  $i$ 's in US and European money prices, which is

$E_{\$/\epsilon} = P_{US}^i / P_E^i$  (2.7)

### 2.1.2.1.2. Purchasing Power Parity (PPP)

The PPP law states that the exchange rate between two countries' currencies equals the ratio of the countries' price levels. In other words, there should be no arbitrage opportunity for someone to buy goods cheap in one country and sell them in another for a profit. The PPP theory predicts that a fall in a country's domestic purchasing power (that is, an increase domestic inflation) will be associated with proportional currency depreciation in the foreign exchange market. Based on this underlying principle, the PPP approach forecasts that the exchange rate will change to offset price changes due to inflation. The PPP predicts dollar/rand exchange rate as

$$E_{\$/R} = P_{US}/P_R \quad (2.8)$$

Where

$P_{US}$  = US price level and

$P_R$  = South African price level.

According to the PPP, if for example a commodity basket costs \$100 in the United States and R700 in South Africa, PPP predicts the dollar/rand exchange rate of \$0.14 per rand (\$100 per basket/ R700 per basket). If the US price levels were to double (\$200 per basket), so would the dollar price of the rand: PPP would imply that the exchange rate is \$0.29 per rand (\$200 per basket/ R700 per basket).

The major difference between the law of one price and the PPP is that while the law of one price takes into consideration one good/product, the PPP uses a basket of goods in its estimation of exchange rate. Also, although the two laws inter-relate, even when the law one price does not hold for all commodities, prices and exchange rates should not stray too far from the relation predicted by the PPP.

Contrary to the doctrine of PPP, there has not been a close correspondence between movements in exchange rates and movements in the ratio of national price levels, especially during the 1970s (Mussa, 1984). In addition, Edwards and Savastano (1999) noted that models built on PPP based definitions of the equilibrium exchange rate performed poorly when confronted with data from the early years of the post-Bretton Woods system of generalised floating of major currencies. More recently,

weaker interpretations of the PPP, longer data samples, and better empirical tests have been able to explain the movements of exchange rate, but only in more developed countries where reliable data can be easily extracted. This gave rise to the structural deviations from PPP which is the Balassa-Samuelson effect.

The Balassa-Samuelson effect, based on the independent 1964 work of Bela Balassa and Paul Samuelson describes the distortion in purchasing power parity (PPP) resulting from the international differences in relative productivity between the tradeable goods sector (mainly manufacturing and agriculture) and non-tradeable goods sectors (services). It explains that countries with high productivity growth also experience high wage growth which leads to higher real exchange rates. It suggests that an increase in wages in the tradeable goods sector of an emerging economy will also lead to higher wages in the non-tradeable sector of the economy. The accompanying increase in inflation makes interest rates higher in faster growing industrialised economies than it is in slow growing developed economies (MacDonald and Ricci, 2001, Asea and Mendoza, 1994)

### 2.1.2.1.3. Uncovered interest rate parity (UIRP)

The uncovered interest rate parity (UIRP) predicts that *“high yield currencies should be expected to depreciate”* (Bekaert et al., 2007). That is, all things being equal, the expected future spot exchange rate is a function of the current spot rate and real interest rate of each country. Investors take into account the current interest rate in both countries and consider their expected exchange rate before embarking on investment. According to Aggarwal (2013), UIRP is difficult to test as expectations of future exchange rates are not directly observable.

Economists put forward an equation for UIRP which is:

$$s_{t+1} - s_t = r_t - r_t^* + \varepsilon_{t+1} \quad (2.9)$$

Where

$s_{t+1}$ =future spot exchange rate

$s_t$ = current spot exchange rate

$r_t$ =domestic interest rate

$r_t^*$ =foreign interest rate

### 2.1.2.2. Branches of the monetary approach

The monetary price model is made up of two major models, the flexible prices monetary model and the sticky prices (overshooting) model.

#### 2.1.2.2.1. Flexible prices monetary model

As proposed by Frenkel (1976), the exchange rate, which is the relative price of currency, is determined by the supply and demand of money. An increase in the supply of domestic money causes a proportionate depreciation. An increase in domestic income or a decrease in expected inflation rate raises the demand for domestic money and causes an appreciation in the exchange rate. The equation is given as:

$$e = (m - m^*) - \phi(y - y^*) + \lambda(\delta\Delta p - \delta\Delta p^*) \quad (2.10)$$

Where

$i - i^* = \delta(\Delta e)$  : The UIRP equation

$e = p - p^*$  : The PPP equation

\*denotes foreign elements

$m$ = log of domestic money supply

$\phi$ =the money demand elasticity with respect to income

$y$ =log of domestic real income

$\lambda$ =the money demand semi elasticity with respect to interest rate

$p$ =log of domestic price level

$i$ = domestic short term interest rate

#### **2.1.2.2.2. Sticky Prices (Overshooting) model**

As proposed by Dornbusch (1976) and later by Frankel (1979), changes in nominal money supply also changes the real money supply because prices are sticky and thus have real effect on the exchange rate. The PPP does not hold in the longrun, so that a given increase in the money supply raises the exchange rate proportionally, but only in the long-run. In the short-run prices are sticky, interest rate falls, generating incipient capital outflow, which causes currency to depreciate but only up to a point at which the rational expected rate of appreciation cancels out the interest rate differential, which will lead to overshooting of the spot rate.

### **2.2. Other theoretical approaches to exchange rate determination**

Apart from the asset approach there are other approaches to exchange rate determination. These do not fall under the traditional asset approach but have linkages due to the use of some monetary instruments in exchange rate determination. A few of them are highlighted below:

#### **2.2.1. The Fisher Effect and the International Fisher Effect (IFE)**

The Fisher effect, developed by American economist Irving Fisher (1867-1947), explains the long-run relationship between inflation and interest rates. According to the Fisher effect, all things being equal, a rise in a country's expected inflation rate will eventually cause an equal rise in interest rate. The equation is given as:

$$(1 + i) = (1 + r)(1 + \pi) \quad (2.11)$$

Where

$i$  = nominal interest rate

$r$  = real interest rate

$\pi$  = expected inflation rate.

In predicting exchange rate, a rise in the interest rate of a country relative to foreign interest rates leads to a currency depreciation in the foreign exchange market. This is described as the International Fisher Effect (IFE). IFE is an exchange rate model designed by Irving Fisher in the 1930s. It is founded on present and future risk-free nominal interest rates as opposed to pure inflation, and is used to forecast and explain present and future spot currency price movements.

$$E = \frac{i_1 - i_2}{1 + i_2} \approx i_1 - i_2 \quad (2.12)$$

Where

$E$  = the percentage change in exchange rate

$i_1$  = interest rate for country 1

$i_2$  = interest rate for country 2.

If real interest rates are the same in all countries due to free capital movement and because of law of one price, then any difference in interest rates will be due to inflation level at the different countries. If the real interest rates in countries have not affected inflation rate, the capital will move to the country with the higher interest rate. Countries with high interest rate will register capital inflow which will result in appreciation in exchange rate.

### **2.2.2. Balance of Trade**

Countries with low interest rate will experience capital outflow which will result in depreciation in exchange rate. This links it to the interest rate parity model discussed in the asset approach. The interest rate parity model shows that exchange rate can be predicted by taking into account the differences in nominal exchange rates.

Husted and Melvin (2010) show that although there is a recent shift in emphasis away from exchange rate models that rely on international trade in goods to those based on financial assets, there is still a useful role for trade flows in asset approach models, since trade flows have implications for financial-asset flows. Current spot exchange

rates are influenced by changes in expectations concerning future trade flows, as well as by current international trade flows. They explain that the short-run effect of some new event determining the balance of trade can differ from the long run result, for example, in a case where the long-run equilibrium under floating exchange rates is balanced trade, that is, exports equal imports. Disturbance to the initial equilibrium such as a new oil cartel formation may result in large balance of trade deficits in the short-run; but in the long run, as all prices and quantities adjust to the situation, the long-run equilibrium of balanced trade is achieved. The new long-run equilibrium exchange rate will be higher than the old rate, because foreigners will have larger stocks of domestic currency, while domestic residents will hold less foreign currency due to the period of the trade deficit. During the period of trade deficits in the short-run, the exchange rate will tend to be below the new equilibrium rate. Therefore, as the outflow of money from the domestic economy proceeds with the deficits, there is steady depreciation of the domestic currency to maintain the short-run equilibrium, where quantities of monies demanded and supplied are equal.

### 2.2.3. Balance of Payment (BOP)

The relationship between the BOP and exchange rates can be illustrated by the use of a simplified equation:

$$(X - M) + (CI - CO) + (FI - FO) + FXB = BOP \quad (2.13)$$

Where

X = exports of goods and services

M = imports of goods and services

CI = capital inflows

CO = capital outflows

FI = financial inflows

FO = financial outflows

FXB = official monetary reserves.

Under a fixed exchange rate system, the domestic government is obligated to ensure that the BOP is near zero. The government must intervene in the foreign exchange market and buy or sell domestic currencies to bring the BOP back to near zero when

it deviates, to ensure a fixed exchange rate. It is therefore imperative for a government to maintain significant foreign exchange reserve balances to allow it to intervene in the foreign exchange market effectively. Under a floating exchange rate system, which is the case in most countries, the domestic government has no responsibility to peg its foreign exchange rate. The exchange rate movement is altered in accordance with the current and capital account balances to obtain a BOP near zero. Countries operating with managed floats rely on market conditions for day-to-day exchange rate determination. In addition, they often find it necessary to take action to maintain their desired exchange rate values. They influence the motivators of the market activities through direct intervention in the foreign exchange market (that is, they change relative interest rates to alter the market's valuation of a specific exchange rate), intervention in the forward exchange market, and direct operations in foreign assets to defend exchange parity. Unfortunately, because of high volume of transactions, governments may no longer be able to defend a fixed parity because of the constraints on their actions, which results in a "crisis" in the balance of payments (Krugman, 1979).

Conversely, Mussa (1984) maintained, based on empirical evidence, that there is no strong and systematic relationship between movements in nominal or real exchange rates and current account balances that allows for an explanation of a substantial fraction of actual exchange rate movements. Therefore, movement in the current account balance is not strong enough to significantly affect the nominal or real exchange rate. It can therefore not be used as an estimator of future exchange rate movement.

#### **2.2.4. Relative Economic Strength Approach**

The relative economic strength approach looks at the strength of economic growth in different countries in order to forecast the direction of exchange rates. The rationale behind this approach is based on the idea that a strong economic environment and potentially high growth is more likely to attract investments from foreign investors.

This approach not only looks at the relative economic strength between countries, it takes a more general view and looks at all investment flows. The interest rate is also

taken into consideration when examining economic strength. High interest rates will attract investors looking for the highest yield on their investments, causing demand for the currency to increase, which again results in an appreciation of the currency. The currency will depreciate when interest rates fall.

Although the economic strength approach does not directly forecast the exchange rate, as it is a multidimensional rate that is rather difficult to define or capture using in a single indicator, it gives an indication to stakeholders of the direction in which the domestic currency might go, i.e. whether it will either appreciate or depreciate in value.

### **2.2.5. Efficient Market Hypothesis and the Random Walk Model**

A market is said to be efficient if it fully and correctly reflects all relevant information in determining prices (Malkiel, 1989). The efficient market hypothesis (EMH) is mostly used in the capital market and argues that stock prices are essentially random and therefore there is no scope for profitable speculation in the stock market. In essence, the only way to make the most profit is to predict tomorrow's prices on the basis of today's price. In other words, it is believed that market prices for stock are perfect, with no room for undervalued or overvalued stock. The EMH may be classified into three (3) levels. The first is the weak EMH in which prices fully reflect the information contained in historical data. The next is the semi-strong EMH, wherein current stock reflects not only historical data of prices, but all publicly available information. The third level is the strong EMH which implies that all public and private information are made available to all market participants.

The Random walk model (RWM) falls under the category of the weak EMH. The RWM postulate that asset prices, such as stock prices and exchange rate follow a random walk, that is, they are non-stationary (Gujarati and Porter, 2009), meaning that day-to-day changes in the stock prices are purely random and therefore should have a zero mean value and constant variance  $\sigma^2$  (Enders, 2004). The model emphasises that the price of a stock (or exchange rate in the context of this study) should advance according to the stochastic difference equation:

$$y_{t+1} = y_t + \epsilon_{t+1} \tag{2.14}$$

Or 
$$\Delta y_{t+1} = \epsilon_{t+1} \tag{2.15}$$

Where

$y_t$  = price of a share of stock (exchange rate) on day

$t$  = time

$\epsilon_{t+1}$  = random disturbance term that has the expected value of zero.

The more general stochastic difference equation is stated as:

$$\Delta y_{t+1} = \alpha_0 + \alpha_1 y_t + \epsilon_{t+1} \tag{2.16}$$

The random walk hypothesis requires the restriction  $\alpha_0 = \alpha_1 = 0$ . Rejecting this restriction is equivalent to rejecting the theory. The mean of random disturbance term  $\epsilon_{t+1}$  must be equal to zero with no evidence of being predictable, otherwise the RMM is invalid.

According to Mussa (1984), monthly changes in exchange rates are frequently quite large and almost entirely random and unpredictable. Only a small fraction of such changes has been anticipated by the market (when examining the behavior of spot exchange rates) as measured by the forward discount or premium. Therefore, it may be almost impossible to forecast exchange rate movement perfectly as a result of volatility of the market.

### 2.3. The Taylor Rule based Exchange Rate

*“The Taylor (1993) rule is a simple monetary policy rule linking mechanically the level of the policy rate to deviations of inflation from its target and output from its potential”* Hofmann and Bogdanova (2012). The Taylor rule is a monetary policy rule that stipulates change in the nominal interest rate as a result of changes in inflation, output and other economic conditions. The original Taylor rule states:

$$i_t^* = \pi_t + \phi(\pi_t - \pi^*) + \gamma y_t + r^* \tag{2.17}$$

Where  $i_t^*$  is the target short term nominal interest rate for time t,  $\pi_t$  is the price inflation rate for period t,  $\pi^*$  is the inflation target,  $y_t$  is the output gap measured by the deviation of real output from its potential level and  $r^*$  is the equilibrium real interest rate.

Engel and West (2004) show that the Taylor rule model, when expressed as a present value relationship, has a modest positive correlation with the actual real Dollar (\$) /Deutsche Mark (DM) rate over the 1979-1998 period. An interesting implication of the model is that an increase in expected future inflation in a country actually causes the currency to appreciate. The reason for this is that under the Taylor rule, the policymaker raises interest rates more than the increase in expected inflation. This aspect of the model plays an important role in tracking the actual \$/DM rate.

According to Molodtsova and Papell (2009)

*“The Taylor rule specifies that the central bank adjusts the short-run nominal interest rate in response to changes in inflation and the output gap. By specifying Taylor rules for two countries and subtracting one from the other, an equation is derived with the interest rate differential on the left-hand-side and the inflation and output gap differentials on the right-hand-side. If one or both central banks also target the purchasing power parity (PPP) level of the exchange rate, the real exchange rate will also appear on the right-hand-side. Positing that the interest rate differential equals the expected rate of depreciation by uncovered interest rate parity (UIRP) and solving expectations forward, an exchange rate equation is derived.”*

Based on the above statement, they derived the exchange rate forecasting equation

$$\Delta s_{t+1} = \omega - \omega_\pi \pi_t + \tilde{\omega}_\pi \tilde{\pi}_t - \omega_y y_t + \tilde{\omega}_y \tilde{y}_t - \omega i_{t-1} + \tilde{\omega} \tilde{i}_{t-1} + \tilde{\omega}_q \tilde{q}_t + \eta_t \quad (2.18)$$

Where  $s_t$  is the natural log of the nominal exchange rate  $\Delta(\$/R)_{t+1}$ , defined as the US dollar price of one unit of the domestic currency, so that an increase in  $s_t$  is a depreciation of the US dollar.

The theoretical implications for the interrelationships in equation (2.18) are explained as follows:

- $\pi_t \uparrow \rightarrow i \uparrow \rightarrow \$ \downarrow / R$  : A rise in inflation in US leads to an increased interest rate leading to an appreciation of US currency relative to rand (capital outflow from SA leading to rand depreciation)
- $\tilde{\pi} \uparrow \rightarrow \tilde{i} \uparrow \rightarrow \$ \uparrow / R$  : A rise in SA inflation leads to higher interest rates and depreciation of dollar relative to rand (capital inflow into SA leading to rand appreciation)
- $y_t \uparrow \rightarrow i \uparrow \rightarrow \$ \downarrow / R$  : A rise in US output above potential leads to an overheated economy which leads to an increase in interest rates (amongst other things) which leads to an appreciation of dollar relative to rand (rand depreciation)
- $\tilde{y}_t \uparrow \rightarrow \tilde{i} \uparrow \rightarrow \$ \uparrow / R$  : A rise in SA output above potential leads to rise in SA interest rate which leads to depreciation of dollar relative to rand (appreciation of rand)
- $i_{t-1} \uparrow \rightarrow i \uparrow \rightarrow \$ \downarrow / R$  : Interest rate smoothing implies gradual increments to a targeted amount (optimal high interest rate). This leads to appreciation of dollar relative to rand (rand depreciation)
- $\tilde{i}_{t-1} \uparrow \rightarrow \tilde{i} \uparrow \rightarrow \$ \uparrow / R$  : Interest rate smoothing in SA leads to higher interest rate in SA and a depreciation of the dollar (appreciation of rand)

## 2.4. Conclusion

This chapter examined some of the theoretical literature that has attempted to explain the movement of the exchange rate and forecast the same. Due to the volatile nature of exchange rate as a result of the flexible exchange rate regime adopted by most countries, it has become imperative to introduce more variables to provide forecasts with minimum errors. The next chapter explores empirical literature explaining exchange rate movements. This literature takes into account some traditional monetary approaches but more especially newer econometric models in explaining and forecasting exchange rate movement in our present complex world.

## CHAPTER THREE

### EMPIRICAL LITERATURE REVIEW

#### 3.0. Introduction

Over the years, researchers have developed various statistical methods of exchange rate estimation and prediction. Although most of the recent studies have been heavily influenced by the work of Meese and Rogoff (1983), with the advent of new computing technology in econometric modelling, economists have been able to improve on formulating models that attempt to outperform the random walk model. According to Ricci et al. (2008), the determinants of exchange rates are very extensive as empirical analysis differs in choice of underlying real exchange rate fundamentals, in part because of data availability considerations.

Since the main focus of the next two chapters is to derive econometric models in the South African context that best predict the rand-dollar exchange rate movement, this chapter will provide a succinct review of the literature that will shed light on the models to be developed in the succeeding chapters.

The remainder of this chapter focuses on the empirical approach to exchange rate determination and forecasting, which begins with the seminal work of Meese and Rogoff (1983) in and proceeds to examine other research done in the field. Section 3.2 focuses on exchange prediction with commodity prices included as this variable will be included in the models later on. Lastly, sections 3.3 and 3.4 focus on the South African experience in exchange rate forecasting and the real side of exchange rate development in South Africa.

#### 3.1. Empirical approach to exchange rate determination

Meese and Rogoff (1983) compared time series and structural models of exchange rate based on their out- of- sample prediction accuracy. They used seasonally adjusted monthly data from March 1973 to June 1981 to estimate the dollar/mark,

dollar/pound, and dollar/yen exchange rates. The structural models examined were the flexible-prices monetary (Frenkel - Bilson (1976, 1978, 1979)) model, the sticky-price monetary (Dornbusch – Frenkel (1976, 1979, 1981)), model and the sticky-price asset (Hooper – Morton (1982)) model.

According to Meese and Rogoff (1983), the quasi reduced form specification of all three models is subsumed in the general specification:

$$s = a_0 + a_1(m - m^*) + a_2(y - y^*) + a_3(r_s - r_s^*) + a_4(\pi^e - \pi^{*e}) + a_5\overline{TB} + a_6\overline{TB}^* + \mu \quad (3.1)$$

Where

$s$  = log of the dollar price of foreign currency

$m - m^*$  = log of the ratio of the US money supply to the foreign money supply

$y - y^*$  = log of the ratio of the US to foreign real income

$r_s - r_s^*$  = short- term interest rate differenced

$TB$  and  $\overline{TB}$  = the cumulated US and foreign trade balances

$\mu$  = disturbance term.

All three models, according to the research, exhibit first degree homogeneity in the relative money supply, resulting in  $a_1=1$ . In addition, the Frenkel - Bilson model assumes PPP constraints, resulting in  $a_4 = a_5 = a_6 = 0$ . The Dornbusch – Frankel model, which allows for slow domestic price adjustment and consequent deviations from the PPP sets  $a_5 = a_6 = 0$ . In the Hooper – Morton model none of the coefficients are constrained at zero, as the model extends the Dornbusch- Frankel model to allow for changes in long- run real exchange rate.

The results of the testing formed the following conclusions:

- The structural models in particular failed to improve on the random walk model in spite of the fact that their forecasts were based on realised values of the explanatory values.
- Allowing for separate coefficients on domestic and foreign incomes and money supplies yields no gain in out-of-sample forecasting accuracy. Neither does including domestic and foreign price levels as additional explanatory variables.
- The random walk model almost consistently has the lowest root mean square error over all horizons and across all exchange rates.

Meese and Rogoff (1983) noted that although the random walk model outperformed the structural models of the 1970s it does not predict perfectly, as errors still arise. The mean-squared error of the model's prediction of the exchange rate (using realised values of the explanatory variables) had a tendency to be lower than the mean-squared error of the naïve model that predicted no change in the exchange rate. According to the researchers, the reasons for the poor performance of the structural models may be a combination of simultaneous equation bias, sampling errors, stochastic movements in the underlying parameters, or misspecification (as a result of oil shocks, change in global trade patterns, and/or changes in policy regimes).

Wu and Hu (2009) attempted to shed new light on the Meese-Rogoff puzzle by incorporating both the non-linear adjustment and Harrod-Balassa-Samuelson (HBS) effect in a model to re-examine the predictability of nominal exchange rates. Based on careful empirical investigation, they provide solid evidence to beat the random walk forecast model. They argued that given the short time span of data, combining the HBS effect with non-linear adjustment of real exchange rates is useful in providing evidence of nominal exchange rate predictability.

Wang and Wu (2012) also attempted to examine the Meese-Rogoff puzzle from a different perspective. They did this by showing that economic fundamentals were useful in interval forecasting of exchange rates. They applied semiparametric forecast intervals to a group of models for 10 OECD exchange rates. In general, out-of-sample forecast intervals generated by the models were tighter than those generated by the random walk, given that the intervals covered realised exchange rates equally well. The evidence of exchange rate predictability was more pronounced at longer horizons. A benchmark Taylor rule model was found to perform better than PPP, monetary, and

forward premium models. The reductions in the lengths of forecast intervals relative to random walk intervals can be substantial (10% or more) at long horizons.

Rossi (2013) provided a survey of successive studies that have achieved successes in improving upon the benchmark set by random walk principles, using theoretical and empirical innovations. The theoretical improvements utilised asset pricing models and Taylor rules and, separately, empirical advances have included nonlinear methods.

Eichenbaum and Evans (1995) and Chinn (2006) in separate but identical research explained exchange rate movements using the rational expectations and the uncovered interest rate parity (UIRP) arguments. They explained that immediate appreciation of the dollar against a domestic currency will be followed by forecasted (and actual) depreciation. One could therefore derive the exchange rates forecasting equation by replacing the interest rate differential with the expected rate of depreciation and use the variables from the two countries' Taylor rules to forecast exchange rate depreciation. Although the forward premium argument seems like a plausible argument, the UIRP does not hold in the short-run. The two strands of research did not provide a complete solution to the problem of outperforming the random walk.

Molodtsova and Papell (2009), exploiting econometric work by Clark and West (2006), tested the out-of-sample predictability of nominal exchange rate changes using Taylor rule fundamentals for 12 OECD countries in relation to the United States over the post-Bretton Woods period, from 1973 to 2006. While real-time data were not readily available during the post-Bretton Woods period for most of the countries, they constructed output gaps as deviations from "quasi-revised" trends in potential output, where the trends, while incorporating data revisions, are updated each period so as not to incorporate ex-post data. Although they found strong evidence of short-run predictability with quasi-revised data for most of the considered currencies using Taylor rule fundamentals, the model did not produce forecasts with real-time data.

In addition, Molodtsova and Papell (2009) noted that the link between higher inflation and forecasted exchange rate appreciation potentially characterises any country where the central bank uses interest rate as the instrument in an inflation targeting policy rule.

In their view, three additional predictions can be made.

1. If the US output gap increases, the US Federal Reserve (US Fed) will raise interest rates and cause the dollar to appreciate. If the foreign country also follows a Taylor rule, an increase in the foreign output gap will raise the foreign interest rate and cause the dollar to depreciate.
2. If the real exchange rate for the foreign country depreciates and it is included in its central banks Taylor rule, the foreign central bank will raise its interest rate, causing the foreign currency to appreciate and the dollar to depreciate.
3. If there is interest rate smoothing, a higher lagged interest rate will increase current and expected future interest rates. Under uncovered interest rate parity (UIRP) and rational expectations, any event that causes the Fed to raise the federal funds rate will produce immediate dollar appreciation and forecasted dollar depreciation.

Based on the empirical and theoretical evidence presented, they believed that an increase in the US interest rate will produce both immediate and forecasted dollar appreciation. Similarly, any event that causes a foreign central bank to raise its interest rate will produce immediate and forecasted dollar depreciation.

Rossi (2012), in commenting on the work of Molodtsova and Papell (2012), noted that when using predictors such as the Taylor rule it becomes crucial to contemplate the possibility that the performance of the predictor may be time-varying. As shown in Molodtsova and Papell (2012), during the latest financial crisis, the forecasting ability of the Taylor rule model worsened significantly. Failing to acknowledge the possibility that the model's relative performance may change over time would incorrectly lead the researcher to conclude that the Taylor rule model does not forecast well, when, in reality, this conclusion is heavily influenced by the financial crisis period. However, examining the evolution of predictive ability over time is not simple. Simply utilising existing tools with the existing critical values may lead to spurious evidence of predictive ability. Fortunately, tools that are designed to evaluate the out-of-sample predictive content over time are available and can make a difference. Also, the choice of the window size might be potentially important, especially in the presence of instabilities, although the results in the Molodtsova and Papell (2012) analysis are overall robust to the latter.

Research carried out by Molodtsova et al. (2011) using real-time data to evaluate out-of-sample predictability of the U.S. dollar/euro exchange rate from the inception of the euro in 1999 to the end of 2007. The major result was that the null hypothesis of no predictability was rejected against the alternative hypothesis of predictability with Taylor rule fundamentals for a wide variety of specifications that included inflation and a measure of real economic activity in the forecasting regression. The strongest evidence came from the simplest specifications that closely resemble the original Taylor rule, where the interest rates set by the Federal Reserve (US Fed) and the European Central Bank (ECB) responded only to inflation and a measure of real economic activity. The results are robust to the inclusion of inflation and real economic activity forecasts, rather than realised values, in the forecasting regression and to testing for either short-horizon exchange rate predictability of one-quarter or longer-horizon predictability of up to 1 year.

In their analysis of factor model forecasts of exchange rates, Engel et al. (2008) highlighted three forecasting models that use measures of observable fundamentals, which are the Taylor rule model, the monetary model and deviations from purchasing power parity (PPP). According to the researchers, the yardstick of measuring of forecasting performance was root mean squared prediction error (root MSPE). The data used in the analysis was quarterly data on 17 bilateral US dollar exchange rates with OECD countries, 1973-2007. It was found out that these models have lower MSPE than a random walk model for long (8 and 12) quarter horizon predictions over the latter part of the forecasting sample (1999-2007). These differences, however, were usually not significant at conventional levels. Predictions that span the entire two decades (1987-2007) or the early part (1987-1998) of the forecast sample generally had higher MSPE than a no change forecast. The basic factor model and the factor model supplemented by PPP fundamentals performed best.

Using a comprehensive real-time dataset for 15 OECD countries, which was constructed by merging the OECD Original Release and Revisions Database and Historical Real-Time Data for OECD, Ince and Molodtsova (2015) evaluated real-time short-term out-of-sample exchange rate predictability during the post-Bretton-Woods period using Taylor rule fundamentals, PPP models, Taylor rule differentials and Monetary models. According to Ince and Molodtsova (2015), the Taylor rule fundamentals model of Molodtsova and Papell (2009) provides stronger evidence of

predictability than the Taylor rule differentials model of Engel et al. (2008) and much stronger evidence of predictability than the conventional Purchasing Power Parity and monetary models. They added that the two most successful specifications with Taylor rule fundamentals did not include the real exchange rate and can either include or exclude the lagged interest rates in the central bank's Taylor rule. The models provide evidence of out-of-sample exchange rate predictability for 9 out of 15 countries in the sample. Using real-time data instead of quasi-real-time data, as in Molodtsova and Papell (2009) and Ince and Molodtsova (2015), the findings confirm that out-of-sample exchange rate predictability with Taylor rule fundamentals has survived the financial crisis and the period when the federal funds rate was at the zero lower bound. In addition, the role of the forecast origin and forecast horizon in real-time exchange rate predictability within a quarter was explored. Exchange rate predictability using five different definitions of the exchange rate change was used in doing so. It was found that the evidence of predictability dropped significantly as the forecast horizon was reduced from three to two months ahead. The number of rejections declined even more, as the forecast horizon further reduced to one month. Among the three one-month exchange rate changes with different forecast origins, the strongest evidence of predictability was found for the model that originated at the end of the third month in a given quarter.

Byrne et al. (2014), computing the information set with calibrated, rather than estimated coefficients, estimated time-varying Taylor rules and examined their predictive content for exchange rates in a framework that also allows for the parameters of the forecasting regression to change over time. They focus on three alternative forecast windows and four quarterly horizons. For most forecast windows and horizons, their approach yielded a lower Root Mean Squared Forecast Error (RMSFE) than the random walk without drift (RW) for at least half of the currencies in the sample. Results were particularly strong in the windows that cover the recent financial crisis and recovery period (2007Q1-2013Q1), where seemingly significant changes in the fundamentals ensued. Although their findings confirm that Taylor rules are relevant in predicting exchange rates, they also reveal the importance of accounting for nonlinearities, especially in the more recent unsettled times.

According to Byrne et al. (2014), Engel et al. (2008), Molodtsova and Papell (2012), and Rossi (2012), Taylor rules outperform the random walk benchmark in out-of-

sample forecasting, especially at short-horizons when the empirical exchange rate models are adjusted on an information set.

Asari et al. (2011) applied the vector error correction model (VECM) approach in explaining the relationship between interest rate and inflation towards exchange rate volatility in Malaysia for the period 1999-2009. The presence of cointegration between variables suggested a long term relationship among the variables under consideration. The results from the research show that the inflation rate impacts the interest rate as indicated by Granger-cause. Subsequently the interest rate influences the exchange rate as shown by the Granger cause test. Taking into account a long -term relationship, interest rate moves positively while inflation rate goes negatively towards exchange rate volatility in Malaysia. The implication of this study is that increasing the interest rate can be efficient in restraining exchange rate volatility.

Using weekly data for eight US dollar exchange rates during the recent floating exchange rate regime, Sarno and Valente (2004) concluded that a Markov-switching VECM (vector error correcting mechanism) for spot and forward exchange rates that explicitly takes into account the mounting evidence that the conditional distribution of exchange rates is well characterised by a mixture of normal distributions produces very satisfactory one-week-ahead density forecasts. The model was found to outperform its more parsimonious linear counterpart as well as the random walk model.

Chen and Leung (2003) introduced an error correcting extension which is the Bayesian vector error correction (BVECM) of the Bayesian vector auto regression (BVAR) to forecast 1 month ahead changes of three Asia- Pacific (Korea, Japan and Australia) currency exchange rates and compared BVECM's out-of-sample forecasting performance with those produced by the BVAR and the random walk models. Using data from 1980 to 1994 for all currencies, in terms of the conventional forecast evaluation statistics of root mean squared errors (RMSE) and uncovered interest parity (UIP), the BVECM was able to improve upon the BVAR forecasts for every exchange rate examined in the study. The results of the regression tests (both  $R^2$  and F-statistic) also exhibited that the BVECM produced out-of-sample forecasts that were systematically less biased and more efficient than those produced by the BVAR. The results of the market timing tests also indicated that both the BVAR and the BVECM

have economically significant value in predicting the directional change in two of the three exchange rates. Nonetheless, the BVECM was shown to be able to provide directional change forecasts that were equally or more economically significant than the corresponding BVAR. In addition, the results of the study provided additional evidence to support the use of the UIP relationship in forecasting exchange rate changes. Both the BVECM and the BVAR based on the UIP were able to forecast the 1 month ahead changes in exchange rates better than the naive model (random walk model).

### **3.2. Exchange rate prediction/forecasting with commodity prices**

South Africa is regarded as a commodity exporter, and the rising trend in international commodity prices generally causes the exchange rate to appreciate as foreign investors become more interested in commodity markets equities and bonds (de Jager, 2012). An increase in the world prices of the commodities that a country trades in (either export or import) would also tend to appreciate the real exchange rate. Such an increase would induce higher wages and a higher price of non-tradable goods (MacDonald and Ricci, 2004). For small open economies, such as South Africa (SA), prices for most of the commodities exported are determined on the international market and the volume of exports do not have an impact on the prices set by these markets. SA is therefore said to be a price taker. Since commodities represent a large portion of SA exports and GDP, fluctuation in commodity prices may lead to fluctuations in exchange rate due to its impact on the terms of trade.

According to Lafrance and Van Norden (1995) a rise in commodity prices leads to improvements in a country's terms of trade by raising the value of the exports. An increase in exports revenue leads to higher domestic income, which then increases aggregate demand. Higher demand places upward pressure on prices and thus on the inflation rate. If the central bank pursues a policy of economic stability, it will most likely raise interest rates to decrease aggregate demand in order to bring the economy back to equilibrium. An increase in interest rates leads to an appreciation of the country's currency. Therefore, an increase in the world price of commodities leads to an

appreciation of the domestic currency through its impact on the banks' reaction to increased aggregate demand.

Ferraro et al. (2015) in their analysis suggested that commodity prices can predict commodity currencies exchange rates at a daily frequency, in the sense of having a stable "out-of-sample fit" relationship. However, the predictive ability was not evident at quarterly and monthly frequencies. The main focus of the research was on the Canadian-U.S. dollar exchange rate and oil prices, although they demonstrated that similar results held for other commodity prices/exchange rates pairs, such as the Norwegian krone-U.S. dollar exchange rate and oil prices, the South African rand-U.S. dollar exchange rate and gold prices, the Australian-U.S. dollar and oil prices, and the Chilean peso-U.S. dollar exchange rate and copper price. When using contemporaneous realised daily commodity price changes to predict exchange rate changes, the predictive power of commodity prices is robust to the choice of the in-sample window size, and it does not depend on the sample period under consideration. When using the lagged commodity prices to predict exchange rates, the predictive ability is more temporary and appears only for some commodities and only in daily data after allowing the relative forecasting performance to be time-varying. Both the out-of-sample and in-sample analyses suggested that the frequency of the data is important to detect the predictive ability of commodity prices, as the out-of-sample predictive ability breaks down when considering monthly and quarterly data. It was noted that non-linearity and cointegration do not significantly improve upon the simple linear commodity price model.

Zhang et al. (2016) also make use of high frequency data in explaining the casual relationship between commodity prices and exchange rates in typical commodity economies. The country-commodity relationships used were: Canada-crude oil, Australia-gold, and Chile-copper. They used daily and 5-minute data, which is of great interest to financial market participants who have short decision intervals, and also reduces time-aggregation effects. In addition, they applied the concept of multi-horizon causality measures to compare the strength of causal relationships, to provide more powerful non-causality tests, and to determine how long the causal effects will last. Their results suggest that unconditional and conditional causality running from commodity prices to exchange rates is stronger than that in the opposite direction across multiple horizons, after removing potential dollar effects. Their results also

underscore the fact that the interpretation of causality depends on time units and observation intervals (data frequency), and that causality measures present a more informative analysis of Granger causality than tests of non-causality alone.

Gloria (2010) based her work on Molodtsova and Papell (2009) in investigating if the addition of commodity prices to the exchange rate forecasting model improved its forecasting performance. The research focused on the dollar exchange rate of Canada, South Korea, Australia, New Zealand and South Africa using their main commodity export prices of crude oil (Canada and South Korea), coal, lamb and gold respectively. Although the exchange rate forecasting model improved with the inclusion of commodity prices the case was not so with South Korea. The model did not outperform the random walk model for South Korea. According to the researcher, this may have been as a result of not having a *de-facto* flexible exchange rate regime or South Korea's central bank not following the Taylor rule in setting monetary policy.

The work of Amano and Van Norden (1995) investigated the impact of the terms of trade on the variations in the real exchange rate between Canada and the United States. The authors found out that there was indeed a causal relationship running from the terms of trade to the exchange rate. They developed an econometric forecasting equation using Error Correcting models (ECM) that outperformed the random walk at short horizons. Using modern unit-root and cointegration techniques, they used commodity prices to capture the long-term effects on the exchange rate and a measure of the Canada-US interest rate differential to reflect the deviation of the real exchange rate from its expected long term level. Their work also proved that terms of trade fluctuations as opposed to monetary factors can explain much of the variation in the real exchange rate since 1973. In their analysis the authors use monthly data for all variables. The real exchange rate (RPFX) is defined as  $\$US/\$CA$  (i.e. the price in US dollars of one unit of Canadian dollar), deflated using the consumer price index (CPI) from both countries. The authors split the terms of trade (commodity export prices divided by manufactured import prices) into two components, energy commodities and non-energy commodities to obtain TOTENERGY and TOTCOMOD respectively. The authors point out that it is essential not to use an aggregate measure of the terms of trade but to use commodity and energy terms of trade as distinct variables in the forecasting equation. The relationship between the energy component of the terms-of-trade measure and the real exchange rate could be explained by the

fact that the measure of the energy component used also includes energy prices. They also capture the monetary influence on the short-term deviation from the long term interest rate values. They additionally include a measure of the Canadian-US interest rate differential, RDIFF, defined as:

$$RDIFF = (i \text{ Canada} - I \text{ Canada}) - (i \text{ US} - I \text{ US}) \quad (3.2)$$

Where

$i$  = short term 30day interest rate

$I$  = long term market yield (interest rate) on industrial bonds.

All variables except the interest rate differential are expressed in natural logarithms. After using three (3) different stationarity tests and confirming that the real exchange rate and two components of the terms of trade are non-stationary, they are able to reduce their specification to a single equation estimates by the least squares method. They also performed stationary tests on RDIFF and found it to be stationary, thus providing some evidence that monetary policy should have only a transitional effect on the real exchange rate while term of trade shocks should be permanent. The equation arrived at is:

$$\Delta RPFX_t = \alpha(RPFX_{t-1} - \beta_0 - \beta_C TOTCOMOD_{t-1} - \beta_E TOTENERGY_{t-1}) + \gamma RDIFF_{t-1} \quad (3.3)$$

Disintegrating the real exchange rate movements, reach three conclusions were attained:

1. The Canada-US interest rate differential accounts for only a small portion of real exchange rate variations as opposed to terms-of- trade shocks.
2. Energy price shocks (i.e. increases or decreases in energy commodity prices) are responsible for most of the exchange rate variation in three out of the four sub-periods considered.
3. Large and persistent energy price shocks still have significant effects on the exchange rate four years later; large but short-lived shocks have negligible impact.

Lafrance and Van Norden (1995) maintained that resource-based industries account for an important part of Canada's exports, suggesting a role for commodity prices in real terms in explaining real exchange rate movements. The authors used similar specifications to Amano and Van Norden (1995) but a different data set. As commodity prices are mainly determined in world markets and tend to be volatile they are among the most important external shocks affecting the Canadian economy. Energy and non-energy commodity prices have evolved differently since the early seventies. They were therefore included as two separate variables in the exchange rate equation. In addition to commodity prices, the close integration of Canadian and U.S. capital markets means that the Canada-U.S. exchange rate is sensitive to the evolution of interest rates in both countries. The exchange rate equation therefore includes the differential between Canadian and U.S. short-term interest rates (as opposed to the differential between long and short interest rate differential in Amano and Van Norden (1995)) as an additional explanatory variable to reflect financial market conditions.

The major change in specification is the inclusion of the change in real exchange rate in the previous period as an additional exogenous variable outside the error correction term in an attempt to further capture the short-run dynamics of the exchange rate movement. The equation considers only nominal interest rate differentials, although in principle real interest rate differentials are more appropriate.

$$\Delta RFX_t = \alpha(RFX_{t-1} - \beta_0 - \beta_C COM_{t-1} - \beta_E ENE_{t-1}) + \gamma INT_{t-1} + \delta(RFX_{t-1} - RFX_{t-2}) \quad (3.4)$$

Where

$\Delta RFX_t$  = the difference between the previous period's value (based on quarterly averages) of the real exchange rate (RFX) and its estimated long-run or equilibrium value

$COM_{t-1}$  = Real non-energy commodity prices

$ENE_{t-1}$  = Real energy prices (ENE)

$INT_{t-1}$  = Canada-U. S short-term interest rate differential (INT)

$RFX_{t-1} - RFX_{t-2}$  = The change in the real exchange rate over the previous period

The equation above explains changes in the Canada-U.S. real exchange rate. Its structure distinguishes long-term forces (associated with real commodity prices) that have gradual but persistent effects on the exchange rate from other factors whose effects are more short-lived. The energy price series is a U.S. dollar crude oil price index; non-energy commodity prices are represented by the Bank of Canada's production weighted U.S. dollar commodity price index. Both indices are deflated using the U.S. implicit GDP deflator. The interest rate differential is the difference (in per cent per annum divided by 100) between Canadian and U.S. 90-day commercial paper rates. The real exchange rate is defined as the nominal exchange rate (in U.S. \$ per Can. \$) multiplied by the ratio of Canada's GDP deflator to that of the United States. All the variables except the interest rate differential are expressed in logarithms. The exchange rate equation was estimated by the least-squares method over the 1972Q2 to 1994Q3 period. The results indicate that all the explanatory variables have statistically significant effects.

Chen and Rogoff (2003) studied the real exchange rate behaviour of Canada, Australia, and New Zealand. These three well developed small open economies are highly integrated into the global capital markets and are active participants in international trade and are regarded as price takers in world markets for the majority of their commodity exports. In addition, their currencies are labeled commodity currencies because commodities constitute a significant component of their exports. According to the authors, in the past decade, commodity products have accounted for 60% of Australia's exports and more than a half of New Zealand's exports. In the case of Canada, more than a quarter of its exports rely on commodity products.

Chen and Rogoff (2003) find robust evidence that commodity prices have significant impact on real exchange rates. Each country's real exchange rate is calculated based on three different reference currencies: the US dollar, the British Pound, and a non-US-dollar currency basket. The commodities chosen reflect major non-energy products produced in each country because the authors argue that Australia, Canada, and New Zealand are not large net exporters of energy commodities. The commodity prices used are quarterly averaged world market prices in US dollars, deflated by the US CPI. Commodity price indices for each country are then constructed by geometrically averaging the deflated commodity prices using the corresponding domestic production share as a weight. The researchers use commodity prices instead

of standard measures of terms-of-trade. They find that, for Australia and New Zealand, the connection between their real exchange rates and the world price of their commodity exports is quite strong and stable. In contrast, the link between the two variables for Canada appears to be primarily a long term co-integrating relationship, and is thus much more sensitive to de-trending. They also acknowledge that standard measures of terms of trade do not react much to movements in world commodity prices. They thus conclude that world commodity prices are much better at capturing exogenous terms-of-trade shocks than standard measures of terms of trade.

Chen (2004) research was based on Chen and Rogoff (2003) finding that commodity price (non-energy commodities only) fluctuations can explain real exchange rate behaviour. The research incorporated commodity prices into the classical exchange rate models (as discussed by Meese and Rogoff (1983)) to improve their in-sample fit and out-of-sample forecasting performance. The countries analysed were Australia, Canada and New Zealand. The anchor currencies used compute the quarterly nominal exchange rate were the US dollar, the British pound, and the Japanese Yen. Out-of-sample forecasts were conducted for quarters 1, 4, and 8. The models used in the paper are:

- Augmented relative Purchase Power Parity (PPP) model:

$$s_t = \alpha + \beta_{cp} p_t^{com} + \beta_p (p_t^* - p_t) + \varepsilon_t \quad (3.5)$$

- Augmented asset approach flexible price monetary model:

$$s_t = \alpha + \beta_{cp} p_t^{com} + \beta_m (m_t^* - m_t) - \beta_y (y_t^* - y_t) + \varepsilon_t \quad (3.6)$$

- Augmented flexible price monetary model:

$$s_t = \alpha + \beta_{cp} p_t^{com} + \beta_m (m_t^* - m_t) - \beta_y (y_t^* - y_t) + \beta_i (i_t^* - i_t) + \varepsilon_t \quad (3.7)$$

- Augmented sticky price monetary model:

$$s_t = \alpha + \beta_{cp} p_t^{com} + \beta_m (m_t^* - m_t) - \beta_y (y_t^* - y_t) + \beta_i (i_t^* - i_t) + \beta_\pi (\pi_t^* - \pi_t) + \varepsilon_t \quad (3.8)$$

Where

$s_t$  =exchange rates

$\beta_p$ = coefficient on the relative CPIs

$\beta_{cp}$ = coefficient of commodity price (most be positive sign)

$p_t^{com}$ = the world price in US dollars of the exported non-energy commodity

$\beta_m$  = the elasticity with respect to money stock

$\beta_y$ = income elasticity of money demand

$\beta_i$ = interest semi-elasticity

$\beta_\pi$ = expected inflation semi elasticity

Using commodity prices as an additional fundamental Chen (2004) re-examines the performance of four standard macroeconomic models in explaining both in- and out-of-sample nominal exchange rate behaviour. It was found that the inclusion of commodity prices improves the in-sample fit of several models, and in general offers more support for long-run co-integration relations between exchange rates and fundamentals. These findings suggest that properly accounting for terms-of-trade fluctuations may be an important piece of the puzzle for explaining previous empirical failures. In terms of the predictive content of these models in short- to medium- horizon forecasts (1 quarter to 2 years), the paper shows that the inclusion of commodity prices as an additional fundamental can improve the predictive accuracy of some, though not all, of the standard models. Also, it was found that several commodity-price-augmented equations not only provide strong evidence of exchange rate predictability, they also outperform a random walk in forecast accuracy by a statistically and economically significant amount. However, there does not appear to be one single model that can provide such superior predictive performance in all forecast horizons and across all country pairs.

Hatzinikolaou and Polasek (2005) used post-float nominal Australian data and conclude that the nominal Australian dollar is indeed a commodity currency, with a long-run elasticity of the exchange rate with respect to commodity prices estimated at

0.939. This finding is consistent with Chen (2002), and Chen and Rogoff (2003), with the former using nominal and the latter using real exchange rate data. The long-run elasticity that they found was higher than the 'conventional wisdom' elasticity of 0.5.

Schaling et al. (2014) examined the 'commodity currency' hypothesis of the rand, which suggests that the currency moves in line with commodity prices, and analysed the linked causality using nominal data between 1996 and 2010. After much permutation, it was concluded that the relationship is dynamic over time owing to the portfolio-rebalance argument and the Commodity Terms of Trade (CTT) effect. In the absence of an error correction mechanism this disconnect may be prolonged. The implication may be that while futures and forward commodity prices may be useful leading indicators of future currency movements the price risk management strategies may need to be adjusted over time.

### **3.3. South African perspective on exchange rate estimation and forecasting**

This section provides a summarised account of the work done on exchange rate estimation and forecasting within the South African context. Being a country with its peculiarities in international trade and relations, it adopts a monetary policy framework with inflation targeting at its core. The chapter explores the work of various researchers who strive to apply several economic models of exchange rate determination and forecasting within the South African context.

Formal inflation targeting was adopted in South Africa as the monetary policy framework in February 2000. The reasons for the adoption were: mainly to give the public a clear monetary policy stance in order to dissolve any uncertainties and set rational expectations on inflation and economy at large; secondly, to improve the co-ordination between monetary policy and other economic policies provided that the target is consistent with other objectives; and lastly, to discipline monetary policy and increase the central bank's accountability. According to Van der Merwe (2004) and Ncube and Ndou (2011), with inflation targeting, the SARB left the exchange rate to be determined by market forces, making it more volatile. Wide fluctuations in the exchange rate of the rand complicated monetary policy decision-making and the planning of enterprises involved in international trade or competing with importers.

Saville (2004) noted that the Taylor rule analysis of interest rates in South Africa is closely related to the South African Reserve Bank's (SARB) stance, with only small errors caused by measurement problems and expectations. The only major disparity stated in the report is that the SARB is overly restrictive in monetary policy stance, which may be very costly for economic growth in South Africa.

The Woglom (2003) study employed monthly data in the estimation of open economy Taylor rule for pre- and post- inflation targeting periods (the periods being 1990:1-1998:6, and 1999:1-2002:12). The study found significant differences in the conduct of monetary policy in the different time periods. It explained further that the short-run response to inflation in the post-inflation targeting period was bigger and significant. Also, because of less interest rate smoothing, the long-run response was smaller in the pre-inflation targeting era.

Kaseeram (2010) postulated that forward looking, output gap models with interest rate smoothing adequately describe Repo rate movements. This acts as an improvement to the Woglom (2003) and Saville (2004) study on three fronts. Firstly, it uses a more appropriate forward- looking framework, as opposed to backward- looking versions of the Taylor rule used by Woglom (2003), since monetary policy authorities rely on forecast of inflation over the next year or two to change the Repo rate. Secondly, the Woglom (2003) report used interest rate on the 3 month Treasury bill to proxy the monetary policy instrument (Repo rate), although the values are close to each other within the time period specified, there are significant differences which can lead to statistical errors . Thirdly, the Kaseeram (2010) research made use of advanced econometric techniques to determine the coefficients of the reaction functions instead of merely taking them as given. The study further explained that the response coefficient of  $\beta$  to expected inflation in an open economy model ranges from 0.83 to 1.77. This implies that a one percentage point increase in the expected inflation rate results in an 83 to 177 basis points rise in Repo rate. In addition, the range of responses ( $\gamma$ ) of Repo rate to output gap lies between 0.19 and 1.61. These values suggest that a one percentage change in output gap brings about a response of between the range of 19 and 161 basis points in the Repo rate.

In the post-inflation targeting era of South Africa, other factors such as the global economic meltdown of 2008/2009 had huge effects on the exchange rate. Although

there were strong economic fundamentals in place, Ngwenya and Zini (2008) noted that declining equity inflow, decline in FDI, and huge current account deficit as a result of enormous trade deficit plagued the strength of the rand. Due to SARB enforcing a floating exchange rate regime, there were no real insolvency issues.

MacDonald and Ricci (2004) employed Johansen's maximum likelihood estimation methodology in a standard VECM specification using data from 1970 to 2002Q1 to estimate the long run cointegrating relationship between real exchange rate and several fundamentals in a vector correction mechanism. It was found that the PPP model suffers greatly from its slow mean reverting property to a constant level – which is its implied long-run equilibrium assumption. The authors also find that the persistent movements in the real effective exchange rate of South Africa are explained by commodity prices, productivity and interest rate differentials vis-à-vis trading partners. A further interesting result concluded from this study was that, in the absence of any further shocks, it would take between 2 and 2½ years for half the gap (or temporary deviation in the exchange rate) to revert back to its equilibrium level.

Other studies, such as Aron et al. (1997), make use of a single equation estimation technique to derive the long-run equilibrium relationship between 1970 and 1995. Their specified model not only provides for a flexible dynamic adjustment of the real exchange rate towards its equilibrium real exchange rate, but also provides for short to medium-run macroeconomic and exchange rate policy effects on the level of the real exchange rate. They suggest that the key explanatory variables of the model would need to include the terms of trade, the price of gold, tariffs, capital flows, official reserves, and government consumption expenditure. According to their calculations, they found that it would take roughly 3½ quarters (0,86 of a year) to eliminate 50 per cent of the shock. Although their estimation period and technique are different to the VECM methodology suggested by MacDonald and Ricci, the estimated period of time for the exchange rate to revert back to its equilibrium level was found to be considerably quicker.

Saayman (2010) makes use of panel data and the behavioral equilibrium approach. The results suggest that the fundamental value of the exchange rate was driven by economic growth, the openness of the economy, its foreign reserves, the real price of gold, and capital expenditure. Saayman (2010) furthermore concludes that although

the exchange rate fluctuates considerably around its equilibrium level, there were no sustained periods of an over- or undervaluation of the exchange rate.

Odhiambo and Lyke (2015) estimated the equilibrium real exchange rate for South Africa employing the fundamental equilibrium real exchange rate approach. They used a dataset covering the period 1975–2012. They also employed the ARDL bounds testing procedure, which has better small-sample properties. Their results show that the fundamental determinants of the equilibrium real exchange rate in South Africa are terms of trade, trade openness, government consumption, net foreign assets, and real commodity prices. The actual real exchange rate appeared closer to the estimated equilibrium rate in South Africa. However, the rand had depreciated in real terms on a year-on-year basis after 1983. This may be due to the drastic trade liberalisation policies that were pursued during and after this period. Tightening trade openness is not an option, as suggested by the researchers, given international agreements but, on the other hand, terms of trade and real commodity prices are beyond the control of South African policies, since they are determined by the world market. According to the researchers, the obvious policy alternative is for South Africa to increase government spending and moderately decrease her net foreign asset position. Finally, the speed of adjustment, when the actual real exchange rate deviates from its equilibrium level, is faster in South Africa.

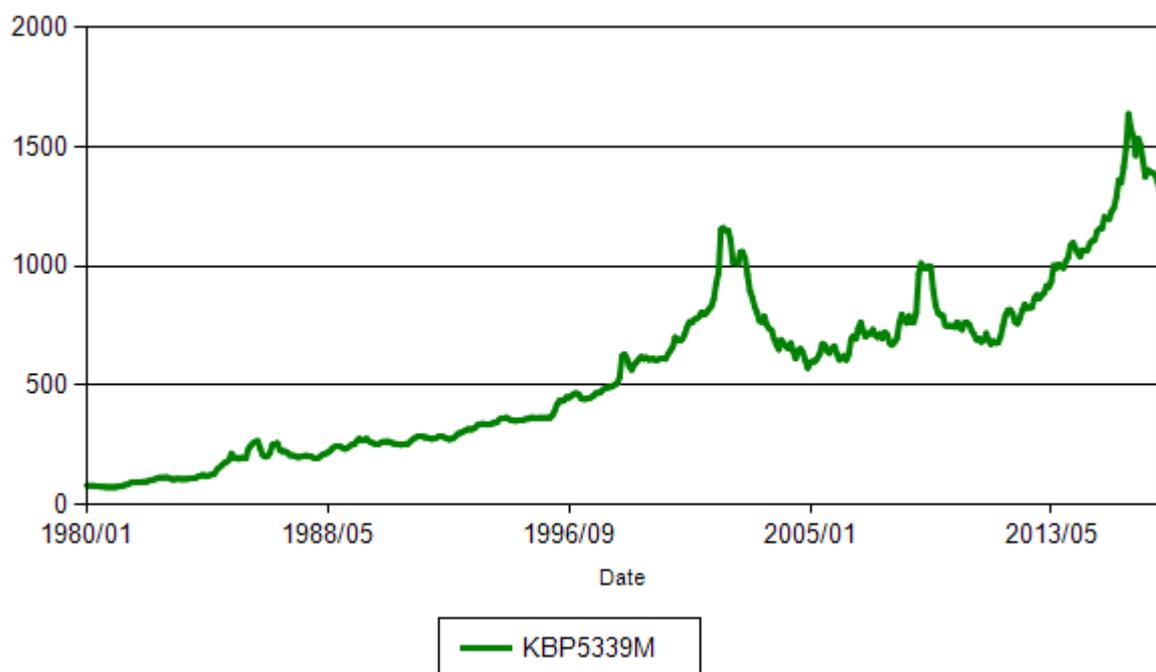
Botha and Pretorius (2009) use and compare both multivariate models such as unrestricted VAR, VECM and VARMA models, and univariate models such as RWM, ARIMA (1,1,1) and ARCH (0,1), to determine exchange movements and forecasting abilities of groups of models. In addition to the past R/US\$ exchange rates, the variables selected for estimation were divided into three (3) major categories, namely: the real side variables, made up of government expenditure to GDP ratio and the current account balances to GDP ratio; the monetary variables made up of the total credit extension, the CPI and the prime rate; the financial variables made up of the balance on financial account. Quarterly time series data from 1990q1 to 2006q4 were used. They used mean absolute deviation (MAD)/mean ratio to compare the forecasting abilities of the models employed. Their findings suggested that in the short-run, multivariate models performed better than the univariate, especially in the one-step-ahead out-of-sample forecasts. However, in the dynamic out-of-sample

forecasts, with longer forecast horizons, the univariate models (ARCH and ARIMA) outperformed the multivariate models, with the exception of the VECM model which outperformed all the models. The RWM, however, did not perform too badly, as it was still in the 5% acceptance range. The research concluded therefore that a combination of the fundamental approach and the technical approach, in a multivariate model such as the VARMA, be used for forecasting the South African exchange rate in the short-run and the VECM for the longer forecast horizon. This research, although with a few similar variables, aims to use both the RWM and VECM for both the short- and long-run and then compare their forecasting abilities.

### 3.4. Real side of exchange rate developments in South Africa

This section links the theoretical aspect of exchange rate forecasting to the empirical aspect. The empirical aspect is affected by various socio-economic and geo-political factors which have affected the volatility of the \$/R exchange rate over the years.

Figure 3.1: Rand per US dollar middle rate R1=100 cents (1980-2016)



Source: South African Reserve Bank (SARB)

Prior to the establishment of a central bank in South Africa, banknotes were printed by commercial banks for issue. These notes could be exchanged for gold as they were backed fully by gold in terms of the gold standard. The South African currency remained on the gold standard during the World War I and commercial banks were indebted to redeem their notes for gold, and at a fixed exchange rate. This was as a result of the terms of an arrangement where the domestic currency was pegged to the British currency (pound sterling) which, in turn, was pegged to the US dollar and, therefore, the gold price. This arrangement ended in March 1919 when the pegging of the pound sterling to the US dollar came to an end, which resulted in the pound sterling depreciating by 1/3 against the US dollar and gold. As a result, gold obtained in South Africa could be sold at a premium in London when converted at commercial banks from bank notes. At the same time, domestic commercial banks had to buy gold at the same premium as in London to provide the necessary backing for their banknotes in issue in terms of the gold standard. In response to a call on Government by commercial banks to be released of this obligation to “trade at a loss”, a Gold Conference was convened in Pretoria in October 1919.

One of the resolutions of the Gold Conference was to request Government to introduce uniform bank legislation for the country, as no such legislation had been introduced since the unification of the country in 1910. Following on this proposal, the Government obtained the services of Sir Henry Strakosch, a British banker, to effect the recommendations of the Gold Conference. Sir Henry was instrumental in ensuring support for his proposal for the establishment of a domestic central bank.

The SARB, the oldest central bank in Africa, opened for business on 30 June 1921. The first banknotes were issued to the public on 19 April 1922. Accordingly, commercial banks were instructed to cease issuing or reissuing their own banknotes with effect from 30 June 1922. At the time of its inception, the SARB had to deal with a situation where the country was nominally on the gold standard, but the system was effectively suspended. Government could issue gold certificates in exchange for gold bullion or specie or banknotes, but declare the certificates non-convertible, although only for a limited period. After applying credit and interest rate policies, South Africa reintroduced the gold standard at the pre-war conversion rate on 18 May 1925. This put the South African pound on par value with the pound sterling, as the UK had returned to a gold standard, also at the pre-war conversion rate, on 25 April 1925.

The US, and subsequently many other countries, entered a period of sharp contraction in economic activity and price deflation, generally known as the 'Great Depression', following a crash in the prices of shares on the New York Stock Exchange in October 1929 and the subsequent curtailment of credit. Amid these depressing economic conditions, the UK suspended the gold standard on 21 September 1931. South Africa also suffered the consequences of the worldwide depression but, nevertheless, decided to retain the gold standard independently from the UK. Full convertibility of banknotes for gold was retained and no restrictions were placed on the export or import of gold, resulting in large gold exports from South Africa.

The gold standard controversy duly developed into a political issue, with the Government of the day supporting it, and the opposition arguing that the gold standard should be abandoned and the domestic currency linked to the pound sterling. Owing to increased capital outflows in December 1932, South Africa abandoned the gold standard on 28 December 1932. This was considered a temporary emergency measure and South African banknotes continued to carry a promise of convertibility until 1992. Analysing the situation with the benefit of hindsight shows that South Africa should have followed the UK in abolishing the gold standard in September 1931. The policy of maintaining the gold standard exacerbated the domestic depression as the SARB had to follow a contractionary monetary policy, thereby aggravating economic hardship.

South African authorities had to consider a new monetary policy framework for the country early in 1933 because the gold standard had been abandoned in 1932. It was decided to link the value of the domestic currency to that of the pound sterling, which implied, inter alia, that the Union of South Africa became part of the Sterling Area. At the outbreak of World War II in 1939 South Africa retained its membership of the Sterling Area and the country accepted the exchange control arrangements pertaining to Sterling Area countries. Domestic monetary policy was also supplemented by an extensive system of direct control measures to curb inflationary pressures during the war. At the end of World War II South Africa became part of the international exchange rate system agreed upon in terms of the Bretton Woods agreement, which implied that the external value of the currency and exchange rate stability remained the primary focus of monetary policy, but at the same time retained its membership and the exchange controls of the Sterling Area. In terms of the Bretton Woods agreement of

fixed (but adjustable) exchange rates, the US dollar served as anchor currency for the international exchange rate system. The value of currencies was linked to the US dollar which was, in turn, linked to gold at a fixed price of US\$35 per fine ounce.

South Africa left the Commonwealth when the country became the independent Republic of South Africa on 31 May 1961. A new decimal currency system with R2, 00 equal to £1 was introduced in February 1961, replacing the previous system comprising the pound, shilling and pence (£/s/d). Exchange control measures initially introduced in terms of the Sterling Area agreement were expanded and adapted for South Africa's unique circumstances, with the introduction of restrictions on foreign investment by residents and on the repatriation of domestic investments by non-residents. In addition, South Africa adopted direct monetary controls aimed at limiting credit demand by the middle of the 1960s, which included the use of credit controls, credit ceilings and deposit rate control.

The Bretton Woods agreement collapsed in 1971 after inflationary pressures had developed in the US in the wake of the Vietnam War. In reaction to the collapse of the Bretton Woods agreement, major industrialised countries introduced a system of floating exchange rates. South Africa pegged the exchange rate of its domestic currency initially to the pound sterling, then to the US dollar, then to a basket of currencies, and then again to the US dollar (although at varying levels after formal devaluations in December 1971 and in September 1975), before a system of managed floating was introduced from January 1979.

Despite the strong value of the currency, it was the system of Apartheid in South Africa that caused the rand to lose its footing on the global market. In June 1974 the South African authorities decided to delink the rand from the dollar, and introduced a policy of independently managed floating. At the time, the rand was trading at 87 cents to the dollar. In the 1980, there was a significant boom in the value of gold, which strengthened the rand's value. However, the value of the rand began to decline alongside the drop in value of gold. In 1983, the Apartheid government abolished the financial rand exchange rate system and key international banks refused to renew credit lines for South Africa, which forced the temporary closure of the foreign-exchange market in the country. In 1985, the rand was at its worst level versus the dollar since its inception, at R2.23.

After democratic elections in 1994 in South Africa some normality returned to South Africa's international relations and the authorities announced a policy of gradually abolishing exchange controls. The exchange rate of the rand against the US dollar has remained in a long-term downward trend that commenced in the early 1980s. The rand/dollar exchange in post-apartheid South Africa had been largely impacted by national and international social, political and economic trends, which have remained in decline.

Political uncertainty surrounding the new government in the country saw the rand weaken to an average R3.55 versus the dollar in 1994. In 1995 the financial rand, an investment currency for non-residents, was abolished. At the next presidential elections in 1999, the election of Thabo Mbeki as president sent the rand's value to an average of R6.11.

The controversial land reform programme that was kicked off in Zimbabwe, followed by the September 11, 2001 attacks on the world trade center in the USA, propelled the rand to its weakest historical level of R 13.84 to the dollar in December 2001. This sudden depreciation in 2001 led to a formal investigation, which in turn led to a dramatic recovery. By the end of 2002, the currency was trading under R 9 to the dollar again, and by the end of 2004 was trading under R 5.70 to the dollar. The currency softened somewhat in 2005, and was trading around R 6.35 to the dollar at the end of the year. At the start of 2006, however, the currency resumed its rally, and as of 19 January 2006, was trading under R 6 to the dollar again. However, during the second and third quarters of 2006 (i.e. April through September), the rand weakened significantly.

Local events, such as increasing debt, socio-political unrest and energy issues have kept the rand in a weakened position. Eskom's power crisis in 2007 caused major issues in the mining and telecommunications sector, ultimately leading to massive production cuts and mine closures. This caused the rand's value to spike up from just above R6 to the dollar in 2006, to over R7 in 2007. By the end of 2014, the rand had weakened to R 15.05 per dollar, partly due to South Africa's consistent trade account deficit with the rest of the world.

The financial crisis of 2007/2008 further exposed the volatile nature of the rand as it depreciated slightly as a result of declining equity inflow, decline in foreign direct

investments (FDI), and a huge current account deficit as a result of an enormous trade deficit. Most recently, the European sovereign debt crisis, which is an extension of the global recession which followed the global financial crisis, has had a massive impact on the global economy and, by extension, the local currency.

In a bid to solve the problems that arose from the global financial crisis, the US Federal Reserve bank, European Central bank, Bank of Japan, and Bank of England decided to embark on a process of quantitative easing. Quantitative easing (QE) is a monetary tool employed infrequently by central banks to save commercial activities by pumping money into the economy, which influences prices and output when short-term interest rates are extremely low (near zero). The effect of QE on South Africa and other emerging economies was increased capital flows and appreciation of local currencies which, in turn, weakened their export competitiveness. A downside was higher exchange rate volatility and fear of inflationary pressure. Tapering, (reducing the pace of monthly assets purchase during QE), was announced to begin for May and June 2013 which almost led to a turnaround in the benefits enjoyed by the emerging markets, South Africa being one. Weakened currency, fall in stock markets, drastic rise in domestic interest rate, and portfolio outflow were a few the effects (SARB (2011) Bronkhorst (2012) Ncube (2014) Rai and Suchanek (2014)).

### **3.5. Conclusion**

This chapter discussed some of the empirical work done in the field of exchange rate prediction. The main focus was on those with a monetary approach to exchange rate determination and also included some empirical backing for including commodity prices. The chapter went further to briefly explain the South African experience in exchange rate fluctuation and discussed the downward trend of the exchange rate, especially against the US dollar. The real side of the exchange rate volatility was also highlighted in this chapter, with a brief explanation of how the exchange rate has been influenced by both internal and external forces from as early as 1919, with its gold standard practice, up until today, with fluctuating commodity prices and international economic policies.

## CHAPTER FOUR

### MODEL SPECIFICATION AND RESEARCH METHODOLOGY

#### 4.0. Introduction

As outlined in chapter one, the main objective of this study is to forecast using econometric models the exchange rate between the South African Rand (R) and its major trading currency- the United States Dollar. The study does so by analysing monthly time series data for the period 1980-2016 using EViews 9.

In light of the study's objective, this chapter discusses relevant statistical estimation concepts, techniques and the econometric specification of the models to be used for estimation in chapter five. This chapter is presented in three sections that cover time series statistical estimation methodology and model specification respectively. Under section 4.1, subsection 4.1.1 gives an account of the issues surrounding stationarity, including its definition, spurious regression issues, the procedure for stationarity testing and various types of stationarity tests. Subsection 4.1.2 presents the concept of cointegration analysis. Subsection 4.1.3 explores vector autoregressive modelling techniques, followed by the vector error correction model discussion in subsection 4.1.4.

The model specification of the study is given in section 4.2, which provides an outline of the theoretical framework, and presents and describes the variables selected for estimation in chapter five and, their respective sources. Included under model specification is the description of the data that is to be used to estimate the three models, viz., the Taylor based exchange rate function, the Johansen VECM and a naïve Random Walk model. Lastly, data issues and transformation are discussed.

Section 4.3. discusses issues around forecasting using the 3 highlighted models. The process of out-of-sample forecasts is discussed with relevant tests to test the accuracy of the forecasting model.

## 4.1. Time Series Methodology of Estimation

In order to address the research hypotheses presented in chapter 1 section 1.3, the relevant time series background and requisite estimation techniques are discussed in the following sub sections. Time series data used in the econometric models are a set of observations on the values that a variable takes at different times. Such data is collected at regular time intervals, unlike the cross sectional data in which one or more variables are collected at the same point in time (Gujarati and Porter, 2009, Gujarati, 2004). This study firstly carried out a preliminary examination of the data series. Descriptive statistical analysis (see section 4.2.1, below) is essential because it enables one to examine the basic features of the variables used, i.e. whether a given data set approximates normal distribution (Pindyck and Rubinfeld, 1998).

### 4.1.1. Stationary and Non-stationary in Time Series

Theoretically, a time series is a collection of random variables ordered in time called a stochastic process (Gujarati and Porter, 2009). A stochastic process whose mean and variance are constant over time and value of the covariance between the two time periods does not depend on the actual time in which the covariance is computed but on the distance or lag between the two time periods and is said to be stationary. In a basic data generating process, suppose the current value of  $Y$  depends on its preceding value  $Y_{t-1}$  and a white noise error term (random shock)  $\mu_t$  that is normally distributed with zero mean and variance  $\sigma^2$ , then the conditions of stationarity hold when:

$$\text{Mean:} \quad E(Y_t) = \mu \quad (4.1)$$

$$\text{Variance:} \quad \text{var}(Y_t) = E(Y_t - \mu)^2 = \sigma^2 \quad (4.2)$$

$$\text{Covariance } (Y_t, Y_{t+k}): \quad \gamma_k = E[(Y_t - \mu)(Y_{t+k} - \mu)] \quad (4.3)$$

Where  $E(Y_t)$ , and  $\text{var}(Y_t)$  are constant and finite and  $(Y_t, Y_{t+k})$  are constant for all  $t$  and all  $k \neq 0$ .  $\gamma_k$  the covariance at lag  $k$ , which is the covariance (time difference) between the values of  $Y_t$  and  $Y_{t+k}$ . If therefore,  $k = 0$  then  $\gamma_0 = \sigma^2$

For a time series data set to be described as stationary, its mean, variance and covariance (at various lags) remain the same no matter at what point they are measured, meaning that, they are time invariant. For example, for a data set that moves from  $Y$  to  $Y_t$  up to  $Y_{t+z}$ ,  $Y_t$  is said to be stationary if the mean, variance and covariance is the same at  $Y_{t+z}$  as it is at  $Y_t$ . The series will always fluctuate around the mean because of its finite variance; this is a term called mean reversion.

According to Gujarati (2004), the weak definition of stationary often holds in practice. A stationary series allows for achievement of significant sample statistics crucial for forecasting future behaviour. Although a stationary series is desired it is not uncommon to encounter a non-stationary time series. A stochastic process is non-stationary if it fails to fulfil any of the above-mentioned conditions. While a stationary time series returns to its mean and fluctuates around it with reasonably constant amplitude, a non-stationary series will have different means at different time segments.

A non-stationary time series is also characterised by a variance that is time-dependent and goes to infinity as time approaches infinity (Engle and Granger, 1987). Consequently, the variance of this variable will become infinitely large as time approaches infinity. The classic example as used by Gujarati and Porter (2009) is the **Random walk model (RWM)**. The RWM being a subset of the EMH (chapter 2, section 2.3.5) may be classified into three types of RWM, (i) a random walk without drift (that is, no constant and intercept term), (ii) a random walk with drift (that is, a constant term present), and (iii) random walk with drift and trend

To highlight the principle of **a random walk without drift**, the series  $Y_t$  is said to be a random walk if:

$$Y_t = Y_{t-1} + u_t \quad (4.4)$$

Where the current value of  $Y$  depends on its preceding value  $Y_{t-1}$  and  $u_t$  (assuming it is white noise error term (random shock) with mean 0 and variance  $\sigma^2$ ). If the initial value of  $Y$  is  $Y_0$ , by successive substitution in equation (4.4), it can be shown that:

$$Y_t = Y_0 + \sum u_t \quad (4.5)$$

Therefore

$$E(Y_t) = E(Y_0 + \sum u_t) = Y_0 \quad (4.6)$$

In other words

$$\text{var}(Y_t) = t\sigma^2 \quad (4.7)$$

In principle, the mean of  $Y$  is equal to its initial value, but as the  $t$  time horizon rises the variance of  $Y$  also increases indefinitely, therefore making it a non-stationary stochastic process because a condition of stationarity has been violated.

For a **random walk with drift**, consider equation (4.8)

$$Y_t = \delta + Y_{t-1} + u_t \quad (4.8)$$

where  $Y_t$  is determined by  $\delta$  which is the drift parameter, an intercept in the random walk model, and  $u_t$  is the white noise error term.

For this type of random walk model, it can be shown in equations (4.9) and (4.10) that both the mean and variance increase over time, causing  $Y$  to drift away from its initial value, meaning that conditions of stationarity are violated.

$$E(Y_t) = Y_0 + \delta t \quad (4.9)$$

$$\text{var}(Y_t) = t\sigma^2 \quad (4.10)$$

A **deterministic trend process (random walk with drift and trend)** can be given as:

$$Y_t = \delta + \beta t + u_t \quad (4.11)$$

where  $u_t$  is the white noise error term. With this process, the mean varies while the variance is constant.

Analytical challenges arise with non-stationary time series. The behaviour of these series can only be studied for one period at a time. Therefore, it cannot be comprehensive to explain behaviour in other time periods, which renders it unfeasible for forecasting purposes. In addition, the estimation of non-stationary time series may also yield unreliable and spurious regression results. Spurious results arise due to various series exhibiting common long-run trends, and regression methodologies falsely ascribing these trends as being valid long-run relationships between variables without there being any economically justifiable relationships between the series in question (Gujarati and Porter, 2009). For these reasons it is crucial to test for

stationarity before any empirical estimation is done to apprehend the underlying data generating process for application of the suitable methodology.

#### **4.1.1.1. Stationarity Testing**

The literature recognises three approaches in which stationarity of a time series can be tested, which are: (1) graphical analysis, (2) correlogram, and (3) unit root analysis. This dissertation employs both graphical and unit root analysis testing in chapter five to test for stationarity.

##### **4.1.1.1.1. Graphical analysis**

Examining stationarity by means of plotting a time series and its accompanying correlogram before pursuing more formal methods of testing for stationarity is considered to be a prerequisite for any stationarity test as it gives an intuitive feel for the nature of the given series.

##### **4.1.1.1.2. Unit Root tests**

Unit root testing is the most commonly used formal approach to examining the nature of time series. Proposed by Dickey and Fuller (1979) (1981), this method involves checking for statistically significant differences of the parameters in the equation. Unit root tests are conducted by running a simple random walk regression such as the one in equation (4.5) for all the time series variables defined in a given econometric model. The aim of the test is to check whether  $\rho = 1$  (i.e., there is a unit root). The equation can also be written as in (4.12) and (4.13) when  $Y_{t-1}$  is subtracted from both sides:

$$Y_t - Y_{t-1} = \rho Y_{t-1} - Y_{t-1} + u_t \quad (4.12)$$

which can be simplified as:

$$\Delta Y_t = \delta Y_{t-1} + u_t \quad (4.13)$$

where  $\delta = (\rho-1)$  and  $\Delta$  is the first difference operator.

Dickey and Fuller (1979) proposed two substitute regression equations for testing the presence of a unit root:

1. Random Walk with drift, contains a constant but no trend:

$$\Delta Y_t = \beta_1 + \delta Y_{t-1} + u_t \quad (4.14)$$

2. Random Walk with drift around a deterministic trend:

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + u_t \quad (4.15)$$

Where

$u_t$  = white noise error term

$t$  = time or trend variable.

One can test for the presence of a unit root, or its lack thereof, through the use of hypothesis testing.

The null and alternative hypotheses are presented as:

Null hypothesis:  $H_0: \delta = 0$  or  $\rho = 1$  (i.e., there is a unit root;  $Y_t$  is non-stationary)

Alternative hypothesis:  $H_1: \delta < 0$  or  $\rho < 1$  (i.e., there is no unit root;  $Y_t$  is stationary)

In estimating equations (4.13), (4.14) and (4.15) using ordinary least squares (OLS), one can simply take the first differences of  $Y_t$  and regress them on  $Y_{t-1}$  to see if the estimated slope coefficient in this regression ( $\hat{\delta}$ ) is zero or not. If it is zero we conclude that  $Y_t$  is non-stationary, but if negative it is stationary. However, this method does not adequately estimate the equations, so one has to follow an alternative route.

The unit root hypothesis testing can be done using the Dickey-Fuller (DF) test. This is done by comparing the tabulated or electronically generated (by statistical packages) tau ( $\tau$ ) statistic against the computed  $\tau$ -statistic found by dividing  $\delta$  or  $\rho$  coefficients by their respective standard errors to obtain  $\tau\delta$  or  $\tau\rho$ . If the computed absolute value of  $\tau$  exceeds the critical  $\tau$ -statistic value, the null hypothesis  $\delta = 0$  or  $\rho = 1$  should be rejected in favour of the alternative; thus, the series is stationary or has no unit root. However, if the computed absolute value of  $\tau$  does not exceed the critical  $\tau$ -statistic value, the null hypothesis should not be rejected; thus, the series is non-stationary or

has unit root (Gujarati and Porter, 2009). Notably, a more widespread set of critical values may be found in MacKinnon (1996), which is also used by numerous statistical packages, including EViews 9.

The DF test of unit root discussed above is conducted under the assumption that the error terms  $u_t$  were uncorrelated. In a case where the  $u_t$  are correlated, Dickey and Fuller (1981) developed another test known as the augmented Dickey-Fuller (ADF) test. This extension is an augmented version of the test where extra lagged terms of the dependent variable are included in order to eliminate autocorrelation. Similar to the DF test, the three alternative regression equations for testing the presence of a unit root using the augmented Dickey Fuller (ADF) test are:

$$\Delta Y_t = \delta Y_{t-1} + \sum_{i=1}^m \alpha_i \Delta Y_{t-i} + \varepsilon_t \quad (4.16)$$

$$\Delta Y_t = \beta_1 + \delta Y_{t-1} + \sum_{i=1}^m \alpha_i \Delta Y_{t-1} + \varepsilon_t \quad (4.17)$$

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \sum_{i=1}^m \alpha_i \Delta Y_{t-1} + \varepsilon_t \quad (4.18)$$

where

$\varepsilon_t$  = pure white noise error term

$\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$ ,  $\Delta Y_{t-2} = (Y_{t-2} - Y_{t-3})$ , etc.

The number of lagged differenced terms to be included is often empirically determined by either the Akaike Information Criterion (AIC) or the Schwarz Bayesian Criterion (SBC) found on the EViews program. The aim is to introduce enough lagged difference terms until the error term is serially uncorrelated. As in the case of the DF test, the usual DF  $\tau$ -statistic is also applicable to the ADF test for the unit root hypothesis testing method discussed.

Another unit root testing procedure that is commonly used is the Phillips-Perron (PP) test. The PP test uses nonparametric statistical methods to take care of the serial correlation error terms without adding lagged difference terms. This is in contrast to the ADF test which adjusts the DF to take care of possible serial correlation in error terms by adding the lagged difference terms. However, the asymptotic distribution of the PP test is the same as the ADF test statistic (Gujarati and Porter, 2009).

#### 4.1.1.2. Remedial Measures

Owing to problems associated with non-stationary time series it is very important to transform these series into stationary time series in order to avoid problems arising from regressing non-stationary time series. The transformations required to make time series stationary depend on the nature of the series in question (Gujarati and Porter, 2009).

If a non-stationary time series becomes stationary after differencing, the series is a difference stationary process (DSP). Additionally, if a time series is rendered stationary after differencing it once, it is said to be integrated at first order, denoted as  $I(1)$ . A  $I(2)$  series contains two unit roots and would require to be differenced twice in order to induce stationarity. However, if it has to be differenced  $d$  times to make it stationary, it is said to be integrated of order  $d$ , denoted as  $I(d)$  (Asteriou and Hall, 2007, Verbeek, 2004). Consequently, a stationary time series is integrated of zero order (i.e.,  $I(0)$ ) since it does not require any differencing (Gujarati, 2004, 2012). Notably, most empirical statistical methods are based on the assumption that time series data tend to have the property of being  $I(1)$  and, upon first differences, are rendered stationary or  $I(0)$ , illustrated as:

$$\Delta Y_t = \delta Y_{t-1} + e_t \quad (4.19)$$

If  $\delta < 0$ , then series  $Y_t$  is  $I(1)$ ,  $\Delta Y_t$  is  $I(0)$

If a non-stationary time series is found to contain a deterministic trend, the appropriate transformation method to render the non-stationary time series stationary would be to detrend the series by regressing it on time. Such a series is called a trend stationary process (TSP). In other words, we run the following regression:

$$Y_t = \beta_1 + \beta_2 t + u_t \quad (4.20)$$

where

$Y_t$  = the time series under study

$t$  = trend variable,

given:

$$\hat{u}_t = (Y_t - \hat{\beta}_1 - \hat{\beta}_2 t) \quad (4.21)$$

which is now stationary.  $\hat{u}_t$  is known as a (linearly) detrended time series.

In light of the significance of stationarity testing, this study makes use of both the ADF and PP tests, but in a case where the two tests are contradictory, the Kwiatkowski-Phillips Schmidt-Shin (KPSS) test has been used as a confirmatory measure (discussed in the appendix). Generally, the KPSS test is used to assess the null hypothesis that a time series is stationary and often gives results contrary to those of the unit tests with the unit root as a null (DF, ADF and PP tests) (Asteriou and Hall, 2007).

#### 4.1.2. Cointegration

Time series data are said to be cointegrated if two or more  $I(1)$  series have their regression errors at  $I(0)$  and OLS regression of the model can be run without the possibility of encountering unreliable and invalid results caused by spurious regressions. The method of cointegration, introduced by Granger (1981) and elaborated further by Engle and Granger (1987), enables researchers to find sense in estimating non-stationary variables as it specifies that although two (or more) series encompass stochastic trends, if they have a long-run equilibrium, or relationship, they will move closer together over time and their differences will eventually stabilise, thus, forming a stationary series (Thomas, 1997). Therefore, the spurious regression problem is resolved. Following Asteriou and Hall (2007) and Verbeek (2004), consider two sets of  $I(1)$  series,  $Y_t$  and  $X_t$ , and suppose there is a linear combination of  $Y_t$  and  $X_t$

$$Y_t = \beta_1 + \beta_2 X_t + u_t \quad (4.22)$$

taking the residuals:  $\hat{u}_t = Y_t - \hat{\beta}_1 - \hat{\beta}_2 X_t \quad (4.23)$

If  $\hat{u}_t \sim I(0)$ , that is, stationary, then  $Y_t$  and  $X_t$  are cointegrated. Engle and Granger (1987) formally define cointegration by stating that time series  $Y_t$  and  $X_t$  are  $I(d, b)$  where  $d \geq b \geq 0$ , denoted as  $Y_t, X_t \sim CI(d, b)$ . If  $Y_t$  and  $X_t$  are  $I(d)$  and there exists a

vector  $(\beta_1, \beta_2)$ , which gives a linear combination of  $Y_t$  and  $X_t$ , such that  $\beta_1 Y_t + \beta_2 X_t \sim I(d - b)$ . The coefficient vector  $(\beta_1, \beta_2)$  is called a cointegrating vector.

#### 4.1.2.1. Testing for Cointegration

According to Kennedy (2008), there are three means by which cointegration can be tested, namely the single equation, vector autoregressive, and error correction approaches. The single equation cointegration approach (which includes tests such as the autoregressive distributed lag bounds testing approach, the Engle-Granger and augmented Engle-Granger, the cointegrating regression Durbin-Watson, the dynamic ordinary least squares, the fully-modified ordinary least squares, and canonical cointegrating regressions tests), typically checks for unit roots in the cointegrating regression residuals. The vector autoregressive approach alternatively determines the number of cointegrating relations and estimates the matrix of cointegrating vectors, whereas the error correction approach examines the coefficient of the error correction term against zero, which is a condition of the Granger representation theorem.

According to Enders (2004), the three most important and popular procedures used to test for cointegration are the Engle-Granger (1987), Johansen (1988) and Stock-Watson (1988) methodologies. For the purpose of this study, the Johansen Test model was used to determine whether a long-run relationship exists in the proposed model.

##### 4.1.2.1.1. The Engle-Granger (EG) and Augmented Engle-Granger (AEG) Tests

The main goal of the EG test is to determine whether the series being considered are cointegrated by investigating the properties of the residuals. Should the residuals be stationary, then the series are cointegrated. This test involves firstly confirming the order of integration of each time series variable via unit root testing, specifically the DF and ADF tests. Once this has been proven and the variables are found to be integrated of the same order, the hypothesised long-run equilibrium or relationship (given in equation (4.22), for example) is then estimated via OLS and the estimated

residuals are retained and tested for stationarity. Equations (4.35) and (4.36) respectively present the DF and ADF test equations of the estimated residuals.

$$Y_t = \beta_1 + \beta_2 X_t + e_t \quad (4.24)$$

$$\Delta \hat{e}_t = a_1 \hat{e}_{t-1} + v_t \quad (4.25)$$

$$\Delta \hat{e}_t = a_1 \hat{e}_{t-1} + \sum_{i=1}^n \delta_i \Delta + w_t \quad (4.26)$$

where

$\Delta$  = the first difference operator

$e_t$  = the residual from the cointegrating regression

$v_t$  and  $w_t$  = the random error terms

As in the DF, ADF and PP tests, the hypothesis testing in the EG and AEG tests is conducted in the same manner. The null and alternative hypotheses are presented as:

$H_0: a = 0$  (i.e., no cointegration)

$H_1: a < 0$  (i.e., cointegration exists)

These hypotheses are tested by comparing the test statistic on the regression coefficient to a special set of critical values depending on the number of explanatory variables in the cointegrating regression computed by Engle and Granger (1987). If  $e_t$  is found to be (0) then  $H_0$  is rejected in favour of  $H_1$ , thus  $Y_t$  and  $X_t$  are cointegrated.

The EG approach is praised for its simplicity, but this method contains a few shortcomings. The EG approach may be misleading if structural breaks are present in the data as it has low power in finite samples. Another problem of this approach is that errors made in the first step of the EG test are carried on to the second step, thus resulting in autocorrelation and therefore the long-run relationship estimates will be biased in finite samples. These drawbacks can be addressed with the use of alternative approaches, some of which are employed by the study. (Asteriou and Hall, 2007, Gujarati and Porter, 2009, Koop, 2013).

#### 4.1.2.1.2. The Johansen Test

With more than two variables in a model there is the possibility of having more than one cointegrating relationship. Therefore, an approach that allows the simultaneous evaluation of multiple relationships is needed, and the Johansen approach does just that. This approach, developed by Johansen (1988) and extended by Johansen and Juselius (1990) (1992, 1994), uses the maximum likelihood tests to check for the cointegration rank for a VAR process. The Johansen cointegration approach allows hypothesis testing to be performed directly on the cointegrating relationships and imposes no prior restrictions on the cointegration space. (Kennedy, 2008)

The Johansen test first investigates the order of integration of each time series variable in the regression through unit root testing. When all variables are found to be cointegrated and in same order the next step is to select the optimal lag length, which is generated via a VAR model estimation process. Prior to estimating a VAR or VECM it is standard practice to first determine the selection of unrestricted VAR order ( $p$ ). The optimal number of lags to be included in the cointegration test and succeeding VAR or VECM model are identified by the Akaike information criterion (AIC), Schwarz information criterion (SIC), Hannan-Quinn information criteria (HQ), the sequential modified likelihood ratio test (LR), and the Final prediction error tests (FPE) as the VAR and VECM methodologies are sensitive to lag lengths. In determining the lag length, the general- to- specific methodology is used. That is, the unrestricted VAR is estimated with all variables in levels with a maximum number of lags, reducing down by re-estimating the model for one lag less until significantly different from zero (Asteriou and Hall, 2007, Enders, 2010).

The third step involves determining the appropriate model regarding the deterministic component in the multivariate system and determine the rank of the number of cointegrating vectors by using the trace and maximum likelihood ratio tests (Asteriou and Hall, 2007, Enders, 2004).

Johansen (1988) proposed the trace and maximum eigenvalue likelihood ratio tests to determine the significance of these recognized correlations. These test statistics are formulated as:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^n \ln(1 - \hat{\lambda}_i) \quad (4.27)$$

$$\lambda_{\max}(r, r + 1) = -T \ln(1 - \hat{\lambda}_{r+1}) \quad (4.28)$$

where

$\lambda$  = the estimated value for the  $i$ th ordered eigenvalue from the long-run coefficient matrix

$T$  = the number of usable observations.

The  $\lambda$ trace statistic tests the null hypothesis that the number of cointegrating vectors is less than or equal to  $r$  (the number of cointegrating relationships) against an unspecified alternative hypothesis. Alternatively, the  $\lambda$ max statistic tests the null hypothesis that the number of cointegrating vectors against an alternative of  $r + 1$  cointegrating vectors. The further the eigenvalues are from zero, the more negative is  $\ln(1 - \lambda_i)$  and  $\ln(1 - \hat{\lambda}_{r+1})$  and the larger the  $\lambda$ trace and  $\lambda$ max statistics, respectively. The trace test is believed to be superior as it can be adjusted for degrees of freedom and is more robust to skewness and excess kurtosis.

#### 4.1.3. Vector Autoregressive (VAR) Model

VAR methodology's ability to handle simultaneous-equation models in which several endogenous variables are considered together makes it a preferred method in macroeconomic time series analysis. According to Sims (1980), in instances where there is simultaneity among variables, there should not be any a priori distinction between endogenous and exogenous variables. Thus, all variables are treated as endogenous and each equation should have an equal number of regressors, leading to the development of the VAR approach. Each endogenous variable is explained by its lagged /past values and the lagged values of all other endogenous variables in the model. In addition, the only equations that can be estimated are the reduced-form equations in which the exogenous/regressors variables are all lagged values of the endogenous variable (Asteriou and Hall, 2007, Kennedy, 2008, Gujarati and Porter, 2009). One of the major requirements for using the VAR is that all the variables be stationary as it is mainly used to establish the short-run relationship among variables. If some of the variables contain unit roots, the variables should be differenced. The

resulting stationary variables can then be used in a VAR model (Koop, 2008). Conversely, Sims (1980) argued that differencing and de-trending non-stationary variables leads to a loss of co-movement information within the data. Differencing could therefore be a futile exercise because the goal of VAR analysis is to examine interrelationships among variables and not the parameter estimates. Enders (2010) concurs with this notion, especially when a structural or primitive model is under investigation.

Enders (2010) therefore explains assuming that a model is made up of two (2) variables,  $Y_t$  and  $Z_t$ , where  $Y_t$  is affected by current and past values of  $Z_t$  and concurrently,  $Z_t$  is affected by current and past values of  $Y_t$ , the bivariate equations model is given by:

$$Y_t = \beta_{10} - \beta_{12}Z_t + \gamma_{11}Y_{t-1} + \gamma_{12}Z_{t-1} + u_{Yt} \quad (4.29)$$

$$Z_t = \beta_{20} - \beta_{21}Y_t + \gamma_{21}Y_{t-1} + \gamma_{22}Z_{t-1} + u_{Zt} \quad (4.30)$$

where  $Y_t$  and  $Z_t$  are stationary, and  $u_{Yt}$  and  $u_{Zt}$  are uncorrelated white noise terms. Both equations constitute a first-order VAR model since the longest lag is in unity. These equations are also said to be structural or primitive VAR equations as  $Y_t$  and  $Z_t$  have simultaneous impacts on each other respectively, given by  $-\beta_{12}$  and  $-\beta_{21}$ . Using matrix algebra, equations (4.29) and (4.30) can be written as:

$$\begin{bmatrix} 1 & \beta_{12} \\ \beta_{21} & 1 \end{bmatrix} \begin{bmatrix} Y_t \\ Z_t \end{bmatrix} = \begin{bmatrix} \beta_{10} \\ \beta_{20} \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix} \begin{bmatrix} Y_{t-1} \\ Z_{t-1} \end{bmatrix} + \begin{bmatrix} u_{Yt} \\ u_{Zt} \end{bmatrix} \quad (4.31)$$

$$\text{or } \beta X_t = \Gamma_0 + \Gamma_1 X_{t-1} + u_t \quad (4.32)$$

Because  $Y_t$  and  $Z_t$  are correlated with their respective errors  $u_{Yt}$  and  $u_{Zt}$  in equations (4.31) and (4.32), they do not meet the standard estimation techniques requirement necessitating that the regressors be uncorrelated with the error term, and in order to be estimated, restrictions must be imposed. According to Sims (1980) we need to make appropriate restrictions to the primitive system. One way to identify the model is to use a recursive VAR. Suppose a restriction that  $\beta_{21} = 0$  is imposed, which implies  $Y_t$  does not have a concurrent effect on  $X_t$ ,  $B^{-1}$  is given by:

$$B^{-1} = \begin{bmatrix} 1 & -\beta_{12} \\ 0 & 1 \end{bmatrix} \quad (4.33)$$

Pre-multiplying the original VAR by  $B^{-1}$  yields:

$$\begin{bmatrix} Y_t \\ Z_t \end{bmatrix} = \begin{bmatrix} \beta_{10} & -\beta_{12}\beta_{20} \\ & \beta_{20} \end{bmatrix} + \begin{bmatrix} \gamma_{11}-\beta_{12}\gamma_{21} & \gamma_{12}-\beta_{12}\gamma_{22} \\ & \gamma_{21} & \gamma_{22} \end{bmatrix} \begin{bmatrix} Y_{t-1} \\ Z_{t-1} \end{bmatrix} + \begin{bmatrix} \mu_{Yt} & -\beta_{12}u_{Zt} \\ & u_{Zt} \end{bmatrix} \quad (4.34)$$

Consequently, estimating the system (4.44) using OLS yields:

$$Y_t = a_{10} + a_{11}Y_{t-1} + a_{12}Z_{t-1} + e_{1t} \quad (4.35)$$

$$Z_t = a_{20} + a_{22}Y_{t-1} + a_{22}Z_{t-1} + e_{2t} \quad (4.36)$$

where:

$$a_{10} = \beta_{10} - \beta_{12}\beta_{20}; a_{11} = \gamma_{11} - \beta_{12}\gamma_{21}; a_{12} = \gamma_{12} - \beta_{12}\gamma_{22}; a_{20} = \beta_{20}; a_{20} = \beta_{20}; a_{21} = \gamma_{21}; a_{22} = \gamma_{22}$$

In equation (4.36), the  $\beta_{21} = 0$  restriction allows shocks of both  $u_{Yt}$  and  $u_{Zt}$  to simultaneously affect  $Y_t$ , but only  $u_{Zt}$  shocks affects the contemporaneous value of  $Z_t$ .

To obtain the VAR model in standard form, which requires no restriction for estimation, both sides of equation (4.34) are multiplied by  $B^{-1}$ , yielding equations (4.35) and (4.36) or simply allowing for standard form VAR model:

$$X_t = A_0 + A_1X_{t-1} + e_t \quad (4.37)$$

where  $A_0 = B^{-1}\Gamma_0$ ;  $A_1 = B^{-1}\Gamma_1$  and  $e_t = B^{-1}u_t$

It should be noted that the renditions presented above were accomplished on the basis of a bivariate first order VAR model purely for explanatory purposes. This study, however, employs a four-variable second order VAR model (see subsection 4.2).

#### 4.1.4. Vector Error Correction Model (VECM)

The VECM is a variant of the VAR model that includes an error correction mechanism (ECM) term (Koop, 2013). The presence of more than two variables gives rise to the possibility of more than one cointegrating relationship (Koop, 2008). The VECM'S ability to resolve spurious regression problems, fitting easily into the general-to-specific approach to econometric modelling and embedding an adjustment process that

prevents the errors in the long-run relationship from increasing, makes it one of the most commonly used econometric methods.

The VECM approach estimates a VAR model, taking into account the error correction mechanism and following the Granger's Representation Theorem (Engle and Granger, 1987). It involves 3 steps. The first step is to estimate the cointegrating relationships between the variables. In the second step, the residuals  $\varepsilon_t$  are obtained from the regression. Lastly, using the error terms, the equations are estimated (Gujarati, 2012).

Alternatively, according to Koop (2013), after first establishing the 'cointegration rank' or the number of cointegrating relationships using the Johansen test, the VECM in the case of two variables Y and X is given as:

$$\Delta Y_t = \varphi_1 + \delta_1 t + \lambda_1 e_{t-1} + \gamma_{11} \Delta Y_{t-1} + \dots + \gamma_{1p} \Delta Y_{t-p} + \omega_{11} \Delta X_{t-1} + \dots + \omega_{1q} \Delta X_{t-q} + \varepsilon_{1t} \quad (4.38)$$

$$\Delta X_t = \varphi_2 + \delta_2 t + \lambda_2 e_{t-1} + \gamma_{21} \Delta Y_{t-1} + \dots + \gamma_{2p} \Delta Y_{t-p} + \omega_{21} \Delta X_{t-1} + \dots + \omega_{2q} \Delta X_{t-q} + \varepsilon_{2t} \quad (4.39)$$

where  $e_{t-1} = Y_{t-1} - \alpha - \beta X_{t-1}$

The error correction variable can be derived by running an OLS regression of Y on X and saving the residuals. The other processes such lag length selection and forecasting can be done using the software package EViews 9.

**Table 4.1: Summary of methodology of estimation**

S/N	Tests	Instruments	Comments
1	Descriptive	Mean, median, minima, maxima, skewness, and kurtosis	To examine the basin features of the variables.
2	Unit root	Augmented Dickey Fuller (ADF), Phillips Perron (PP), and Kwiatkowski, Phillips, Schmidt, and Shin (KPSS)	To test for the order of integration of the variables so as to avoid spurious regression result.
3	Lag length	Akaike information criterion.	To determine the best or correctly specified equation.

4	Diagnostic checking	Normality test, heteroscedasticity test, and Breuch-Godfrey serial correlation test	To check for the robustness as well as if structural break has occurred.
5	Stability	AR root graph	To check for the appropriateness of the model.
6	Cointegration	Johansen-Juselius cointegration test	To check for the presence of long-run relationship among the variables in the model.
7	Causality/VECM	Vector error correction model	To distinguish between the long- run and short-run causality.

Source: Researcher

## 4.2. Model Specification

### 4.2.1. Models of Estimation

This section shall examine the models used in this research for the estimation of the US/R exchange rate. This research set out to forecast the US\$/R exchange rate using the augmented Taylor rule function proposed by Molodtsova and Papell (2009) and including the commodity price of gold. The commodity was chosen based on its composition of the SA commodity price index, that is, by geometrically weighting the world market price in US dollars of each major commodity export, as found in Rogoff and Chen (2002) (2003). In addition, although gold sales have fallen drastically due to a number of production issues, it still made 12, 5% of mineral sales in 2014 (STATSSA, 2015). The augmented Taylor rule when applied to the variables from the South African economy were statically insignificant; therefore, the researcher formulated a VAR/VECM model for forecasting. Both models were then compared to the random walk model using the root mean squared errors as a yardstick for measuring forecasting ability the models.

#### 4.2.1.1. Taylor Rule based Exchange Rate Model

The original form of the model is derived from the work of Molodtsova and Papell (2009) as discussed in chapter two, section 2.4 of this study. They derived the following exchange rate forecasting equation:

$$\Delta s_{t+1} = \omega - \omega_{\pi}\pi_t + \tilde{\omega}_{\pi}\tilde{\pi}_t - \omega_y y_t + \tilde{\omega}_y \tilde{y}_t - \omega i_{t-1} + \tilde{\omega} i_{t-1} + \tilde{\omega}_q \tilde{q}_t + \tilde{\omega}_g \tilde{g}_t + \eta_t \quad (4.40)$$

where

- $\sim$  = variables and coefficients for SA
- $q_t$  = natural log of the real exchange rate defined by  $q_t = s_t + p_t - p_t^*$  where  $p_t^*$  stands for the natural log of US CPI
- $\Delta s_{t+1} = s_{t+1} - s_t$
- $s_t$  = natural log of the nominal exchange rate, defined as the US dollar price of one unit of domestic currency so that an increase in  $s_t$  is a depreciation of the US dollar
- $\pi_t$  = inflation rate given by  $\ln(CPI_t) - \ln(CPI_{t-12})$
- $y_t$  = output gap (GDP) (percentage deviation from the trend, using a HP filter)
- $i_{t-1}$  = lagged SA short-term interest rates (90-day treasury bill rate)
- $g_t$ : = natural log of international price of SA gold

Equation (4.40) is a simple linear equation which describes the adjustment of the bilateral dollar-rand exchange rate to Taylor Rule fundamentals which were outlined in chapter 2, section 2.4.

For this research, the decision is to estimate the real exchange rate as opposed to estimating the change in the nominal exchange rate. Therefore, the exchange rate forecasting equation applied is stated as:

$$q_t = \omega - \omega_{\pi}\pi_t + \tilde{\omega}_{\pi}\tilde{\pi}_t - \omega_y y_t + \tilde{\omega}_y \tilde{y}_t - \omega i_{t-1} + \tilde{\omega} i_{t-1} + \tilde{\omega}_q \tilde{q}_{t-1} + \tilde{\omega}_g \tilde{g}_t + \eta_t \quad (4.41)$$

#### 4.2.1.2. VAR/VECM Exchange Rate Model Estimation

In order to address the research hypotheses presented in the first chapter, estimation techniques discussed in the previous section are employed. For the purpose of this study, equation (4.41) is estimated using VAR, VECM techniques. The dynamics between exchange rates and the variables in the model can be analysed using the following VAR( $p$ ) model:

$$\ln Y_t = a_0 + \sum_{i=1}^p \theta_i \ln Y_{t-1} + u_t \quad (4.42)$$

where

$Y_t = k \times 1$  vector for all four endogenous variables, that is, real exchange rate, gold prices, SA CPI, SA short term (90 day) interest rates

$a_0$ =intercept coefficients

$\theta_i = k \times k$  coefficient matrices for all regressors

$p$ = the VAR order or lag length

$u_t$ = a vector of independently distributed error terms

The above VAR model can only be estimated in that form if all variables are  $I(0)$ . Should the variables be either  $I(1)$  or  $I(2)$  and cointegrated, the VECM presentation of the model is given as:

$$\Delta \ln Y_t = a_0 + \Pi \ln Y_{t-1} + \sum_{t=1}^{p-1} \Phi_i \Delta \ln Y_{t-1} + u_t \quad (4.43)$$

where

$\Delta$  = first difference parameter

$Y_t = k \times 1$  vector for all endogenous variables

$\Pi = k \times k$  long-run multiplier matrix

$\Phi = k \times k$  coefficient matrices describing the short-run dynamic effects

$p$ = VAR order or lag length and

$u_t$  = vector of independently and identically distributed innovations with zero mean.

### 4.2.1.3. Random Walk Model

The third model being estimated and used as a yardstick for measuring forecasting abilities of the other two models is the Random walk model. This has been sufficiently explained previously in section 4.1.1. We shall however compare the models with the random walk with drift in accordance with Meese and Rogoff (1983) which is stated in equation 4.8. as:

$$Y_t = \delta + Y_{t-1} + u_t \quad (4.8) \quad (4.44)$$

where

$Y_t$  is determined by  $\delta$  which is the drift parameter, being an intercept in the random walk model

$u_t$  = white noise error term.

### 4.2.2. Model Diagnostic Inspection

Diagnostic testing is applied to check for the stability and robustness of the models. The diagnostic test employed in this study includes autocorrelation, normality, heteroscedasticity and stability tests. The presence of serial correlation and heteroscedasticity violates the classical assumptions of the OLS and hence invalidates the statistical validity of parameter estimates.

#### 4.2.2.1. Autocorrelation Test

The study conducts diagnostics tests such as the Breusch-Godfrey test to check the null hypothesis of no autocorrelation, instead of the Durbin Watson test, which loses its power in the presence of a lagged dependent variable. It also does not take into account higher order serial correlation, which is a common problem in regression analysis involving time series analysis (Gujarati and Porter, 2009, Asteriou and Hall, 2007). It must be noted that one of the assumptions of the classical linear regression model is that the error term  $\mu_t$  is uncorrelated, that is to say the error term at time  $t$  is not correlated with the error at time  $t - 1$  and any other term in the past. If the error

terms are correlated, the estimator becomes inefficient and may lead to a spurious regression result. Considering the model in Equation (4.45) below:

$$Y_t = \beta_1 + \beta_2 X_{2t} + \beta_3 X_{3t} + \dots + \beta_k X_{kt} + \mu_t \quad (4.45)$$

where

$$\mu_t = \rho_1 \mu_{t-1} + \rho_2 \mu_{t-2} + \dots + \rho_n \mu_{t-n} + \varepsilon_t \quad (4.46)$$

the Breusch-Godfrey LM test combines the two equations:

$$Y_t = \beta_1 + \beta_2 X_{2t} + \beta_3 X_{3t} + \dots + \beta_k X_{kt} + \rho_1 \mu_{t-1} + \rho_2 \mu_{t-2} + \dots + \rho_n \mu_{t-n} + \varepsilon_t \quad (4.47)$$

Therefore, the null and alternative hypotheses are:

$$H_0: \rho_1 = \rho_2 = \dots \rho_n = 0 \text{ no serial correlation}$$

$H_1$ : At least one of the  $\rho$ s is not zero, which implies that there is serial correlation.

#### 4.2.2.2. Normality Test

According to Gujarati (2012), a normality assumption ( $\mu_t \sim N(0, \sigma^2)$ ) is required in order to conduct single or joint hypothesis testing about model parameters. The Jarque-Bera (JB) test of normality is an asymptotic test based on the OLS residuals. This test formalises the idea of joint hypothesis by testing if the coefficient of kurtosis and coefficient of skewness are jointly zero. It is a weighted average of the squared sample moments corresponding to skewness and excess kurtosis. Skewness is the extent to which the distribution is asymmetric: that is, one side of the distribution is not a mirror image of the other. It is estimated by the coefficient of skewness:

$$S = \frac{\sum(Y_i - \bar{Y})^3 / n - 1}{s^3} \quad (4.48)$$

where the denominator  $s$  is the standard deviation. Kurtosis on the other hand refers to the peakedness of the distribution. It is estimated by the coefficient of kurtosis:

$$K = \frac{\sum(Y_i - \bar{Y})^4 / n - 1}{s^4} \quad (4.49)$$

The JB test first computes the skewness and kurtosis measures of the residuals and uses the following test statistics:

$$JB = n \left[ \frac{s^2}{6} + \frac{(k-3)^2}{24} \right] \quad (4.50)$$

where  $n$ =sample size,  $s$ =skewness coefficient, and  $k$ =kurtosis. For a normally distributed variable,  $s=0$ , and  $k=3$ .

Under the null hypothesis of a normally distributed error, the residuals are normally distributed and the JB statistic has a Chi-Squared distribution with two degrees of freedom. The histogram should be bell-shaped and the JB should not be significant, i.e. the p-value should be larger than 0.05.

#### 4.2.2.3. Heteroscedasticity Test

The assumption of the classical linear regression model of a constant (equal) variance and independent of  $i$ , which is illustrated in Equation 4.51 below:

$$var(u_i) = \sigma^2 \quad (4.51)$$

Therefore, having equal variance means that the disturbances are homoscedastic. But it is quite common for this assumption to be violated in regression analysis. In such cases where the homoscedasticity assumption is violated, the variance of the error depends on each of the observation in the sample, i.e.:

$$var(u_i) = \sigma_i^2 \quad (4.52)$$

$i = 1, 2, 3, 4, \dots, n$

The study tests the null and alternative hypothesis as:

$H_0$ = the residuals from the model as homoscedastic

$H_1$ =the residuals are heteroscedastic

Rejecting the null hypothesis ( $H_0$ ) and accepting the alternative hypothesis will mean that the random variables have unequal variance

#### 4.2.2.4. Stability Test

In testing for the stability of the models and appropriateness of the autoregressive model (AR), the AR Root table or graph is used. If all roots have absolute values less than one and lie inside the unit circle we can conclude that the model is stable.

### 4.3. Data Information

This section covers the data sources and preliminary transformation to be used in estimation.

#### 4.3.1. Justification of Variables Selected

This study employs the use of real exchange rates, South African consumer price index, South Africa Short term interest rates (90-day Treasury bill), dollar gold prices, and South African GDP (output gap) which proved to be exogenous to the model. The data is from 1980 M1 TO 2016 M7. The variables are used to forecast the USA/SA exchange rates. The motivation behind the choice of these variables is based purely on theoretical and empirical works discussed in chapters two and three, respectively. The variables chosen for this study are defined in the table below.

**Table 4.2: Variables selected**

Symbol	Name	Definition	Source
$s_t$ /LNEX	Natural log of Nominal US/R exchange rate	US price of one unit of Rand	SARB <a href="http://www.resbank.co.za">www.resbank.co.za</a> KBP5339M Cited:14/10/2016
CPI <sub>SA</sub> /LNSACPI	Consumer Price Index (SA) Seasonally adjusted 2012=100	CPI tracks the rate of change in the prices of goods and services purchased by consumers. Headline CPI is used by the SARB in setting interest rates.	Stats SA <a href="http://www.statssa.gov.za">www.statssa.gov.za</a> Cited: 14/10/2016
CPI <sub>US</sub> /LNUFCPI	Consumer Price Index (US) Seasonally adjusted 1982-1984=100	A measure of the average monthly change in the price for goods and services paid by urban consumers between any two time periods.	Economic Research Division, Federal Reserve Bank of St. Louis <a href="http://fred.stlouisfed.org">http://fred.stlouisfed.org</a> Cited: 14/10/2016
$\tilde{\pi}_t$ /INFSA	SA Inflation Rate	A process of continuous increase of general price level. Derived from CPI	Stats SA <a href="http://www.statssa.gov.za">www.statssa.gov.za</a> Cited:14/10/2016

$\pi_t$ /INFUS	US Inflation rate	A process of continuous increase of general price level. Derived from CPI	Economic Research Division, Federal Reserve Bank of St. Louis <a href="http://fred.stlouisfed.org">http://fred.stlouisfed.org</a> Cited: 14/10/2016
$\tilde{y}_t$ /YGAPSA	Output gap; deviation from GDP (SA) Seasonally adjusted, 2010 constant prices	Calculated in millions of rand	GDP retrieved from SARB <a href="http://www.resbank.co.za">www.resbank.co.za</a> Cited:14/10/2016
$i_t$ /USTBILL	US Interest Rate: 91 Day	The federal funds rate is the interest rate at which depository institutions trade federal funds (balances held at Federal Reserve Banks) with each other overnight.	Federal Reserve Bank of St. Louis <a href="http://fred.stlouisfed.org">http://fred.stlouisfed.org</a> Cited: 14/10/2016
$\tilde{i}_t$ /SATBILL	SA Interest rate	90 Day Treasury bill Percentages; Not seasonally adjusted	Federal Reserve Bank of St. Louis <a href="http://fred.stlouisfed.org">http://fred.stlouisfed.org</a> IR3TTS01ZAM156N Cited: 25/10/2016
$q_t$ /LNRER	Natural log of real exchange rate	Real exchange rate is the nominal effective exchange rate adjusted for inflation. In terms of this research it is given as: $q_t = s_t + p_t - p_t^*$ where $p_t^*$ is the natural log of the US CPI	
$g$ /LNGOLD	Gold Prices	The dollar price of South African gold as a commodity	SARB <a href="http://www.resbank.co.za">www.resbank.co.za</a> KBP5357M Cited 14/10/2016

Source: Researcher

### 4.3.2. Data Issues

Monthly data used in the study ranges from 1980M01-2016M08. For estimation purposes, the data 1980m01-1999m12 was used. For forecasting, the research used 2000m01-2016m08. The EViews 9 statistical software package is used for analysis of the data. The data in the study is transformed as follows:

#### 4.3.2.1. Data Conversion

All the data were transformed to give a uniform base year of 2012=100.

GDP data is quoted on quarterly frequency both on SARB and FRED. In order to transform the data into monthly values equivalent to all the time series variables to be used for analysis in the study, the following process is used. The quarterly data was inputted into EViews 9. Thereafter, it was transformed using the quadratic match function of the software.

The bilateral SA-USA (rand-dollar) real exchange rate ( $q_t$ ) was derived from the nominal bilateral exchange rate ( $s_t$ ) and CPI of both SA and USA. It is derived as:

$$q_t = \left( s_t * \left( \frac{CPI_{SA}}{CPI_{US}} \right) \right) * 100 \quad (4.53)$$

The equation above gives the real exchange index with 2012 being the base year (Mohr, 2008, Enders, 2010).

#### **4.3.2.2. Natural Log Transformation**

Natural log transformations on all variables are performed. The log transformation of variables compresses the scales in which variables are measured and allows for coefficients to be interpreted as elasticity values, which enables the researcher to interpret the percentage change between two or more variables. Log transformations also serve to reduce heteroscedasticity in the data, and remove nonlinearity and seasonal trends in time series data that can be interpreted as non-stationary by stationarity tests by stabilising the variance. (Lütkepohl and Krätzig, 2004, Gujarati, 2004)

#### **4.4. Forecasting Approaches**

Gujarati and Porter (2009) and Koop (2008) identified five major approaches to economic forecasting within the time series data framework. These are (1) exponential smoothing methods, (2) single equation regression models, (3) simultaneous-equation regression models, (4) autoregressive integrated moving average (ARIMA), and (5) vector autoregression (VAR) models.

The exponential smoothing methods are methods of fitting a suitable curve to historical data of a given time series. The Single equation regression models makes use of economic theory in selection of relevant variables and select an appropriate model from the time series data which may be used in forecasting. The use of simultaneous-equation regression models has been on the decline mainly because of their poor forecasting performance as the selection of variables in the equation are heavily

dependent on prevalent policy - a sudden policy change renders the models useless for forecasting. The ARIMA Models place emphasis on probabilistic or stochastic properties of time series and are not derived from any economic theory. The VAR methodology resembles the simultaneous-equation models in that several endogenous variables are considered together. Each endogenous variable is however explained by its lagged or past values and the lagged values of all other endogenous variables in the model. There are no exogenous variables used in the forecasting model.

This research uses the single equation regression models for the augmented Taylor rule equation and VAR (and VECM) models to forecast the rand-dollar exchange rate in line with the estimation of section 4.2.

#### **4.4.1. Out-of-sample Forecast**

In addition, this research performs out-of-sample forecasts. That is, it withholds some of the sample data from the model identification and estimation process, then uses the model to make predictions for the hold-out data in order to see how accurate they are and to determine whether the statistics of their errors are similar to those that the model made within the sample of data that was fitted.

For the single equation regression model (the augmented Taylor rule in this case) one month ahead forecasts are constructed based on the OLS rolling window regression beginning in 1980m1. Each model is initially estimated using the first 240 data points (1980m01-1999m12) and the one-month-ahead forecast is generated (2000m01). The first data point is then dropped, and additional data is added at the end of the sample and the model is re-estimated. A one-month-ahead forecast is generated at each step. The last 240 data points estimated is for the period 1996m10 – 2016m07, which generates the forecast for the last date (2016m08). The forecasting period is accordingly 1980m1 to 1999m12.

The VAR modelling process is slightly different. As stated earlier, the VAR modelling uses two or more time series variables in forecasting. That is, data for periods  $t = 1, \dots, T$  is used to forecast periods  $T+1, T+2, T+3$  and so on. For a VAR(1) (one forecast ahead) model involving two variables for example, Koop (2013) explains thus:

Say variables Y and X are to be forecasted, where

$$Y_t = \alpha_1 + \delta_1 t + \phi_{11} Y_{t-1} + \beta_{11} X_{t-1} + e_{1t}, \quad (4.54)$$

$$X_t = \alpha_2 + \delta_2 t + \phi_{21} Y_{t-1} + \beta_{21} X_{t-1} + e_{2t} \quad (4.55)$$

Setting  $t = T + 1$ , an expression for  $Y_{T+1}$  and  $X_{T+1}$  is obtained:

$$Y_{T+1} = \alpha_1 + \delta_1(T + 1) + \phi_{11} Y_T + \beta_{11} X_T + e_{1T+1} \quad (4.56)$$

$$X_{T+1} = \alpha_2 + \delta_2(T + 1) + \phi_{21} Y_T + \beta_{21} X_T + e_{2T+1} \quad (4.57)$$

The equation cannot be used to directly obtain  $Y_{T+1}, X_{T+1}$  since  $e_{1T+1}, e_{2T+1}$  is not stated, neither are the coefficients. If the error term is ignored and the coefficients are replaced by OLS estimates, we obtain a forecast which is denoted by:

$$\hat{Y}_{T+1} = \hat{\alpha}_1 + \hat{\delta}_1(T + 1) + \hat{\phi}_{11} Y_T + \hat{\beta}_{11} X_T \quad (4.58)$$

$$\hat{X}_{T+1} = \hat{\alpha}_2 + \hat{\delta}_2(T + 1) + \hat{\phi}_{21} Y_T + \hat{\beta}_{21} X_T \quad (4.59)$$

The OLS estimates of the coefficients  $Y_T, X_T$ , and  $T - 1$  can be obtained from the original data or the output from a regression.

These forecasting processes are however summarised using the EViews 9 software. The OLS is validated using t and F tests.

#### 4.4.2. Forecast Evaluation

Friedman (1953) noted that “The only relevant test of validity of a hypothesis (model) is comparison of its prediction with experience”, while according to Gujarati (2006), the criterion for choosing a model best suited for the economy would be that whose theoretical predictions are borne out of actual experience. Therefore, in this section, the aim is to compare the forecasting abilities of the Taylor rule with that of the VAR/VECM model and that of the naïve Random walk model using the RMSE (root mean squared error) as the yardstick for measurement. Accordingly, a smaller RMSE implies better model accuracy (Hilmer and Hilmer, 2014)

To evaluate the out-of-sample performance of the models, the Root Mean Squared Error (RMSE) is calculated once the forecasting exercise is done. As is the standard

in the literature, Meese and Rogoff (1983), the  $RMSE_m$  of the model is compared to the  $RMSE_{rw}$  of a martingale difference process (random walk without drift). If the RMSE of the random walk is smaller than the model's RMSE then the model forecasts worse than a random walk. Statistical tests are performed to test the null hypothesis.

$H_0: RMSE_m = RMSE_{rw}$  against the alternative

$H_1: RMSE_{rw} > RMSE_m$ .

Rejecting the null hypothesis means that the model performs better than a random walk.

According to Gujarati (2012) and Cameron (2005) measures of forecast accuracy are based on forecast errors, therefore the root mean square error is given as:

$$RMSE = \sqrt{\frac{1}{T} \sum_{t=1}^T e_{h+t,t}^2}$$

(4.60)

where

$Y_t$  = value of the forecast variable Y at time t

$Y_{t+h,t}$  = forecast value of Y h periods ahead, forecasts being made at time t

$Y_{t+h}$  = actual value of Y at time (t+h)

$e_{t+h,t}$  = forecast error

$\frac{Y_{t+h} - Y_{t+h,t}}{Y_{t+h}} = p_{t+h,t}$  percentage forecast error

Other measures of accuracy are:

Mean Absolute Error (MAE)

$$\frac{1}{T} \sum_{t=1}^T |e_{t+h,t}|$$

(4.61)

Mean Absolute Percentage Error (MAPE):

$$\frac{1}{T} \sum_{t=1}^{t=T} |p_{t+h,t}|$$

(4.62)

Theil Inequality Coefficient (TIC)\*

$$\frac{\sqrt{\sum_{t=T+1}^{T+h} (\hat{Y}_t - Y_t)^2 / h}}{\sqrt{\sum_{t=T+1}^{T+h} \hat{Y}_t^2 / h} + \sqrt{\sum_{t=T+1}^{T+h} Y_t^2 / h}}$$

(4.63)

\*This coefficient lies between 0 and 1,0 indicating perfect fit.

This study will only use the RMSE (equation 4.60) to decide the relative forecasting abilities of the three models to be estimated in the next chapter.

#### 4.5. Conclusion

This chapter has given a comprehensive account of the econometric methods and models that the study utilises. This chapter discussed extensively the process of estimation with time series data. It places emphasis on stationarity and cointegration testing and how to handle situations that arise. It goes further to describe the three forecasting models being used, the evaluation thereof via the use of RMSE, sources of data, and transformation of said data. The next chapter focuses on the results obtained using Eviews 9 as the primary software for estimation.

## CHAPTER FIVE

### RESULTS AND DISCUSSION

#### 5.0. Introduction

The chapter attempts to address the major objective of the study, which is to assess whether the amended Taylor rule model and/or the Johansen VAR/VECM outperform the naïve random walk model (RWM) with regard to predicting exchange rate movements. To this end, this chapter presents and discusses the results of the quantitative analysis of the augmented Taylor rule model as proposed by Molodtsova and Papell (2009) with commodity prices included, to forecast the rand-dollar exchange rate. Similar variables used in the augmented Taylor rule model are also included in the Johansen VAR/VECM for the purposes of predicting the rand-dollar exchange rate. The forecasting performance of these two models is then compared to that of a naive RWM via the use of the root mean squared out-of-sample forecasting errors. In order to make provision for the peculiarity of the South African economy being a commodity-driven one to a significant extent, the study included commodity prices as an additional variable in both the augmented Taylor rule and the Johansen VECM, which aimed to improve the forecasting ability of the model.

To facilitate the clear presentation and discussion of results, the chapter is arranged thus: Section 5.1 presents preliminary examinations of the data utilised in the study in order to portray its basic features. Thus, the section presents basic descriptive statistical and graphical evidence to summarise the properties of the natural log-transformed indicators for real exchange rates, gold prices, inflation rate, output gap, SA CPI, and the 90-day interest rates which are expressed in percentages.

Section 5.2 engages in stationarity testing of the variables used in estimation and gives a clear picture of the stationary and non-stationary variables after the unit root tests are carried out. Section 5.3 discusses the model estimation and forecasting. In this section the random walk, Taylor rule and the VAR/VECM models estimated. In addition, the chapter is concerned with determining the order of integration, which is done through the use of the augmented Dickey Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips Schmidt-Shin (KPSS) tests. The vector autoregressive (VAR) and vector error correction model (VECM) analysis processes and results are

presented also in section 5.3. Specifically, the section firstly estimates the short-run relationships. Secondly, the existence of a long-run relationship among real exchange rate, gold prices, SA CPI and the 90-day interest rates is ascertained by the Johansen cointegration methodology. Accordingly, the VECM is estimated, allowing the researcher to determine the short-run dynamics of the long-run relationship and attain short-run elasticity coefficients of the four-variable-model. Section 5.4. discusses the diagnostic tests carried out on the VECM model for serial correlation, normality and heteroscedasticity.

Section 5.5 is engaged in forecasting. The forecasting abilities of the augmented Taylor rule model and the VAR/VECM model are compared against the random walk model using the root mean squared errors (RMSE) as a yardstick for measurement. A discussion of overall findings is provided and conclusions concerning the study's hypotheses are drawn.

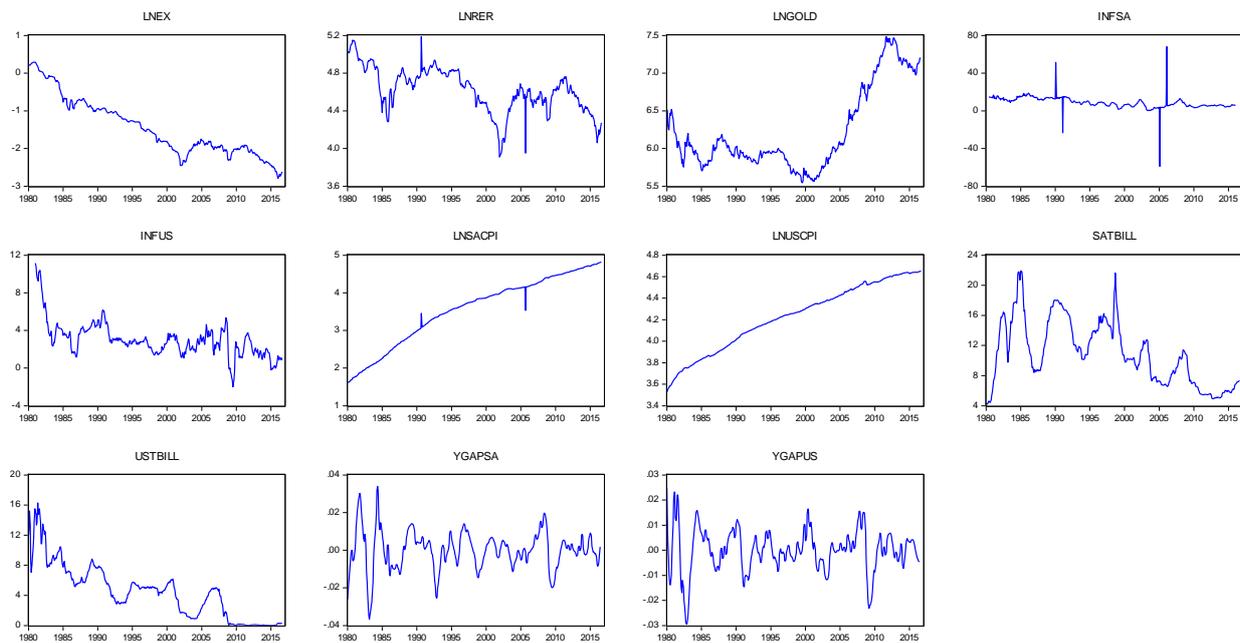
## **5.1. Description of Data**

Preliminary inspection of the data series being investigated is an essential aspect of research work. It gives an initial idea of the properties of the said data before any empirical econometric analysis is carried out.

### **5.1.1. Graphical Analysis of Data**

In order to provide a visual inspection of the time series data used in this study, graphical plots of each series were constructed. Accordingly; displays plots for each of the variables against time in natural log form and percentages for interest rate in figure 5.1.

Figure 5.1: Graphical plots of variables



Source: Researcher's estimation results

A review of Figure 5.1 leads to the deduction that all the series are likely to be non-stationary. SA Inflation appears to be fairly stable, except for a few spikes and dips around 1990 and 2005. After a sharp decline around 1983, inflation in the US appears to be on a gradual decline, as seen on the graph. Gold prices (LNGOLD) experienced a gradual decline in price from 1980-2001, but from 2002, as seen in the graph, there was a sharp increase until prices plateaued in 2011, with a resulting decline from 2012. The real exchange rate (LNRER) is characterised by a sharp decline and recovery. From the graph, there seems to be an upward trend from 2011-2015, having experienced a downward trend from 2001-2011. The consumer price index (LNSACPI) has a smooth upward trend except for sharp deviations in 1991 and 2006. The treasury bill (SATBILL) experiences sharp decline and recovery. The US treasury bill (USTBILL) appears to have gradually declined over the years to now stabilise to less than 1% from around 2009 till the end of the period under study. Lastly, the output gaps (YGAPSA and YGAPUS) seem to revolve around a trend but this will be verified by conducting unit root tests. However, to confirm the researcher's initial intuition, formal (statistically verifiable) stationarity tests are conducted in section 5.3. of this chapter.

### 5.1.2. Descriptive Statistics

The distribution of the series can be determined by evaluating different statistical measures:

**Table 5.1: Descriptive Statistic Results**

	LNEX	LNRRER	LNGOLD	INFSA	INFUS	LNSACPI	LNUSCPI	SATBILL	USTBILL	YGAPSA	YGAPUS
Mean	-1.441701	4.619381	6.228050	8.706885	2.983370	3.555398	4.225474	10.96705	4.480136	1.50E-12	2.44E-12
Median	-1.623124	4.629180	5.985873	8.233808	2.803018	3.772758	4.258909	10.47500	4.720000	0.000484	0.000410
Maximum	0.289818	5.184979	7.482260	68.13823	11.14955	4.812997	4.650740	21.90000	16.30000	0.033830	0.024923
Minimum	-2.796067	3.909680	5.545724	-58.84362	-1.978199	1.609438	3.525556	4.190000	0.010000	-0.036588	-0.029506
Std. Dev.	0.769800	0.237257	0.547260	6.589786	1.835949	0.903457	0.305197	4.305020	3.616077	0.010419	0.008558
Skewness	0.555004	-0.363482	0.946850	-0.375021	1.389195	-0.567713	-0.373880	0.407145	0.749926	-0.233329	-0.462720
Kurtosis	2.377374	3.082181	2.508435	47.25569	7.413369	2.161477	2.023090	2.265028	3.422691	4.494602	4.289585
Jarque-Bera	29.69601	9.812532	70.17513	34937.80	485.0180	36.52574	27.74746	22.05959	44.51740	44.74181	45.98034
Probability	0.000000	0.007400	0.000000	0.000000	0.000000	0.000000	0.000001	0.000016	0.000000	0.000000	0.000000
Sum	-634.3485	2032.527	2740.342	3726.547	1276.883	1564.375	1859.209	4825.500	1971.260	6.56E-10	1.07E-09
Sum Sq. Dev.	260.1476	24.71163	131.4775	18542.59	1439.293	358.3268	40.89081	8136.075	5740.369	0.047437	0.032009
Observations	440	440	440	428	428	440	440	440	440	438	438

Source: Researcher's estimation result

The data series' descriptive statistics, as presented in Table 5.1, illustrate positive skewness in the distribution of INFUS, LNGOLD, SATBILL and USTBILL, indicating that their distributions are skewed to the right and therefore have longer right tails relative to their left tails. Consequently, the negative skewness value for the other variables implies that the distributions have a longer left tail compared to the right. The skewness and kurtosis can be combined in determining whether a random variable follows a normal distribution. The presence of skewness might indicate the presence of outliers in the series which could potentially create a problem of heteroscedasticity in the residuals of the regressions. For normal distribution, the skewness and kurtosis are equal to 0 and 3 respectively. The minimum and maximum estimates show the degree of variations in the variables, implying a level of stability/instability in the series over the study period. The standard deviation measures how closely or widely spread the individual variables are with respect to their mean value. The Jarque-Bera (JB) test of normality is a test of the joint hypothesis incorporating both the skewness and kurtosis tests.

### 5.1.3. Correlation Matrix

The correlation matrix, given in Table 5.2, indicates the existence of positive and negative correlations between all the variables, in line with economic theory and consistent with the trends exhibited in the variables in Figure 5.1.

Table 5.2: Correlation Matrix Results

	LNEX	LNRRER	LNGOLD	INFSA	INFUS	LNSACPI	LNUSCPI	SATBILL	USTBILL	YGAPSA	YGAPUS
LNEX	1.000000	0.746741	-0.461241	0.466620	0.685270	-0.965754	-0.955849	0.573326	0.872048	0.049354	0.013897
LNRRER	0.746741	1.000000	-0.097806	0.223300	0.530835	-0.553281	-0.558351	0.293829	0.522789	-0.010487	0.018931
LNGOLD	-0.461241	-0.097806	1.000000	-0.199282	-0.285782	0.576006	0.637241	-0.684318	-0.578550	0.006923	0.009456
INFSA	0.466620	0.223300	-0.199282	1.000000	0.339043	-0.498629	-0.491455	0.350550	0.457360	0.148741	0.122190
INFUS	0.685270	0.530835	-0.285782	0.339043	1.000000	-0.644856	-0.619533	0.334038	0.764996	0.439131	0.322019
LNSACPI	-0.965754	-0.553281	0.576006	-0.498629	-0.644856	1.000000	0.992796	-0.625943	-0.893119	-0.056820	-0.005345
LNUSCPI	-0.955849	-0.558351	0.637241	-0.491455	-0.619533	0.992796	1.000000	-0.658371	-0.885202	-0.037658	0.004058
SATBILL	0.573326	0.293829	-0.684318	0.350550	0.334038	-0.625943	-0.658371	1.000000	0.619997	0.203302	0.000758
USTBILL	0.872048	0.522789	-0.578550	0.457360	0.764996	-0.893119	-0.885202	0.619997	1.000000	0.278382	0.202889
YGAPSA	0.049354	-0.010487	0.006923	0.148741	0.439131	-0.056820	-0.037658	0.203302	0.278382	1.000000	0.510428
YGAPUS	0.013897	0.018931	0.009456	0.122190	0.322019	-0.005345	0.004058	0.000758	0.202889	0.510428	1.000000

Source: Researcher's estimation results

For the data set there exists a situation of comparatively low simple correlations, suggesting the existence of no multicollinearity, since the correlations are less than the 'rule of thumb' figure of 0.8 (Gujarati and Porter, 2009). However, Gujarati and Porter (2009) page 338, does caution that:

*“high zero-order correlations are a sufficient but not a necessary condition for the existence of multicollinearity because it can exist even though the zero-order or simple correlations are comparatively low (say, less than 0.50).”*

Therefore, the results do not provide a comprehensive guide to the presence of multicolliniarity, especially because of the presence of more than two explanatory variables.

### 5.2. Stationarity Tests

As discussed in the previous chapter stationarity tests are to be conducted before estimation. This is of great importance as it gives an idea of the properties of the series

under examination to avoid spurious results. This research therefore establishes the order of integration of each variable that enters the multivariate model of this study. The ADF and the PP tests of stationarity are conducted with confirmation using the KPSS test.

For this study, the unit root testing procedure adopts a method that determines the significance of the restriction conditions in order to decide which deterministic component (if any) should be included in each series unit root equation. Hence, all three unit root equations (with a time trend and constant term, with constant only, and with no deterministic component) are estimated from the least restrictive condition to the most restrictive and stopping when a deterministic condition is found to be significant before proceeding to establish the order of integration for each variable.

Table 5.3 reports the unit root ADF and PP test results, with the KPSS test being a confirmatory test measure in the case of inconclusiveness. As discussed in the previous chapter, both the ADF and PP tests are conducted on the null hypothesis that the data generating process has a unit root, while the KPSS test is used to assess the null hypothesis that a time series has no unit root. In performing the main tests (ADF and PP), if the computed test statistic (t statistic) value is greater than the critical value then the null hypothesis is rejected, hence, there is no unit root or the variable is non stationary. For the KPSS test, the computed test statistic value needs to be smaller than the critical value in order for its null hypothesis not to be rejected.

**Table 5.3: Summary of Unit Root test results**

Variable	Test	Lag	Restrictions	T stats	Inference
LNGOLD	ADF	0	None	-17.78459**	I (1)
	PP	6	None	-17.69742**	I (1)
	KPSS	5	Constant, Linear Trend	0.100200**	I (1)
LNEX	ADF	0	Constant, Linear trend	-14.93717	I (1)
	PP	10	Constant, Linear trend	-14.58565	I (1)
	KPSS	4	Constant, Linear trend	0.050716	I (1)
LNRER	ADF	0	Constant	-26.20257*	I (1)
	PP	10	Constant, Linear trend	-26.57681**	I (1)
	KPSS	16	None	0.120146**	I (0)
LNSACPI	ADF	5	Constant	-4673336*	I (0)
	PP	6	Constant	-37.75962**	I (0)
	KPSS	16	Constant, Linear trend	0.638881**	I (0)
LNUSCPI	ADF	2	Constant	-5.238981*	I (0)
	PP	7	Constant, Linear trend	-4.238318*	I (0)
	KPSS	9	Constant, Linear trend	0.166692*	I (1)
SATBILL	ADF	0	None	-12.21585**	I (1)
	PP	4	None	-12.24895**	I (1)
	KPSS	11	Constant	0.132718*	I (1)

USTBILL	ADF	17	Constant, linear trend	-5.551297*	I (0)
	PP	8	None	-2.113835**	I (0)
	KPSS	16	Constant, Linear trend	0.026059*	I (1)
INFSA	ADF	13	Constant, linear trend	-4.237445*	I (0)
	PP	12	Constant, linear trend	-18.82809*	I (0)
	KPSS	216	Constant	0.253951*	I (1)
INFUS	ADF	15	Constant, linear trend	-4.525625*	I (0)
	PP	1	Constant, Linear trend	-4.775154*	I (0)
	KPSS	15	Constant, Linear trend	0.114885*	I (0)
YGAPSA	ADF	16	None	-6.453658**	I (0)
	PP	11	None	-5.12381**	I (0)
	KPSS	15	None	0.01605**	I (0)
YGAPUS	ADF	10	Constant, linear trend	-6.0204631*	I (0)
	PP	8	Constant, Linear trend	-5.431743*	I (0)
	KPSS	15	Constant, Linear trend	0.016604*	I (0)
Notes:					
<ul style="list-style-type: none"> <li>• * and ** indicate statistical significance at 1% and 5% levels, respectively.</li> <li>• The optimal lag lengths for the ADF tests are automatically determined by the Schwarz Information Criterion (SIC).</li> <li>• The bandwidths for the PP and KPSS tests are automatically determined by the Newey West Bartlett Kernel selection.</li> </ul>					

Source: Researcher's estimation results

Results in Table 5.3 indicate that both the ADF and PP tests do not reject the null hypothesis of the existence of a unit root when LNGOLD, LNRER, LNSACPI, and SATBILL are in levels but reject the null hypothesis for LNUSCPI, USTBILL, INFSA, INFUS and YGAPSA. With the presence of unit root, the variables were differenced making them stationary, thus I(1). This finding suggests there may be one or more cointegrating vectors between the variables and, therefore, the model could be feasibly employed within the VECM framework using the I(1) variables.

### 5.3. Model Estimation

As stated in chapter 4, sections 4.2.1. and 4.2.2., the model is estimated in-sample and forecasted out-of-sample using the augmented Taylor rule model, VAR/VECM model, and the Random walk model. This section aims to first estimate using the Random walk model in section 5.3.1. The augmented Taylor rule process is explained in 5.3.2., followed by the VAR/VECM in 5.3.3.

### 5.3.1. The Random Walk model estimation

The random walk with drift, in accordance with Meese and Rogoff (1983), is stated in equation 4.8. as:

$$Y_t = \delta + Y_{t-1} + u_t \quad (4.8) \quad (5.1)$$

where  $Y_t$  is determined by  $\delta$ , which is the drift parameter, and an intercept in the random walk model, and  $u_t$  which is the white noise error term.

In addition, having performed the unit root tests, it shows the presence of a constant in LNRER (real exchange rate). Therefore, using Eviews 9, we estimate and the results are as follows:

**Table 5.4: Random Walk Estimation**

Dependent Variable: LNRER  
Method: Least Squares

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.185110	0.087217	2.122400	0.0348
LNRER(-1)	0.960655	0.018305	52.48078	0.0000
R-squared	0.920768	Mean dependent var		4.759321
Adjusted R-squared	0.920434	S.D. dependent var		0.173561
S.E. of regression	0.048957	Akaike info criterion		-3.187407
Sum squared resid	0.568044	Schwarz criterion		-3.158315
Log likelihood	382.8951	Hannan-Quinn criter.		-3.175683
F-statistic	2754.232	Durbin-Watson stat		2.126296
Prob(F-statistic)	0.000000			

Source: Researcher's Estimation results

Estimating the real exchange rate (LNRER) using the random walk model with drift (constant) implies that the real exchange on average, increases by 0.185110 percent per month, which is explained by the positive value of the drift variable. Every other movement of the exchange rate is nested in the white noise error term  $u_t$ .

### 5.3.2. The Taylor rule estimation model

As stated in chapter 4, section 4.2.1., the augmented Taylor rule for estimating exchange rate is stated as:

$$q_t = \omega - \omega_\pi \pi_t + \tilde{\omega}_\pi \tilde{\pi}_t - \omega_y y_t + \tilde{\omega}_y \tilde{y}_t - \omega i_{t-1} + \tilde{\omega} i_{t-1} + \tilde{\omega}_q \tilde{q}_{t-1} + \tilde{\omega}_g \tilde{g}_t + \eta_t \quad (5.2)$$

where ~ indicates variables and coefficients for SA

and where

- $q_t$  = natural log of the real exchange rate defined by  $q_t = s_t + p_t - p_t^*$  where  $p_t^*$  stands for the natural log of US CPI
- $s_t$  = natural log of the nominal exchange rate, defined as the US dollar price of one unit of domestic currency so that an increase in  $s_t$  is a depreciation of the US dollar relative to the rand
- $\pi_t$  = inflation rate given by  $\ln(CPI_t) - \ln(CPI_{t-12})$
- $y_t$  = output gap (GDP) (percentage deviation from the trend, using a HP filter)
- $i_{t-1}$  = lagged SA short-term interest rates (90-day treasury bill rate)
- $g_t$  = natural log of international price of SA gold

The estimation results are reflected in Table 5.5 below:

Table 5.5: Taylor Rule Estimation

Dependent Variable: LNRER  
Method: Least Squares

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.749601	0.451105	-1.661700	0.0994
INFUS	0.003400	0.006657	0.510782	0.6105
INFSA	-0.000860	0.001555	-0.553130	0.5813
YGAPUS	-0.729680	0.651687	-1.119680	0.2653
YGAPSA	-0.542568	0.608643	-0.891439	0.3747
USTBILL(-1)	0.006210	0.005145	1.206928	0.2301
SATBILL(-1)	0.003556	0.002083	1.706837	0.0907
LNRER(-1)	0.723540	0.057651	12.55043	0.0000
LNGOLD	0.327639	0.090658	3.614025	0.0005
R-squared	0.898099	Mean dependent var		4.751497
Adjusted R-squared	0.890620	S.D. dependent var		0.184563
S.E. of regression	0.061040	Akaike info criterion		-2.681370
Sum squared resid	0.406121	Schwarz criterion		-2.470047
Log likelihood	167.2008	Hannan-Quinn criter.		-2.595566
F-statistic	120.0830	Durbin-Watson stat		1.916548
Prob(F-statistic)	0.000000			

Source: Researcher's Estimation results.

The equation uses both  $I(0)$  and  $I(1)$  variables, which is allowed by Charemza and Deadman (1995). If the dependent variable is  $I(1)$ , i.e., integrated of order one, then at least some of the regressors must also be integrated of the same order, otherwise one is trying to explain something that is non-stationary by a set of explanatory variables that are not. Similarly, if the dependent variable is stationary then it cannot be explained by an integrated ( $I(1)$  or higher order) explanatory variable, otherwise the model will be mis-specified. With one regressor, the order of integration of  $y$  and  $x$  must match for the specification to make economic sense. With more than one regressor and an integrated dependent variable it is possible to have a mixture of integrated and stationary regressors. For example, we could add some (stationary) dummy variables – or in the case of this study INFUS, INFSA, YGAPUS YGAPSA – to a regression with integrated  $y$  and  $x$ . A useful rule of thumb is that one cannot explain something non-stationary with solely stationary variables. Any non-stationary regressor will transmit its non-stationarity to the dependent variable, so you cannot explain a stationary variable with a non-stationary one. In the case of this LNER (dependent variable), and the regressors: USTBILL, SATBILL and LNGOLD are  $I(1)$ , hence the regression was deemed plausible. The problem of serial correlation is solved by including the lagged value of LNRER in the equation as a dependent variable.

The results show that the real exchange rate (LNRER) movement can be explained from the other variables in the augmented Taylor rule model, with the exception of inflation rates of both countries (INFSA, INFUS), the output gap for the two countries (YGAPSA, YGAPUS), and the 90-day treasury bill rate for the US (USTBILL). These variables are statistically insignificant and may not be able to explain the exchange rate movement according to the augmented Taylor rule model.

The SATBILL, which is the 90-day treasury bill rate, gave statistically significant results at the 10% level of significance. Therefore, a one percent rise in the treasury bill rate has a 0.36 percent appreciation of the exchange rate. In the same vein, the LNRER (-1) and LNGOLD have statistically significant value with their respective coefficients at the 1% significance level in both cases. A one percent rise in lagged real exchange rate causes a 0.72 percentage appreciation of the current real exchange rate. Furthermore, a one percent rise in the gold price causes a 0.33 percentage appreciation of the real exchange rate.

### **5.3.3. VAR and VECM Estimation Processes**

This section covers the vector autoregressive (VAR) and vector error correction model (VECM) analysis processes. Estimated results are interpreted in the following subsections.

#### **5.3.3.1. Stability of the VAR**

The study used the Autoregressive (AR) roots test (inverse roots of AR characteristic polynomial) to examine the stability of the VAR process and found that that no roots lie outside the unit circle, thus the stability condition holds, as shown in Table A2 and Figure A1, Appendix A. According to Johnston and DiNardo (1997) and Lütkepohl and Krätzig (2004), if each root has a modulus less than one, all the endogenous variables in a VAR system will be  $I(0)$  and therefore the variables to be estimated in the VAR model require no differencing. Since all the moduli in the AR table are strictly less than one, a VAR approach may be appropriate to estimate short-run interactions in the dynamic model of this study. However, the highest modulus of 0.998 is also very close to one, suggesting that the Johansen VECM approach may also be successfully estimated to test for cointegrating effects.

#### **5.3.3.2. Lag Length Selection**

Prior to estimating a VAR or VECM it is standard practice to first determine the selection of unrestricted VAR order ( $p$ ). The optimal number of lags to be included in the cointegration test and succeeding VAR or VECM model are identified by the Akaike information criterion (AIC), Schwarz information criterion (SIC), Hannan-Quinn information criteria (HQ), the sequential modified likelihood ratio test (LR), and the Final prediction error tests (FPE) as the VAR and VECM methodologies are sensitive to lag lengths.

In determining the lag length, the general- to- specific methodology is used. That is, the unrestricted VAR is estimated with all variables in levels with a maximum number of lags, reducing down by re-estimating the model for one lag less until significantly different from zero (Asteriou and Hall, 2007, Enders, 2010). The AIC and FPF suggests an optimal lag of three (4). The SC and HQ suggested an optimal of two (2)

lags. Ultimately, a lag length of 4 was selected as proposed by the AIC and FPF criteria. The results are presented in Appendix A, Table A2.

This finding suggests that a second order ( $p = 4$ ) VAR model is most appropriate. Therefore, a first order ( $p-1$ ) VECM can be estimated since EViews estimates the VAR model in level form and takes the first difference of the VAR variables to estimate the VECM. Thus, under the VECM framework, one degree of freedom is lost, therefore reducing the lag order by one. Thus, a second order ( $p = 4$ ) VAR in the VECM framework is estimated as a first order ( $p = 3$ ).

### **5.3.3.3. Cointegration Test**

This section highlights the cointegration tests carried out on the VAR/VECM. The processes and estimated results are interpreted in the following sub-sections.

#### **5.3.3.3.1. Deterministic Components**

This step is concerned with determining whether an intercept and trend should be included in the model. According to Asteriou and Hall (2007) and Harris (1995), five different deterministic models (i.e., cases) can be considered:

- Case 1: No intercept or trend in the cointegrating equation(s) or VAR. This rarely occurs in practice since the intercept is needed in order to account for adjustments in the unit of measurements of the variables in the model.
- Case 2: Intercept but no trend in the VAR model. In this instance, the intercept is restricted to the long-run model.
- Case 3: Intercept in the cointegrating vector with no trend in the cointegrating vector and VAR model. It is assumed that the intercept in the cointegrating equation is cancelled out by the intercept in the VAR, therefore leaving only one intercept in the short-run.
- Case 4: Intercept in both the cointegrating equation and the VAR model, a linear trend in the cointegrating equation but not in the VAR model. In this model, no time trend exists in the short-run.

- Case 5: Intercept and quadratic trend in the cointegrating equation, and an intercept and linear trend in the VAR model. This case is also not a plausible option as it is problematic to interpret from an economics standpoint.

Accordingly, Table 5.6, below, shows the five assumptions that can be made regarding the possible cointegrating relations that might exist among all the variables in the study's model.

Table 5.6: Johansen cointegration test assumptions

Lags interval: 1 to 3

Selected (0.05 level\*) Number of Cointegrating Relations by Model

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	2	2	1	1	0
Max-Eig	2	2	1	0	0

\*Critical values based on MacKinnon-Haug-Michelis (1999)

Source: Researcher's Estimation results

Within the context of Table 5.4, cases 1 and 5 are deemed far-fetched for macroeconomic time series data in practice, therefore emphasis is placed on the remaining options. For the remaining three cases, the results show strong evidence of the existence of a long-run equilibrium relationship among all variables in the model. Specifically, in cases 2 and 3 the trace and maximum eigenvalue tests confirm the existence of two and one cointegrating vectors, respectively. In case 4, the trace test suggests one cointegrating vector while the maximum eigenvalue test finds none. Attempts were made to estimate case 2, but they yielded implausible results (not reported), from an economic perspective as the coefficients for case 2 were unrealistically large. Case 4 was not considered as there appear to be no cointegration relationships present according to the maximum eigenvalue test. Case 3, which allows for a linear intercept but no trend in the cointegrating equation, is chosen as the appropriate model and, interestingly, conforms to the nature of the series, as discussed in the previous section. Thus, the study proceeded to estimate the Johansen cointegration test of the variables in levels based on case 3.

### 5.3.3.3.2. Cointegration Test Results

As previously discussed in chapter four, given that  $p$  is the number of variables and  $r$  is the rank (i.e., number of cointegrating vectors), the trace test statistic examines the null hypothesis that  $r \leq p$  against the alternative. Conversely, the maximum eigenvalue statistic test tests the null hypothesis that the number of cointegrating vectors is  $r$  against an alternative of  $+1$  cointegrating vectors. For both tests, the null hypothesis can be rejected if the computed test statistics are greater than their critical values and thus cannot be rejected should the computed test statistics be less than the critical values.

Table 5.7: Cointegration test results

		Trace			Max-Eigen		
Hypothesised		Trace	0.05		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**	Statistic	Critical Value	Prob.**
None *	0.064307	58.18828	47.85613	0.0040	28.98019	27.58434	0.0329
<b>At most 1</b>	<b><u>0.040049</u></b>	<b><u>29.20809</u></b>	<b><u>29.79707</u></b>	<b><u>0.0584</u></b>	<b><u>17.82086</u></b>	<b><u>21.13162</u></b>	<b><u>0.1367</u></b>
At most 2	0.025412	11.38723	15.49471	0.1888	11.22268	14.26460	0.1434
At most 3	0.000377	0.164557	3.841466	0.6850	0.164557	3.841466	0.6850

Source: Researcher's Estimation results

As Table 5.7 shows, at the 5 per cent (5%) significance level, the hypothesis of no cointegrating vector is rejected by both the trace and the maximum eigenvalue tests since their test statistics of 58.19 and 28.98 (respectively) are greater than their respective critical values of 47.86 and 27.58. The alternative hypothesis of the existence of a single cointegrating relationship was, however, not rejected since the trace statistic of 29.21 is less than the critical value of 29.797 and the maximum eigenvalue statistics of 17.65 is smaller than the critical value of 21.13. Hence, the analysis concludes that one long-run cointegrating equation exists among LNRER, LNGOLD, LNSACPI and SATBILL and thus justifies the use of the error correction term (ECM) to show short-run dynamics, which is then estimated via the  $a$  coefficients.

### 5.3.3.3.3. The VECM Estimation

As reported previously, the AR roots test reveals that one of the roots has a value very close to one. This finding, together with the fact that all the series in the study's multivariate model are I(1), shows that it is feasible to use the VECM method and test if a long-run relationship exists between the series. For this purpose, the Johansen test of cointegration is applied. However, prior to generating the test, the appropriate model regarding the deterministic component in the multivariate system needs to be ascertained. That is, the deterministic component of intercept in the cointegrating vector with no trend in the cointegrating vector and VAR model.

Since the presence of long-run relationship has been established using the Johansen test, we proceed to estimate the vector error correction model in order to distinguish between the long-run and short-run relationships in the exchange rate forecasting model. The results of the long-run relationship between the real exchange rate (LRER) and the other variables are presented in Table 5.8.

**Table 5.8: Results of Long-run Cointegration Equation**

Vector Error Correction Estimates  
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1			
LNRER(-1)	1.000000			
LNGOLD(-1)	-0.787351 (0.27312) [-2.88281]			
LNSACPI(-1)	0.456039 (0.14344) [ 3.17930]			
SATBILL(-1)	-0.144367 (0.03457) [-4.17664]			
C	0.248358			
Error Correction:	D(LNRER)	D(LNGOLD)	D(LNSACPI)	D(SATBILL)
CointEq1	-0.010690 (0.00472) [-2.26416]	0.007097 (0.00347) [ 2.04813]	-0.013163 (0.00353) [-3.73079]	0.111773 (0.04062) [ 2.75138]
D(LNRER(-1))	0.275210 (0.08054)	0.109548 (0.05911)	-0.028092 (0.06018)	-0.203054 (0.69297)

	[ 3.41717]	[ 1.85325]	[-0.46678]	[-0.29302]
D(LNRER(-2))	-0.053897 (0.08353) [-0.64522]	-0.053697 (0.06131) [-0.87583]	-0.020893 (0.06242) [-0.33470]	-1.270177 (0.71875) [-1.76720]
D(LNRER(-3))	0.048625 (0.08071) [ 0.60246]	-0.068156 (0.05924) [-1.15054]	0.082133 (0.06031) [ 1.36179]	0.683133 (0.69447) [ 0.98368]
D(LNGOLD(-1))	0.147741 (0.06809) [ 2.16975]	0.130985 (0.04998) [ 2.62094]	0.083346 (0.05088) [ 1.63801]	-2.205024 (0.58588) [-3.76359]
D(LNGOLD(-2))	0.035021 (0.06760) [ 0.51804]	-0.109853 (0.04962) [-2.21401]	0.057395 (0.05052) [ 1.13615]	0.478228 (0.58168) [ 0.82216]
D(LNGOLD(-3))	0.032496 (0.06754) [ 0.48114]	0.013061 (0.04957) [ 0.26347]	-0.032414 (0.05047) [-0.64225]	-0.014571 (0.58113) [-0.02507]
D(LNSACPI(-1))	-0.929200 (0.10353) [-8.97537]	-0.110047 (0.07598) [-1.44827]	-0.693261 (0.07736) [-8.96119]	0.287489 (0.89079) [ 0.32273]
D(LNSACPI(-2))	-0.333054 (0.10810) [-3.08097]	0.082104 (0.07934) [ 1.03483]	-0.439624 (0.08078) [-5.44226]	1.473137 (0.93014) [ 1.58379]
D(LNSACPI(-3))	-0.246766 (0.09971) [-2.47473]	0.062426 (0.07319) [ 0.85298]	-0.301087 (0.07451) [-4.04074]	-0.503114 (0.85798) [-0.58639]
D(SATBILL(-1))	0.003129 (0.00571) [ 0.54809]	5.31E-05 (0.00419) [ 0.01266]	0.004625 (0.00427) [ 1.08408]	0.455720 (0.04913) [ 9.27673]
D(SATBILL(-2))	0.001316 (0.00626) [ 0.21026]	-0.006217 (0.00459) [-1.35342]	-0.001369 (0.00468) [-0.29263]	0.014253 (0.05385) [ 0.26467]
D(SATBILL(-3))	-0.000374 (0.00563) [-0.06637]	0.000862 (0.00413) [ 0.20869]	0.001431 (0.00421) [ 0.34013]	0.062633 (0.04845) [ 1.29278]
C	0.009383 (0.00305) [ 3.07734]	0.001809 (0.00224) [ 0.80844]	0.017596 (0.00228) [ 7.72321]	-0.003695 (0.02623) [-0.14085]
R-squared	0.238926	0.061492	0.376239	0.290023
Adj. R-squared	0.215481	0.032581	0.357024	0.268152
Sum sq. resids	1.227623	0.661313	0.685512	90.88732
S.E. equation	0.053936	0.039587	0.040304	0.464083
F-statistic	10.19074	2.126916	19.58009	13.26043
Log likelihood	661.5613	796.4178	788.5834	-276.8285
Akaike AIC	-2.970465	-3.589073	-3.553135	1.334075
Schwarz SC	-2.839531	-3.458139	-3.422201	1.465009
Mean dependent	-0.001699	0.002184	0.007300	0.006927
S.D. dependent	0.060894	0.040248	0.050264	0.542481

Source: Researcher's Estimation results

The results for the long-run relationship among the variables in the VECM which was estimated with a lag order of 3 is highlighted in Equation 5.4.

$$\begin{aligned} \lnrer = & -0.25 + 0.79\ln gold - 0.46\ln sacpi + 0.14\text{satbill} \\ & [2.88]^* \quad [-3.17]^* \quad [4.18]** \end{aligned} \tag{5.4}$$

where

- the values in the parentheses [] are the t-statistics of the estimated coefficients.
- \* and \*\* indicates significance at the 1 and 5 percent level of significance respectively.

Note the long-run relationship result generated by Eviews is presented in an ECM format, hence the signs are opposite to their actual direction, i.e., it is written as follows in ECM form:

$$\lnrer_t - 0.25 - 0.79\ln gold_t + 0.46\ln sacpi_t - 0.14\text{satbill}_t = u_t = ECM_t$$

The estimated long-run coefficient of LNGOLD, which is 0.79, is positive and significant at the 1 percent level of significance, which shows that a rise in gold price causes the real exchange rate to appreciate. This implies that a dollar increase in gold price will lead to a 0.79 rand per dollar in real exchange rate.

The estimated coefficient for LNSACPI is negative (-0.46) and statistically significant at the 1 percent level of significance. This shows that a 1% increase in the consumer price index will bring about a 0.46 percent depreciation in real exchange rate. On the other hand, SA treasury bill rate exhibited a positive effect on real exchange rate, that is, an appreciation due to attracting capital inflows. A 1% rise in the treasury bill rate causes a 14.44%<sup>1</sup> appreciation of the rand-dollar exchange rate.

The result for the error correction term presented in Table 5.8, which measures the speed of adjustment to long-run equilibrium after a shock in the system is presented as follows. The error correction coefficient for the real exchange rate (LNRER) shows

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<sup>1</sup> Note the model is in a log-lin format with respect to the interest rate. (SATBILL) is in levels while the dependent variable (LNRER) is in logs, hence the SATBILL coefficient must be multiplied by 100.

how quickly LRER, adjusts to its long-run equilibrium as a result of deviating from it in the previous period. The significant and correct a negative sign on the coefficient suggests that if LNRER oversteps its long-run relationship with the other variable by 1% in the previous period then in the current period there will be a 0,011% adjustment, which suggests that the readjustment to equilibrium is slow, for it will take 91 months (7.6 years) for return to equilibrium to occur. This is similar to the findings of MacDonald and Ricci (2004) and Aron et al. (1997) who indicated that the real exchange is slow in adjusting back to equilibrium, although theirs is still faster than the findings of this study.

The error correction coefficients for LNGOLD, LNSACPI and SATBILL have the correct signs and are statistically significant at the 5 percent level for the former and 1% for the remaining two respectively. LNGOLD and SATBILL have to adjust upward this period, while LNSACP adjusts downwards as a result of LNRER overshooting its long-run equilibrium in the previous period.

The speed of adjustment for all three variables is similar with a coefficient of 0.01 which suggests that they will take about 100 months (8.3 years) to fully adjust back to equilibrium as a result of LNRER overstepping its long-run relationship with the explanatory variables in the previous period.

#### 5.4. Diagnostic Tests Results

Diagnostic tests were carried out on the VECM model for serial correlation, normality and heteroscedasticity checks.

**Table 5.9: Diagnostic tests**

Heteroskedasticity Test: ARCH

F-statistic	1.702614	Prob. F(3,429)	0.1658
Obs*R-squared	5.094808	Prob. Chi-Square(3)	0.1650

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	1.314360	Prob. F(36,386)	0.1117
Obs*R-squared	47.60994	Prob. Chi-Square(36)	0.0933

Source: Researcher's Estimation Results

The diagnostic result shows the absence of serial correlation in the model since the probability value of the Breusch-Godfrey Serial Correlation LM (0.1117) is statistically insignificant at the 5 percent level of significance. The null hypothesis of no serial correlation in the model is therefore accepted. The heteroscedasticity test result also indicates the absence of heteroscedasticity since the probability value of the ARCH test (0.1658) is statistically not significant at the 5 percent level of significance.

## 5.5. Forecasting

After the processes of estimation, the research goes further to generate the forecasting errors, which are then used to generate the RMSE for the 3 models. The model with the lowest root mean squared errors (RMSE) is then selected as the best model. Although, there are other yardsticks for measurement as described in Chapter 4, section 4.3.2, the focus is on the RMSE.

**Table 5.10: Forecast model evaluation**

	Random Walk (out-of-sample)	VECM (out-of-sample)	Taylor Rule (out-of-sample)
RMSE	0.286092	5.811032	0.780900
MAE	0.230641	5.809738	0.560413
MAPE	5.352326	100.0173	12.39415
TIC	0.031330	0.98802	0.081716

Source: Research forecast results

RMSE = Root mean square error; MAE= Mean Absolute Error; MAPE= Mean Absolute Percentage Error; TIC= Theil Inequality Coefficient.

From the table above, the RMSE of the random walk model outperforms both the Taylor rule model and the VECM, as it possesses a value (0.286092) which is much lower than that of the Taylor rule (0.780900) and the VECM (5.811032). The Taylor rule model outperforms the VECM, which may be irregular as the condition for

introducing the VECM into this research was because of the presence of non-viable variables in the forecasting equation (See section 5.4.2.). This may raise the argument that if the variables (INFUS, INFSA, YGAPUS, YGAPSA and USTBILL) are substituted with other but similar variables, it may yield better results. That however is beyond the scope of this research, although the dynamics may be explored in further research.

Considering the overall results obtained, in line with the hypothesis stated in chapter 1 (section 1.3), the following conclusions can be drawn:

- Hypothesis 1 is rejected as the Taylor rule model proposed by Molodtsova and Papell (2009) with commodity prices included does not perform better than the Random walk model in forecasting the \$/R exchange rate.
- Hypothesis 2, which states that the VAR/VECM model performs better than the augmented Taylor rule model (commodity prices included) in forecasting the US\$/Rand exchange rate, is rejected as well.
- Hypothesis 3 is accepted as the Random walk model outperforms both the augmented Taylor rule model and the VAR/VECM models.

## **5.6. Conclusion**

This chapter provided an empirical analysis of this research study using the EViews 9 statistical software package. Preliminary examinations of the data were conducted and some of the variables were found to be non-stationary in levels but stationary in first difference. The study estimated the random walk model (with drift), augmented Taylor rule model and the VAR/VECM models. The study also carried out VAR (2) system cointegration analysis, and a VECM (1) system. The chapter went further to forecast the exchange rate out-of-sample (2000m01-2016m08) using the three highlighted models. The RMSEs were calculated and compared. Overall, the research found that in as much as a long-run relationship exists between real exchange rate, gold prices, SA CPI, and SA 90-day treasury bill for the VECM estimation, the same is not so for the augmented Taylor rule function. In addition, forecasting using the three (3) highlighted models shows that the random walk outperforms both the Taylor rule and the VECM models.

## CHAPTER SIX

### CONCLUSION AND RECOMMENDATIONS

#### 6.0 Introduction

This chapter summarises the present study and gives policy recommendations based on the findings. The chapter consists of three sections. Section 6.1 presents the summary of the study and discusses the empirical findings. Policy implications and recommendations are laid out in section 6.2, while section 6.3 provides the study's strengths, weaknesses (limitations of study) and policy prescriptions. Section 6.4 outlines recommendations for future research.

#### 6.1 Summary of the Study

The South African government continues to engage in inflation targeting As a monetary policy instrument for economic growth acceleration – a strategy which ultimately affects exchange rate movements, both directly and indirectly (Kaseeram, 2010). Adapting the theoretical framework of Molodtsova and Papell (2009) to the South African economy, this study attempted to forecast the US\$/R exchange rate using Taylor rule fundamentals with commodity prices included. The researcher carefully selected macroeconomic variables that have been considered in the econometric models for empirical analysis of the research study in this dissertation through statistical estimation techniques as per Molodtsova and Papell (2009). These variables include real exchange rate, interest rates, GDP as proxy for output gap, using HP trend flitters, and with the consumer price index (CPI) being the proxy for inflation rate, and gold prices as the proxy for commodity price. Specifically, the study set out to empirically forecast the exchange rate using the Taylor rule fundamentals and to measure the impact of commodity prices on the forecasting ability of the model. The objective of the study centered around four hypotheses which were constructed to examine how key macroeconomic variables such as commodity prices, interest rate, inflation rate, and real exchange rate may impact out-of-sample forecast of exchange rates using monthly data from 1980 and 2016.

However, upon estimation, it was discovered that some of the variables were not statistically significant enough to forecast using the Taylor rule model. The researcher therefore sought out a more appropriate model for estimation and then derived the VAR/VECM model. The VAR/VECM estimated the US\$/R exchange rate, using variables such as the real exchange rate, gold prices as proxy for commodity prices, the South African consumer price index, the South African 30-day treasury bill rate, and the South African output gap (derived from the GDP, but shown to be an exogenous variable). Furthermore, through this study, the key determinants of US\$/R exchange rate movement in both the short and long-run were identified.

To achieve the study's objective and address the respective hypotheses, preliminary examinations of the data were conducted through the use of visual and unit root tests. There was found to be a mix of stationary and non-stationary variables in levels, however, these were transformed after first differencing ( $I(1)$ ). Both the unrestricted VAR and VECM techniques were estimated, since the AR table used for establishing the stability of the unrestricted VAR at a lag length of 4 contained a root with a modulus of 0.99. The study proceeded to estimate a first order VECM, which took into account both short and long-run relationships. The important result of the Johansen VECM approach is that when the bilateral dollar and rand exchange rate oversteps its long-run relationship with the other variables the adjustment process to return to equilibrium is very slow, which is an indication of serious frictions in the South African economy which serve to hinder the smooth and quick adjustment back to long-run equilibrium.

Comparing the augmented Taylor rule, VECM model, and the Random Walk model for accuracy in forecasting ability gave the results that the random walk outperformed all the other models. An intriguing fact however was the Taylor rule model's ability to outperform the VECM. However, this finding makes sense since the Taylor rule relied on more of the variables that the South African Reserve bank uses in setting the Repo rate; the very same variables have a strong influence in the exchange rate movement. The results from the Random Walk model is fully understandable, for South Africa is a small, open, middle-income emerging market economy that is vulnerable to various internal and external risks and constraints which deterministic models are not always able to capture efficiently. While Random Walk models, which are governed on the basis of the efficient market hypothesis, predict tomorrow's exchange rate movements on the basis of today's value, which fully reflect the information contained in historical

data, in other words, all anticipated factors are fully incorporated as well as the shocks and publically available information to most of the market participants up to the very instant at which the rate is measured. It is indeed a tall order to require deterministic models to possess this level of information depth and sophistication in regard to predicting exchange rate movement.

## **6.2 Policy Implications and Recommendations**

The policy implications of this research are that although macroeconomic variables do contribute to exchange rate movement, they cannot explain all aspects fully, while the Random Walk by its very nature as explained above is able to outperform deterministic macroeconomic models. This therefore makes it difficult for policy makers in predicting the future and providing appropriate and economic direction. It is recommended that other indicators apart from exchange rate, and more sophisticated econometric modelling, be used in the policy making process.

The main policy implication from the Johansen VECM study is that once the exchange rate over(under)steps its long-run equilibrium with other long-run cointegrating variables the adjustment process back to equilibrium for all the variables involved is very slow. This calls for the South African authorities to strive to adopt policies which make the economy more open and efficient, i.e., the economy should: undertake further financial and trade liberalisation; remove bottle necks in the economy with regard to administrative pricing and wage setting behaviour that places upward pressure on inflation; remove policy uncertainties; adopt growth enhancing approaches with regard to the economic path over the medium to long term; follow prudent fiscal and monetary policies. Over time, all these policy suggestions would maintain growth at its highest potential, and anchor inflation and, hence, short-term interest rate to that of our major trading partners, and thus lead to stable predictable exchange rate movement.

### **6.3 Limitations Strengths, Weaknesses and Policy Prescriptions**

Inasmuch as there may be dependent variables that attempt to forecast and explain the movement of the exchange rate, according to this research, the simple random walk model is still the best estimator of the US\$/R exchange rate movement. This stance is in agreement with the unbeatable random walk puzzle of Meese and Rogoff (1983). However, Moosa and Burns (2014) tested the claim of the unbeatable random walk model to find out if it is a myth or reality. They expressed the opinion that the random walk model cannot be beaten if the yardsticks for measuring forecast accuracy are conventional means such as the mean absolute error, mean square error, and the root mean square error. The reason for this is that regular macroeconomic models produce significant forecasting errors because they are unable to explain the stylised facts about movements in exchange rates, such as bubbles followed by crashes and volatility clustering. Instead, when forecasting power is measured in terms of direction accuracy and profitability, the static model outperforms the random walk. In addition, the Government of Australia (2009) Exchange Rate Forecasting Review (2009) stated that the long-run average model (LRA) produced lower forecasting errors (RMSEs) than the random walk, thereby making it a preferred model, because it has the advantage of simplicity and intuitive appeal, being less reliant on specialised economic expertise to maintain and update. The LRA is a simple approach based on the assumption that the exchange rate returns to a long-run average (in linear fashion) over the budget period. It is based on the principle of PPP i.e. the idea that exchange rate ultimately returns to some equilibrium value over time. Future research may explore the possibility of forecasting in the South African context using the models stated.

### **6.4 Recommendations for future research**

This research used the linear Taylor rule model for forecasting. Further research may approach forecasting with the use of a non-linear Taylor rule such as the non-linearly mean-reverting models described in Taylor et al. (2001). Another model, utilised by Clarida et al. (2003), is the term-structure forecasting model of exchange rates based on a regime-switching vector equilibrium correction model. These models, amongst a

number of others, have proven to outperform the random walk in the various studies; researchers may apply it to the US\$/R exchange rate to examine their forecasting abilities. Further research may also take into consideration other macroeconomic variables, not covered in this research, that may perform better in forecasting exchange rates. This research came up with results opposite to those of Botha and Pretorius (2009), although, the variables employed varied to some extent, from those used in this body of work. The VECM was said to outperform both the univariate and multivariate models in the dynamic out-of-sample forecasts. Therefore, the recommendations made by Botha and Pretorius (2009) that a combination of the fundamental approach and the technical approach, in a multivariate model such as the VARMA, be used for forecasting the South African exchange rate in the short-run, and the VECM for the longer forecast horizon, may be employed in addition to more modified explainable variables.

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## APPENDIX

**Table A1: Optimal lag length Results**

Lag	LogL	LR	FPE	AIC	SC	HQ
1	1979.001	NA	1.33e-09	-9.087969	-8.937287	-9.028481
2	2131.931	300.1946	7.05e-10	-9.721901	-9.420537*	-9.602924
3	2165.730	65.72172	6.49e-10	-9.804308	-9.352260	-9.625841*
4	2182.365	32.03624	6.47e-10*	-9.807244*	-9.204514	-9.569288
5	2192.789	19.88341	6.64e-10	-9.781430	-9.028018	-9.483986
6	2203.306	19.86550	6.81e-10	-9.756046	-8.851952	-9.399113
7	2223.187	37.18456*	6.69e-10	-9.774013	-8.719236	-9.357591
8	2234.407	20.77862	6.85e-10	-9.751886	-8.546426	-9.275975

\* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

**Table A2: Autoregressive Root results**

Roots of Characteristic Polynomial

Endogenous variables: LNRER LNGOLD

LNSACPI SATBILL

Exogenous variables: C

Lag specification: 1 2

Root	Modulus
0.998770	0.998770
0.986286	0.986286
0.949461 - 0.006539i	0.949483
0.949461 + 0.006539i	0.949483
-0.489212	0.489212
0.463306	0.463306
0.363687	0.363687
0.102186	0.102186

No root lies outside the unit circle.

VAR satisfies the stability condition.

**Figure A1: Autoregressive Root results**

Inverse Roots of AR Characteristic Polynomial

