University of the Western Cape

Economics and Management Sciences

Department of Economics

Taylor rule influence on the setting of the repurchase rate by the South African Reserve Bank (1989-2009)

by

Simbarashe Murozvi

(2760615)

A mini-thesis submitted in partial fulfilment of the requirement for the degree of Master of Commerce (Economics) in the Department of Economics,
University of the Western Cape.

Supervisor: Professor L. J. Loots

15 November 2014

Resubmitted 11 March 2016

ETHICAL STATEMENT

The author gratefully acknowledges the ethical standards in pursuing the thesis. The study used official published data. Therefore, there is no possibility that ethical standards were compromised. Furthermore, the researcher applied strictly all rules and regulations required when carrying out the research to ensure an independent, quality, integrity and impartial research outcome.

DECLARATION

I Simbarashe Murozvi, the undersigned, hereby declare that the work contained in the thesis entitled *Taylor rule influence on the setting of the repurchase rate by the South African Reserve Bank (1989-2009)* is my own original work and has not been in its entirely or in part submitted for any degree or examination in any university. All the sources used or quoted in the thesis have been indicated and acknowledged by complete references.

Signature: ---

Date: ---

ABSTRACT

Monetary policy rules are guidelines applied by policy makers when adjusting monetary instruments towards reaching policy objectives like price stability. The South African Reserve Bank (SARB) uses the repurchase (repo) rate at which it lends to commercial banks as its monetary instrument. This study examines whether the SARB considers the output gap when deciding on changes to the repo rate. In order to test the above hypothesis the study applied a simple multiple linear regression model (quantitative methods).

The hypothesis was tested based on the following independent variables: consumer price index (headline), natural real interest rate, potential output and actual output using the Eviews and STAMP econometric software packages. The study focussed on the time period between 1989 and 2009 when the central bank governors were targeting the repo rate as an instrument towards achieving their monetary policy objectives.

The results illustrate evidence of 82 % to 92 % correlation in the movements between the predicted Taylor rule with the univariate model and the actual repo rate. This means that the behaviour the SARB monetary policy conduct was sufficiently structured and influenced by the developments of both inflation and the output gap, even though the SARB have not consciously implemented a Taylor model. In short, the output gap and inflation rate gap pressures influenced strongly the monetary policy decisions of the SARB, even before the formal adoption of an inflation targeting framework.

Keywords: Inflation Targeting, Potential Output, Monetary Policy Rules, Taylor Rule, Natural Real Interest Rate, Output Gap, Inflation rate gap, Real Interest Rate Gap, South African Reserve Bank, Central Bank Reaction Function.

TO MY GRANDMOTHER

ACKNOWLEDGEMENTS

To be where I am today is the result of the collective efforts of a number of people. Firstly, I would like to give all the glory to God, because without Him I am nothing. Even though it has been a difficult couple of years, I thank Him because in spite of all my challenges, I managed to pull through. Thank you, Lord.

Secondly, I would also like to acknowledge my family, for all the support they have given me during the course of my postgraduate studies, especially to my parents, Mr and Mrs Murozvi. I would not be here if it were not for them.

Last but not least, I am highly indebted to Professor Lieb Loots, my supervisor, for his patience and guidance. For this, I will forever be grateful, and I have greatly benefited from his guidance and advice.

Special thanks are due to the UWC staff members, fellow students and friends.

TABLE OF CONTENTS

CHAPTER THREE
METHODOLODY

CHAPTER FOUR
EMPIRICAL ANALYSIS

CHAPTER FIVE
CONCLUSION

LIST OF ABBREVIATIONS

ADF	Augmented Dickey-Fuller
BER	Bureau for Economic Research
BK	Baxter-King
BLUE	Best Linear Unbiased Estimator
CPI	Consumer Price Index
CPIX	Consumer Price Index
DSGE	Dynamic Stochastic General Equilibrium
EARIR	Ex-ante Real Interest Rate
ECM	Error Correction Model
ECT	Error Correction Term
EPRIR	Ex-post Real Interest Rate
EW	Exponential Wald
FIM	Financial Indicators Model
GDP	Gross Domestic Product
HP	Hodrick-Prescott
IID	Independently Identical Distribution
IT	Inflation Targeting
KF	Kalman Filter
KPSS	Kwiatkowski Phillips Schmidt Shin
LWM	Laubach and Williams Model
MPC	Monetary Policy Committee
MPTM	Monetary Policy Transmission Mechanism
MVM	Multivariate Model
NRIR	Natural Real Interest Rate
OLS	Ordinary Least Squares
OMO	Open Market Operations

PF	Production Function
Repo rate	Repurchase Rate
SARB	South African Reserve Bank
SSE	Sum of Squared Residuals
STAMP	Structural Time Series Analyser, Modeller and Predictor
Stats SA	Statistics South Africa
US	United States of America
UVM	Univariate Model
VAR	Vector Autoregressive
VECM	Vector Error Correction Model

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE
INTRODUCTION

1.1. Introduction

Modern economists have reached a consensus on the monetary policy objective of attaining price stability (Smal & De Jager, 2001: 03). There are different ways in which price stability can be attained. According to Van der Merwe (2004: 01) the inflation targeting (IT) policy framework is one of the most used monetary policy frameworks in many central banks. This use stems from the fact that the IT policy framework provides transparent, credible and coherent results (Epstein, 2003: 05). Therefore, the success of a policy framework in attaining price stability promotes macroeconomic stability as was the case during the Great Moderation.

Davis and Kahn (2008: 03-5) explained the Great Moderation as a successful period of decreased macroeconomic volatility experienced in the United States of America (USA) from 1985 to 2000. Over this period, the standard deviation of quarterly real GDP declined by half and that of inflation declined by two thirds. Cabanillas and Ruscher (2008: 05) also found a similar result for the Euro zone where the standard deviation of yearly real GDP growth fell by 45 per cent from 1970 to 2000.

According to Taylor (2009: 14) using the counterfactual Federal Reserve Bank (Fed) reaction function, if the Fed had adhered to the Taylor rule model as was the case under the Great Moderation there would not have been a global financial crisis in 2007-08. Taylor (2009: 61) blamed government actions that went off track, specifically the consistently low interest rate in the USA as a stimulus of monetary excesses which led to the global financial crises. Taylor (2010: 166-167) noted that adhering to the Taylor rule model that takes into consideration capacity utilisation enables the attainment of macroeconomic stability, economic development and employment creation.

In South Africa, the SARB does not explicitly indicate that they follow the Taylor rule model or consider the output gap, in addition to the inflation rate, when deciding on changes to the short-term nominal interest rate (repo rate). This study examines whether the SARB unannounced or implicitly applied the Taylor rule model when deciding on changes to the repo rate during the governorships of Dr Chris Stals (referred to as Stals hereafter) and Mr Tito Mboweni (referred to as Mboweni hereafter) over the period 1989-2009.

1.2. **Background and rationale of the study**

The South African monetary authorities target inflation as their policy objective (Van der Merwe, 2004: 05). According to the SARB (2007: 03) its formal IT framework uses the repo rate as a monetary policy instrument which they adjust as an anti-inflation measure to achieve the desired inflation rate of between 3 to 6 per cent. Reid and Du Plessis (2010: 05) noted that the success of this anti-inflationary measure in stabilising the inflation rate provides greater transparency, confidence and credibility in the operation of the central bank. Therefore, the setting of the repo rate is crucial for the SARB in attaining price as well as macroeconomic stability.

Taylor (1993: 202) proposed a monetary policy reaction function that can be applied by central banks as a guideline when setting the short-term nominal interest rate (repo rate). The policy rule is known as the Taylor rule. The Taylor rule model considers pressures developing from the deviation of total production and the inflation rate from their targeted values. These distortionary pressures are of utmost importance to the central bank policy makers when implementing their anti-inflationary measure. According to Orphanides (2007: 18) the Taylor rule model is recommended for central banks due to its ability to keep inflation low and recessions mild or infrequent.

Prior to the adoption of the formal IT framework, the inflation rate trended downwards until it stabilised within the range of 3 to 6 per cent. However, after its implementation, the inflation rate was in nineteen quarters above 6 per cent, in four quarters below 3 per cent and in sixteen quarters within the targeted range (see Figure 3.2 below). This reflects the failure of the SARB monetary policy actions to entirely contain inflation within the stipulated range over the study period. Therefore, this raises the question whether there were policy changes or an objective change in the pursuit of monetary policy by the SARB. The rationale for this study is to analyse whether there was an implicit use of the Taylor rule model in the setting of the repo rate over the period 1989-2009.

1.3. **Research problem**

Monetary authorities had changed policy instruments since the introduction of monetarism (Bryant, Hooper & Mann, 1993: 30). According to Hafer (2001: 14) monetarism is a term used to explain the argument that changes in the growth rate of monetary aggregates have an influence on economic activities and the price level. In short, if the central bank implements a good policy anchor for the growth rate of monetary aggregates, they will achieve their price stability goal. Nevertheless, during the 1990s when financial liberation and structural changes distorted the strong linkages between monetary aggregates and the price level, monetary targets (anchors) were rendered ineffective in stabilising the inflation rate. Gonzalez and Vera (2001: 02) argued that the failure of the monetary stock targets in stabilizing inflation led more central banks into adopting the IT framework.

Anti-inflationary monetary policies based on monetary aggregates on their own do not address issues of economic development and employment creation well (Epstein, 2007: 03). Taylor (1993: 202) became associated with a monetary policy rule that gives equal weight to economic growth (output and employment) as well as the price level and that can be used by central bank authorities as a guideline or rule of thumb in their repo rate decision making process. The Taylor rule model success in containing inflation as well as in fostering macroeconomic stability generates spill over effects on economic development and employment creation. This reflects the importance of the output gap as well as inflation gap pressures in stabilizing as well as promoting economic growth. The thesis addresses the following question: To what extent has the Taylor rule influenced the setting of the short-term nominal interest rate (repo rate) by the SARB over the period 1989 to 2009?

1.4. **Aims and objectives**

The thesis aims to establish the influence of the Taylor rule model in the setting of the repo rate in South Africa in order to deduce whether the SARB had considered the output gap, in addition to inflation being the foremost variable, towards changes in the repo rate over the period 1989-2009. In this regard, the overall objective of the paper is to test the hypothesis that the SARB implicitly applied a Taylor-type rule to guide them in the setting of the policy rate (later the repo rate). In order to achieve the overall objective, the study must:

- Estimate the potential output trend, the output gap and the natural real interest rate;

- Estimate the Taylor rule model predictions;
- Compare the Taylor rule model predictions to the actual repo rate;
- Conclude whether the Taylor rule model implicitly influenced the SARB when setting the repo rate.

1.5. **Research methodology**

The study obtained the data for its analysis from the SARB reports and statistical figures in terms of the repo rate, consumer price index (headline), 10-year government bond yields and gross domestic product (potential and actual) as published on the SARB website. The thesis study period stretches from 1989 to 2009. This period is demarcated by the tenure of two different governors who had different monetary policy strategies, both of which were focusing on the policy interest rate as their monetary policy instrument in stabilising the inflation rate. The formal IT framework inflation target range of 3 to 6 per cent was applied as a benchmark for the inflation rate over the latter part of the study period, i.e. from 2000 to 2009.

The study adopted a simple multiple linear econometric method, often used in the literature, to test the hypothesis that the SARB used the Taylor rule model as a benchmark model in setting the repo rate. According to Taylor (1993: 203) the Taylor rule model is a simple linear equation characterised by four variables that guide monetary policy. These variables are (1) a measure of actual inflation (core inflation), (2) the natural real interest rate, (3) the inflation rate gap and (4) the output gap.

Eviews and STAMP econometric software packages were used to test the hypothesis applying the Ordinary Least Squares (OLS) method. According to Gujarati (2009: 71) the OLS technique is simple to use, easy to understand and it satisfies the BLUE (Best Linear Unbiased Estimators) properties. The variables used in the Taylor rule model were tested for stationarity using the Augmented Dickey-Fuller and KPSS unit root tests. The methodology and related matters are discussed at length in Chapter 3.

1.6. **Chapter outline**

Price stability is important for the economy to attain macroeconomic stability as well as economic growth. In South Africa, it is the mandate of the South African Reserve Bank to ensure that inflation is contained within the targeted range of 3 to 6 per cent. Taylor (1993:

202) proposed a model to set the nominal interest rate which includes the output gap and inflation rate gap pressures. The literature on the Taylor rule is discussed at length in Chapter 2.

Inflation and output gap pressures play an important role in undermining macroeconomic stability. Hence, the study examines whether these pressures influenced monetary policy changes during Stals's and Mboweni's governorships. In order to test the above hypothesis the study used a simple multiple linear econometric method (quantitative analysis) applying the Ordinary Least Squares (OLS). The literature on the methodology applied in the empirical testing of the Taylor rule model hypothesis is discussed at length in Chapter 3.

In the empirical analysis of the Taylor rule model hypothesis, the data generating processes of the variables were examined thoroughly so as to avoid the problem of reporting spurious regressions. The examination of the variables included testing for stationarity and cointegration. The empirical analysis of the Taylor rule model is discussed in Chapter 4. Furthermore, the empirical analysis aims to test whether there had been an implicit influence of the Taylor rule model in the conduct of monetary policy in South Africa. Chapter 5 concludes the discussion of the Taylor rule hypothesis.

CHAPTER TWO
LITERATURE REVIEW

2.1. **Introduction**

Central bank authorities apply monetary policy rules as guidelines when adjusting monetary instruments towards reaching policy objectives like price stability. The repurchase rate (repo rate) is a monetary instrument used by the South African Reserve Bank (SARB). Section 2.2.4 focusses on the repo rate. According to Van der Merwe (2004: 05) the SARB targets headline inflation (Consumer Price Index, or CPI) in its inflation-targeting framework in order to achieve price stability in the economy.

During the period 1989 to 2009, the SARB could not effectively contain the inflation rate within the post-2000 period specified range of 3 to 6 per cent at all times. The inflation rate reflects a downward trend prior to 2000 and a fluctuating trend around the 3 to 6 per cent band over the post-2000 period (see Figure 3.2 below). This raises the question whether another objective might have informed the SARB in the pursuit of its primary objective. Based on this possibility, the purpose of this thesis is to examine whether the SARB monetary policy reaction function considered the output gap as well as the inflation rate gap, as suggested by the Taylor rule model, when deciding on changes to the repo rate. In order to test the above hypothesis, this chapter offers a detailed discussion of the Taylor rule literature.

Established in 1921, the SARB has been consistent, credible, coherent and transparent in its monetary policy actions (SARB, 2010: 31). Section 2.2 focusses briefly on the SARB's monetary policy framework. Since 1960, the South African monetary policy instruments evolved from the money supply target to the inflation-targeting (IT) framework. According to Svensson (1999: 623) central bankers are virtually unanimous about the adoption of IT as a monetary policy framework. Section 2.3 focusses on the IT framework.

Casteleijn (2001: 15) noted that there had been significant monetary policy framework changes in many countries including South Africa since the early 1980s. These policy framework changes emanate from a consistent failure to achieve policy objectives like improving employment levels. Hence, there are growing concerns about securing price stability by following a framework that nurtures a better economic performance.

Therefore, a policy rule that takes into consideration both output and inflation pressures can foster a better economic performance as well as offer a better understanding of the conduct of monetary policy. Taylor (1993) proposed a central bank reaction function (later known as the Taylor rule) which includes both the output and inflation rate gap pressures as a benchmark rule in determining the optimal monetary policy stance. The Taylor rule is widely applied as a yardstick in many central banks. Section 2.4 discusses the Taylor rule model.

The Taylor rule model estimation is not a simple and straightforward task. This complexity stems from the existence of ambiguities in the model variables, especially the unobserved potential production trend and the natural real interest rate. The unobserved variables are discussed in Sections 2.4.3 and 2.4.4. Criticisms of the Taylor rule model are discussed in Section 2.4.5. Apart from the uncertainties in its estimation, the Taylor rule model offers a good yardstick when evaluating the central banks' historical monetary policy stance in respect of whether it was too accommodative or too restrictive. Section 2.5 concludes the literature review.

2.2. **The South African Reserve Bank**

2.2.1. Background

According to the SARB (2010: 31), "the SARB was established in 1921 in terms of the Currency and Bank Act No 31 of 1920". This Act consolidated the banking legislation in South Africa, and it authorised the SARB with the right to issue bank notes for twenty-five years (Rossouw, 2011: 05). The Reserve Bank Act of 1944 succeeded the Currency and Bank Act No 31 of 1920 (SARB, 2010: 31). Under the Reserve Bank Act of 1944, the central bank was given the right to issue loans as well as to invest and trade in bills. To strengthen flexibility and effectiveness in the conduct of monetary policy, the current Reserve Bank Act No 90 of 1989 was introduced. The SARB (2010: 32) argues that the amendments to this Act have been in line with the major characteristic of the initial Act and international developments.

In terms of Section 224 (1) of the South African Constitution, the primary or ultimate objective of the SARB is as follows: "to protect the internal and external value of the currency in the interest of balanced and sustainable growth in the Republic". In order to achieve the above objective as well as increase the central bank's accountability, Section 224

(2) stipulates that the SARB shall execute its functions or duties independently. This implies that the SARB has operational autonomy as well as instrument independence.

Although the SARB has independence to operate on its own, there is regular communication between the Central Bank governor and the minister of finance on monetary policy changes. The amendment of the SARB's primary objective is through a two-thirds majority vote in Parliament. However, in cases of non-compliance by the SARB, with respect to the ultimate objective of the central bank, the Constitutional Court resolves such cases (Casteleijn, 2001: 04).

2.2.2. Monetary policy regime since 1960

According to Fourie and Burger (2009: 349) monetary policy is defined as combined efforts by monetary authorities to change the money supply, availability of credit and interest rates with an expectation to influence money demand, spending, production, income, the inflation rate, the exchange rate and the balance of payments in order to achieve macroeconomic stability. Bryant, Hooper and Mann (1993: 30) state that the monetarism school of thought dominated the conduct of monetary policy during the 1970s as well as early 1980s. According to Hafer (2001: 14) monetarism is a term given to describe the argument that changes in the growth rate of monetary aggregates (various measures of the money stock) have a major influence on the demand side of short-run economic activity (nominal GDP) and the price level.

Financial liberation as well as structural changes encountered in the 1990s distorted the strong relationship amongst growth in money supply, output and prices (Casteleijn, 2001: 05). As a result, monetary policy based on money aggregates became ineffective[1]. Gonzalez and Vera (2001: 02) argued that the failure of these aggregates to effectively capture the correlation between money supply and prices, because of the non-monetary nature of inflation at times, led more central banks to adopt the IT framework in the conduct of monetary policy. Table 2.1 below outlines the evolution of monetary policy in South Africa.

[1] This supports the move towards the discretionary or eclectic monetary policy approach by Stals, and it illustrates the motive behind the adoption of inflation targeting as opposed to monetary aggregates.

Table 2.1: **South Africa's monetary policy regime since 1960**

Years	Monetary Policy framework
1960 - 1981	Direct control (Liquid assets ratio-based system with quantitative controls over interest rates and credit)
1971 - 1976	Credit ceilings
1980 - 1985	Mixed system during transition
1986 - 1999	**Discretionary or eclectic approach**
1986 - 1990	Monetary targets (M3)
1990 - 1998	Cost of cash reserves-based system with pre-announced monetary target (m3)
1998 - 1999	Daily tenders of liquidity through repurchase transactions (repo system), plus pre-announced m3 targets and informal targets for core inflation
2000	Formal inflation targeting

Source: SARB (2010: 117)

On August 8th 1989, Dr Chris Stals assumed duties as the governor of the SARB. Rossouw (2011: 11) states that upon his appointment the SARB focussed more on achieving a stable inflation rate. Stals succeeded in containing inflation through implementing eclectic or discretionary monetary policy. Rossouw (2011: 11) noted that under the Stals governorship, the SARB monetary policy evolved from money supply growth targets to money supply growth guidelines, and subsequently the informal inflation targeting as reflected in Table 2.1 above.

Mr Tito Mboweni succeeded Stals on 7th August 1999 as the new governor of the SARB. Rossouw (2011: 12) states that under Mboweni's tenure monetary policy evolved from a monetary target with an informal inflation target towards a full-fledged IT framework as shown in Table 2.1 above. Mboweni faced a huge challenge in implementing the IT framework (Rossouw, 2011: 11). In spite of the challenges, the IT framework became widely accepted as a suitable monetary policy. Mboweni initiated the Monetary Policy Committee (MPC)[2] in order to address monetary policy issues specifically with respect to the adjustment or setting of the repurchase rate (Rossouw, 2011: 12). The introduction of the MPC strengthened the credibility of the SARB by bringing certainty over monetary policy decisions.

[2] The MPC consist of fifteen members (four voting members as well as eleven policy officials and economic researchers).

2.2.3. *Monetary Policy Committee decision making process*

The MPC formally meets every six weeks, and after each meeting the monetary policy statement is publicised (SARB, 2010: 125-127). According to Casteleijn (2001: 10) the MPC process of decision making is characterised by five steps. First, in the first two weeks an intensive investigation of the available measurements and data is performed for the domestic as well as foreign economies. Second, before the end of the fourth week the research department reports its findings on different economic model simulations based on different scenarios and economic shocks.

Third, in the fifth week a detailed draft of the economic forecasts together with the reviews of South Africa's domestic and international trading economies is created by the research department. Fourth, in the sixth week the MPC members meet. After a thorough analysis of new developments and the current economic conditions, the MPC then drafts the monetary policy statement which they publicises at the end of their meeting. Lastly, the SARB can then on the basis of the decision reached at the end of the MPC meeting either change the repo rate or leave it unchanged.

2.2.4. *The Repurchase rate*

Du Plooy (1998: 02) cited in De Angelis, Aziakpono and Faure (2005: 04) defined the repo rate as a simultaneous sale and future repurchase agreement of assets or securities. In other words, the commercial banks in need of liquidity sell securities (bonds and other financial instruments) to the central bank with a legally binding contract to repurchase equivalent securities for an agreed price at a future date or at a call in exchange for cash reserves. The repurchase rate is the difference between the spot sale price and the future repurchase price. In simple terms, the repo rate is the interest rate charged by the central bank for borrowed cash reserves.

According to the SARB (2007: 03) its formal inflation-targeting framework uses the short-term repo rate as one of its basic monetary policy instruments. Rossouw and Padayachee (2011: 64) noted that in March 1999 the repo rate replaced the bank rate. From 2000 onwards the SARB formally applied the repo rate as an anti-inflation measure to stabilise the inflation rate between the IT framework range of 3 to 6 per cent. Other instruments of the SARB accommodation policy include the cash reserve requirement, open market operations and direct measures like interest rate ceilings (Fourie & Burger, 2009: 351).

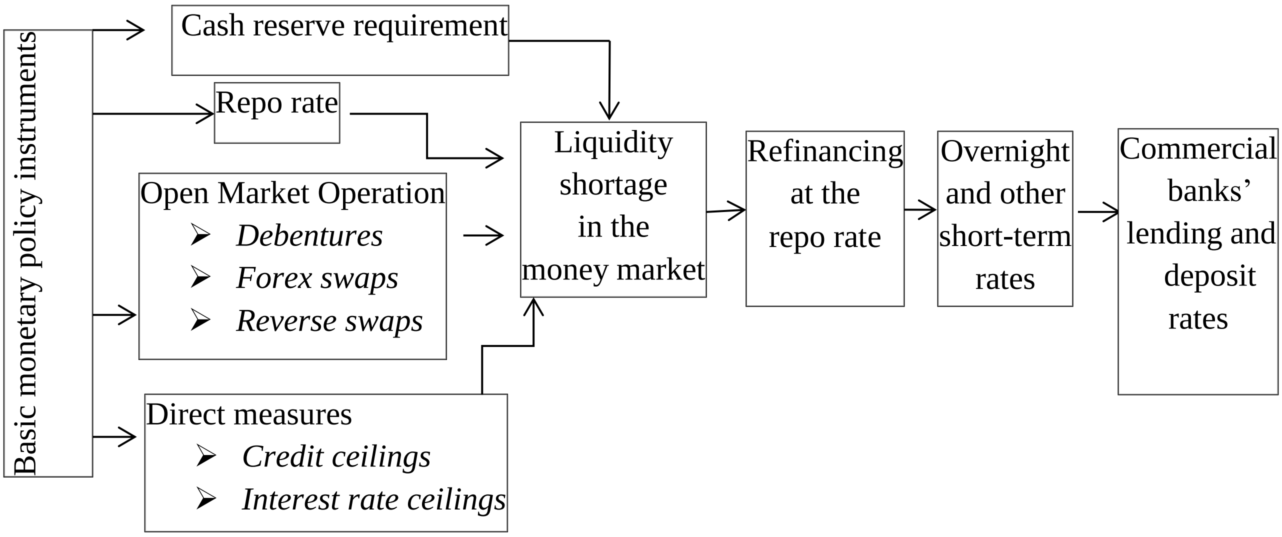
The repo rate is a crucial element of the SARB accommodation policy that signals to market participants the intentions and wishes of the central bank as well as being a major determinant of the market interest rates in general. Mboweni (2000: 03) argued that the repo rate primarily affects domestic production based on two channels, namely demand for goods and services as well as the exchange rate. This means that the repo rate adjustment effect on inflation directly impacts the behaviour of local and foreign consumers. Eventually the growth or slack in domestic production, employment and economic growth reflects the adjustment in consumer behaviour.

The SARB (2010: 126) argued that efficiency in the effectiveness of the repo rate is achieved through central bank intervention in the market to compel commercial banks to borrow in order to modify central bank balances. In other words, the SARB regularly participates in the money market by draining excess liquidity leading to a liquidity shortage. These shortages compel commercial banks to borrow funds at the repo rate from the central bank. The repo fixed rate system allows the SARB to effectively influence money market interest rates (De Angelis *et al.*, 2005: 03).

According to the SARB (2010: 127) the adjustment of the repo rate initiates a complex process (Monetary Policy Transmission Mechanism[3] (MPTM)) through which the adjustment is transmitted to achieve the rate of inflation in the specified range of 3 to 6 per cent. The repo rate directly affects market interest rates through its effect on the marginal cost of funding as illustrated by the diagram below.

[3] Consult Smal and De Jager (2001) for a discussion of the monetary policy transmission mechanism.

Figure 2.1: The monetary policy implementation framework



Source: SARB (2010: 127)

The diagram above describes the monetary policy implementation framework. The four monetary policy instruments, namely the repo rate, the cash reserve requirement, open market operations (OMO) and direct measures are used to create liquidity in the money market by the Reserve Bank. This then compels commercial banks to demand liquidity from the Reserve Bank at the repo rate. As the commercial bank incurs a cost of borrowing it also increases its costs.

Therefore, market interest rates are influenced positively and directly by the repo rate. Hence, a successful inflation-targeting framework requires the interbank market rates to respond immediately to the adjustment in the repo rate. Reid and Du Plessis (2010: 21) concluded that the SARB repo rate system has managed to be effective, consistent, transparent and credible in its inflation-targeting policy actions.

2.3. **Inflation Targeting**

According to Barker (2007: 188), during the 1960s, it was generally agreed that a trade-off exist between the inflation rate and unemployment rate (Phillips Curve). The trade-off implies that unemployment in a country could be decreased through increasing the inflation rate. The SARB (2010: 115) noted that the above relationship broke up as empirical evidence often reflects positive correlation between inflation and the unemployment rate. Furthermore, the SARB (2010: 115) also noted that policies that promote higher inflation lead to poor economic performance, dampen savings and investments and limit the economy's potential to grow. In this regard, Small and De Jager (2001: 03) noted that almost all modern monetary economists have reached a consensus that price stability must be the ultimate goal in monetary policy formulation.

According to the SARB (2010: 115) price stability is attained in an economy when price levels do not affect the decision-making process of economic agents concerning economic issues. There are different ways in which price stability can be attained most effectively. The best choice or method to follow is a highly debatable issue and this debate ultimately remains unresolved. However, Svensson (1999: 623) noted that in maintaining price stability there is a growing consensus towards the adoption of the IT policy framework because of its credible results. In addition, Van der Merwe (2004: 01) also noted that most central banks are adopting the IT framework because of money stock targets failure.

2.3.1. Definition of inflation targeting

According to Mishkin (2001: 01) an IT framework is a monetary policy strategy which is characterised by the following five elements: "(1) public announcement of medium term numerical targets for inflation, (2) an institutional commitment to price stability as the primary goal of monetary policy, to which other goals are subordinated, (3) an inflation inclusive strategy in which many variables, and not just monetary aggregates or the exchange rate, are used for deciding on the setting of policy instruments, (4) increased transparency of the monetary policy strategy through communication with the public and markets about plans, objectives and decisions of monetary authorities and, (5) increased accountability of the central bank of attaining its inflation objectives".

The characteristics above imply that the IT framework is more than a mere announcement of the numerical target for a specified period. Kahn and De Jager (2011: 74) noted that a very important feature of the inflation targeting strategy is that there exists a pre-announced target of inflation. This pre-announced target provides a benchmark over which the central bank can be assessed in terms of its accountability. More so, the target defines the objective of monetary policy. Nevertheless, the role of the central bank is to keep inflation contained by committing to credible, transparent and consistent decisions that reduce the scope for time inconsistency problems.

According to Kahn and De Jager (2011: 77) the IT framework is generally characterised by the following loss function:

$$L_t = E_t \sum_{i=0}^{\infty} \beta_t \left[\left(\pi_{t+1} - \pi^T \right) + \lambda \left(y - y^* \right) \right]$$

The function above reveals that the central bank expected loss is a function of the inflation rate gap (actual inflation rate minus targeted rate) and the output gap (actual output minus potential output). The value of λ represents the output gap weight. To achieve the smallest loss the central bank needs to ensure that the total output and the inflation rate are as close as possible to their targeted and/or potential values.

Kahn and De Jager (2011: 77) noted that when the value of λ is equal to zero then this reflects a central bank strictly implementing an IT policy, whilst if the value of λ is greater than zero this reflects that the central bank is adopting a flexible IT policy. Kahn and De Jager (2011: 78) further noted that the practice of strict inflation targeting is implemented by few if any central banks. The international trend among central bankers goes in favour of the flexible inflation targeting strategy.

2.3.1. International experience

According to Mishkin (2001: 01) New Zealand was the first nation to implement the IT framework in 1990. Rossouw and Padayachee (2011: 65) argued that since 1990 the IT framework had gained more popularity to the extent that by the middle of 2010 it was implemented by 24 countries including South Africa. This stems from the empirical outcomes of stable macroeconomic conditions attributed to the IT framework. In implementing inflation-targeting monetary policy, there are many approaches a central bank can adopt. This implies that operationally, there are differences over the chosen target within the IT framework concerning the level and specification of the target (Kahn and De Jager, 2011: 75).

Another difference exists over the chosen policy time horizon. Kahn and De Jager (2011: 75) noted that most countries target a point, usually with a specified allowance deviation from the target. On the other hand, South Africa is amongst countries that specify a target range within which inflation should be contained over time or in the medium term.

Since 1990, there has not been any economy that has dropped the IT framework once they had implemented it. Frankel (2013: 01) asserts that the IT framework's great setback was witnessed at the onset of the global financial crisis of 2007-08. The housing assets bubble consequences were severe to the global economic system with open economies that have non-regulated financial markets suffering the most. In this regard, South Africa's regulation of the financial market played a crucial role in protecting the economy even though the crisis affected it via trade channels (Naude, 2009: 05).

2.3.2. South African experience

South Africa adopted the formal IT framework in February 2000 (Van der Merwe 2004: 01). Prior to the adoption of the formal IT framework, an informal IT strategy was in use (SARB (2010: 118). The informal IT framework targeted an inflation rate (CPIX) between the range of 1 to 5 per cent. According to SARB (2010: 119) the informal inflation targeting was successful in driving the inflation rate from double digits of about 15 per cent in the late 1980s to a single digit of approximately annual average rate of 5.02 per cent in 1999.

Casteleijn (2001: 05) cited higher core inflation in South Africa relative to its key trading partners as the reason for replacing the informal IT strategy. On the other hand, the SARB (2010: 119) proposed four reasons for abandoning the informal IT strategy. Firstly, the informal IT framework created uncertainties amongst the public concerning the SARB monetary policy stance. Secondly, the formal IT framework encourages the co-ordination of monetary policy and other economic policies. Thirdly, the formal IT framework encourages discipline of monetary policy as well as increases the central bank's accountability. Lastly, the formal IT framework affects positively the process of expectation formation, which leads to reduced inflation and increased confidence over the operation of the central bank.

According to Casteleijn (2001: 07) the SARB targeted to achieve an average rate increase in the Consumer Price Index (CPIX) within the range of 3 to 6 per cent since the adoption of the formal IT framework in 2000. The CPIX is an inflation measure that excludes the mortgage interest costs. SARB (2010: 12) argued that the CPIX was initially targeted for metropolitan and other urban areas as the public in these areas understand this measure. Rossouw and Padayachee (2011: 66) argued that the CPIX was adopted even though it had a disadvantage of being affected by exogenous shocks. However, CPI replaced CPIX in January 2009. This was because of the Statistics South Africa (Stats SA) adoption of a rental equivalence measure for housing which does not use the mortgage interest costs (SARB 2010: 121). The adoption of the rental equivalence measure provides a better measure for inflation in the IT framework as it is not highly influenced by policy decisions.

Epstein (2007: 03) argued that the IT framework on its own does not address issues of economic development and employment creation well. This is due to the fact that it needs to be complimented by other economic policies as well as structural changes within the economy. Nevertheless, stable inflation is still a necessary condition for promoting sustainable economic growth and development as well as job creation in the economy. Furthermore, Gonzalez and Vera (2001: 22) argued that output gap changes might generate unfavourable pressures causing a failure of the IT strategy to stabilise prices. In this regard, Taylor (1993: 202) proposes a monetary policy rule that can be used by central bank authorities as a guideline or rule of thumb in monetary policy decision making.

2.4. **Taylor rule**

2.4.1. Introduction

In the late 1940s, Simons and Keynes were the two competing intellectual leaders concerning the debate on rules as opposed to discretion (Asso, Kahn & Leeson, 2007: 05). According to Asso *et al.* (2007: 06), Simons (Chicago "rules party") advocated a price level rule monetary policy whilst John Maynard Keynes and followers advocated a real output rule. The introduction of the Taylor rule model integrated the two schools of thought as the model's policy reaction equation encompasses both the price level and the real output with equal weight applied to both variables.

The Taylor rule is committed to time consistency, transparency and independence (Asso *et al.,* 2007: 05). According to the time consistency theories by Kydland and Prescott (1977), Barro and Gordon (1983) and Blanchard and Fisher (1993) cited in Taylor (1993: 198) a policy rule is characterised as an optimal rule or pre-commitment solution to a dynamic optimisation problem whilst a discretionary policy is characterised as an inconsistent, cheating or short-sighted solution to a dynamic optimisation problem. In discretionary policy, the determination of appropriate policy stance as well as instrument is done from scratch in every period with no concern of following a well-defined contingency plan (Taylor, 1993: 198).

Taylor (1993: 197) argued that policy rules are more advantageous relative to discretionary policies in improving economic performance, and evidence illustrates an increased consensus in favour of policy rules. According to Orphanides (2007: 18) the Taylor rule is recommended for central banks due to its ability to keep inflation low and recessions mild or infrequent. In addition Clarida, Galí and Gertler (2000: 149) noted that self-fulfilling expectations are stabilized by the Taylor rule as the central bank responds to economic shocks in a manner that stabilises inflation and output growth in the economy as well as in people's expectations.

However, a pure policy rule might be difficult to follow especially in situations of unforeseen external shocks. Therefore, applying some discretion at times guided by a mechanical rule (like the Taylor rule model) adds an advantage as it promotes transparency, credibility and confidence about a central bank's operations.

2.4.2. The Taylor rule model

Taylor (1993: 202) proposed a macroeconomic rule that can be applied by central banks as a guideline when setting the short-term nominal interest rate (repo rate). Rudebusch and Svensson (1998: 45) argued that the Taylor rule model has provided stable inflation and has encouraged output growth in a broad range of macroeconomic situations. These effects have been confirmed by empirical results of model simulations applied by different researchers (see Levin, Wieland & Williams (1999), Clarida, Gali & Gertler (2000), Rudebusch & Svensson (1998) and Judd & Rudebusch (1998)).

An extensive literature has been devoted to examining Taylor-type macroeconomic policy rules (Orphanides (2007), Gonzalez & Vera (2001), Ndahiriwe & Naraidoo (2012) and Clarida *et al*. (2000)). Travaglini (2010: 09) argued that the Taylor rule linear model has been subjected to a variety of modifications as researchers try to account for the adjustment speed and other dynamics that are not considered in the initial model as well as other explanatory variables. In the case of South Africa, more work has been directed towards analysing whether linear or non-linear Taylor rule models better explain the conduct of monetary policy in and out of sample by the SARB (see Naraidoo & Paya (2012) and Ndahiriwe & Naraidoo (2011)). Evidence is in favour of non-linear models. Nevertheless, this thesis applies a simple linear Taylor rule model.

Judd and Rudebusch (1998: 13) concluded that the original linear Taylor rule model predictions best describe the USA monetary policy under the governorship of Paul Volcker and Alan Greenspan, even though the Federal Reserve Bank (Fed) did not explicitly say whether they followed the Taylor rule or not. Taylor (2010: 166) cites the Taylor rule as a reason for the relatively stable rate of inflation from the mid-1980s through the late 2000s, a period known as the Great Moderation. Over the Great Moderation volatility of quarterly real output declined by half whilst the volatility of inflation fell by two thirds. Cabanillas and Ruscher (2008: 05) also found the same result for the Euro zone where the volatility of yearly real GDP growth fell by 45 per cent over the period 1970 to 2000. Figure 2.2 below illustrates the Great Moderation.

Figure 2.2: <u>The Great Moderation</u>

Source: Taylor (2010: 166)

According to Taylor (2009: 02) using the counterfactual Fed reaction function it is noted that if the Fed had adhered to the Taylor rule model they would not have encountered the 2007-08 global financial crisis. Taylor (2009: 33) argued that the Fed went off track in the late 2000s as they did not follow the Taylor rule guideline model in setting the Fed fund rate. More specifically Taylor (2010: 166-168) blames the consistent low interest rate in the US economy over the period 2003-2006 as a cause of the financial imbalances that fuelled the Housing Bubble, and subsequently led to the 2007-08 global financial crises. Therefore, adhering to a policy rule like the Taylor rule model promotes macroeconomic stability.

The Taylor rule reaction function suggests that when setting the nominal interest rate, the central bank should also consider pressures developing from the deviation of total production as well as the inflation rate from their targeted values. According to Taylor (1993: 202) the central banks' reaction function should comprise of four components. First, a measure of actual inflation (core inflation). In line with Taylor (1993: 202), the inflation rate over the past four quarters is applied as a proxy for the actual inflation (core inflation) in the thesis. Second, the natural real interest rate. The sum of these first two components is known as the nominal natural short-term interest rate. Third, the deviation of total production from the targeted real output (output gap), and lastly, the difference between current inflation rate and the targeted inflation rate (inflation rate gap).

The above four elements can be represented in an equation as follows:

$$i_t = \pi_t + r_t^* + \beta_\pi\left(\pi_t - \pi^*\right) + \beta_\gamma\left(\gamma_t - \overline{\gamma}\right)$$

where i_t = desired short-term interest rate (repo rate) set by the central bank, π_t = inflation rate over the previous four quarters (measured by GDP deflator or headline CPI), r_t^* = natural real interest rate, β_π = the positive inflation rate gap weight, β_γ = the positive output gap weight, $\pi_t - \pi^*$ = inflation rate gap (current inflation rate less the targeted inflation rate), $\gamma_t - \overline{\gamma}$ = output gap (actual real output less potential real output). The inclusion of the actual inflation measure (π_t) on the right hand side of the Taylor equation expresses the reaction function in real terms.

According to Taylor (1993: 202) the policy model works as follows, *ceteris paribus,* if the current rate of inflation is greater than the targeted benchmark rate (positive inflationary gap pressure) then monetary authorities respond by increasing the nominal interest rate with a percentage point equal to the inflation rate gap multiplied by the appropriate coefficient (β_π). On the other hand, *ceteris paribus,* if the actual output is greater than potential output (positive output gap inflationary pressure) the central bank responds by increasing the nominal interest rate by the output gap multiplied by the appropriate coefficient (β_γ) to stimulate the economy. In addition, if the economy is experiencing high pressures from both inflation and output, the monetary authorities respond by increasing the nominal interest rate to tighten monetary policy.

In the original Taylor rule model (Taylor 1993: 202), the natural real interest rate and the targeted inflation rate were assumed at a constant rate of 2 per cent whilst the output gap and the inflation rate gap proportions ($\beta\pi$ and βy, respectively) were assumed at 0.5 per cent. Taylor (1999: 323) in 1999 reviewed the weight applied to the inflation rate gap to be 1 + β_π (1.5) as a better descriptor of historical monetary policy. As a result of empirical work of Flint, Levin, Tryon and Williams (1997) cited in Taylor (1999: 325) a value closer to 1 for the output gap coefficient (β_γ), had been suggested as it appeared more likely to promote macroeconomic stability. Nevertheless, Orphanides (2007: 06) criticised Taylor for not applying econometric tests in order to determine the assumed coefficients.

According to Clements (2004: 12) the assumed coefficients do not come from the Fed's explicit pronouncement. They were inferences made from the performance of the USA economy based on the restrictiveness and accommodative behaviour of the Fed when inflation deviates from 2 per cent. Taylor (1993: 202) acknowledged that the assumed statistical coefficients are in line with the USA statistical data, and they vary depending on the economic conditions in the country of study. Hence, they can be modified to fit the situation or country under study. Therefore, the thesis estimates these parameters applying the Ordinary Least Squares approach over the study period.

The assumed coefficients are the main cause of debate amongst economists as there is no clarity and consensus on the appropriate relative weights applied to the inflation rate gap and the output gap in the model. Although the debate about the coefficients is still unresolved, there has been some consensus concerning the functional form as well as the signs on the coefficients in the policy model. For example, the parameters of the models are expected to be positive for them to prescribe a stabilising policy rate.

In spite of these ambiguities, Taylor (1993: 198) argued that a policy rule could be determined, implemented and used more effectively when the basic principles underlying the model are well adhered to. Taylor (1993: 201) found that it is preferable to give more weights to the prevailing economic conditions (inflation rate gap and the output gap), and give a little or no attention to the exchange rate. Therefore, adhering to the Taylor rule that takes into consideration capacity utilisation is a step towards achieving macroeconomic stability, economic development and employment creation (Taylor, 2010: 166-167).

Garratt, Lee, Pesaran and Shin (2006: 117) argued that the debate of the role played by output in maintaining macroeconomic stability is unresolved. This is because there is relatively little scope for adjusting aggregate output in the long run using monetary policy. Therefore, monetary policy aims at reducing short-run variations in aggregate output from its potential (long-run) level. In short, the role of the Taylor rule reaction function is to prescribe a short term interest rate that stabilises the economy in the event that both or neither aggregate output deviates from potential level nor inflation deviates from the targeted range. Nevertheless, applying a Taylor rule model is not a straightforward task due to the existence of unobserved variables in the model. These variables are potential output and the natural real interest rate.

2.4.3. The concepts of potential output and output gap

Another controversial variable in the Taylor rule equation is potential output and by implication also the output gap. Garratt *et al.* (2006: 117) wrote that the idea behind the potential output comes from Okun (1962) where long-run output was conveyed as output available at full employment utilising all the available resources. As a result, Conway and Hunt (1997: 02) cited in Smit and Burrows (1999: 03) defined potential output as the maximum aggregate output (goods and services) produced by the economy with no adjustment to the rate of inflation. This implies that a higher output growth above potential output (positive output gap), tends to decrease unemployment at a cost of raising wages over time which directly increase inflation.

According to the Taylor rule model, a rise in actual output growth relative to the potential output would imply that the economy is operating above capacity. Consequently, the excess capacity exerts extra pressure on the existing employees and production resources leading to a rise in inflation. In this regard, the central banks' reaction will be to increase the nominal real interest rate by β_{γ} (0.5 according to Taylor or a value close to 1 as argued by other authors) multiplied by the output gap in order to decrease output growth and ease the strained resources. Therefore, the central bank aims to smooth out deviations in production by maintaining output growth at its potential level (zero output gap).

According to Klein (2011: 01) the output gap is determined by subtracting potential output from the actual output. This deviation is a vital variable that threatens macroeconomic stability (Claus, Conway and Scott, 2000: 07). It is a crucial indicator of future inflationary pressures in the economy as well as an important linkage between the real sector (production side) and inflation. Garratt *et al.* (2006: 119) argued that the medium-term determinants of the output gap convey information about changes over time in capital stock, labour force and factor productivity (aggregate supply capabilities), and that these medium-term determinants play an essential role in establishing a sustainable output and employment growth path for the economy.

Smit and Burrows (1999: 04) argued that the quantity and quality of a country's factors of production and the level of technology influence the potential output trend. More so, Kahn and De Jager (2011: 74) noted that labour productivity, capital, land, infrastructure, government regulation and policies as factors that influence the level of the potential output. In spite of the good understanding of the data-generating factors of potential output, it is still unobservable and yet it plays a crucial role in stabilising an economy.

Smit and Burrows (1999: 04) argued that the problem with output gap estimates originate from the non-observable potential output and subsequently the implied output gap is not observable; rather both are estimated using some modelling techniques. This is confirmed by Garratt *et al.* (2006: 117) who stated that empirically the potential output level is frequently determined as a trend in output obtained through some filtering methods. These empirical measures are purely statistical constructs and barely contain any economic theory. Section 3.5 discusses approaches to estimate the potential output in testing the Taylor rule hypothesis.

A variety of measures have been adopted for measuring potential output, and these measures can be categorized into two major groups, namely the economic and the statistical techniques (Smit & Burrows 1999: 03). The economic measures adopt the use of a Cobb-Douglas production function mostly under a constant elasticity of substitution assumption. On the other hand, Klein (2011: 03) states that the statistical measures (time series functions) are classified as univariate, multivariate and structural vector autoregression approaches. The most used univariate methods in the literature are the Hodrick Prescott filter, the production function approach and the Kalman filter (Smit & Burrows 1999: 09). According to Klein (2011: 04) many central banks have adopted the structural vector autoregression approach in estimating the potential output. Casteleijn (2001: 11) confirmed the same for the SARB as part of their new suite of macroeconomic models.

2.4.4. The concept of natural real interest rate

The Natural Real Interest Rate (NRIR) is another unobserved variable in the Taylor rule model. According to Wintr, Guarda and Rouabah (2005: 07) Henry Thornton and Thomas Joplin pioneered the concept of the NRIR. Knut Wicksell (1898, 1907) later improved on it. Wicksell's influential paper investigated the connection between movements in the real rate of interest and the price level. Consequently, from the investigation he formulated the concept of a neutral rate of interest (natural rate) on loanable funds and commodity prices.

In simple terms, Wicksell (1907) established that the real rate gap (market *ex-ante* real rate less the NRIR) directly influences the price level. Therefore, Wicksell (1907) demonstrated that, *ceteris paribus,* if the central bank lowers the market real interest by 1 per cent below its natural rate and leaves it for a prolonged period, then prices of goods and services will rise and rise without any limit. On the contrary, *ceteris paribus,* if the central bank raises the market real interest rate by 1 per cent above its natural rate and leaves it for a prolonged period, then prices of commodities will fall and fall till they reach zero.

The Wicksellian idea went out of favour a century ago. However, the success of the Taylor rule in providing a sound benchmark model in monetary policy decision-making processes have necessitated a revisit to the idea (Wintr *et al.*, 2005: 06). The NRIR is included as an intercept term in the Taylor rule model. Taylor (1993) assumed that the NRIR was constant at 2 per cent for the USA economy from 1987 to 1991. The constancy of the NRIR is refuted under the Neo-Wicksellian framework as its nature is time-varying. The time-varying trait of the NRIR stems from the underlying fundamental determinants of the NRIR which vary over time. These determinants include risk premia, the time preference rate and financial market institutional structures.

According to Justiniano and Primiceri (2010: 14), *ceteris paribus,* if there is a prolonged positive real rate gap, consumers are inclined to delay spending as cost of borrowing is high and they can benefit from higher returns attained from savings. These actions lead to a fall in output relative to potential, and a negative output gap develops. Thereafter, in the absence of economic shocks or imbalances, inflation tends to fall due to the weaker demand for goods and services driving prices and wages downwards. Therefore, the economy experiences a recession. In such recessionary instances, the central bank authorities respond by reducing the ex-ante real interest rate until it equilibrates with the NRIR in order to stimulate aggregate demand and redirect the economy back to its stable growth path.

Justiniano and Primiceri (2010: 14) also state that, *ceteris paribus*, if there is a prolonged negative real rate gap, firms and consumers are encouraged to increase their investment and spending levels. These actions will cause output to expand relative to its potential level and a positive output gap develops. As a consequence, the economy experiences an expansionary period. The growth in total production as a result of the growth in aggregate expenditure will over time drive up wages and prices causing an increase in inflation. Therefore, in response the central bank authorities increase the market short-term real rate. This action will reduce the supply constraints as well as the inflationary pressures and redirect the economy back to its stable growth path.

Woodford (2003: 28) asserts that the resurgence of the Wicksellian framework necessitates that the NRIR be a time-varying variable that is consistent with a neutral policy stance. In order to achieve that it aims at a natural rate that stabilises inflation as compared to general prices. The thesis follows developments in the Wicksellian framework by applying a time varying NRIR in the empirical testing of the Taylor rule hypothesis. Unfortunately, the time varying NRIR cannot be directly observed. Therefore, various methods of estimating time varying NRIRs are applied in the thesis. These techniques are discussed in Section 3.6 below.

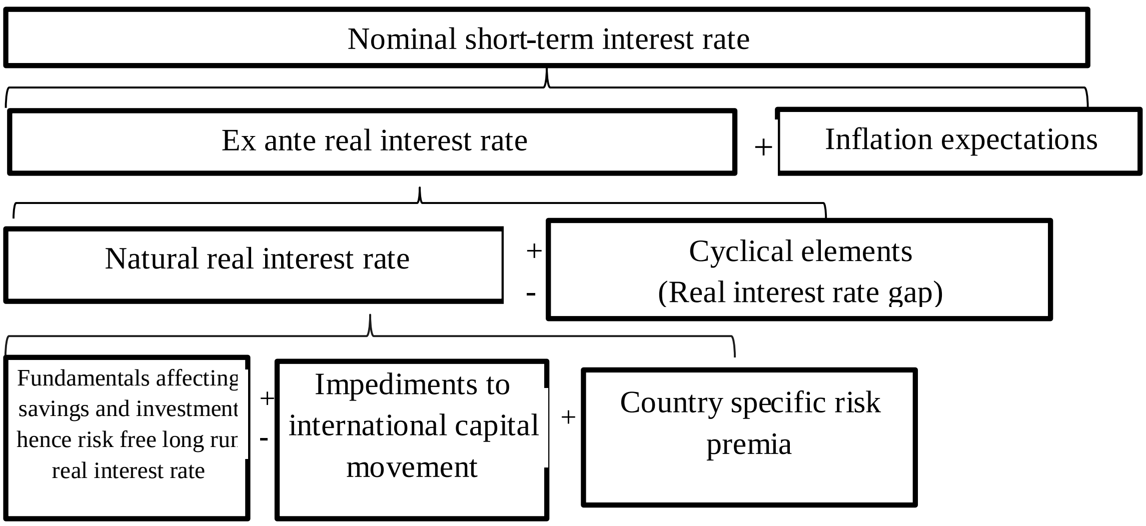
According to Wintr *et al.* (2005: 07) the time-varying definition of the NRIR depends on the time horizon one considers. First, the long-term perspective defines the NRIR as a rate that is stable and consistent with all markets in equilibrium. That is, over the long run the observed variables and unobserved variables should take the same value on average. Therefore, there is no pressure for any resource to change. In the South African context, Bruggemans (2008) applied this definition in estimating the potential prime interest rate. According to this definition, the term NRIR is used interchangeably with the term equilibrium real interest rate.

Second, the medium-term perspective defines the NRIR as a rate that achieves a zero output and inflation rate gap (inflation and output at its potential level). Laubach and Williams (2003: 1064) described the medium-term NRIR as a rate that prevails when the effects of demand and supply shocks have entirely faded away. This definition is widely cited and empirically modelled using multivariate approaches as well as semi-structured models (see Laubach & Williams (2003), Garnier & Wilhelmsen (2005) and Wintr *et al.* (2005)). The thesis follows the Laubach and Williams (2003) model in its NRIR determination. This is because it produces a time varying NRIR that corresponds to the intercept term in the Taylor rule model (see Section 3.6 for more details on estimation of the semi-structured models).

Lastly, the short-term perspective defines the NRIR as a rate that yields price stability in each period (Laubach & Williams, 2003: 1064). In short, this definition refers to an optimal NRIR that is achieved when prices are fully flexible. This definition is widely cited and empirically applied in Dynamic Stochastic General Equilibrium (DSGE) models, dealt with by Woodford (2003), Neiss & Nelson (2001) and Giammariolli & Valla (2003) amongst others. DSGE models provide a time-varying NRIR that have an economic interpretation. However, Larsen & McKeown (2004: 09) argued that DSGE models are highly sensitive to the assumptions made with respect to the calibration of inputs which can be a barrier in estimating the NRIR.

In light of the NRIR definitions discussed above, the decomposition of the nominal short-term interest rate (repo rate) in Figure 2.3 below sheds more light on understanding the concept.

Figure 2.3: <u>The nominal short-term interest rate decomposition</u>



Source: Archibald and Hunter (2001: 20)

According to Archibald and Hunter (2001: 21), given a risk free world with an integrated economy where capital moves freely, the relative degree of savings and investment yields a single rate of interest for the world commonly known as the risk-free long-run rate of interest. According to Woodford (2003: 70) the riskless rate of interest is only driven by fundamental factors that compel people to save or invest. The factors that drive savings include households' preferences, population growth and capital stock. Investment decisions are driven by increased returns resulting from the advancement in technology. Owing to its risk-free nature, the riskless real rate of interest is relatively more stable over time.

Nevertheless, the world economy is not characterised as a risk-free environment. Espinosa-Vega, Smith and Chong (2000: 01) argued that in the period prior to the 1990s South Korea and Taiwan had experienced a long history of barriers to free flow of capital. These barriers prevail due to differences in each economy's specific capital movement regulations as well as taxation. In addition, investor bias towards their home country is another barrier to the free flow of capital. This stems from the fact that domestic investors might be risk averse due to the uncertainty caused by risks as well as the legal framework of offshore investing; hence, they favour their own country.

Archibald and Hunter (2001: 21) noted that country specific risks are other factors that illustrate the existence of barriers to free capital flow. Owing to differences in legal frameworks and governance, countries with high risk (poor governance and macroeconomic instability) have to provide an extra return on investments in order for them to attract capital. The extra return is known as risk premia.

In light of the above, the sum of the riskless real rate of interest, barriers to capital flow and country risk premia makes up the NRIR as illustrated in Figure 2.3 above. These components of the NRIR are not directly observable[4]. Archibald and Hunter (2001: 20) argued that barriers to capital flow might yield a prior inconclusive effect on the NRIR. However, country risk premium will always produce a positive effect. In short, the assumption of a riskless rate of interest never holds as a result of the risk premia's impact on the NRIR. Nevertheless, the NRIR has low frequency transitional movements over time as the structural factors that determine it vary gradually over time (Laubach & Williams, 2003: 1066).

The market ex-ante real interest rate is the sum of cyclical elements and the NRIR. The cyclical factors are known as the real interest rate gap. The real interest rate gap occurs due to

[4] This constitutes the major problem in estimating the natural real interest rate.

monetary policy trying to lean against inflationary pressures in the economy (Archibald & Hunter, 2001: 22). To arrive at the nominal short-term rate of interest one has to add expected inflation to the market ex-ante rate. Expected inflation is another unobserved variable that is difficult to model.

Apart from being an intercept term in the Taylor rule model, the NRIR can be applied on its own to evaluate whether the monetary policy stance at a specific time period is contractionary or expansionary. Therefore, it is important to monitor the level of the NRIR irrespective of its high uncertainty in order to achieve macroeconomic stability.

2.4.5. Critiques and benefits of the Taylor rule model

It is essential to understand that the Taylor rule model is not a strict monetary policy rule. It is a guideline or rule of thumb. Orphanides (2007: 11) argued that the Taylor rule guideline could result in misleading outcomes due to the existence of unobserved variables as well as the unavailability of real time data. The major problem with the Taylor rule is the availability of data when policy decisions are being made as many variables are either going through some revision or else they are not available at all (Svensson, 2002: 14). Kohn (2007: 02) noted the unavailability of the potential output and the NRIR data as the major problem with the Taylor rule model. The unavailability of data prevents policy makers to effectively apply the Taylor rule model as a guideline in real time. Often, the rule provides an evaluation of historical monetary policy decisions.

Greenspan (1997, cited in Asso *et al.*, 2007: 02) argued that the Taylor rule model assumed the future is similar to the past. Therefore, the consistent implementation of the Taylor rule does not imply an appropriate policy stance in cases where the central bank is highly discretionary (Clements, 2004: 14). This was revealed from the banking crisis (early 1990s) as well as the global financial crisis (2007-08) experience. Hence, history cannot be used as an infallible guide to the future. Furthermore, in periods of recession and zero lower bound nominal interest rate the Taylor rule yields a less effective monetary policy stance (Belke & Klose, 2012: 10). This can be explained by the fact that a higher real interest rate can further dampen the recovery from a recession whilst a low real interest rate may help improve the recovery but at a cost of increasing inflationary pressure.

The central bank can react pre-emptively or with some policy inertia. Clements (2004: 15) argued that the policy officials, as a consequence, might behave differently to what the Taylor rule model predicts. For instance, a forward-looking discretionary central bank like the SARB can respond pre-emptively in expectation of distortionary future conditions by increasing the repo rate as they anticipate future inflationary pressures. Alternatively, the SARB can rather prefer to do nothing if they feel the adjustment to output or inflation is temporary.

Knedlik (2004: 03) supplemented Ball (1999) by including the exchange rate dynamics to the central bank reaction function especially in a small emerging economy. This stems from Balls (1999: 142) argument that with an open economy, the exchange rate plays an important role in establishing macroeconomic stability; hence, it should be a vital part of the monetary policy reaction function. According to Comert and Epstein (2011: 102) the SARB has started being aware of the exchange rate volatility especially in manufacturing and the trade competing sectors. As a result, Comert and Epstein (2011: 102) noted that the SARB has been responsive to exchange rate dynamics excessively around the early 2000s as they were defending the value of the rand through the adjustment of reserves.

Kannan, Rabanal and Scott (2000: 05) argued that apart from considering the inflation rate gap and the output gap, it is important to also consider other financial variables like asset prices. This is because asset prices play a major role in distorting macroeconomic stability of many economies as was the case from the recent 2007-08 global financial crisis. In the case of South Africa, Ndahiriwe and Naraidoo (2010: 10) concluded that the SARB focus closely on financial assets prices in their monetary policy conduct. However, their response to financial assets is governed by the macroeconomic environment, for example business cycles.

Apart from asset prices, Taylor (2009: 49) argued that fixed exchange rate regimes and government interventions together with external institutions (IMF, advisors) can hinder the success of the Taylor rule. Travaglini (2010: 28) also noted that structural breaks, implementation of stop and go policies, lack of consistency, fixed exchange rate regimes, capital flow reversals and bubbles act as barriers to the estimation of the Taylor rule.

The benefits of applying the Taylor rule model explained by a simple linear equation are that it is easy to use, apply and understand. In addition, Kohn (2007: 02) cites the following benefits of using a simple linear policy rule. First, it provides a valuable yardstick for policy makers. Second, it helps financial market players in the formation of expectations of the future course of monetary policy. Lastly, it improves the public and central bank's communication. More so, the systematic application of the Taylor rule warrants a more predictable, transparent, credible and effective monetary policy stance. It also increases the accountability of central bank actions as well as eliminates uncertainties.

2.5. **Chapter Conclusion**

Central bankers apply a variety of policy instruments in their pursuit of the price stability objective. Over the study period, the SARB adopted monetary stock targets, informal inflation targets and subsequently formal inflation targets in their pursuit of the price stability objective (as discussed in Section 2.2). The current inflation-targeting framework is not very satisfactory in terms of improving employment levels in the country because of structural problems. Therefore, this thesis attempts to deepen our understanding of the role of a Taylor-type rule in the implementation of monetary policy, both before and after the adoption of the formal IT framework. This chapter reviewed literature on the Taylor rule.

The Taylor rule model has empirically assisted many central bankers in their pursuit of price stability. Section 2.4 discussed the Taylor rule model. The underlying economic ideas behind the Taylor rule model illustrate important theoretical insights to policy makers about the economic dynamics. However, empirically the policy rule takes for granted the ability of policy makers to precisely measure unobserved variables. These variables are the main cause of debate in the estimation of the Taylor rule model. This is because there is not a consensus on describing the actual behaviour of the unobserved variables.

However, there are consensuses on the underlying determinants as well as the expected signs on the coefficients of the unobserved variables. This implies that a number of economic and statistical approaches can be used to reveal the behaviour of these variables. The procedures for deriving the unobserved variable are discussed at length in Chapter 3. It is important to exercise caution when interpreting the results from the Taylor rule model as the model is characterised by a great deal of uncertainty.

Therefore, the benchmark rule can be applied empirically as a check of whether the central bank's ex-post monetary policy stance was accommodative or restrictive. The next chapter discusses the techniques for evaluating the hypothesis whether the SARB decisions to change the repo rate are influenced by considering the output gap, as well as the inflation rate gap.

CHAPTER THREE

METHODOLODY

3.1. Introduction

Taylor (2010: 166-168) argued that the consistent low interest rate in the USA economy stimulated monetary excesses that fuelled inflation which led to the 2007-08 global financial crisis. According to Taylor (2009: 60) these low nominal interest rates resulted from the central banks' discretionary monetary policy getting off track. Therefore, the setting of the nominal short-term interest rate by the central bank plays a crucial role in the sustainability of macroeconomic stability in the economy.

Before the adoption of the formal IT framework in 2000 the inflation rate was nudged downwards until it seemed to stabilise by 1999/2000 around a range of 3 to 6 percent. That probably contributed to the decision in 2000 to formally adopt the IT framework with an inflation target range of between 3 and 6 percent. Since 2000 the inflation rate in South Africa move above 6 per cent a couple of times but appears to have been brought back to within the formal IT framework targeted range (see Figure 3.2 below). The purpose of this study is to analyse the hypothesised SARB reaction function with particular focus on testing whether a Taylor-type model, i.e an output gap as well as an inflation gap, influenced the setting of the policy rate.

In order to test the Taylor rule hypothesis, this thesis adopts a simple linear Ordinary Least Squares (OLS) technique to be discussed in Section 3.3.2. This technique is easy to use and understand. It is the most applied approach in macroeconomic research. Granger and Newbold (1974) cited in Dolado, Gonzalo and Marmol (2001: 01) noted that the data-generating processes underlying variables used in the analysis are stochastic and hence non-stationary. The use of non-stationary variables results in a spurious regression. In order to achieve non-spurious results all variables used in the Taylor rule hypothesis testing are subjected to tests for stationarity, order of integration and cointegration.

Stationarity and order of integration of the Taylor rule variables are evaluated using unit root tests (see Section 3.4.2) whereas cointegration is examined using the Engle-Granger[5] approach (see Sections 3.4.3.1). The Engle-Granger cointegration technique is the most applied technique in empirical macroeconomic research because it is easy to implement and understand. The cointegration test is applied to the Taylor rule variables namely consumer price index (headline inflation), Natural Real Interest Rate (NRIR), repo rate, 10-year government bond yield and gross domestic product (see Section 3.2 for the variables discussion).

According to Kahn and Farrell (2002: 02) the standard procedure of approximating the real interest rate comes from the Fisher equation. Therefore, it can be argued that the nominal short-term interest rate is altered following changes in two variables, namely the expected inflation rate and the real interest rate. These two variables do not account for pressures developing from economic activities. Taylor (1993: 202) proposed a monetary policy reaction function (later known as the Taylor rule), with the output gap and inflation rate gap, that accounts for the state of economic activity as well as inflationary pressures. Underlying this, the Taylor rule model takes for granted the ability of policy makers and advisors to precisely measure its unobserved variables using econometric techniques. These unobserved variables include potential output, the output gap and the NRIR.

The output gap refers to the deviation of actual output from its potential level. According to Harvey (2000: 01) the output gap is subjected to debate due to the uncertainty in the specification of the potential output trend dynamics. As a result, Section 3.5 focusses on the production function approach, Hodrick-Prescott filter, Baxter-King filter and the Kalman filter techniques for estimating potential output. These approaches are applied in the estimation of the potential output trend and the output gap.

Another unobserved variable in the Taylor rule model is the NRIR. Wicksell (1907) a century ago pioneered the NRIR concept based on ideas put down by Henry Thornton and Thomas Joplin. The growing focus on Taylor rule type models led to the resurgence of the NRIR concept in monetary policy discussions. This concept is characterised by uncertainties in its estimation process. Owing to these uncertainties, this thesis applies all approaches discussed

[5] The Johansen approach was also run to determine the number of cointegrating relationships in the Taylor rule models and at-most one cointegrating relationship was found. As a consequence, the thesis entirely focussed on the Engle granger approach for cointegration testing of the Taylor rule hypothesis.

in Section 3.6 below in the estimation of the NRIR in order to gain insight into the concept and its dynamics.

Section 3.7 offers a summary of all the approaches used in evaluating the Taylor rule hypothesis. Although there is uncertainty in the measurement of the Taylor rule variables, the model still offers an optimal benchmark when evaluating the central bank's historical monetary policy degree of accommodation or restrictiveness.

3.2. **Data**

Taylor (1993: 202) states that the central bank's policy reaction function should be a function of the actual inflation rate, NRIR, the output gap and the inflation rate gap. This section focuses on the variables applied in the testing of the Taylor rule hypothesis for the South Africa economy over the period 1989-2009. This study utilises the repurchase rate, consumer price index (headline inflation), 10-year government bond yield and real gross domestic product data. These variables are extracted from SARB reports and statistical figures, Statistics South Africa, and other published studies. The potential gross domestic product and the NRIR are statistically estimated (see Sections 3.5 and 3.6) due to the fact that these variables are not directly observable (Smit & Burrows 1999: 03).

Eviews econometric software package is utilised to evaluate the Taylor rule hypothesis. Owing to the uncertainties involved in estimating unobserved variables, the STAMP (Structural Time Series Analyser, Modeller and Predictor) econometric software package is used to evaluate the underlying salient features of the data generating processes of each variable. An advantage of using STAMP is the ability of the package to identify structural breaks and outliers. This is achieved through the auxiliary residual tests. According to Koopman, Harvey, Doornik and Sherpard (2009: 70) auxiliary residuals are smoothed error terms that play a crucial role in unveiling information hidden in error terms.

3.2.1. Repurchase rate

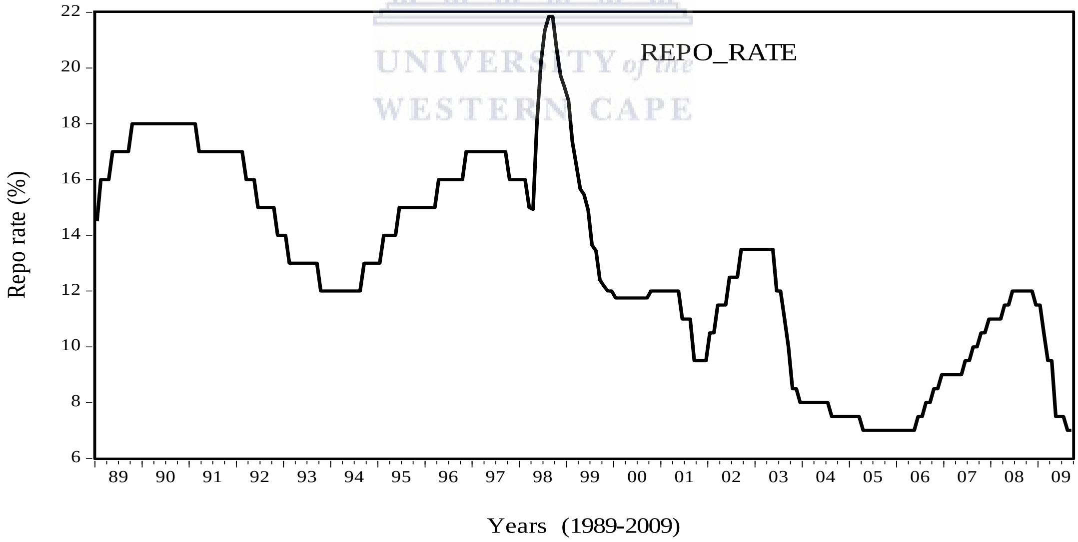
The repurchase or repo[6] (r) rate is the dependent variable in the Taylor rule model. Upon appointment, Dr Stals inherited a relatively high repo rate of approximately 17.32 per cent for the first three years as the governor of the SARB. At the same time inflation (headline) was

[6] See Section 2.2.4 for a discussion of the repo rate.

relatively high averaging 15%, this could be the reason for the high nominal interest rate. The success of the eclectic monetary policy in stabilising prices in the early 90s led to a significant drop in the repo rate. During the democratic transformation, the repo rate was as low as 12 %. In the post 1994 period, the repo rate increase gradually over time to 15% by the year 1997. The period 1998-99 reflects a sharp increase in the repo rate. This period coincides with the Asian crisis. However, the increase was short lived.

The Mboweni governorship reflects a general decline in the repo rate which was in line with the international trends in the nominal interest rate changes (IMF, 2014: 02). According to the IMF (2014: 09-14) the world decline in the interest rates can be explained by (1) a gradual decline in the investment to GDP ratio from the 1980s, (2) an increasing emerging markets savings to investment ratio highly noticeable in the post 2000 period (3) improvements in fiscal policies especially those of the advanced economies, and (4) portfolio shifts from the risky equity assets towards safe assets (government-guaranteed bonds). Figure 3.1 below reflects the path of the repo rate from 1989-2009.

Figure 3.1: **<u>The South African repurchase rate 1989-2009</u>**



Source: SARB (2015)

According to the auxiliary residuals, the Mboweni governorship showed three level breaks in the repo rate. These correspond with the sharp falls experienced during 1999, 2003 and 2009. The 1999 sharp decrease can be explained by a change in governorship as well the 1998-99 Asian crisis whilst, the 2003 sharp decrease can be explained by the SARB intervention in the exchange rate market to support the value of the rand. The adjustments made to the repo rate by these two governors were targeted at achieving a stable inflation rate.

3.2.2. The inflation rate

According to Van der Merwe (2004: 05) the SARB adopted an inflation target range of an average increase in the consumer price index (CPIX) between 3 to 6 per cent since 2000. The consumer price index target was chosen because it is meaningful and easily understood by the general public. In short, the CPI inflation measure improves the credibility of the central bank. The targeted range was made a continuous range measured on a monthly basis with a twelve month window period from 2006 and beyond. According to the SARB (2010: 121) CPIX was replaced by CPI in 2009 following the Statistics South Africa (Stats SA) adoption of a rental equivalence measure for housing which is not directly influenced by monetary policy decisions.

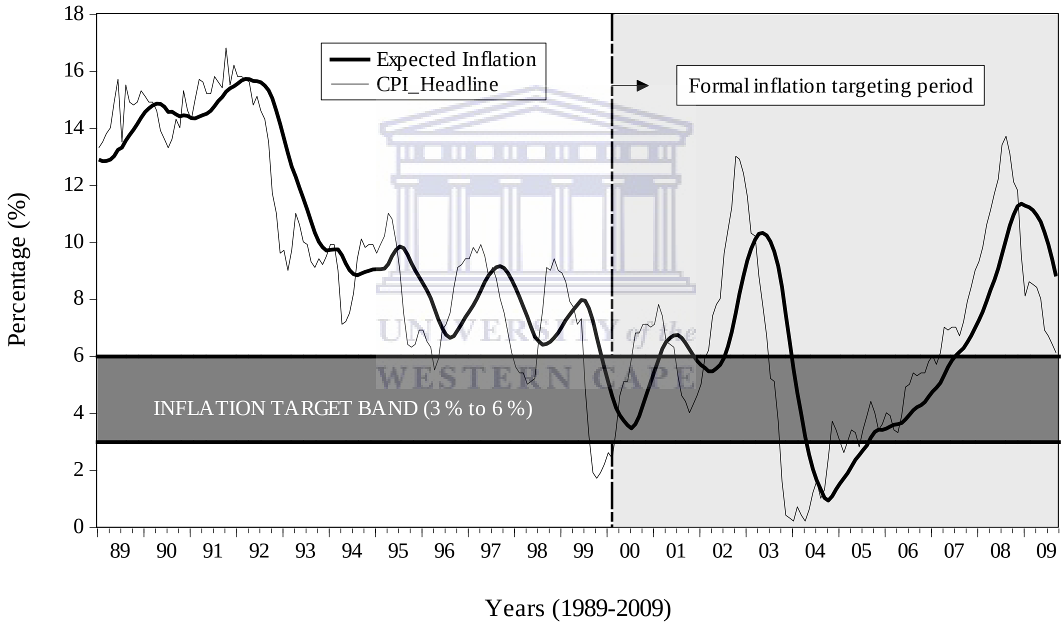
Statistics South Africa (2013: 04) defines the CPI as "a current social and economic indicator that is constructed to measure changes over time in the general price level of consumer goods and services that households acquire, use or pay for". Although the CPI is the sole target of the SARB, Ellyne and Veller (2011: 19) argued that supply-side volatile effects[7] influence the trajectory of the headline CPI. Consequently, if the central bank responds to these volatile inflationary pressures, then it will undermine societal welfare through decreasing aggregate demand as well as prices of commodities that are relatively sticky (Du Plessis, 2014: 04). Therefore, the policy step will not be desirable.

Nevertheless, Woodford (2003: 3) argued that a central bank policy reaction to inflationary pressures should be targeted, with a greater weight, towards the commodities with relatively sticky prices. This means central banks should respond to inflationary pressures that are a result of changes in relatively sticky commodities (core inflation). According to Marcus (2014: 04) core inflation has proved to be a good policy guide in the conduct of monetary policy. As a result, the SARB publishes both their core inflation and headline inflation forecast estimates.

[7] The supply side volatile effects are ascribed to changes in international commodity prices, indirect taxes as well as natural disasters.

In the South African literature, there had been a growing interest in core inflation (see Rangasamy (2009); Blignaut, Farrell, Munyama & Rangasamy (2009); Ruch & Bester (2011); Du Plessis (2014); Du Plessis, Du Rand & Kotze (2015) and Ruch, Balcilar, Modise & Gupta (2015)). Empirical evidence from these important contributions reflects a number of techniques used to characterise the trajectory of core inflation. However, the thesis follows Taylor in applying the previous four quarter inflation average as a measure of actual inflationary pressures in the economy. In line with Taylor 1993, the lagged inflation provides a proxy for expected inflation. Figure 3.2 outlines the inflation rate over the previous four quarter and the CPI headline inflation rate over the period 1989-2009.

Figure 3.2: Four quarters inflation rate vs CPI headline



Source: SARB and author manipulation (2015)

Figure 3.3 reflects low variability on the expected inflation (four quarter inflation average) measure relative to the trajectory of CPI headline. Both measures reveal a general downward trend over the Stals governorship. The period 1989-92, characterised by financial sanctions on the South African apartheid era government, reflects a very high inflation rate averaging approximately 15 per cent. The adoption of the discretionary or eclectic monetary policy by Stals stabilised inflation in single digits.

Figure 3.2 further reveals that during the Stals governorship, both inflation rate measures were above 6 per cent most of the time, although the trend was downwards. The CPI headline was below 6 per cent (albeit not yet an official 'target') only during the last couple of years of the Stals governorship. The apparent success of the SARB under Stals to bring down the inflation rate to a level where it could be sustained may well have provided the impetus to the formal adoption of IT with the inflation target range of 3 to 6 per cent. Under the governorship of Mboweni, both inflation rates were three times above 6 per cent, but seems to have been brought back subsequently to within the targeted range. The SARB intervention in the foreign exchange rate market in the early 2000s, following a severe depreciation of the rand, as well as the 2007-8 global financial crisis led to sharp increases in the inflation rate.

3.2.3. Natural Real Interest Rate

The NRIR[8] is one of the Taylor rule model explanatory variables. According to Bernhardsen and Gerdrup (2007: 52) the mid-term definition of the NRIR concept implies a monetary policy stance that is neutral. That is a policy stance which is not expansionary or contractionary, but consistent with the closed output gap. According to Arnon (2011: 344) the Swedish economist Wicksell demonstrated the NRIR concept in 1907. In the original Taylor rule model, the NRIR was included as a constant intercept term set at a value of 2 per cent. Woodford (2001: 14) disagrees with the notion of a constant NRIR. Rather, he advocated for a varying NRIR over time as shocks that influence it also vary with time. In line with the developments in the Wicksellian framework, the thesis will use a time varying NRIR in testing the Taylor rule hypothesis.

Bernhardsen and Gerdrup (2007: 52) explained that in terms of the Wicksellian idea, prices either increase or decrease depending on whether the market real interest rate is below or above the NRIR respectively. Unfortunately, the precise value of the time varying NRIR cannot be observed directly. Therefore, the NRIR is estimated using methods cited in Section 3.6. These approaches aim to decompose the market real interest rate into the NRIR and cyclical elements (real rate gap) as reflected in Figure 2.3.

Das, Gupta, Kanda, Tipoy and Zerihun (2012: 26) argued that the market real interest rate is a vital explanatory variable in macroeconomics and financial models. These models include the

---

[8] For a detailed discussion of the natural real interest rate, see Section 2.4.4.

Taylor rule, neo-classical growth models, and consumption–based asset pricing models as well as other monetary policy transmission mechanism models (Neely & Rapach, 2008: 609). In these models, the market real interest rate is calculated either as the nominal interest rate less the expected inflation rate (Ex-Ante Real Interest Rate (EARIR)) or as nominal interest rate less actual inflation rate (Ex-Post Real Interest Rate (EPRIR)). Kahn and Farrell (2002: 11) argue that the EPRIR and EARIR measures of the market real interest rate follow a similar or common trend with a marginal difference over the long run.

Kahn and Farell (2002: 05) state that the Fisher equation is the standard procedure to estimate or approximate the real interest rate value. According to the Fisher equation the EARIR on a bond held to maturity is equal to the nominal interest rate less expected inflation over the bond lifetime as illustrated by the equation below.

$$r^{ea}{}_{t} = i_t - E_t \pi_t$$

Where $r^{ea}{}_{t}$ = the ex-ante real interest rate, i_t = nominal interest rate at time t and $E_t \pi_t$ = the expected inflation rate at time t of the rate of inflation from period t to maturity.

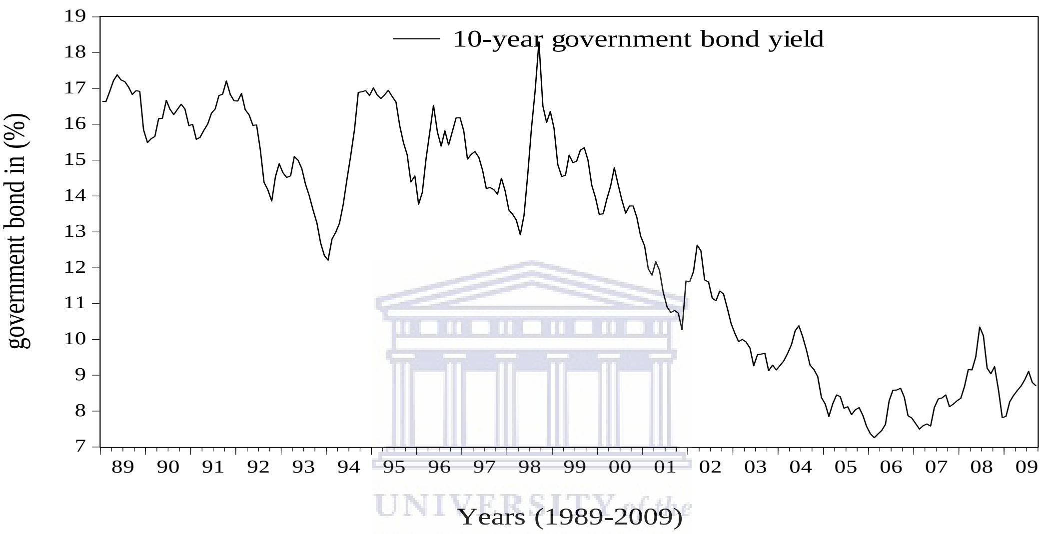
Based on the Fisher equation, the market EARIR is applied as the market real interest rate in the derivation of the natural real interest rate for the testing of the Taylor rule hypothesis. Unfortunately, expected inflation cannot be directly observed hence the inflation over the previous four quarters will be applied as a proxy for the expected inflation rate. The use of the lagged inflation transforms the Taylor rule model into real terms. Another approach that can be adopted for deriving the NRIR is through decomposing the long-term government bond yield.

3.2.4. 10-year government bond yield

The 10-year government bond yield is one of the variables used in the determination of the NRIR. According to Bomfim (2001: 04) financial market information provides a better measure of the rate of return on financial market instruments. Therefore, this implies that adjustments in the long-term nominal interest rate reflect investors' predictions of expected inflation as well as the short-term interest rate. Figure 3.3 below outlines the South African long-term nominal interest rate.

Under the governorship of Stals, the 10 year government bond rate fluctuated around the mean of 15.48 per cent. The high rate of return on the bond rate in the late 80s can be attributed to the balance of payments constraints caused by capital outflows after the 1985 debt crisis as well as the financial sanctions imposed on the apartheid regime (Du Plessis & Smit, 2005: 22). As the financial sanctions were lifted, South Africa started experiencing capital inflows which contributed to the downward trend in the early 90s.

Figure 3.3: <u>The South Africa 10-year government bond yield (1989-2009).</u>



Source: SARB (2013)

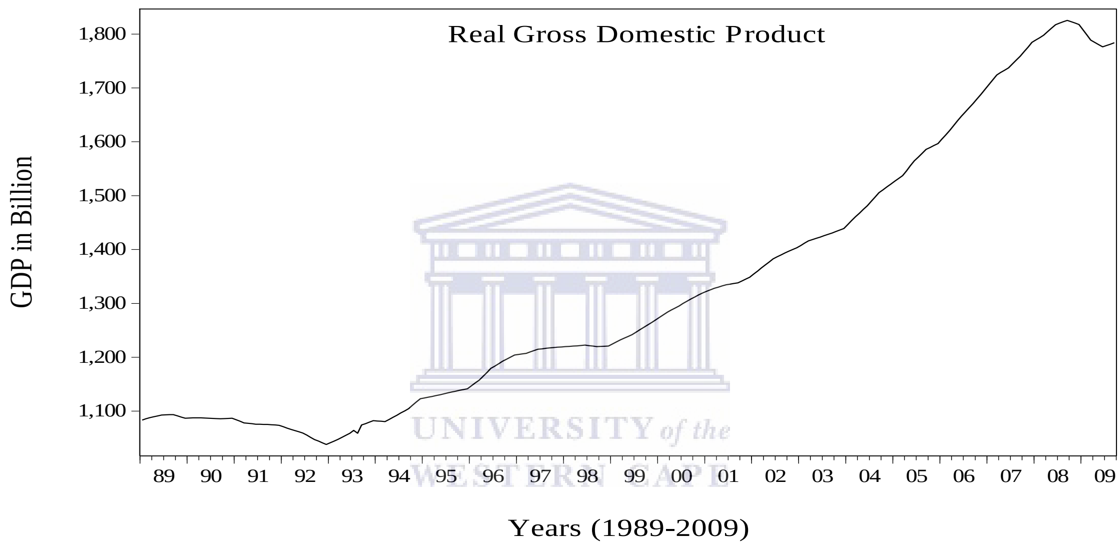
Mboweni's governorship reflected an average gradual decrease in the government bond rate. There were markedly increases in the early 2000s as well as the period of the financial crisis, however they were short lived. According to the auxiliary residuals from the STAMP package, there was an outlier in 1996 and a level break in 1994. Changes in the nominal short term interest rate are transmitted through the goods or financial market to changes in the productivity growth in the country.

3.2.5. Gross Domestic Product

Gross Domestic Product (GDP) is another explanatory variable in the Taylor rule model. Mohr and Fourie (2004: 66) define GDP as "the total market value of all final goods and services produced within the boundaries of a given country at a particular time period (usually one year)". GDP is primarily used as a barometer measure of capacity utilisation in the economy. In this study, GDP is used to derive the potential output trends (see Section 3.5) as well as the output gaps.

Three approaches are applied to calculate GDP in South Africa. These are the expenditure approach, the income approach and the production approach. Statistics South Africa compiles the production side of GDP whilst the South African Reserve Bank compiles the expenditure side (Stats SA, 2013: 13). Figure 3.4 below outlines the real gross domestic product for South Africa over the period 1989-2009.

Figure 3.4: <u>Real gross domestic product of South Africa 1989-2009</u>



Source: SARB (2012)

Figure 3.4 shows the South African real GDP trend over the period of study. The data reflect a downwards phase until the end of 1992. From early 1993, there was a continuous growth in GDP which ended in late 2008 and then declined till the end of the study period. According to the auxiliary residuals, the GDP trend illustrates a significant drop (outlier) in output in late 1993, which can be explained by a speculative panic over the forthcoming 1994 elections.

3.2.6. Conclusion on variables

The Taylor rule model states that the central bank reaction function should be a function of the actual inflation rate, NRIR, the inflation rate gap and the output gap. This section discussed all the variables used for the Taylor rule hypothesis testing. All the variables above reflected stochastic trends. This implies that these variables are non-stationary in their raw state (levels format). The Eviews and the STAMP software packages were used to evaluate the dynamic feature of the data-generating processes in the variables. In order to evaluate the Taylor rule hypothesis these variables are applied in the regression analysis.

3.3. **Framework**

3.3.1. Regression analysis

Regression analysis is the process of explaining complex noisy data using a mathematical equation in the least simple manner. Maddala (1977: 97) argued that Sir Francis Galton developed the concept of regression analysis in 1889. In economics as well as other disciplines, regression analysis is used primarily for prediction and/or forecasting. The method of regression analysis is a widely applied statistical tool in determining relationships between economic variables (Desai 1979, Gujarati 2009 and Mills 1990). Maddala (1977: 104) noted that a simple linear regression explains the correlation between a dependent and an explanatory variable. However, a multiple linear regression focusses on a dependent variable and a number of independent or explanatory variables. This paper uses the multiple linear regression method.

According to Maddala (1977: 104) a multiple linear regression illustrating the relationship between a dependent variable and a set of explanatory variables ($X_0, X_1, ..., X_n$) is represented by the equation below:

$$Y = \beta_0 X_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots\ldots + \beta_n X_{n-1} + e_t$$

where $\beta_0, \beta_1, \ldots\ldots, \beta_n$ are unknown parameters, $X_0, X_1, ..., X_n$ are independent non-random variables, the subscript n denotes the number of regressors as well as their parameters and e_t is an innovation term. The innovation term e_t reflects the deviation of the estimated observation relative to the actual observation, and it is assumed to be equal to zero $(E(e) = 0)$. The innovation term is also known as the error term or irregular term or the regression residual.

After establishing the multiple linear regression, where the explained variable (Y) is assumed to have a linear relationship with the explanatory regressors $(X_0, X_1, ..., X_n)$ that are disturbed by a random irregular term, then the problem is left to find the best estimates of the parameters or betas $(\beta_0, \beta_1, ..., \beta_n)$. This problem is resolved by applying a widely used technique called the method of least squares.

3.3.2. Method of least squares

According to Maddala (1977: 83) in statistical analysis the method of least squares is used to choose the best fit curve that has the minimal sum of residual squares (least squares error) from a set of data. Greene (2003: 42) argued that in cases were the true model is not a linear regression the best-fit line from the least square method still yields a robust optimal predictor of the dependent variable. In addition, Desai (1979: 44) noted that the method of least squares assumes independent and normally distributed error terms with the expected error equal to zero. Therefore, the least squares method of approximation to find the beta coefficients aims to estimate betas that minimise the sum of squared residuals (SSE).

Woodridge (2005: 43) explained the SSE for all the nth data points using the following equation:

$$SSE = \sum_{t=1}^{n} e_t^2 = \sum_{t=1}^{n} \left[Y_1 - (\hat{B}_0 + ... + \hat{B}_N) \right]^2$$

The above equation produces the betas that minimise the sum of squared residuals. These betas are called the least squares estimates. The combination of betas that are least squares estimates presents a global minimum point amongst all possible values in any given data set. Therefore, if an estimator is linear and has a variance that is less than or equal to that of any other estimate applied to the data of interest, then the estimator (beta) is said to be a Best Linear Unbiased Estimator (BLUE) for the estimated value or betas.

Desai (1979: 42) notes that the mass of the probability density function of the estimator is concentrated around the true parameter value given that the estimator has the BLUE characteristics. The BLUE properties of the OLS estimate are often referred to as the Gauss-Markov Theorem. According to Gujarati (2009: 71) the OLS technique is simple to use, easy to understand and it satisfies the BLUE properties. Furthermore, OLS estimators are easier to compute and use than any non-linear methods. The linear specifications in econometric modelling are adopted partly for computational convenience since the Ordinary Least Squares (OLS) technique is directly applicable to them (Desai, 1979: 12).

Therefore, regardless of the fact that one had the best linear unbiased estimators (BLUE), it is important to test for cointegration in the variables. According to Desai (1979: 42) prior to the introduction of cointegration time series econometric analysis based on the assumption of stationarity was characterised by spurious regressions. This was because the underlying data generating processes were assumed to be stationary whilst they were a realisation of stochastic processes. Thus, time series analysis using stochastic (non-stationary) variables in economics suggest relationships amongst variables that do not exist (spurious results). Hence, cointegration is crucial for a thorough understanding of the relationships between economic variables.

3.4. **Evaluating cointegration**

According to Harris (1995: 06) cointegration refers to the existence of a stationary linear trend derived from multiple interrelated non-stationary variables to form a long-run relationship. Cointegration vectors are important in regression analysis as they reflect long-run relationships among multiple non-stationary variables. Cointegration is a crucial element of time series modelling as it imitates an economic system converging to a long-run equilibrium (Harris, 1995: 06). Hence, failure to test for it results in spurious regression or nuisance regression. According to Dolado *et al*. (2001: 01) the influential paper by Granger and Newbold (1974) proved that with non-stationary data the traditional statistical testing techniques might propose significant relationships (spurious regression) where actually none exists in the data.

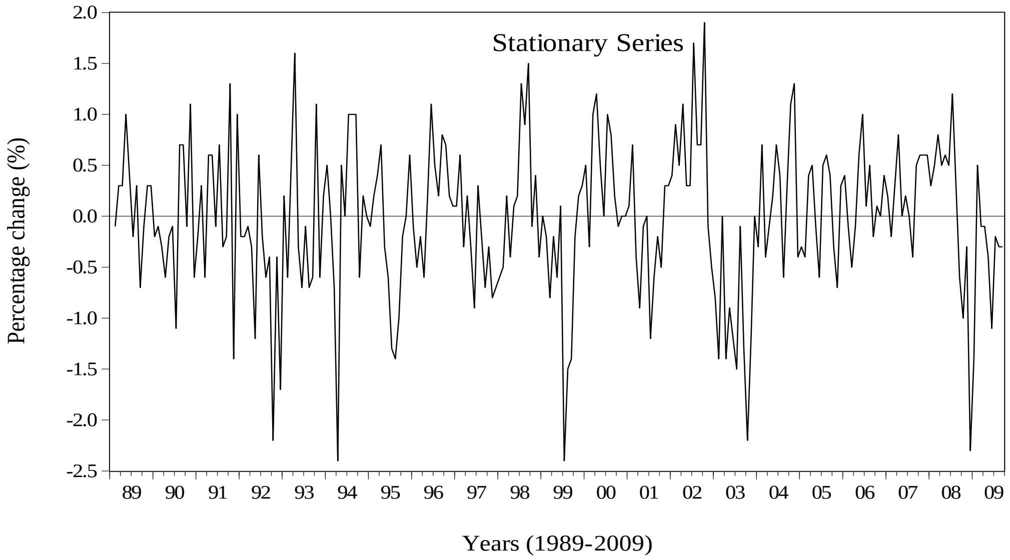
The findings by Granger and Newbold (1974) further stimulated research towards the construction of econometric models that are realistic and useful. According to Dolado *et al.* (2001: 02) Granger (1981) contributed a step towards solving the problem of spurious regression by suggesting that variables with a stationary growth rate reflect linear relationships within the levels format. Engle and Granger further developed and formalised the idea of integrated variables (Engle & Granger, 1987: 252). They termed their finding cointegration.

Cointegration is widely applied in time series empirical research in order to deduce the true economic relationships amongst variables. According to Hendry and Juselius (2001: 01) in a multivariate linear regression where variables are non-stationary $(I(1))$ there can be a number of unique vectors such that the error terms are stationary. Chatfield (2000: 146) explained the concept of cointegration as a combination of two random walk variables $\mathrm{X_t}$ and $\mathrm{Y_t}$ at time period t which are integrated of order d such that a unique stationary vector (α) exists. Therefore, if $Y_t - \alpha X_t = e_t$, and e_t is integrated of order less than d then it is said that variables $\mathrm{X_t}$ and $\mathrm{Y_t}$ are cointegrated denoted as $X_{t,}\ Y_t \sim \mathrm{CI}(d-p)$. The first step in testing for cointegration is to examine whether or not the variables are stationary.

3.4.1. Stationary and non-stationary

According to Gujarati (2009: 740) a stationary variable is defined as, "a random variable that has a constant mean and variance, and its covariance over two periods depends only on the gap over the two time periods". This implies a mean reversion variable that revolves within a constant range over time. Sorenson (1997: 03) explained that stochastic processes are integrated of order(ρ), denoted as $\mathrm{I}(\rho)$, if they need to be differenced (ρ) times to eliminate unit roots (see Section 3.4.2 for a discussion of unit roots) and attain stationarity. Therefore, stationary variables are $\mathrm{I}(0)$. Figure 3.5 presents a stationary (mean reversion) series.

Figure 3.5: <u>A stationary CPI headline inflation first differenced series</u>

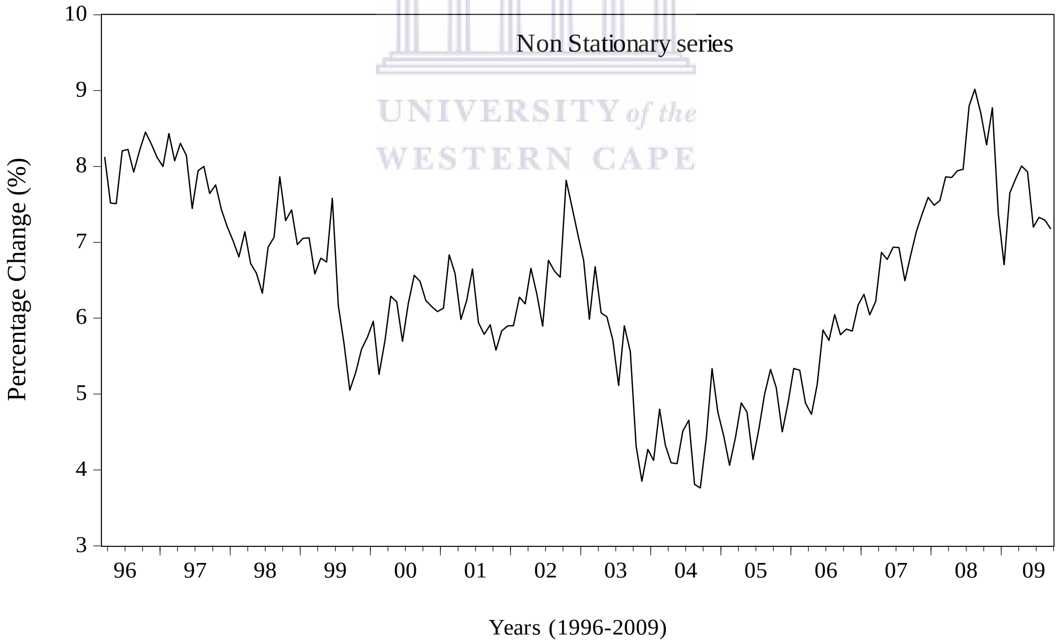


Source: SARB and author manipulation (2013)

The statistical theory applied in the 1980s was based on the classical theory assumption of stationarity as noted by Hendry and Juselius (2000: 01). This implies that the distributions of time series variables were assumed stable over time. The problem with assumed stationary processes is that inferences are often spurious and unacceptable. This is because a non-stationary series diverges from the mean at all points in time, and its variance increases with the sample size.

Dolado *et al.* (2001: 02) argued that in practise almost all the macroeconomic time series are often non-stationary. For example, variables like production, inflation, consumption and employment share this property. Therefore, any inferences made from the regression of non-stationary variables in their levels format (original form) yields causality conclusions that do not exist (spurious regression). These problems of spurious regression generally increase with sample size (Harris 1995: 20). Figure 3.6 outlines a non-stationary (non-mean reversion) series.

Figure 3.6: <u>A non-stationary Kalman filtered CPI headline inflation variable</u>



Source: SARB and author manipulation (2013)

Statisticians working with time-series models in the 1980s suggested a solution for solving the spurious problem as simply using first differenced variables. This is because first differenced (growth rate) variables are usually stationary even though their original states are not (Harris, 1995: 19). Gujarati (2009: 418) notes that it might be interesting to examining economic theories based on the variables' growth rate rather than the levels or original format. Nevertheless, focusing on the growth rate can result in not making complete use of economic theory especially when the theory is formulated for variables in their levels format.

Aadland (2005: 08) argued that another method to solve the spurious problem involves eliminating a linear time trend in variables and formulating the economic relationships applying detrended[9] data. However, detrended data characterise short-term relationships well at the opportunity cost of the long-term causal relationship information.

A system characterised by cointegrating variables illustrates convergence towards equilibrium whenever it is in disequilibrium. That is, with stationary cointegrated variables complex economic relationships can be understood, and policy makers can draw informed conclusions. Gujarati (2009: 822) argued that stationarity (order of integration) of a variable depends on the number of unit roots it contains. Therefore, to determine whether a variable is stationary or non-stationary a unit root test is applied.

3.4.2. Unit root testing

Dolado *et al.* (2001: 02) argued that unit roots are a common phenomenon in all macroeconomic time series modelling. They are a result of the previous persistent shocks to the economic system which do not disappear over time. The presence of unit roots in variables reflects the dynamic features of the data generating processes. Harris (1995: 15) noted that a stationary variable does not contain a unit root. In short, a stationary variable is characterised by mean reversion whereby unexpected shock effects dissipate with time and the system reverts to equilibrium.

On the contrary, non-stationary variables have unit roots and they are characterised by random walk processes. Non-stationary variables have a variance that depends on time and this poses serious problems for forecasting (Davidson & MacKinnon 2003: 604). More so, non-stationary variables experience prolonged effects from unexpected shocks. Variables like GDP, the exchange rate, the inflation rate and capacity utilisation are characterised by unit roots.

[9] Detrending a variable is the process of removing the deterministic trends from a series by subtracting the mean of the variable ($\bar{Y}_t$) from the actual value of the variable (Y_t) so that the variable becomes trend stationary.

Many economists believe that the exchange rate follows a random walk process. In short, the price of the currency today depends upon its price yesterday and an error term (random shock). This can be represented by an equation as follows:

$$B_t = \rho B_{t-1} + \mu_t \quad \text{or you can rewrite it as} \quad B_t - \rho B_{t-1} = \mu_t \qquad -1 \leq \rho \leq 1$$

where B_t is the price of the currency today and μ_t is a stationary error term. The general idea behind unit root testing is to examine the value of the coefficient rho (ρ). Therefore, one can simply manipulate the equation above by applying the lag operator so that $LB_t = B_{t-1}$, $L^2 B_t = B_{t-2}$ and so on. Then the equation above can be written as $(1-L)B_t = \mu_t$ when rho $\rho = 1$. The term unit root refers to the polynomial root in the lag operator. In short, if one sets $(1-L) = 0$ then; $L = 1$ hence the name unit root.

Based on the equation above, if ρ is equal to one (contain a unit root) then the exchange rate series become a random walk process which is non-stationary. This implies that the price of the currency yesterday does not provide any relevant information in predicting the price of the currency today. If the coefficient rho (ρ) is greater than one then the exchange rate series reflects an explosive characteristic. When the coefficient (ρ) is less than one then the exchange rate series is stationary. Therefore, if the exchange rate series reflects stationarity $(\rho < 1)$ then, the price of the currency yesterday provide relevant information in determining the price of the currency today.

There are numerous techniques of testing the presence of unit roots in the data. Unit root tests are commonly applied in empirical macroeconomic research to deduce the order of integration in a variable. Harris (1995: 28) noted that the Augmented Dickey-Fuller (ADF) approach is more popular because of its simplicity and its more general nature. However, there are other tests for unit roots. These include Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test and CRDW-test introduced by Phillips and Perron based on the Durban-Watson statistic (Maddala & Kim (1998: 122). According to Gujarati (2009: 758) the Phillips and Perron test applies nonparametric statistical methods to address the issue of serial correlation in the error terms but with no lagged difference terms.

Stock and Watson (2001: 109) argued that the Dickey-Fuller unit root test is incapable of detecting all the serial correlation in some time series data. Therefore, the extended Dickey-Fuller test (ADF) captures higher order autoregressive roots. According to Gujarati (2009: 758) the ADF achieves the foregoing by adjusting the Dickey-Fuller test for serial correlation through adding lagged difference values of the dependent variable. Harris (1995: 34) described the ADF test by the following equation.

$$\Delta Y_t = B_1 + \partial Y_{t-1} + \sum_{t=1}^{m} \alpha_i \Delta Y_{t-i} + \varepsilon_t$$

where ε_t = a white noise residual term, ΔY_{t-i} = the lagged differenced terms for Y_t, B_1 = constant term, Δ = difference operator, Y_{t-1} = previous value for Y_t and $\delta = (\rho - 1)$.

The ADF tests the null hypothesis of non-stationarity ($\partial = 0$) and the alternative hypothesis is that of stationarity ($\partial \prec 0$). It is based on the idea that if the series contain a unit root $(\rho = 1)$ then the lagged Y_{t-1} series provides no relevant information in predicting the change in Y_t. In that case the series becomes a random walk process, and the ADF computed test-statistic will reflect a less negative (greater) value than the critical test-statistic value at any level of significance, then the null hypothesis ($\partial = 0$) is not rejected. The reverse is true if the null hypothesis is rejected.

An alternative approach to test for unit roots is the KPSS test. Mahadeva and Robinson (2004: 29) argued that the KPSS test is amongst the tests that examine the null hypothesis of stationarity (no unit root). However, these tests have not yet been used widely in empirical research. According to Maddala and Kim (1998: 120) the KPSS test assumes that the dynamic features of the variable at hand are described by the following equations.

$$y_t = \delta_t + \xi_t + e_t$$

$$\xi_t = \xi_{t-1} + u_t, \qquad u_t \sim iid\left(0,\ \sigma_u^2\right)$$

$$H_0 : \sigma_u^2 = 0 \ \text{ or } \xi_t \text{ is constant}$$

where e_t = a stationary white noise process and ξ_t = a random walk process. Therefore, the KPSS test examines whether the random walk process is present in the variable. This is achieved by examining if the error term element of the random walk process varies.

Brooks (2008: 331) notes that the major criticism of unit root tests is that their power is low when the data generating process contains no unit root but it has a root close to unit (ρ = 0.95). Thus given a $\rho = 0.95$ these tests are poor at deciding whether $\rho = 1$ or $\rho = 0.95$ especially with small samples. This problem is attributed to the fact that either the null hypothesis is correct or there is not enough data to enable rejection. Brooks (2008: 331) suggests the use of unit root tests that test whether the null hypothesis of either stationarity or non-stationarity can be accepted or rejected.

Therefore, to achieve confirmatory results that are robust and consistent in the testing of the Taylor rule hypothesis both the ADF and KPSS tests for unit roots were adopted. In addition, differences or conflicting results can occur from the test procedures reflecting that the unit root test models rely on different econometric assumptions or there is not enough data to enable rejection. However, one expects the same outcome (Brooks, 2008: 330). After testing for stationarity in the Taylor rule variables and confirmed mean reversion, the next step in empirical modelling is testing for cointegrating relationships.

3.4.3. The methods for cointegration

3.4.3.1. The Engle-Granger Approach

Introduced by Robert Engle and Clive Granger (1987) the Engle-Granger technique is used for testing cointegration. According to Alogoskoufis and Smith (1991: 99) the Engle-Granger technique was developed from the concept of Error Correction Model (ECM). Gilbert (1986: 300) noted that Phillips (1954) first introduced the concept of ECM in economics through analysing feedback control mechanics for stabilisation policy. Thereafter, Sargan (1964) explicitly tested the ECM econometrically when he analysed the techniques for estimating structural equations that contain auto-correlated residuals (Alogoskoufis & Smith 1991: 99).

The Engle-Granger procedure is a residual two-step procedure. The first step in the Engle-Granger approach involves the estimation of the long-run static regression equation and the analysis of the error terms. According to Tolulope and Ajilore (2013: 141) the estimated residual terms are a measure of disequilibrium. For any economic equilibrium theory model, with non-stationary variables, to converge towards equilibrium it requires the existence of a stationary vector. Otherwise, any fluctuation from equilibrium will persist forever (non-temporary). Therefore, the Engle-Granger technique examines whether or not the residual terms from a regression are stationary[10] based on the assumption that at most one cointegrating vector exists (Harris, 1995: 53).

According to Engle and Granger (1987: 254) the basic idea of the error correction model is simply that a proportion of deviation from equilibrium from the current period is corrected for in the next period. Therefore, after determining the presence of a stationary residual vector, the second step in the Engle-Granger approach is to estimate an error correction model (ECM) formulated to characterise the short run fluctuations and the subsequent mean reversion adjustments (see section 3.4.3.1.2 below). Furthermore, the Engle-Granger technique was extended to cater for seasonally integrated variables (Hylleberg, Engle, Granger & Yoo, 1990) and multi-cointegrated variables (Granger & Lee, 1990).

3.4.3.1.1. The long-run model

According to Enders (2004: 322) cointegration entails that variables which are cointegrated have a long-run equilibrium relationship. Therefore, before estimating the long-run regression, each variable used in the empirical analysis is examined for order of integration using the ADF and KPSS unit root tests. Enders (2004: 336) states that if at least one of the variables is found to be of a different order of integration then one cannot continue with the estimation of the long-run regression until all variables are at least integrated of the same order. More so, when variables exhibit a different order of integration (for example I (1) and I (2)), then one might examine whether or not the variables are multi-cointegrated.

When the Taylor rule variables are found to be integrated of the same order, preferably I (1), then one continues with the estimation of the long-run regression using the OLS method (as discussed in Section 3.3.2). Cointegration refers to the existence of a vector after regressing stochastic variables integrated of the same order such that the residual error term is stationary. Therefore, after regressing the Taylor rule long-run model, the residual error terms (e_t) are subjected to the ADF unit root test.

Since the residual terms originate from the estimated cointegration parameter, Davidson and MacKinnon (2003: 609) noted that the ADF finite sample distribution and its asymptotic distribution are not the same. Therefore, Bierens (1994: 219) argued that the ADF critical test

[10] The null hypothesis is a non-stationary residual term whilst the alternative hypothesis is of stationary residual terms.

values no longer apply to an estimated regression result as the test is directly applied to the residuals. As a result, MacKinnon (1996) cited in Davidson and MacKinnon (2003: 614) developed a program for more accurate finite sample critical values based on the assumption that the disturbance terms are normally distributed. Hence, MacKinnon (1996) critical values are adopted for evaluating stationarity of the residual terms.

Thereafter, if it is established that the regression residuals are stationary (I (0)) then this means a cointegrating vector exists amongst the Taylor rule variables. In short, there exists a cointegrating long-term relationship in the Taylor rule model. Tolulope and Ajilore (2013: 142) cite that the availability of a stationary residual vector in the model implies the possibility of an error correction mechanism based on the Engle-Granger representation theorem. Therefore, Davidson and MacKinnon (2003: 618) noted that after determining the existence of a cointegrating vector one continues with the specification and estimation of the short-run regression (ECM). This is because statistical inferences derived from the OLS estimate of the short-run error correction model are reliable and super consistent. The ECM had been widely applied in the literature on linear modified Taylor type models see (Tolulope and Ajilore (2013), Judd and Rudebusch (1999) & Boamah (2012)).

3.4.3.1.2. The error correction model

The second step in the Engle-Granger technique involves estimating the short-run Error Correction Model (ECM). An ECM is an equation specified with stationary variables integrated of the same order and an Error Correction Term (ECT). The ECM implies that the restricted dynamics short-run model converges to the imposed long-run model. That means when variables are cointegrated the ECM includes both the long-run and short-run effects. In addition, Enders (2004: 338) argued that the short run ECM regression estimated applying stationary data is efficient, non-spurious and the OLS estimates are BLUE[11]. Therefore, an ECM will offer policy makers relevant information about the relationships of the variables in the model as well as the adjustment speed after a disturbance from equilibrium.

According to Brooks (2008: 338) the stationary ECT is also referred to as the adjustment coefficient. It reflects how much of the adjustment to equilibrium is corrected for or takes place each period. When the ECT is negative, it reflects convergence towards equilibrium

[11] For a discussion of BLUE estimates, refer to Section 3.11 above.

whilst if it is positive it reflects divergence. Furthermore, if the ECT absolute value is near to one it indicates a fast convergence to the equilibrium whilst a value near to zero indicates a slow convergence.

In the ECM, the lagged values of the residual term are used to adjust for the error of estimation as illustrated in the simple Taylor rule short-run ECM regression equation below:

$$\Delta r_t = \beta_0 \Delta \pi_t + \beta_1 \Delta r_t^* + \beta_2 (\pi_t - \pi^*) + \beta_3 (\gamma_t - \bar{\gamma}) + \beta_4 (u_{t-1}) + e_t$$

where the independent variable is the desired repo rate (r_t) being explained by the actual inflation rate (π_t), NRIR (r_t^*), inflation rate gap ($\pi_t - \pi^*$), the output gap ($\gamma_t - \bar{\gamma}$), the lagged ECT of the regression (u_{t-1}) as well as the residual error (e_t) of the regression. The Δ denotes the change or first difference.

After estimating the short-run ECM, it is important to evaluate the accuracy of the estimated equation by running a few tests (Enders, 2004: 338). These include checking for the speed of adjustment, normality, autocorrelation, heteroskedasticity, misspecification and the existence of long-run convergence in the equilibrium variables. If the estimated model has passed the tests, then the estimated ECM coefficients are used to show the Taylor rule prediction of the repo rate.

3.4.3.1.3. Limitations of the Engle-Granger model

Bierens (1994: 207) noted that the Engle-Granger technique is only applicable where only one cointegrating vector is assumed to exist in the estimated model. As a result, Enders (2004: 37) concluded that the Engle-Granger technique when faced with more than one cointegrating relationship does not have the capacity to provide an accurate estimation. Therefore, Harris (1995: 72) noted that there is little advantage to start testing for cointegration using the Engle-Granger technique when the number of cointegrating vectors is unknown. However, Hendry and Juselius (2000: 16) argued that the multivariate Vector Auto-Regressive (VAR) representation approach proposed by Johansen (1988) offer more advantages to start cointegration testing and it has become popular in empirical testing for cointegration.

According to Ericsson and MacKinnon (1999: 08) the Engle-Granger and Johansen cointegration approaches examine whether the feedback parameter of the cointegration vector is non-zero. However, they differ in their underlying assumptions about the data-generating processes. Subsequently these assumptions determine the pros and cons of the procedure in empirical testing. Harris (1995: 80) noted that in the Johansen approach for every stationary variable added the number of linearly independent rows increases correspondingly. Therefore, the stationary variables (output gap and the inflation rate gap) by determination in the Taylor rule model will increase the number of linearly independent rows in the data.

In light of the above, it is important to exercise extreme caution when interpreting the Johansen approach results as the results can be misleading. More so, Gujarati (2009: 789) noted that the coefficients on a VAR model are often difficult to interpret as the residual terms and the explanatory variables are contemporaneously correlated (identification problem). There are numerous approaches applied in empirical modelling for specifying restrictions in order to achieve identification of the VAR model parameters. These include orthogonalised reduced form errors using Choleski decomposition (Sims 1980), consistent restrictions from economic theory and prior empirical research and block exogeneity method suggested by Blanchard and Watson (1986).

According to Buckle, Kim, Kirkham, McLellan and Sharma (2002: 06) in some instances the VAR model restrictions may correspond to the theoretical correct view of the its structure however, there are many occasions where restrictions can be unreasonable[12]. In practise, VAR model analysis typically reports impulses responses, granger-causality tests and forecast error variance decomposition as these statistical tests are often more informative than the estimated parameter as well as the coefficient of determination (R^2) (Stock and Watson, 2001: 05). As a result, the VAR model parameter estimates are often not reported. Therefore, the thesis will not report the Johansen estimates, however it was applied to examine the number of cointegrated relationship in the data and the evidence reveals at most one cointegrated relationship.

Therefore, due to the importance of the parameter estimates, the stationary variables in the Taylor rule model and the evidence of at most one cointegration relationship in the Taylor

[12] For example if variables in the Taylor rule are contemporaneously correlated and monetary policy follows the Taylor rule then the Choleski decomposition will not allow domestic sector (GDP) responses to foreign variables and to monetary policy to be differentiated.

rule models, the Engle-Granger approach was adopted for the empirical evaluation of cointegration and its estimates will be reported. The Engle-Granger cointegration approach has been widely applied in empirical modelling of Taylor type reaction functions (see Osterholm (2003), Sauer and Sturm (2003) and Tolulope and Ajilore (2013)). Furthermore, from the Taylor rule equation the following variables are tested for cointegration: repo rate, inflation rate gap, NRIR and the output gap. However, the unobserved variables (potential output and NRIR) are estimated prior to the cointegration test.

3.5. **Modelling the potential output trends**

3.5.1. Introduction

Bryan and Cecchetti (1993: 195) assert that monetary policy objectives are mainly focussed on attaining price and output stabilisation. This is mainly achieved through the development of a loss function that accesses the weights awarded to these objectives. Thereafter, then choose the appropriate policy strategy and operating procedures to achieve a better outcome. However, these theories take for granted the policy makers' ability to precisely measure the variables of interest, namely the underlying price inflation, the natural unemployment rate, the level of potential output, the output gap and the NRIR.

According to Blanchard and Fisher (1993: 17) macroeconomists have struggled with characterising output fluctuations over time due to the problem of separating trend and cycle elements from a variable. However, based on the class of Gaussian linear time series models most economists believe that short-run fluctuations in the economy evolve along an underlying growth path which can be thought of as a trend. Therefore, by construction the trend is non-stationary and cycle stationary. However, the dynamics of this underlying trend are not known with precision and cannot be observed directly (Smit and Burrows, 1999: 03). Hence, there exist numerous assumptions on the underlying dynamics of the potential output trend.

Nxedana (2009: 06) noted that the SARB raised concerns in their first quarterly bulletin of 2009 about the growing output gap both locally and internationally. The output gap entails macroeconomic stability distortions (Pybus, 2011: 07). This reflects the importance of potential output in stabilising the economy. Based on the unobservable nature of the potential output dynamics, it has to be estimated. Various methodologies including structural and statistical approaches are applied in the determination of potential trends. According to Smit and Burrows (1999: 03) potential output estimation techniques can be categorised as theoretical methods, univariate methods, multivariate methods and structural methods.

The theoretical, univariate and multivariate models regard the problem at hand as purely statistical where a series for potential output is generated from the actual data (GDP) either in relation to other variables or not. These approaches rely solely on historical values of the variable of interest (GDP). Empirical examples of these approaches include Beveridge-Nelson (1981) and the unobserved components proposed by Stock & Watson (1986), Clark (1987), Harvey and Peters (1989) and Harvey & Trimbur (2003) as well as the filters like Hodrick-Prescott (1997) discussed in Section 3.5.3, Baxter-King (1995) discussed in Section 3.5.4 and Kalman filter (1960) discussed in Section 3.5.5.

The statistical models are highly criticised for their disregard of crucial economic relationships and explanatory variables. In the determination of potential output trend such crucial explanatory variables include the inflation rate, labour force and capital stock. Structural approaches apply these crucial explanatory variables to estimate potential output and these include the production function approach.

3.5.2. The Production Function Approach

The production function (PF) method is one of the structural techniques applied in estimating a potential output trend. Cotis, Emelskov and Mourougane (2005) cited in Kemp (2012: 03) argued that the production approach is the most preferred approach in estimating the dynamics of potential output trend. This is because the model incorporates economic relationships of variables like capital stock, working population, and factor productivity as well as structural unemployment. Therefore, the estimated PF trend has an economic theory interpretation to it.

Scacciavillani and Swagel (2002: 947) noted that the Cobb-Douglas function is generally applied in the PF approach as illustrated by the equation below:

$$Y_t = A_t K_t^{\alpha} L_t^{\beta}$$

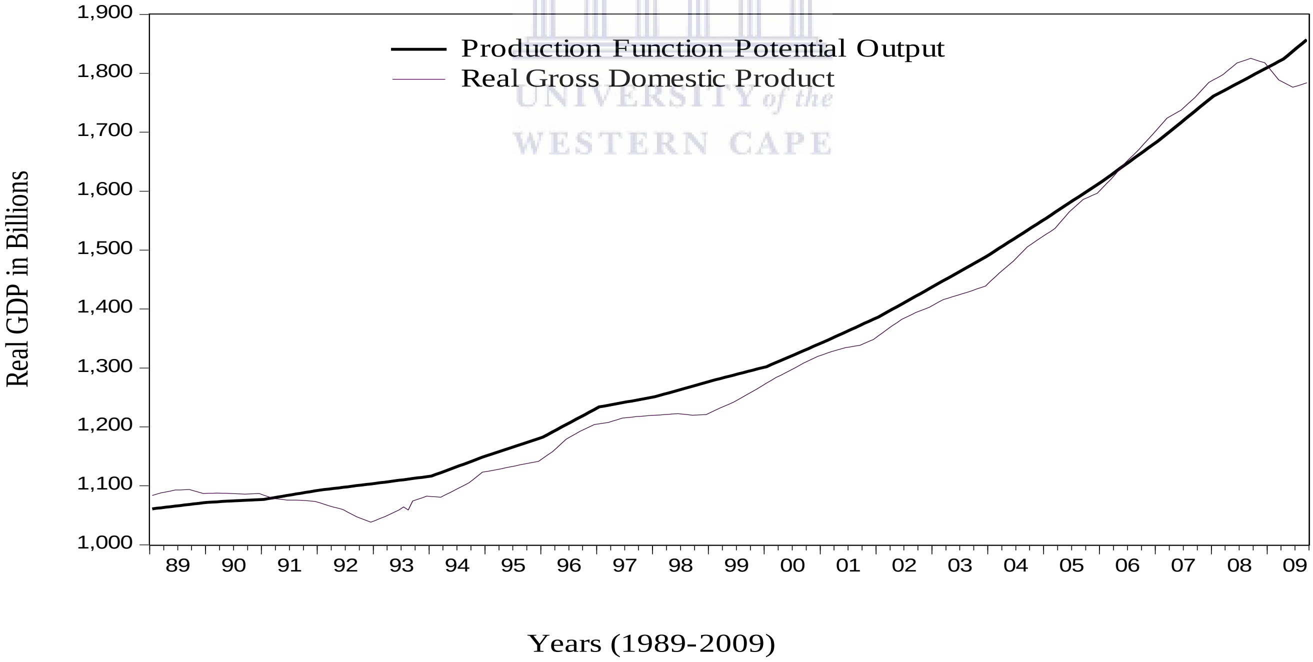
where the actual real GDP (Y_t) at time t depends on the unobserved total factor productivity (A_t), the capital stock (K_t) inputs and actual labour employed (L_t). The α coefficient represents the capital income share whilst β coefficient represents the labour share. More so, α plus β should be equal to one. The potential output trend is found by amending the above function as follows:

$$Y_t^{Pot} = A_t^* K_t^{\alpha} L_t^{*\beta}$$

where Y_t^{Pot} = the potential output, A_t^* = the unobserved total factor productivity, K_t = the actual production inputs of capital stock and L_t^* = the potential labour employed.

According to Cheng, Chung and Yu (2011: 06) the production function approach allows one to identify the growth of the factor input that gave rise to growth in potential output. This advantage allows for a deeper understanding of the underlying economic dynamics behind changes in the output gap. This advantage also allows for offering informative advice for policy makers. Using South African data over the period 1989 to 2009, the PF potential output trend is presented by Figure 3.7 below.

Figure 3.7: <u>Production function potential output trend</u>



Source: SARB and author manipulation (2013)

Figure 3.7 above outlines the PF potential output trend and real GDP. It shows that since early 1991 until mid-2006 the South African economy was performing below its potential output level. According to Du Plessis, Smit and Sturzenegger (2007: 12) this under-performance stems from the drop in GDP due to the anti-apartheid sanctions as well as the debt standstill effects depressing GDP growth. The growth in GDP from 1994 onwards contributed to the recovery from the drop in GDP ending in 1993. However, this distortion is accounted for in the empirical estimation of the Taylor rule hypothesis.

Empirical examples of research in South Africa that applied the production function include Kemp (2012), Cheng *et al.* (2011), Du Toit & Moolman (2003) and De Brouwer (1998). In addition, Kemp (2012: 05) argued that the production function approach has the advantage of reliable estimates at the end of the sample relative to other statistical methods.

Du Toit and Moolman (2003: 98) argued against the PF method due to the fact that it requires abundant data that most policy advisors and makers do not have at their disposal, such as capital stock. More so, the production function approach utilises estimates from the Hodrick-Prescott filter (to be discussed in Section 3.5.3) to smooth out or determine potential factor inputs like potential labour employed in the model. This passes on the pitfalls of the Hodrick-Prescott filter to the estimated PF input trends leading to unreliable or biased estimates. Therefore, considerable caution needs to be applied when reporting the estimates of this approach.

3.5.3. Hodrick-Prescott filter

The Hodrick-Prescott (HP) approach is a statistical method mostly used in macroeconomic research specifically in business cycle decomposition of raw data into a trend and cycle. The HP filter is commonly applied due to the fact that it can make non-stationary data become stationary for integrated series up to the fourth order. In South Africa, potential output has been traditionally estimated using the HP filter, as in Burger & Marinkov (2006), Geldenhuys & Marinkov (2007), Fredderke & Schaling (2005) and Woglom (2003).

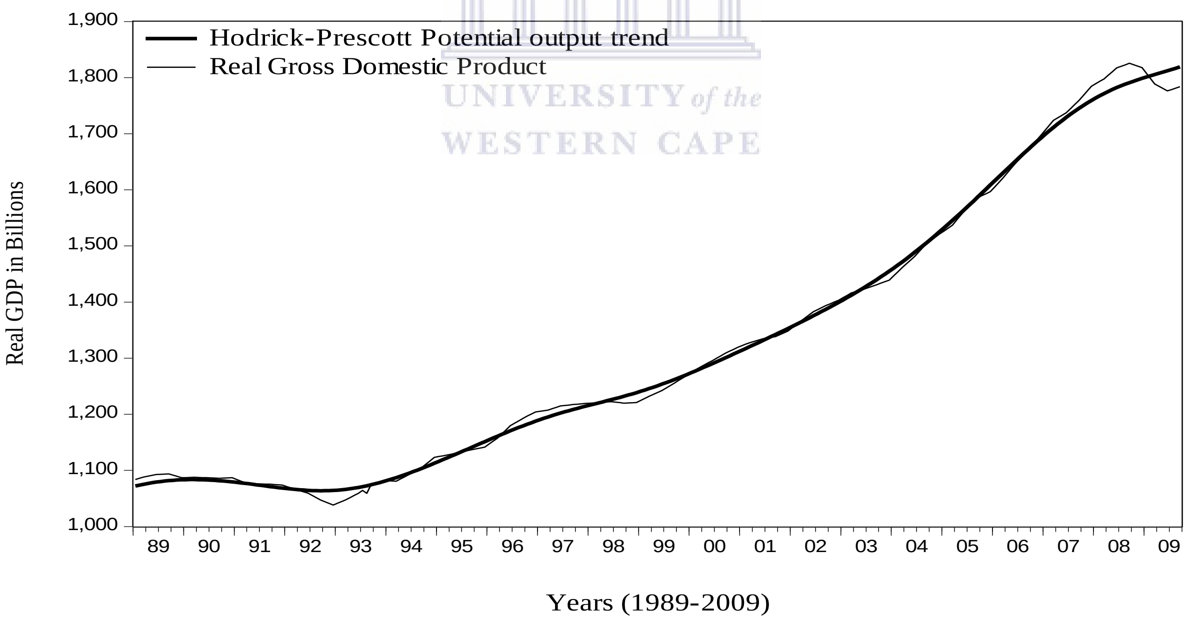
Guay and St-Amant (1997: 04) explained the main idea of the Hodrick-Prescott filter as minimising the gap between actual output (Y) and trend output ($\hat{Y}$) subjected to a penalty that constrains the deviations in the second difference of the potential trend as illustrated by the equation below:

$$Min\sum_{t=1}^{t}\left(y_t-\hat{y}_t\right)^2+\lambda\sum_{t=2}^{T-1}\left[\left(\hat{y}_{t+1}-\hat{y}_t\right)-\left(\hat{y}_t-\hat{y}_{t-1}\right)^2\right]$$

where the first component is the summation of all squared deviations (these penalise cyclical components in the model) whereas the second component is the sum of the trend component second differences squared penalised by λ. The element λ in the equation above represents the degree of flatness in the trend components.

When the sensitivity coefficient λ is set too small then the result reflects the curviness of the variable whilst if it is set too high then the result shows more or less a straight line. Karagedikli and Plantier (2004: 04) argued that for quarterly data, the smoothness parameter is set at 1600 as suggested by Hodrick and Prescott (1997). The number 1600 implies that changes in the variance of the slope portion be constrained to 0.000625 (1/1600) times the estimated variance. Figure 3.8 below outlines the HP filter potential output trend and the actual gross domestic product for South Africa over the period 1989 to 2009. It reflects that the South African economy performed relatively close with some slight deviation to their potential output over the period.

Figure 3.8: Hodrick-Prescott Potential output trend



Source: SARB and author manipulation (2013)

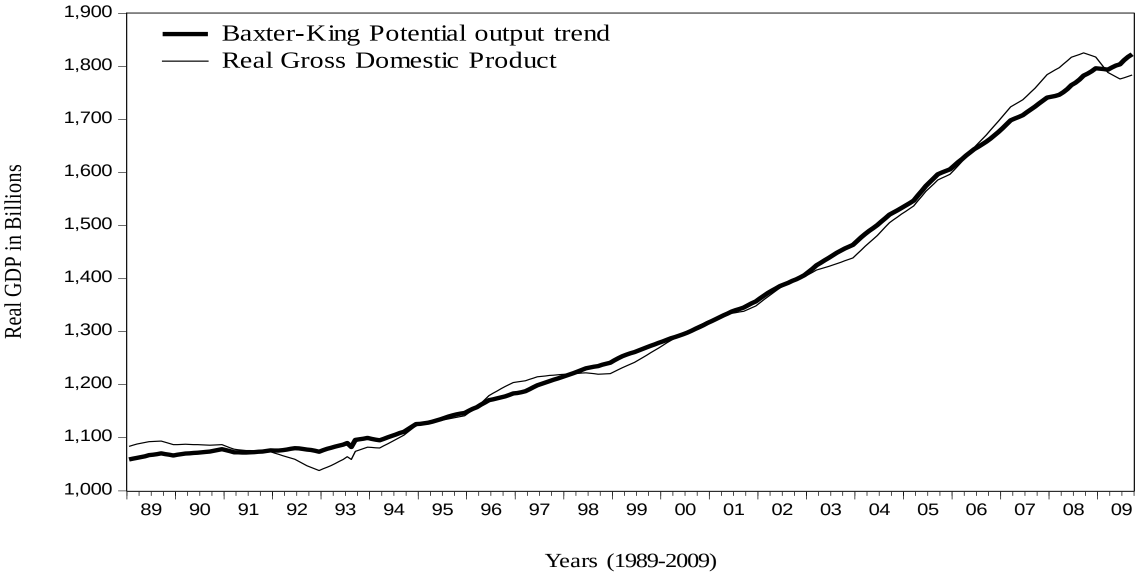
Adema (2003: 17) argued that the HP filter is very sensitive to the data in the sample, and it is too mechanical with end point bias as well as it does not explicitly have an economic theory basis. Furthermore, Scacciavillani and Swagel (2002: 947) argued that the parameter λ has a substantive effect on the result. Moreover, it has to be specified by the user of the filter, which then may lead to spurious results if wrongly specified. Therefore, considerable caution needs to be applied when reporting the estimates of this approach.

3.5.4. Baxter-King Approach

Another univariate approach to decompose a time series was developed by Baxter and King (1995) known as the Baxter-King band-pass filter (BK). Baxter and King (1995: 02) developed the band-pass filter based on the notion of the business cycle definition proposed by Burns and Mitchell (1946). Burns and Mitchell's influential research found that cyclical elements of time series usually span the period of not less than six quarters and not more than thirty-two quarters. As a result, Baxter and King (1995: 03) defined their linear BK filter as a filter that eliminates very slow and very high frequency elements of a series retaining the potential trend element over the period of six and thirty-two quarters.

Kaunermann, Krivobaraka and Semmler (2011: 05) argued that Stock and Watson (1998) applied this filter on the USA macroeconomic time series data and it had achieved quite some reputation in practice. The advantage of this approach compared to the HP filter is that it creates the cyclical component of a variable based on identifying a range for its duration. That is, the business cycle and the high frequency component that reflects irregularities or seasonal effects do not affect the trajectories of potential output. The diagram below presents the potential output trend using the BK approach and the actual real gross domestic product trend for South Africa over the period 1989-2009.

Figure 3.9: Baxter-King potential output trend



Source: SARB and author manipulation (2013)

Figure 3.9 above reflects that the South African economy had been performing relatively close to the potential output trend over the study period. The trajectory followed by the BK filter potential output trend shows a more penalised trend as compared to the HP potential trend above.

Aadland (2005: 08) noted that the band-pass filter involves a trade-off of weights versus observations. That is, at high rates of weights assigned some observations are lost especially at the endpoints of the sample. Azevedo (2011: 03) supports this view and he noted that the BK filter increases high frequency noise and creates phase shifts. These distortions can distort the potential trend. Therefore, in testing the Taylor rule hypothesis, a large sample is used in the estimation of this approach so as to avoid loss of observations. However, caution needs to be applied when reporting the estimates of this approach.

3.5.5. Kalman filter approach

According to Mills (1990: 214) the state space approach is used to model time series economic models. The state space technique is a dynamic and powerful instrument empirically applied successfully in macro econometric models. According to Harvey (1993: 101) the state space approach is applied when modelling rational expectations, measurement errors, missing observations and unobserved components. This technique is not only widely applied in macro econometrics but in other fields like engineering and finance. It is mostly combined with the Kalman filter (KF) algorithm to allow for model differences and similarities to be observed in a unified framework of analysis.

The Kalman filter plays a major role in providing optimal forecasts as well as providing a method of estimating the unknown model parameters especially in time series data. Harvey (1993: 102) describes the Kalman filter as a recursive data-generating algorithm. It generates a set of equations that permits a sequential update of the one-step-ahead estimates (mean and variance) of the unobserved variable once new information becomes available conditional on all the prior information. This shows that for every estimate of the unobserved variable all the necessary prior information and the underlying statistical processes are taken into consideration at the time of prediction or forecasting.

According to Harvey (1993: 102) the Kalman filter procedure is performed in two revolving phases. The initial step involves generating an optimum predictor of the next observation conditional on all the available measurements. In order to achieve the first step, the Kalman filter uses all the prior information about the unobserved variable's data-generating process. Furthermore, the filter considers the interaction between the unobserved variable and other variables within the model. This entails the economic relationship between the variables as well as the structures of how the error terms behave. In addition, the Kalman filter also utilises all the available knowledge about starting values of the unobserved variable.

The second step involves the inclusion of a new observation of the estimator in the system for the prediction of the next observation. According to Mills (1990: 240) the Kalman filter[13] method is described by the measurement and transition equations below.

$$x_t = Z_t \delta_{t-1} + \varepsilon_t \qquad t = 1, 2, ..., T$$

$$\delta_t = T_t \delta_{t-1} + R_t v_t \qquad t = 1, 2, ..., T$$

where δ is a state vector, Z_t, T_t and R_t are vectors of parameters, ε and v_t are scalar Independently Identically Distributed (IID) error terms. According to Lutkepohl, *et al.* (2001:

[13] For a thorough discussion of the filter technical aspect one can consult Mills 1990: 240.

630) the error terms (ε and v_t) are assumed to be normally distributed with a zero mean, a constant variance and a zero covariance. The measurement equation (first equation above) derives the output as a function of the state system whilst the transition equation (second equation above) illustrates how the series evolved given the inputs.

According to Harvey and Proietti (2005: 03) the specification of the starting values or conditions with respect to the distribution of the variable is a crucial element of the state space technique. If the starting variance of the Kalman filter's initial state variable is equal to zero, this implies perfect knowledge of the initial state variable, which is unrealistic. In practise, it is customary to assign a large number to the variance reflecting the uncertainty around the initial values (Harvey & Proietti 2005: 07). Stock and Watson (1998: 03) argued that state space modelling can be biased based on the model, filtering and parametric uncertainty.

The Kalman filter for the Taylor rule potential output derivation is performed in line with the Clark (1987) model. Clark (1987) developed a model that applies the Kalman filter to separate a variable into a trend and a cycle as outlined by the following equations.

$$Y_t = \hat{Y}_t + C_t \quad \text{..............................}(I)$$

$$\hat{Y}_t = \hat{Y}_{t-1} + D_{t-1} + \in_t \text{..........................}(II)$$

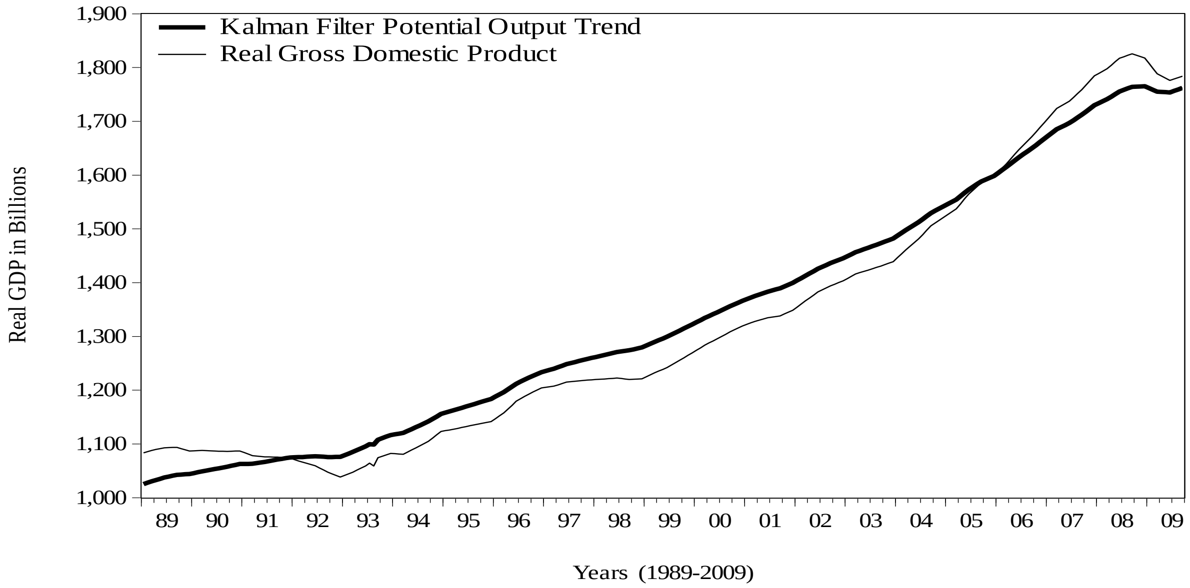
$$D_t = D_{t-1} + \omega_t \text{....................................}(III)$$

$$C_t = B_1 C_{t-1} + B_2 C_{t-2} + v_t \text{....................}(IV)$$

where $\in_t$, ω_t, v_t = IID irregular noise processes with standard deviations $\sigma_{\in_t}, \sigma_{\omega_t}, \sigma_{v_t}$ respectively, C_t = the cycle elements, Y_t = current GDP, $\hat{Y}_t$ = current potential output, D_t = drift term in potential output.

This model relies on the idea that irregular terms in economic variables are purely recurring and stationary. Equation (I) shows that GDP at time t is modelled as a trend plus cycle. The trend component is assumed non-stationary whilst the cyclical element is assumed stationary. Equation (II) illustrates the potential output trend as a local approximation of a linear trend (non-stationary) with a drift term. The drift term follows a random walk process. Equation (IV) specifies cyclical elements of the trend as a stationary finite autoregressive process. The diagram below outlines the Kalman filter potential output trend.

Figure 3.10: <u>Kalman filter potential output trend</u>



Source: SARB and author manipulation (2013)

Figure 3.10 above illustrates the potential output derived from the Kalman filter approach against the real GDP for South Africa. It shows that from the early 1990s to the mid-2000s the South African economy was performing below its potential level. This outcome is in line with the PF approach predictions. Empirical examples of research that applied the Kalman filter include Morrison & Pike (1977), Harvey (2000), Basdevant, Bjorkstein & Karagedikli (2004) and Vitek (2006).

3.5.6. Conclusion on potential output

The precise estimation of the potential output trend is important in evaluating the Taylor rule hypothesis. This stems from the fact that the potential output trend influences the result as well as the judgement about how the SARB reacts to deviation of the output gap in their conduct of monetary policy. Canova (1998), Adema (2003), Scacciavillani & Swagel (2002) and Aadland (2005) noted that the different approaches for estimating potential output are subject to debate and there is no universally agreed approach to measure it. The problem stems from differences in assumptions about whether the potential trend is deterministic or stochastic and if stochastic, to what degree. Therefore, the derivation of potential output trend in the testing of the Taylor rule hypothesis is based on all the approaches discussed above, in order to obtain a broad understanding of the underlying dynamics.

3.6. **Modelling the natural real interest rate**

3.6.1. Introduction

The theoretical idea of the natural real interest rate concept has attracted a growing attention in many central banks over the past years (Garnier & Wilhelmsen, 2005: 04). As has been noted in Section 2.4.4 the real interest rate gap provides a yardstick when evaluating whether historical monetary policy decisions were too accommodative or too restrictive. That is, *ceteris paribus*, if the real interest rate gap is negative, monetary policy stance is accommodative. This stems from the fact that the lower market EARIR creates excess demand by firms and households to finance investment and spending respectively as the cost of borrowing is low. Consequently, the excess demand by firms and households stimulates economic growth and eventually inflation starts to rise. Therefore, the central bank responds by increasing the nominal short-term interest rate until the real interest rate gap is zero.

Manrique and Marques (2004: 12) argued that the concept of NRIR is analogous to the natural unemployment rate of Friedman (1968). Owing to the unobserved nature of the NRIR concept, Giammariolli and Valla (2003: 07) stated that there is no single agreed upon approach to measure the concept from the available techniques. Therefore, in estimating the NRIR different models are used. These methods have different assumptions and specifications derived from the researcher's interpretation of the time varying NRIR. These modelling approaches are classified according to the time horizon definition of the NRIR as discussed in Section 2.4.4.

One simple alternative that relates to the long run horizon definition is averaging actual historical EARIR over time (Garnier & Wilhelmsen, 2005: 06). The underlying idea of this approach is that in the long run economic variables are stable because positive and negative shocks had offset each other. That is there is no tendency for variables to change or be redistributed. According to Williams (2003) cited in Wintr *et al.* (2005: 08) this technique can only offer consistent estimates in periods where inflation and output growth have been relatively stable. However, in periods of substantial fluctuations it tends to be biased. Bomfim (2001: 04) argued that this technique does not consider the correlation or dynamic linkages between the NRIR and other economic variables.

The use of market financial indicators is an alternative method applied in terms of the medium term definition. Bomfim (2001) pioneered the use of yield curve inflation indexed bonds to derive the NRIR. The idea behind his approach is that the more precise prediction of the NRIR stems from the market participant's prediction of the long-term yields of their financial assets. This approach can only be applied using inflation-indexed bonds. However, South Africa does not have these types of bonds. Nevertheless, in line with the idea behind the use of financial market data, this paper develops a model to deduce the NRIR for the South Africa economy (see the financial indicator model below). Wintr *et al.* (2005: 08) argued that this approach can be biased by the relative term premia and liquidity premia as well as irrational behaviour by market participants. In addition, this approach does not account for the relationships and dynamics between the NRIR and output gap.

Another medium term alternative approach to the estimation of the NRIR is through applying a semi-structured macroeconomic method. Laubach and Williams (2003) pioneered this approach and it became the basis for most dynamic multivariate estimations of the time varying NRIR. Laubach and Williams (2003) jointly estimated the NRIR, potential output trend and potential output growth rate applying a semi-structured macroeconomic model. Wintr *et al.* (2005: 08) argued that this technique is widely applied in modelling the NRIR due to its robustness and tractability under different economic conditions (Orphanides & William (2002), Clark & Kozicki (2004) and Basdevant *et al.*, (2004)). This paper also adopts this approach in estimating the NRIR. This is because it produces a time varying NRIR that corresponds to the intercept term in the Taylor rule model, and the linear approximation of the NRIR in these models best describes the low frequency movements in the NRIR.

According to Wintr *et al.* (2005: 08) the medium-term and long-run horizon models are highly criticised for their inability to utilise all economic information available to policy makers. As a result, various economists have developed short-term horizon (Dynamic Stochastic General Equilibrium, or DSGE) models that incorporate all economic information (see Goyal 2008, Giammariolli & Valla 2003, Lombardi & Sgheri 2007 and Fuentes & Gredig 2001). This technique produces a time varying NRIR with a structural interpretation to it. Larsen and McKeown (2004: 09) noted that there has been a growing trend in estimating DSGE models, yet the assumptions behind the solutions and calibration methods in these models are a major obstacle.

The source of the problem in the modelling of the NRIR is the uncertainty in its estimation. This intractable problem stems from the uncertainty encountered in measuring the various components of the short-term interest rate. Kahn and Farrell (2002: 03) noted that the extent of error could be enormous. As noted by Giammariolli and Valla (2003: 07) that there has not been a unified approach to the modelling of the NRIR, the adoption of different approaches can be insightful. As a result, this paper adopts four different models to derive the NRIR for the Taylor rule hypothesis testing. These are the financial indicator model, a univariate model, a multivariate model and the Laubach and Williams (2003) model.

3.6.2. The financial indicator model

According to Bomfim (2001: 04) financial market players and researchers use the long-term government bond yield as a measure of the expected real rate of return from long-term investments. Therefore, the long-term government bond rate reflects the investors' precise predictions of the expected future inflation and the short-term real interest rate movements. In light of the above, this model (hereinafter referred to as FIM) utilises financial market data to deduce the implied NRIR. It focusses on the 10-year government bond yield.

The idea behind the model is that the long-term bond yield embeds the real rate of return from investment (EARIR) plus the expected inflation rate. In short, the model derives the NRIR through decomposing the long term government bond rate. The equations below outline the government bond-yield decomposition model:

$$g_t = r_t^{ea} + E(\pi_t) \quad \text{.......................................(i)}$$

$$r_t^{ea} = r_t^{*} + \lambda_t + e_t \quad \text{...(ii)}$$

$$\mathrm{r}_\mathrm{t}^{*} = \mathrm{r}_{\mathrm{t}-1}^{*} + \eta_\mathrm{t} \ldots\text{.....................................(iii)}$$

$$\lambda_t = a_1 \lambda_{t-1} + a_2 \lambda_{t-2} + \omega_t \text{..........................(iv)}$$

where g_t = 10 year government bond yield, e_t, η_t and ω_t = IID innovation processes with standard deviations $\sigma_{e_t}^2$, $\sigma_{\eta_t}^2$, $\sigma_{\omega_t}^2$ respectively, a = parameters, λ_t = cyclical elements, r_t^* = NRIR, r_t^{ea} = EARIR and $E(\pi_t)$ = expected future inflation.

Equation (i) above illustrates the long-term government bond nominal rate dynamics as composed of the real rate of return (EARIR) plus the expected inflation. In this model, the inflation rate over the previous four quarters is used as a proxy for the unobserved expected inflation rate. Furthermore, in equation (ii) the EARIR is assumed to be composed of the NRIR and the cyclical elements as demonstrated in Figure 2.3[14]. The NRIR follows a random walk process (see equation (iii)) whilst the cyclical elements follow a moving average process (see equation (iv)).

Although this model can provide insights, its major drawback is that long-term rates can fluctuate relative to short-term rates due to reasons other than the real interest rate gap (Basdevant *et al.*, 2004: 15). For example, expectations about high future inflation can lead to an upward movement in the long-term rate (Bomfim, 2001: 04).

3.6.3. A univariate model

A univariate model (hereinafter referred to as UVM) is one of the approaches applied to estimate the salient features of the NRIR. According to Cuaresma, Gnan and Ritzberger-Gruenwald (2003: 09) these models offer a flexible framework for decomposing a variable in order to identify the unobserved components embedded in the data. This technique is a pure statistical approach based on the assumptions behind the behaviour of the data generating process. As was noted from Figure 2.3 the EARIR is composed of the NRIR plus cyclical factors. Therefore, the UVM approach aims to extract the cyclical elements applying the Kalman filter algorithm.

Du Plessis (2004: 01) noted that a cycle plays an important role in explaining the extent of fluctuations in economic activities. In order to achieve the derivation of the NRIR the STAMP package is used to decompose the EARIR into a trend and a cycle. Koopman, *et al.* (2009: 60) argued that “the STAMP package derives a deterministic cycle as a sine-cosine wave based on a specified period whilst a stochastic cycle is created by shocking the cycle with disturbances and a damping factor”. These stochastic cycles are applied in the modelling of pseudo-cyclical behaviour that characterises time series data particularly in economics (Koopman *et al.*, 2009: 60).

The UVM for the decomposition of the EARIR follows the model derived by Harvey and Peters (1989) for trend and cycle decomposition as outlined by the equations below:

$$r_t^{ea} = r_t^* + \psi_t + e_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots(a)$$

[14] See Section 2.4.4.

$$r_t^* = r_{t-1}^* + b_{t-1} + \eta_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots(b)$$

$$b_t = \mathrm{b}_{t-1} + \omega_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(c)$$

$$\psi_t = \mathrm{a}(L)\psi_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(d)$$

where e_t, η_t and ω_t = IID irregular error terms with standard deviations $\sigma_{e_t}^2$, $\sigma_{\eta_t}^2$, $\sigma_{\omega_t}^2$ respectively, L = finite polynomial lag operator, ψ_t = cyclical elements, r_t^* = NRIR, b_t = slope of the NRIR and r_t^{ea} = EARIR.

Equation (a) shows that the EARIR series at time (t) is composed of the NRIR (trend) plus cycle innovation (see Figure 3). In equation (b), the NRIR is assumed to follow a stochastic trend that illustrates its time varying nature. Equation (c) shows the movement of the stochastic trend over time. Furthermore, the cyclical elements are modelled as autoregressive processes (see equation (d)). Although the univariate model exploits the salient feature of the EARIR through a simultaneous estimation of the data generating processes, it is highly criticised for not applying any useful economic information at hand (Larsen & McKeown, 2004: 12).

3.6.4. A multivariate model

A multivariate model (hereinafter referred to as MVM) is another technique applied to estimate the natural real interest rate. It estimates a time varying NRIR based exclusively on the statistical characteristics of the data without imposing any economic theory. According to Cuaresma *et al.* (2003: 06) the MVM offers a flexible framework for decomposing unobserved components through allowing for potential cross-correlation across the data. The idea behind a MVM is a simultaneous decomposition of interrelated variables into trends and cycles.

The multivariate decomposition model of the NRIR follows the model derived by Clark (1987) as outlined by the equations below:

$$Y_t = T_t + C_t + \mathrm{e}_t^y \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots(I)$$

$$T_t = T_{t-1} + k_{t-1} + e_t^T \ldots\ldots\ldots\ldots\ldots(II)$$

$$k_t = k_{t-1} + e_t^K \ldots\ldots\ldots\ldots\ldots\ldots\ldots(III)$$

$$C_t = v_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (IV)$$

where Y_t is a vector composed of EARIR, inflation rate and aggregate output, T_t is a vector of the trend components, C_t is a vector of the cycle elements with v_t illustrating a sine-cosine wave and e_t are the disturbance innovation terms.

The MVM aims to derive the NRIR through decomposing a vector of variables into a trend and cycle as illustrated by equation one. The trend component is assumed to follow a random walk process with a drift-term, shown in equation II and III. The cycle element is specified as a sine-cosine wave with time evolving parameters, shown in equation IV. The innovations terms in the model, unobserved variables and their cycles are assumed to be mutually uncorrelated with any other error in the model. Therefore, the MVM exploits common statistical relationships of the data. The STAMP software package applying the Kalman filter algorithm is adopted for the estimation of this model.

Although the multivariate model enables one to understand the underlying relationships of economic variables, the model is criticised for its reliance on statistical methods without application of economic theory. Therefore, semi-structured models like the Laubach and Williams (2003) are preferred as they utilise economic theory dynamics.

3.6.5. The Laubach and Williams (2003) model

Garnier and Wilhelmsen (2005: 06) argued that there should be consistency over the negative relationship between the real interest rate gap and the output gap as inferred from economic theory. In other words if the NRIR is below the market EARIR (positive real interest rate gap) then actual GDP should be below the potential level (negative output gap). Therefore, potential output and the NRIR should be determined simultaneously. Laubach and Williams (2003) pioneered a concurrent estimation of the NRIR, potential output and potential output growth rate in a semi-structured macroeconomic model applying the Kalman algorithm. The technique produces a time varying NRIR that is in line with the low frequency dynamics of the economy.

The Laubach and Williams (2003) model (hereinafter referred to as LWM) is constructed based on the knowledge of the salient features of the series using economic theory. The specification of the inflation rate in this model stems from the resurgence of the Phillips curve idea. Harvey (2011: 07) notes that a popular model that reflects this resurgence is the hybrid new Keynesian Phillips curve model. The LWM approach provides a balance between ad-hoc statistics methods on one hand and the theoretical structural model (DSGE) on the other hand (Garnier & Wilhelmsen, 2005: 06). The model dynamics are illustrated by the following equations:

$$y_t = a_1(L)(y_{t-1} - y^*_{t-1}) + a_2(L)(r_{t-1} - r^*_{t-1}) + e^y_t \text{.....................}(A)$$

$$\pi_t = b_1(L)\pi_{t-1} + b_2(y_{t-1} - y^*_{t-1}) + e^\pi_t \text{................................}(B)$$

$$r^*_{t-1} = \alpha_1 g_t + z_t \text{..}(C)$$

$$z_t = c_1(L)z_{t-1} + e^z_t \text{..}(D)$$

$$y^*_t = y^*_{t-1} + g_{t-1} + e^{y^*}_t \text{...}(E)$$

$$g_t = g_{t-1} + e^g_t \text{...}(F)$$

where t = time notation, e_t = serially uncorrelated IID irregular terms, a, b, c, α = parameter coefficients, y_t = output gap, y_t = logarithm of real GDP, y^*_t = logarithm of potential GDP, L = lag operator, r_t = EARIR, r^*_t = NRIR, g_t = trend growth and z_t = catch all variable for all other determinants of the NRIR.

First, equation (A) specifies a simple reduced-form aggregate demand (IS) curve. The IS curve is a real sector macroeconomic instrument that demonstrates the negative correlation between the real rate of interest and real aggregate production in the economy. In this model the IS curve explains the output gap dynamics based on its own lags as well as the real interest rate gap lags and an innovation term. According to Laubach and Williams (2003: 04) the lagged output gap and the irregular term control for transitory and short-run dynamics. Subsequently, changes in the NRIR reflect the persistent shocks. According to Wintr *et al.* (2005: 10) when the EARIR is equal to the NRIR there are no demand shocks ($e^y_t = 0$). Therefore, the output gap goes to zero. In other words if the real interest rate gap is neutral (zero) then potential and actual GDP are equal and the output gap is zero.

Second, equation (B) specifies a reduced form backward-looking Phillips curve or simply a total supply equation. The backward-looking Phillips curve demonstrates the link between the inflation rate and the real production in the economy. In the model, the inflation dynamics are explained by the lags of the inflation rate and the lagged output gap. The lags illustrate sluggishness in inflation. In the state space model, the equations (A) and (B) are the measurement equations whilst equations (C) to (F) are transition equations that reflect the evolution of salient features of the data-generating processes in the model.

Third, Laubach and Williams (2003: 1064) state that the potential output growth rate is an explanatory variable of NRIR according to economic theory. Equation (C) illustrates the salient features of the NRIR. The NRIR is explained by the potential output growth rate and a catch-all variable that represents all other determinants of the NRIR. These determinants include the riskless long-run real interest, barriers to capital flow, country risk premia, growth in population, consumer rate of time preferences and technology change, amongst others.

Laubach and Williams (2003: 1067) assumed the catch-all variable to follow a stationary autoregressive process as outlined by equation (D). More so, if the catch-all variable is non-stationary the inferences made on the co-efficient α are invalid. On the other hand Garnier and Wilhelmsen (2005: 10) noted that specifying the catch-all variable (z_t) as a random walk process leads to technical problems owing to the pile–up problem. Lastly, equation (E) illustrates the potential output that follows a random walk with a drift where the drift term reflects the potential output growth. The potential output growth is assumed to follow a random walk as outlined in equation (F).

Although the LWM applies the Kalman filter's maximum likelihood algorithm successfully, Clark and Kozicki (2004: 09) argued that the low variability of the irregular term standard deviation on potential output growth rate and NRIR tends to bias the results as well as make it impossible to obtain valid results. This problem stems from the Stock and Watson (1998) pile-up problem. Stock and Watson (1998: 349) noted that there are likely biases involved in the estimation process due to the small relative variance of a variable compared to the overall variability of the model. Hence, the results will not reflect the variability in these variables.

Therefore, the pile up problem exists when the potential output growth rate and NRIR irregular terms exhibit small variability relative to the whole system. In short, this means that the maximum likelihood approximations of the standard deviations on error terms of the trend growth and NRIR are biased towards zero (Laubach & Williams, 2003: 07). As a consequence, no variability is realised from these variables due to the pile-up problem. Laubach and Williams (2003: 07) argued that to avoid the pile-up problem in the estimation of unobserved variables, the solution is to apply the Stock and Watson (1998) unbiased estimator for the standard deviations of both the potential output growth and the NRIR.

According to Roberts (2001: 12) the idea behind the Stock and Watson median unbiased estimator is simply to examine the model for structural stability in the event that there has been a shock to the potential output growth. Therefore, if the shock exists one applies a test to examine for structural stability and the test convincingly rejects the hypothesis of structural stability (Garnier & Wilhelmsen, 2005: 11). A greater magnitude of the shock variance increases the evidence in favour of rejecting the hypothesis of structural stability.

The Stock and Watson approach starts by regressing the potential growth rate (Δy^*) on a constant. However, Aguiar and Martins (2005: 05) argued that instead of applying the OLS procedure the generalised least squares procedure is appropriate. This stems from the fact that the OLS regression residuals have a non-white noise structure that is characterised by the finite order autoregressive process. The regression of potential growth rate on a constant is performed on the entire sample and the subsamples sequentially. The subsamples are determined by examining for structural break dates in the whole sample using the standard trimming procedure ($0.15T \leq T_s \leq 0.85$).

Based on the identified subsamples the residual sums of squares are extracted for the estimation of the Chows F-test (Wintr *et al*., 2005: 25). Letting the residual sum of squares be denoted by SSR the Chows F-test statistic is derived using the equation below:

$$F_t(s) = \frac{(SSR_T - (SSR_{Sub1} + ... + SSR_{SubT-1}))/k}{(SSR_{Sub1} + ... + SSR_{SubT-1})/(T-2k)}$$

where T = whole sample, k = the number of parameters in the equation, SSR_T = the restricted sum of residual squares whilst $SSR_{Sub1} + ... + SSR_{SubT}$ are the unrestricted residual sum of squares from the subsamples.

According to Wintr *et al*. (2005: 25) to obtain the median unbiased estimator of $\hat{\lambda}_g$, the Andrew and Ploberger (1994) Exponential Wald (EW) statistic is applied following the equation below:

$$EW_t = ln\{ \int_b^a exp(0.5 F_t(s))d(s)\}$$

where a and b are upper and lower trimming bounds and F_t (s) is the sequential Chow F statistic. Based on the EW test statistic the Stock and Watson (1998: 354) look-up table is then consulted to retrieve the estimated $\hat{\lambda}_g$. After obtaining the estimated $\hat{\lambda}_g$ from the look-up table, the estimated $\hat{\lambda}_g$ is then divided by the number of observations in the model to yield an unbiased variance $\hat{\lambda}_g$. This variance is then imposed in the estimation of the whole Laubach and William (2003) model.

After obtaining the trend growth variance the whole Laubach and Williams (2003) model is estimated with the catch-all variable in equation (III) being constant to obtain the median unbiased estimator of $\hat{\lambda}_z$. Thereafter, the estimated output gap is examined for structural break following the method applied for the trend growth estimate. After obtaining the median unbiased estimator of $\hat{\lambda}_z$, then the whole Laubach and Williams (2003) model is estimated imposing the estimated unbiased estimators (Laubach & Williams, 2003: 1069).

3.6.6. Conclusion on natural real interest rate modelling

Monetary policy authorities face a variety of uncertainties in their day-to-day policy decision-making process. Policy theories take for granted the authorities' ability to precisely measure the variables of interest, namely underlying price inflation, level of potential output, and the output gap as well as NRIR. However, a good benchmark like the Taylor rule model, applied to inform their policy decisions, plays a major role in their endeavour to achieve price stability.

Apart from being a determinant in the Taylor rule, the NRIR is a good measure to evaluate historical policy stance on its own. However, its estimation is highly uncertain because of the inability to measure precisely the salient features of the NRIR. Hence, there is no single approach agreed upon to estimate it. As a result, this paper adopts four models in the estimation of the Taylor rule hypothesis in order to gain different insights about the time varying nature of the NRIR in South Africa over the period 1989-2009.

3.7. Chapter Conclusion

This chapter provided a description of all the steps that were undertaken in the empirical analysis of whether the SARB applies the Taylor rule model in their inflation targeting framework's reaction function. In order to evaluate the above hypothesis a simple multiple linear econometrics technique applying ordinary least squares method is used as discussed in Section 3.3. Furthermore, Section 3.2 focussed on the variables used to analyse the Taylor rule model hypothesis. In order to ensure robustness as well as avoid the problem of spurious regression in the estimated results, the stationarity tests (see Section 3.4.1) are used to evaluate the Taylor rule model variables for unit roots.

Imbedded in economic variables are cointegrating relationships that extend into the long run. These relationships are of utmost importance to economists as they provide a broader understanding of the dynamics as well as the interrelationships of variables in a system. Therefore, Section 3.4 focussed on techniques to test the order of integration as well as the number of cointegrating relationships in the Taylor rule model variables. The Engle-Granger approach is applied in the study to test for cointegrating relationships.

In addition, due to the unobservable characteristic of the potential output, different approaches are adopted in the derivation of the output gap. These include the Hodrick-Prescott filter, Kalman filter, Baxter-King filter and the production function approach as explained in Section 3.5. This is because one can obtain a better understanding of the variations in the potential trend as well as avoid biased estimates.

Furthermore, Section 3.6 focussed on NRIR which is another unobserved variable of the Taylor rule model. In order to gain a deeper insight as well as obtain unbiased results the paper adopts four approaches to derive the NRIR. The next chapter applies this framework in the empirical testing of the hypothesis whether the SARB considered the output gap, in addition to the inflation gap, when deciding on the repo rate changes, in its pursuit of the price stability objective.

CHAPTER FOUR
EMPIRICAL ANALYSIS

4.1. **Introduction**

The setting of the nominal interest rate is crucial for macroeconomic stability. Taylor (2009: 32) blames the Fed for keeping the nominal interest rate excessively low for a long period leading to the mortgage housing bubble that triggered the 2007-08 global financial crisis. It appears as if during the Stals governorship, in spite of there not having been a formal inflation target, the inflation rate was brought down to fluctuate below the 6 per cent level. Under Mboweni, after the adoption of the IT framework, the inflation rate may well have fluctuated within or around the target range. Therefore, the objective of this study is to examine whether an output gap as well as an inflation gap were considered in the pursuit of monetary policy by the SARB. Specifically, the study focusses on evaluating whether there was an unannounced application of a Taylor-type rule when decisions on changes to the repo rate were made during the period 1989-2009.

In order to achieve the above objective this chapter builds on the theoretical framework in Chapter 3. A number of techniques were adopted, albeit with no consensus, in an attempt to precisely measure unobserved variables in the Taylor rule model. These unobserved variables include the potential output trend, the output gap, the natural real interest rate and the inflation rate gap.

Section 4.2 discusses the derivation of the inflation rate gap following Taylor 1993. This follows from Woodford (2003: 03) argument that an effective central bank response to inflationary pressures should be ascribed to relatively sticky commodity price changes as opposed to the volatile ones. In short, signals of the actual inflationary pressures should be reflected by changes in the medium term trend inflation (core inflation). Therefore, a well anchored inflation rate encourages the use of all available productive resources which in turn leads to a zero or reduction in the output gap.

The output gap refers to the difference between potential output and the actual output. According to Harvey (2000: 01) the output gap is subjected to uncertainty in the specification of the underlying dynamics of the cyclical elements. Section 4.3 discusses techniques for estimating the output gap namely the production function approach, the Hodrick-Prescott filter, the Baxter-King filter and the Kalman filter. These techniques are mostly used in empirical macroeconomics when determining the cyclical and trend elements of an economic variable.

Another unobserved explanatory variable of the Taylor rule model is the natural real interest rate (NRIR). Wicksell (1907) pioneered the NRIR concept. This concept has resurged in macroeconomics due to the growth in Taylor type models. Owing to uncertainty, this thesis discusses four approaches in the estimation of NRIR so as to gain a broader understanding of the NRIR underlying dynamics. Section 4.4 discusses the NRIR estimation techniques.

Granger and Newbold's (1974) influential paper showed that the application of time series variables in their levels format leads to spurious regressions. This is because the levels of many economic variables are non-stationary and they often appear to be near random walks (Harris, 1995: 14). The spurious regression problem is identified by testing for unit roots, order of integration and cointegrating relationships in the model variables. Section 4.5 discusses stationarity properties as well as the order of integration of the data while Section 4.6 focusses on cointegration applying the Engle-Granger technique.

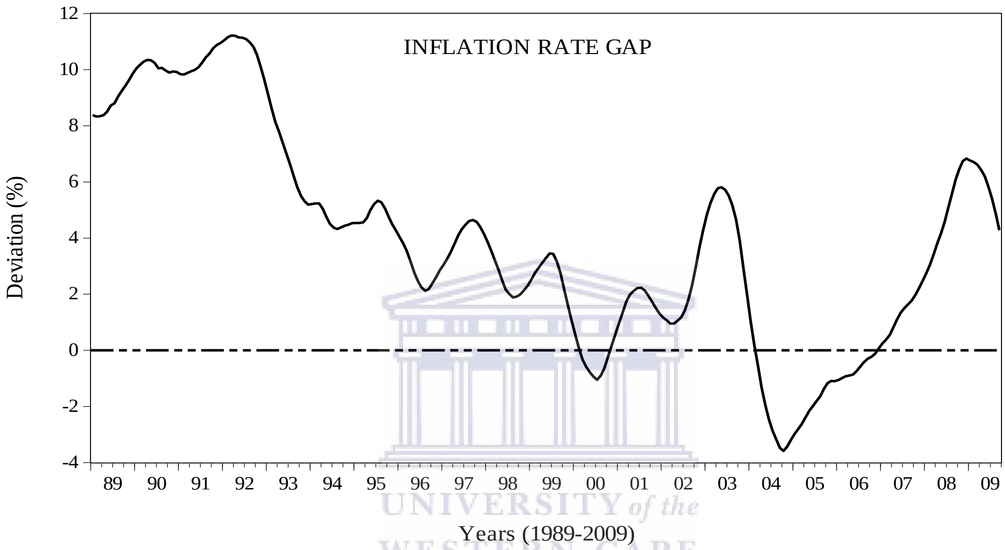
After the cointegration test reveals evidence of a long-run relationship in the data, the next step in evaluating the Taylor rule hypothesis is to compare the estimated Taylor rule model predictions with the actual repo rate series (see Section 4.7). These comparisons ascertain whether there was an implicit application of the Taylor rule model in the conduct of monetary policy by the SARB. Although there is more uncertainty involved in the measurement of Taylor rule variables, the model still offers an optimal yard stick to evaluate the central bank historical monetary policy degree of accommodation or restrictiveness.

4.2. **Deriving the inflation rate gap**

The inflation rate gap is an explanatory variable in the Taylor rule model. It is calculated as the deviation of the actual inflation from targeted inflation. As discussed in section 3.2.2 above, the thesis follows Taylor 1993 use of the previous four quarters inflation average as a measure of the actual inflation realisation in the economy. This means changes in the previous four quarters' inflation rate indicate actual inflationary pressures ascribed to the relatively sticky price commodities (core inflation) that should be stabilised by the central bank in order the achieve the price stability objective.

According to Marcus (2014: 04) the SARB maintained an annual CPI headline target of 3 to 6 per cent as their main inflation target. Therefore, the deviation of the actual core inflation realisations from the inflation target constitutes the inflation rate gap. A mid-point of 4.5 per cent from the formal IT framework targeted range of 3 to 6 percent was applied as the target rate in the calculation of the inflation gap. Figure 4.1 below outlines the trajectory of the inflation rate gap over the period 1989-2009 in South Africa.

Figure 4.1: <u>Inflation rate Gap</u>



Source: SARB and author manipulation (2013)

The inflation rate gap trajectory reflects a mean reverting (stationary) series. Over the Stals governorship, there was a strong drive towards stabilising inflation as shown by the downwards trend in the positive inflation rate gap, albeit with some destabilising pressures experienced in 1994, 1996 and 1998. The political regime change could explain the inflationary pressure of 1994, whilst the South African financial market turmoil and the Asian currency crisis caused increases in the inflation rate gap over the period 1996 and 1998 respectively. During Mboweni governorship, the actual core inflation was within the target range four times. However, there are noticeable sharp destabilising inflationary pressures experienced during the early 2000s, following the central bank intervention in the exchange rate market as a result of a severe depreciation of the rand, and the 2007-8 global financial crisis period.

4.3. **Estimating the output gap**

The output gap is an explanatory variable in the Taylor rule model. It reflects deviations in total production from its potential level. According to Clark (1987: 797) there are different assumptions about the trend and cyclical movements. In the case of linear Gaussian models, economists assume the potential output trend to be non-stationary and the cyclical movements stationary. Nevertheless, in empirical modelling Canova (1998: 485) noted that the dynamics of the potential output trend reflect the behavioural interpretation of the output gap by the researcher[15]. Because of the different assumptions on the cyclical movements, the techniques discussed in Section 3.5 are applied in estimating the output gap in this study. These are the production function approach, the Hodrick-Prescott (HP) filter, the Baxter-King filter and the Kalman filter.

Another concept closely related to the output gap is the business cycle theory. This concept dates back to Burns and Mitchell's (1946) influential research. Burns and Mitchell (1946: 03) define the business cycle as variations in economic activities especially in the firm's activities. These are characterised by expansion and contraction phases that vary in amplitude, frequency and periodicity. Venter (2009: 61) noted that the SARB has estimated turning points of cyclical elements of the South African economy since 1946.

Empirical methods applied to estimate the business cycle illustrate the turning points, peaks and troughs in the economy. In South Africa business cycle turning points are well documented (see Boshoff (2010), Bosch and Ruch (2012), Du Plessis (2004), Du Plessis, Smit and Sturzenegger (2007) and Kabundi (2009)). To ensure consistency in the estimated output gaps, the business cycle downward phases derived by Bosch and Ruch (2012) applying the Bry and Boschan method are presented together with the estimated output gaps.

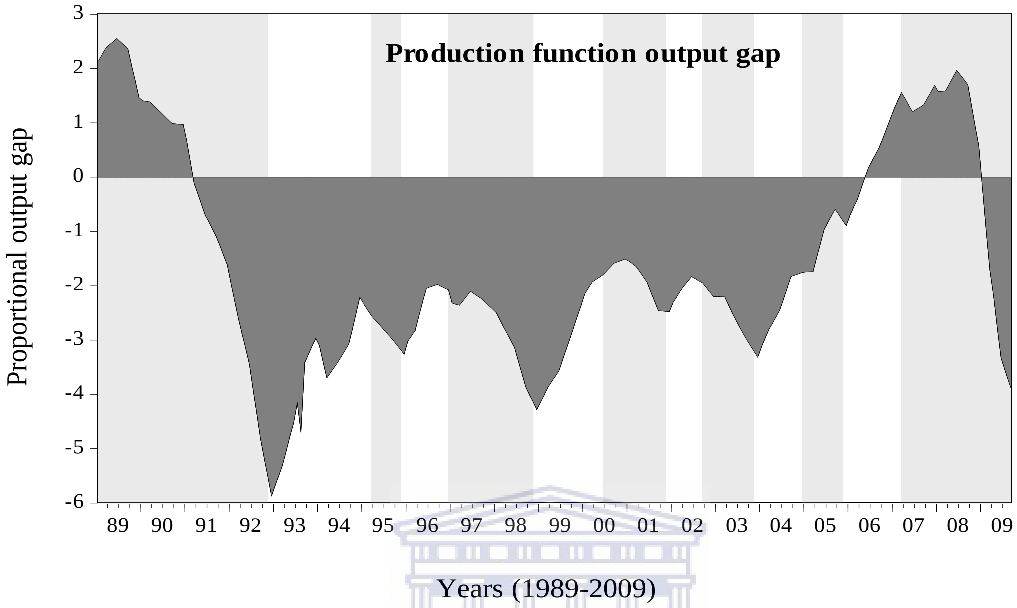
4.3.1. Production function output gap

The Production Function (PF) technique is one of the methods used to derive the output gap. This approach utilises economic theory in predicting the potential output trend. For a detailed explanation of the PF technique, see Section 3.5.2. The PF output gap is calculated as the

[15] This discretionary nature of the transitory movements' interpretation is a major source of debate with no consensus that has been established to date.

deviations of the predicted PF potential output trend from the actual production (GDP) trend. The diagram below presents the PF output gap.

Figure 4.3: <u>The production function output gap</u>



Source: SARB and author manipulation (2013)

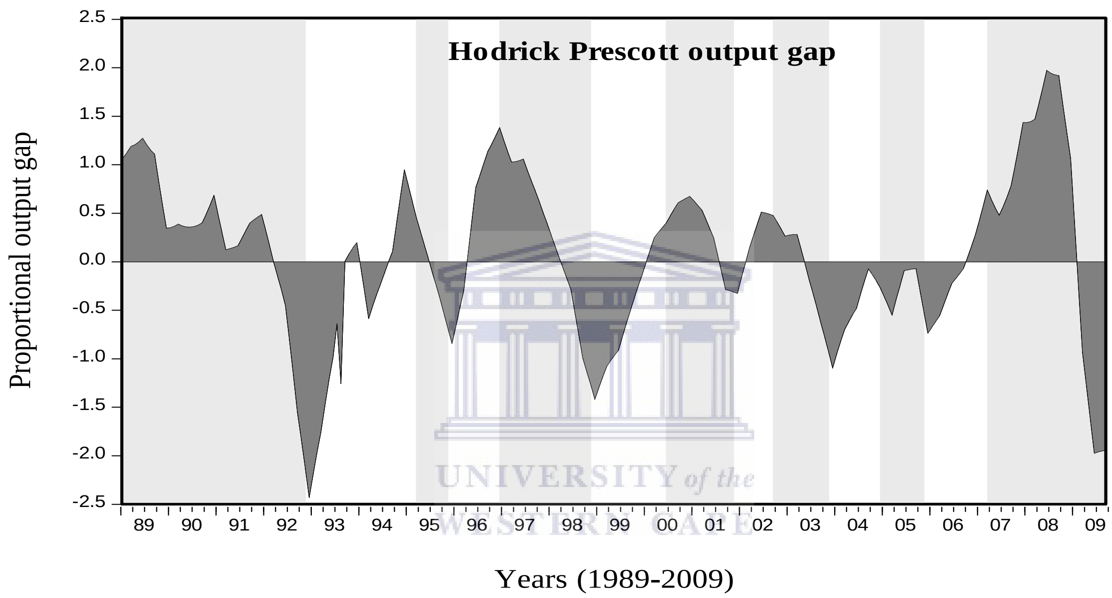
Figure 4.3 illustrates the PF output gap. The downward phases of the South African economy depicted by the Bry and Boschan approach (shaded area in the graph above) correlate well with the estimated output gap dynamics. This implies that during the periods of a business cycle contraction, actual production tends to fall relative to potential production illustrating a deteriorating output gap.

The Stals governorship reflected a sharp fall in actual production relative to potential production from 1989 till 1992. Financial sanctions can explain the sharp weakening in the output gap. Actual production recovered during the Stals governorship but the recovery was not sufficient to meet the potential production capacity of the country. Therefore, the output gap remained negative for the rest of the Stals governorship. The Mboweni governorship is characterised by a general improvement in the output gap, albeit with some fluctuations, from -3.4 in 1999 to 1.6 in 2007. The onset of the financial crisis led to a decline in the output gap.

4.3.2. *Hodrick-Prescott filter output gap*

The Hodrick-Prescott (HP) filter is one of the approaches used to derive the output gap. This approach is purely statistical and highly technical. It is criticised for ignoring important economic relationships amongst variables. For a more detailed explanation of the HP potential output trend, see Section 3.5.3. The diagram below presents the HP filter output gap.

Figure 4.4: <u>Hodrick-Prescott output gap</u>



Source: SARB and author manipulation (2013)

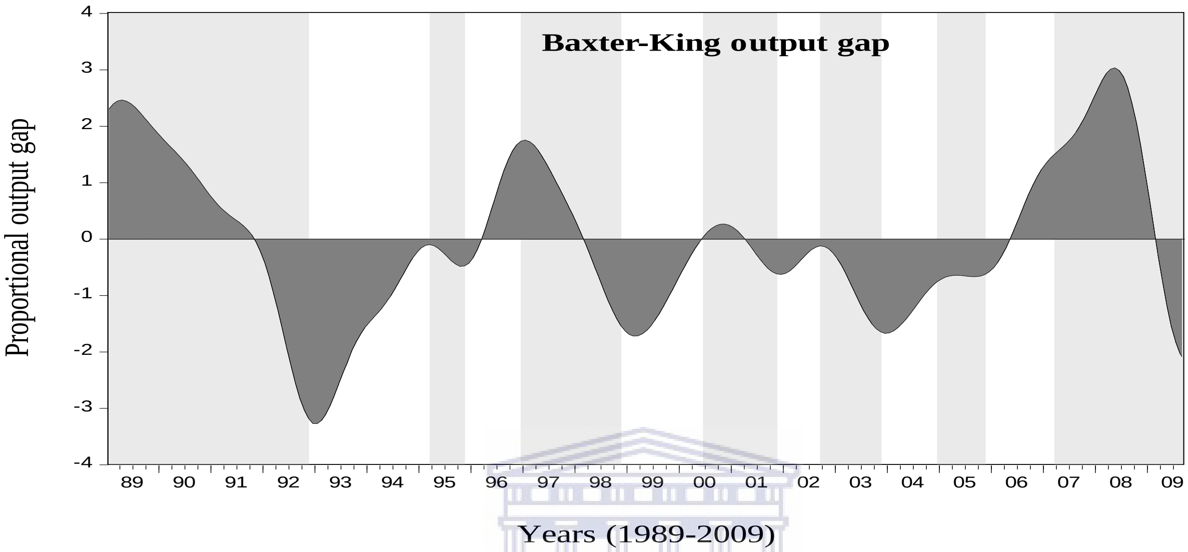
Figure 4.4 outlines the trajectory of the HP filter output gap. It shows a low variation in the output gap relative to the PF approach prediction. This can be explained by the smoothing parameter (penalty) applied by the model. Over the entire study period, the HP output gap tends to be alternating from positive to negative more often than that of the PF approach. However, these alternating fluctuations are in line with the phases of the South African business cycle depicted by the Bry and Boschan approach from Bosch and Ruch (2012).

4.3.3. *Baxter-King filter output gap*

The Baxter-King (BK) approach is one of the methods used to separate trend and cyclical elements in a series. The decomposed cycle is known as the output gap. Baxter and King

(1995: 02) argued that their approach stems from the definition of the business cycle proposed by Burns and Mitchell (1946). For a detailed explanation of the BK technique, see Section 3.5.4. The diagram below presents the BK output gap for the South African economy.

Figure 4.5: Baxter-King filter output gap



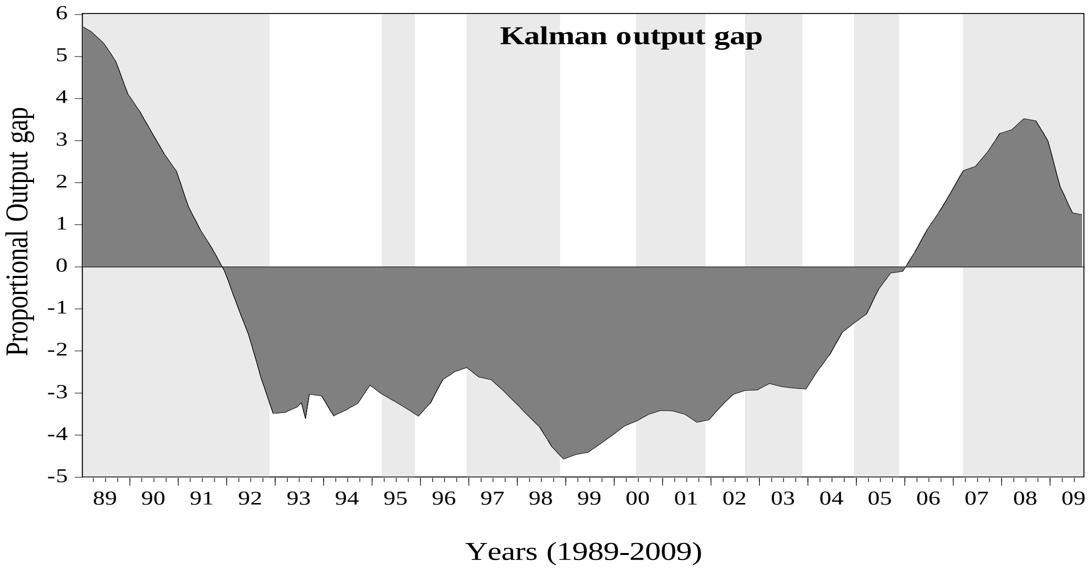
Source: SARB and author manipulation (2013)

The above graph illustrates the BK filter output gap for South Africa over the period 1989-2009. Its movements are in line with the Bosch and Ruch's (2012) business cycle phases. The BK filter output gap demonstrates more variation in the output gap relative to the HP filter approach, but less relative to that of the PF approach. Over the periods of a contraction in actual production, resulting from the financial sanctions (late 1980s), the Asian crisis (1997-08) and the financial crisis (2007-08), there were movements in the output gap from positive to negative values. In short, the contractions imply periods of output gap deterioration.

4.3.4. Kalman filter output gap

Another approach used to estimate the output gap is the Kalman filter (KF). It is applied when modelling rational expectations, measurement errors, missing observations and unobserved components (Harvey, 1993: 101). Nelson, Zivot and Morley (2002: 06) noted that the Kalman filter derives the potential trend component based on the data over time (t). For more details on the Kalman filter, see Section 3.5.5. The diagram below outlines the Kalman filter output gap for the South African economy applying the Clark (1987) model.

Figure 4.6: <u>Kalman filter output gap</u>



Source: SARB and author manipulation (2013)

Figure 4.6 shows that from the early 1990s to the mid-2000s the South African economy was performing below its potential level. This results in the deterioration (movement from positive to negative) of the output gap. The financial sanctions on the apartheid regime as well as the balance of payments constraint can be possible reasons for the output gap deterioration. This outcome is in line with the PF approach findings. The output gap fluctuations correlate well with the business cycle phases for the South African economy.

4.3.5. Conclusion on output gap

The estimated output gaps tend to correlate well with Bosch and Ruch's (2012) reference points of the South African business cycle. However, the relative output gaps differ in magnitude over the period under consideration irrespective of the fact that their movements follow the same trend. The PF and KF techniques reflect a negative output gap from 1991 to 2006 whilst the BK and HP approaches shows an alternating output gap over the same period. This difference in magnitude can be explained by the difference in the assumptions as well as the smoothing parameters applied by each approach.

4.4. **Estimating the natural real interest rate**

4.4.1. Introduction

The natural real interest rate (NRIR) is another component of the Taylor rule model. Although Taylor (1993:202) assumed the NRIR to be a constant rate of 2 per cent based on the USA statistical data, he acknowledge that the NRIR coefficient can be modified to fit the country of study. In addition, Woodford (2003: 28) refuted the constancy of the NRIR and argued that it is a time varying variable. The time varying nature of the NRIR follows from the developments in the Wicksellian framework. Therefore, this thesis applies a time varying NRIR.

The NRIR cannot be directly observed hence it is characterised by high uncertainty in its estimation. As a result, Giammariolli and Valla (2003: 06) argue that there is no single agreed-upon technique for estimating it. In short, there are a number of ways to characterise the dynamics of the time varying NRIR, unfortunately with no consensus on the best approach.

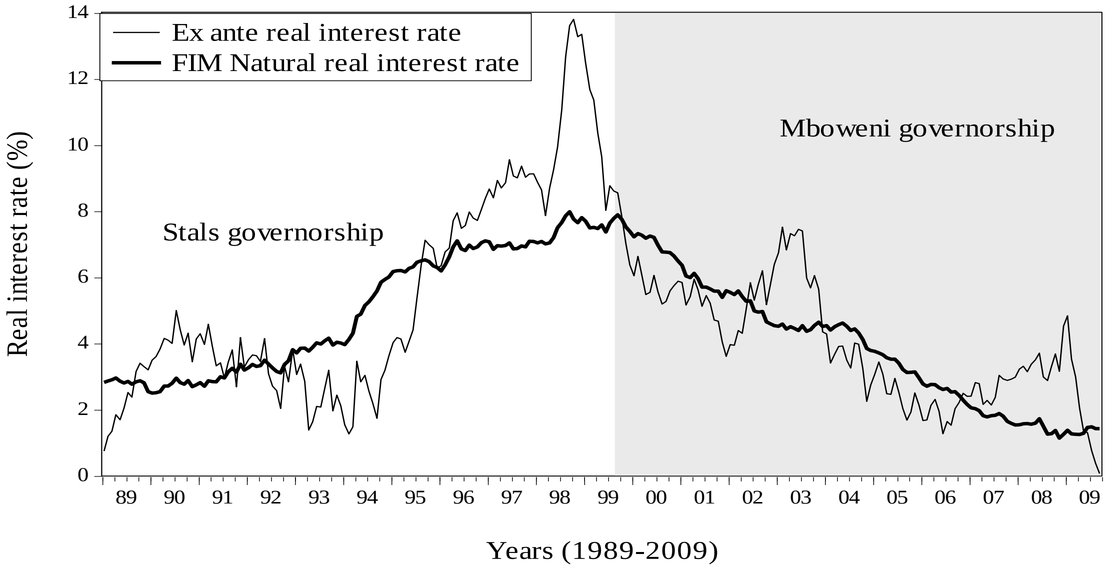
In light of the above, this study adopts four models based on the medium term definition[16] of the NRIR concept. These models are the financial indicators model (FIM), a univariate model (UVM), a multivariate model (MVM) and the Laubach and Williams (2003) model (LWM). Although the usefulness of the NRIR is undermined by ambiguities in its estimation, the concept still offers good insight on whether historical monetary policy was accommodative or restrictive.

4.4.2. The financial indicators model

Bomfim (2001) pioneered the FIM technique to estimate the NRIR. As discussed in Section 3.6.2 financial market data were used to derive the NRIR by applying the Kalman algorithm. The FIM NRIR, derived from decomposing the long-term government bond yield over the period 1989 – 2009, is represented in Figure 4.7 below.

[16] See Section 2.4.4 for the time horizon definition of the natural real interest rate.

Figure 4.7: Financial indicators model natural real interest rate



Source: BER and author manipulation (2013)

Figure 4.7 illustrates the South African NRIR and the EARIR. The NRIR varies from one to eight per cent over the study period. The Stals governorship reflects a NRIR that fluctuates around three per cent before 1994; then after the political transition the rate shows an upward trend reaching its highest value of eight per cent in 1998. On the other hand, Mboweni's governorship reflects a downward trend in the NRIR.

The correlation coefficients in Table 4.1 provide evidence of a negative correlation between the output gaps and the real interest rate gap even though it is not a perfect one to one negative relationship.

Table 4.1: Summary of the correlation between the FIM real rate gap and the output gap

	BK output gap	HP output gap	Kalman output gap	Prod output gap
FIM Real rate gap	-0.1018 (-1.6077)	-0.075 (1.1743)	-0.2871 (-4.7103)**	-0.2013 (-3.2298)**

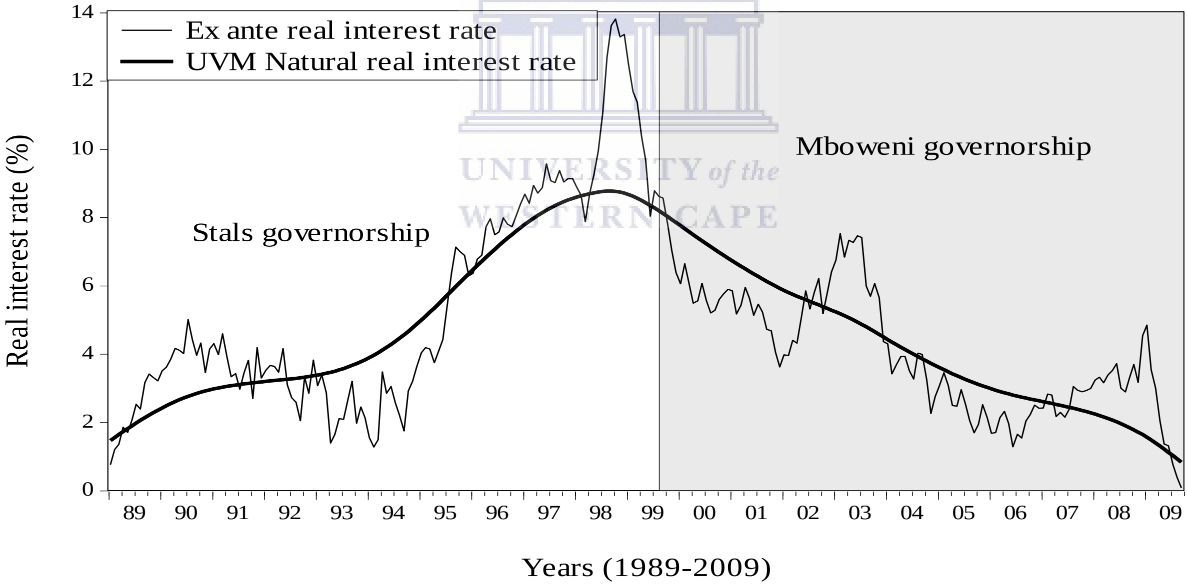
BK = Baxter-King band-pass filter, HP = Hodrick-Prescott filter, Kalman = Kalman filter and Prod = Production function model, ** = 5 % level of significance and t-statistics in parenthesis.

The Kalman filter reflects a higher statistically significant correlation coefficient followed by the production function approach. The HP filter and the BK filter reveal lower correlation coefficients that are statistically insignificant. Furthermore, the real interest rate gap reflects that from 1989 until the political transition monetary policy in South Africa was relatively accommodative, and for the rest of the 90s it was more restrictive excluding the period of the Asian crisis (1997-98), shown in Appendix 1. For most of the 2000s monetary policy was characterised by a relative accommodative policy stance.

4.4.3. A Univariate model

A univariate model (UVM) is an alternative technique used to examine the dynamics of the NRIR. This model relies purely on statistical mechanisms based on the underlying assumption of the data-generating process of the NRIR. As discussed in Section 3.6.3 the UVM NRIR was derived in line with Harvey and Peters (1989) applying the Kalman algorithm. The trajectory of the UVM NRIR is presented by the diagram below.

Figure 4.8: <u>Univariate model natural real interest rate</u>



Source: BER and author manipulation (2013)

Figure 4.8 illustrates the NRIR and the EARIR movements. The NRIR varies from 0.81 to 8.75 per cent during period 1989-2009. Under the Stals governorship, the NRIR was relatively stable with an average of approximately 3 per cent prior to 1994. Then thereafter there is a markedly sharp increase towards the end of Stals governorship. On the other hand, the Mboweni governorship inherited a high NRIR which over time reflects a noticeable gradually decrease until the end of his tenure. The gradual decrease in the post 2000 period is in line with international trends in interest rates movements. Table 4.2 below tabulates the correlation coefficients between the real interest rate gap and the output gaps.

Table 4.2: <u>Summary of the UVM real rate gap and the output gap correlation</u>

	BK output gap	HP output gap	Kalman output gap	Prod output gap
UVM Real rate gap	0.4948 (8.9496)**	0.3767 (6.3926)**	0.3443 (5.7650)**	0.3885 (6.6273)**

BK= Baxter-King band-pass filter, HP = Hodrick-Prescott filter, Kalman = Kalman filter and Prod = Production function model, ** = 5 % level of significance and t-statistics in parenthesis.

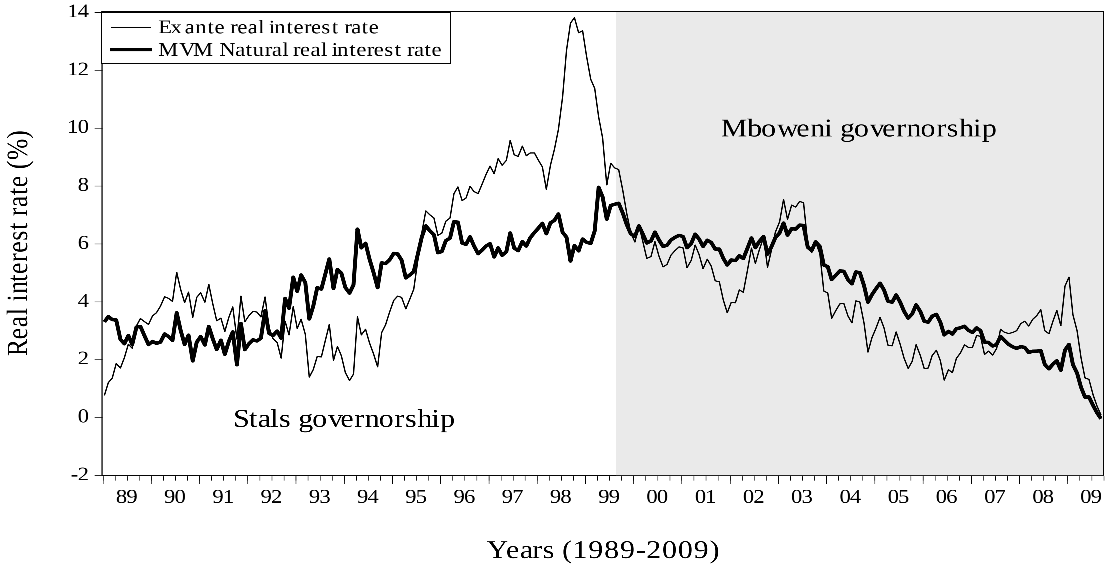
The table 4.2 reflect a positive correlation between the UVM real rate gap and the four output gap approaches which are statistically significant at 5 % level of significance. This outcome is contrary to the correlation relationship suggested by economic theory of a one to one negative relationship.

During Stals governorship, the UVM real interest rate gap reveals three phases of contractionary monetary policy (see Appendix 1). These coincide with the recessionary periods emanating from the financial sanctions on the apartheid era government (1989-91), the 1996 South African financial sector turmoil and the Asian currency crisis (1998). On the other hand, the Mboweni governorship reveals two phases of contractionary monetary policy period which are also in line with the period when actual output was below the potential output level.

4.4.4. A Multivariate model

Another technique that is widely used to estimate the NRIR is the multivariate approach. According to Cuaresma *et al.* (2003: 06) this approach exploits the dynamic feature of a series based on the cross correlation between the Gaussian innovation processes in the model. As discussed in Section 3.6.4, the MVM NRIR was derived in line with Clark (1987) model. Figure 4.9 below presents the MVM NRIR trajectory over the period 1989-2009.

Figure 4.9: <u>Multivariate model natural real interest rate</u>



Source: SARB and author manipulation (2013)

Figure 4.9 reflects that over the study period the NRIR varies between -0.06 to 7.93 per cent. During the Stals governorship, the period prior to 1994 depicts a relatively stable MVM NRIR trajectory with an average of 3.5 per cent. The period post 1994 outlines a gradual upwards trend in MVM NRIR till the end of Stals governorship, albeit with some fluctuations. During the Mboweni governorship, the MVM NRIR shows a gradual fluctuating downward trend until the end of his governorship. Table 4.3 below summarises the correlation coefficients between the real interest rate gap and the output gaps.

Table 4.3: <u>Summary of the MVM real rate gap and the output gap correlation</u>

	BK output gap	HP output gap	Kalman output gap	Prod output gap
Real rate gap	0.4029 (6.9200)**	0.2985 (4.9169)**	0.0696 (1.0965)	0.165 (2.6415)**

BK= Baxter-King band-pass filter, HP = Hodrick-Prescott filter, Kalman = Kalman filter and Prod = production function model, ** = 5 % level of significance and t-statistics in parenthesis.

The MVM real interest rate gap and the output gap correlation coefficients from the MVM show no evidence of a negative correlation between the output gaps and the real interest rate gap even though economic theory suggests a one to one negative relationship. Only the Kalman filter output gap correlation with the real interest rate gap reflects a statistically insignificant positive correlation.

The real interest rate gap illustrates that from the period of financial distress the SARB had a restrictive monetary policy that they started easing from early 1992 until 1994 (see Appendix 1). Thereafter they had a restrictive monetary policy till the end of Stals governorship. The Mboweni governorship had two phases of contractionary monetary policy. This outcome is similar to the univariate model prediction with noticeable differences in magnitude and spread of the policy stance.

4.4.5. The Laubach and Williams (2003) model

The Laubach and Williams (2003) model is a widely used approach to estimate the time varying NRIR. As discussed in Section 3.6.5, Laubach and Williams (2003) pioneered a concurrent estimation of the NRIR and the potential output as well as the potential output growth rate in a semi-structured macroeconomic model based on the Kalman filter algorithm. This model exploits the knowledge of the salient features of the series using economic theory.

The Laubach and Williams (2003) model estimation procedure is not straightforward. This is because the low standard deviations relative to the model variability on the potential output growth rate as well as the NRIR cyclical component tend to be biased towards zero. Therefore, no variability is reflected by the model. This bias is known as the pile-up problem of Stock and Watson (1998).

Because of the pile-up problem, the Laubach and Williams (2003) model's NRIR estimation was carried out in three steps. First, decompose gross domestic product into a trend and cycles to obtain the output gap. Second, determine the unbiased estimators for the trend growth variance and the NRIR variance. Last, estimate the whole model as discussed in Section 3.6.5 imposing the unbiased estimators.

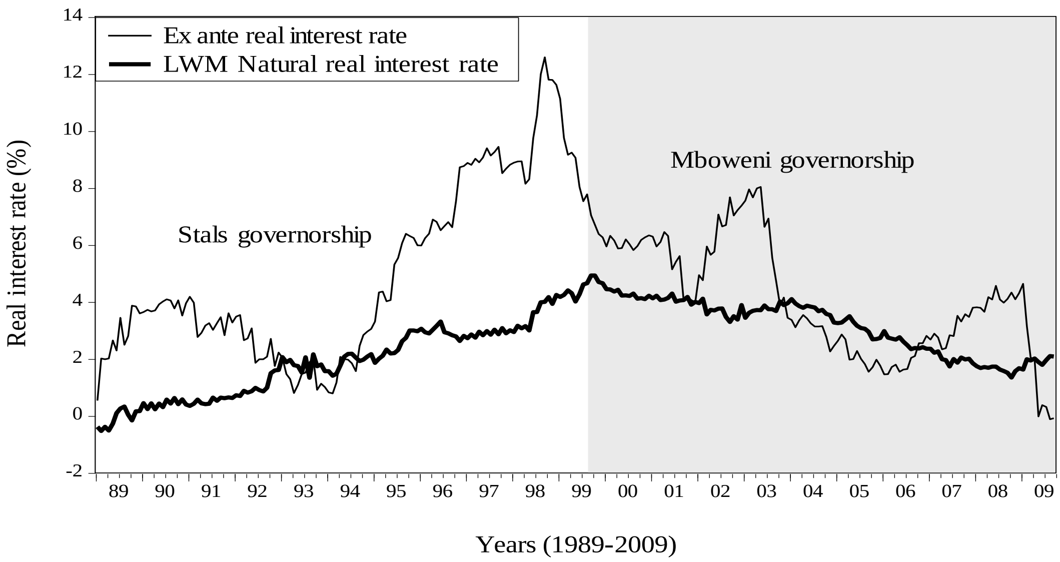
In the first step to derive the NRIR, the Clark (1987) model was applied to decompose GDP as discussed in Section 3.4.5. The second step involves estimating the unbiased estimator of Stock and Watson (1998). This is achieved through a test for stability as discussed in Section 3.6.5. The results from the sequential Chow F-test for examining the stability of potential output growth on a constant shows an estimated F-statistic of 52.774. Based on the F-statistic the null hypothesis of no structural break is rejected. This implies that the coefficients are not stable over the study period. Hence, there is no stability in the estimated potential growth rate (Δy^*) on a constant.

To obtain the median unbiased estimator of $\hat{\lambda}_g$, the Andrew and Ploberger (1994) Exponential Wald (EW) statistic was applied, and it yields a coefficient of 26.0303. Based on the EW test statistic the Stock and Watson (1998: 354) look-up table reflected an unbiased $\hat{\lambda}_g$ estimate of 28.4022. The median unbiased variance $\hat{\lambda}_g$ of **0.1141** was obtained after dividing the unbiased estimator with the number of observations in the model.

After obtaining the unbiased estimator of the potential output growth variance the whole Laubach and Williams (2003) model was estimated with the catch-all variable in equation (III) being constant. Thereafter, the estimated output gap was examined for structural breaks to derive the median unbiased estimator for NRIR cyclical elements. This was achieved by applying the technique used for the derivation of the potential growth rate median unbiased estimator above.

The estimated results from estimating the catch-all variable on a constant demonstrate that the coefficients were stable over the study period. This means that there is evidence of variability in the NRIR cyclical elements. Therefore, one can proceed by assuming that the cyclical elements in the NRIR are stationary and estimate the whole model imposing the growth rate variance. The diagram below outlines the LWM NRIR predictions.

Figure 4.10: <u>The Laubach and Williams (2003) model natural real interest rate</u>



Source: BER and author manipulation (2013)

Figure 4.10 reflects a relatively stable LWM NRIR which varies from -0.53 to 4.91 per cent. During Stals governorship, the LWM NRIR trajectory shows a gradual upward trend until the end of his governorship. The Mboweni governorship reveals a stable trajectory in the early 2000s period and a gradual downward trend after 2004 till late 2008. Thereafter, an upward trend is noticeable till the end of the study period.

The real interest rate gap correlation with the output gap (see Appendix 1) illustrates a greater degree of restrictive monetary policy stances by the central bank over the period of study where the contractions vary with time. The real interest rate gap and the output gap from the LWM reflect a statistically significant negative correlation coefficient of -0.268, albeit not a one to one relationship as expected from economic theory.

4.4.6. Conclusion on natural real interest rate

The preciseness of accurately measuring the NRIR plays a major informative role in advising policy makers. However, the unobservability trait as well as uncertainties in the NRIR empirical measurement process inhibits the practical usefulness of the concept. Nevertheless, it is still a good indicator or benchmark of evaluating historical monetary policy stances. Therefore, the four models discussed above provide insights of the movements and variations in the NRIR over time. The correlations between the output gaps and the real interest rate reflect mixed results. That is the LWM and FIM indicated a negative relationship as suggested by economic theory whilst the UVM and MVM reflected a positive relationship.

Over the governorship of Stals, all the approaches reflect a relatively stable NRIR at approximately 3 per cent prior to 1994, thereafter a marked increase till the end of his governorship. The Mboweni governorship starts with a higher NRIR as compared to Stals for all approaches. However, the trajectory of the NRIR reflects a general gradual downward trend over the entire governorship, albeit with a noticeable stable NRIR in the early 2000s. The downward trend is in line with the international short term interest rates movements.

4.5. **Testing for stationarity**

The dynamics of the variables applied in the analysis of the Taylor rule model hypothesis were tested for stationarity and order of integration using the ADF and KPSS unit root tests. This follows from Brooks (2008: 331) argument that to obtain confirmatory inferences on unit root testing it is important to consider tests that examine the null hypothesis of stationarity as well as the null hypothesis of non-stationarity. Table 4.4 below summarises the ADF and KPSS unit root tests results.

Table 4.4: <u>Summary of the unit roots tests</u>

Variables	ADF LEVELS			ADF 1ST DIFFERENCE			KPSS LEVELS		KPSS 1ST DIFFERENCE		order of integrations
	None	Constant	Constant &trend	None	Constant	Constant &trend	Constant	Constant &trend	Constant	Constant &trend	
Repo rate	-1.11	-1.49	-3.20	-7.87*	-7.90*	-7.89*	1.31	0.12***	0.07*	0.04*	**I(1)**
NRIR FIM	-0.55	-0.24	-0.60	-6.53*	-6.53*	-13.84*	0.57*	0.49	1.13	0.20*	**I(1)**
NRIR UVM	-0.94	-0.76	-0.96	-2.07**	-2.08	-2.96	0.51**	0.48	1.21	0.15*	**I(1)**
NRIR MVM	-0.55	-0.34	-0.47	-4.52*	-4.56*	-5.87*	0.49**	0.48	0.44**	0.20	**I(1)**
NRIR LWM	-0.16	-2.28	-1.13	-10.21*	-10.25*	-10.71*	0.91	0.47	0.77	0.05*	**I(1)**
CPI headline inflation	-1.28	-1.79	-1.14	-6.75*	-6.77*	-6.92*	1.06	0.27	0.04*	0.03*	**I(1)**
CPI Core inflation	-1.35	-2.23	-2.75	-2.77*	-2.81**	-2.95	1.18	0.25	0.10*	0.05*	**I(1)**
Real GDP	2.35	0.68	-2.94	-2.83*	-3.70*	-3.99**	1.92	0.41	0.59*	0.15*	**I(1)**
BK potential trend	4.90	3.67	-2.97	0.99	-5.74*	-7.49*	1.96	0.47	1.60	0.26	**I(1)**
HP potential trend	-	-	-	0.29	-4.11*	3.27***	1.94	0.44	1.08	0.18*	**I(1)**
Kalman potential trend	3.41	0.60	-3.10	-1.85***	-3.88*	-3.99**	2.00	0.35	0.32*	0.12*	**I(1)**
Prod potential trend	2.15	1.93	-1.91	0.24	-2.01	-3.19***	1.98	0.46	1.52	0.10*	**I(1)**
Inflation rate gap	1.83***	-1.97	-2.50	-5.36*	-5.37*	-5.36*	1.19	0.32	0.10*	0.04*	**I(1)**
BK output gap	-2.99*	-3.13**	-3.21***	-4.36*	-4.36*	-4.38*	0.14*	0.12*	0.08*	0.08*	**I(0)**
HP output gap	-4.65*	-4.62*	-4.61*	-5.50*	-5.51*	-5.50*	0.06*	0.06*	0.06*	0.05*	**I(0)**
Kalman output gap	-2.00**	-2.42	-2.89	-3.39*	-3.41**	-3.93**	0.44*	0.43	0.87	0.14*	**I(0)**
Prod output gap	-1.82***	-3.05**	-3.13	-4.50*	-4.55*	-4.55*	0.32*	0.27	0.14*	0.12**	**I(0)**

ADF = Augmented Dickey-Fuller test, KPSS = Kwiatkowski-Phillips-Schmidt-Shin test, NRIR = Natural Real Interest Rate, CPI = Consumer Price Index, BK= Baxter-King filter, HP = Hodrick-Prescott filter, Kalman = Kalman filter, Prod = production function model, *, ** and *** statistically significant at 1%, 5%, 10% level of significance, FIM = Financial Indicators Model, UVM = Univariate Model, MVM = Multivariate Model and LWM = Laubach and Williams (2003) Model.

The results from the ADF unit root test showed that the inflation rate gap and all output gap series were stationary at 5 per cent level of significance whilst the repo rate series was stationary at 10 per cent level of significance when the variables are defined in their original format. On the other hand, all the other series reflected a non-stationary characteristic when the variables are defined in the level format. According to Garratt *et al.* (2006: 117) the stationarity in the inflation rate gap and the four output gaps stems from the underlying assumption in the formulation of these variables (see section 4.2 and 4.3).

The KPSS test results indicate similar outcomes reflected by the ADF unit root test however, in the levels format the NRIR from the FIM, UVM and MVM were stationary at 5 per cent level of significance and the inflation rate gap was non-stationary. This contradiction can be explained by differences in the unit root tests assumptions as well as insufficient data to enable rejection of the null hypothesis.

After first differencing, the ADF test results show evidence of stationarity on all the variables that were non-stationary in the levels format. The KPSS test results confirm similar conclusions. However, the Baxter-King potential output trend still reflects a non-stationary trait after first differencing using the KPSS unit root test albeit it being found stationary in the ADF unit root test. Therefore, after first differencing, the ADF unit root test strongly rejects the null hypothesis (non-stationary series) at the 5 per cent level of significance. Subsequently, the KPSS test results reflects similar outcomes. This implies that with respect to the ADF and KPSS unit root tests all the variables are integrated of order one (I(1)).

After examining the dynamics of the variables for stationarity and order of integration, the next step in testing the Taylor rule hypothesis is to evaluate the presence of long-run relationships in the data applying the Engle-Granger approach.

4.6. **Testing for cointegration (*The Engle-Granger Approach*)**

The first step in the Engle-Granger approach involves estimating a long-run model as explained in Section 3.4.3.1.1. Thereafter the residuals from the estimated regression models are examined for stationarity using the ADF test. Gujarati (2009: 823) noted that since the error terms are based on the estimated cointegration parameter the ADF critical values are no longer appropriate in evaluating the stationarity of the residuals. Instead, MacKinnon (1996) critical values[17] are applied as they are more accurate finite sample critical values (Davidson & MacKinnon, 2003: 614). Based on the ADF test results and the MacKinnon (1996) critical values, if the residuals of the estimated regression models are found to be stationary then a linear combination of two or more stochastic series exists. This means that there is a long-run equilibrium relationship between the variables. Table 4.6 below summarises the residuals ADF test statistics from the estimated long run regression models.

Table 4.6: Summary of the regression error terms

Taylor rule model with	Regression residuals ADF test statistic
BK output gap and FIM NRIR	-4.1797**
BK output gap and UVM NRIR	-5.0344*
BK output gap and MVM NRIR	-5.1742*
BK output gap and LWM NRIR	-4.8935*
HP output gap and FIM NRIR	-4.5777*
HP output gap and UVM NRIR	-4.5017*
HP output gap and MVM NRIR	-4.3539**
HP output gap and LWM NRIR	-4.7738*
Prod output gap and FIM NRIR	-4.5364*
Prod output gap and UVM NRIR	-3.9923**
Prod output gap and MVM NRIR	-4.1743**
Prod output gap and LWM NRIR	-3.8594*
Kalman output gap and FIM NRIR	-4.4906*
Kalman output gap and UVM NRIR	-4.1517**
Kalman output gap and MVM NRIR	-4.4822*
Kalman output gap and LWM NRIR	-3.6383**

BK = Baxter-King filter, HP = Hodrick- Prescott filter, Prod = Production function approach, Kalman = Kalman filter approach, SIC = Schwarz Information Criterion, MacKinnon test statistic 1% = -4.3542, 5 % = -3.7766 and 10% = -3.4769, *, ** and *** statistically significant at 1%, 5%, 10% level of significance, NRIR = Natural Real Interest rate, FIM = Financial Indicators Model, UVM = Univariate Model, MVM = Multivariate Model and LWM = Laubach and Williams (2003) Model.

Table 4.6 presents the ADF residual test statistics. It shows that the residuals from all the estimated long-run Taylor rule models are stationary at 5 per cent level of significance or

[17] See Appendix 2, Table A2 for the calculation of the MacKinnon critical values.

better. This implies that there is evidence of cointegrating relationships in the estimated Taylor rule models. Therefore, given the evidence for the existence of a long run relationship the next step in the Engle-Granger cointegration test is to estimate an error correction model.

The second step in the Engle-Granger approach involves the estimation of the short-run error correction model. This is achieved if the residuals from the estimated long-run model indicate evidence of a unique long run relationship (cointegration) within the estimated variables. As discussed in Section 3.4.3.1.2 the short-run ECM applied lagged values of the residual term to adjust for the estimation disequilibrium. Table 4.7 below tabulates the results of all estimated short-run error correction models.

Table 4.7. Summary of the error correction models

Taylor rule model with	Inflation rate gap	Output gap	ECT	Adjusted R-squared	DW
BK output gap and FIM NRIR	0.4091** (0.1906)	0.9374** (0.3614)	-0.1789** (0.0402)	0.27	2.07
BK output gap and UVM NRIR	0.4583** (0.1930)	1.0529** (0.1869)	-0.1611** (0.0428)	0.26	2.12
BK output gap and MVM NRIR	0.3803** (0.1086)	0.7078** (0.1851)	-0.0878** (0.0289)	0.27	2.18
BK output gap and LWM NRIR	0.3794 (0.2003)	0.8877** (0.1871)	-0.0202 (0.0244)	0.20	2.22
HP output gap and FIM NRIR	0.2926 (0.1931)	0.0423** (0.0131)	-0.1159** (0.0318)	0.26	2.10
HP output gap and UVM NRIR	0.3563 (0.2007)	0.0493** (0.0137)	-0.0862** (0.0359)	0.21	2.12
HP output gap and MVM NRIR	0.3142 (0.1952)	0.0380** (0.0131)	-0.0732** (0.0251)	0.25	2.13
HP output gap and LWM NRIR	0.2653 (0.1768)	0.0434** (0.0133)	-0.0402 (0.0239)	0.24	2.15
Prod output gap and FIM NRIR	0.3395 (0.1991)	0.3722** (0.1216)	-0.1111** (0.0359)	0.21	2.05
Prod output gap and UVM NRIR	0.4145** (0.2003)	0.4711** (0.1194)	-0.1013** (0.0391)	0.20	2.09
Prod output gap and MVM NRIR	0.3178 (0.2018)	0.3831** (0.1225)	-0.0254 (0.0231)	0.20	2.13
Prod output gap and LWM NRIR	0.2889 (0.2000)	0.4663** (0.1101)	-0.0338 (0.0176)	0.21	2.07
Kalman output gap and FIM NRIR	0.3514 (0.1984)	0.5937** (0.1978)	-0.1174** (0.0363)	0.21	2.06
Kalman output gap and UVM NRIR	0.3911** (0.1921)	0.8041** (0.2004)	-0.1319** (0.0383)	0.27	2.11

Kalman output gap and MVM NRIR	0.4069** (0.1138)	0.4596** (0.1936)	-0.0511** (0.0232)	0.23	2.14
Kalman output gap and LWM NRIR	0.3016 (0.1971)	0.5460** (0.1955)	-0.0144 (0.0193)	0.23	2.17

BK = Baxter king band-pass filter, HP = Hodrick- Prescott filter, Prod = Production function approach, Kalman = Kalman filter approach, NRIR= Natural Real Interest Rate, FIM = Financial Indicators Model, UVM = Univariate Model, MVM = Multivariate Model, LWM = Laubach and Williams (2003) Model, ** = 5 % level of significance, ECT= Error Corrected Term and the estimated coefficients are not in parenthesis and their standard error are in parenthesis.

Table 4.7 summarises the results of the Taylor rule short-run error correction models. These estimated models explain on average approximately 23 per cent of the variation in the repo rate series as reflected by the adjusted R-squared above. The output gap coefficients are all positive and statistically significant at 5 per cent level of significance. Based on all output gap measures applied, models with the UVM NRIR prescribe a higher response to the deviation of actual output from its potential value in the policy rate relative to the other models. Whereas, models with the MVM NRIR reflects a low response to the output gap except in the case of the production function output gap.

The majority of the inflation rate gap coefficients are not statistically significant at 5 per cent level of significance with the exception of six Taylor rule models. These models are firstly, the BK output gap combined with FIM NRIR, UVM NRIR and MVM NRIR. Secondly, the PF output gap combined with UVM NRIR and lastly, the KF output gap combined with UVM NRIR and MVM NRIR. The speed of adjustment coefficients from the estimated statistically significant models reflects evidence of a relatively low convergence towards equilibrium with the highest being 17 per cent and the least being 5 per cent.

The results from table 4.7 suggest that the SARB attaches more weight to the output gap as compared to the inflation rate gap in models with the BK, KF and PF output gaps. The low reaction to inflation changes in some of the estimated models could be a reflection of a good anchor of inflation expectations applied by the central bank. Therefore, the monetary policy officials will not respond aggressively to inflation changes when the public believe that the inflation fluctuations are short lived rather they respond aggressively to output gap changes.

In all the estimated models there is no evidence of first order autocorrelation, and the Breusch-Godfrey (LM) test for higher order autocorrelation rejects the null hypothesis of serial autocorrelation in the data (see Appendix 3, Table 2). In addition, there is no evidence of heteroskedasticity in the estimated model. The Jacques-Bera test for normality shows that the residual terms from the Taylor rule models are not normally distributed (see Appendix 3,

Table 3). This is as a result of international as well as domestic shocks to the economy that create large volatility (outliers) in the error terms.

An intervention or dummy variable was introduced to account for the various shocks to the system however, normality was not attained albeit with a tendency towards normality. In addition, a robust estimation technique (MM-estimation in Eviews) was undertaken to also account for outliers in the data but the estimators of interest did not change or deviate from the OLS results hence only OLS estimators were reported.

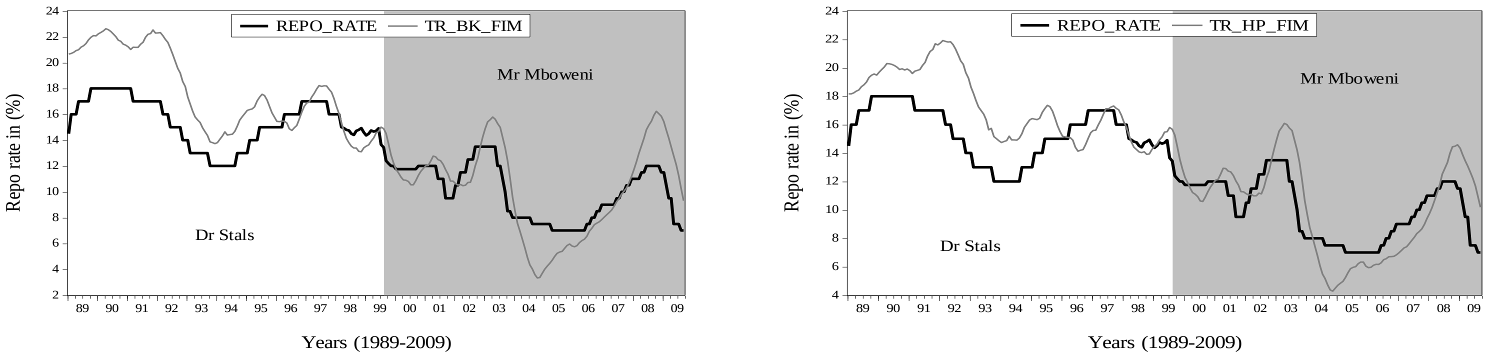
According to Gujarati (2009: 540) even though the estimated models violated the normality assumptions, the OLS estimators still remain the best linear unbiased estimators (BLUE) based on the Gauss-Markov assumptions. More so, the existence of outliers might cause the normality test to reject the null hypothesis regardless of the fact that the rest of the data do come from a normal distribution. Therefore, based on the Gauss-Markov assumptions one would assume that the data applied in the Taylor rule hypothesis testing was drawn from a normal distribution. The next section focusses on the predictions of the Taylor rule models applying the estimated coefficients summarised in Table 4.7 above.

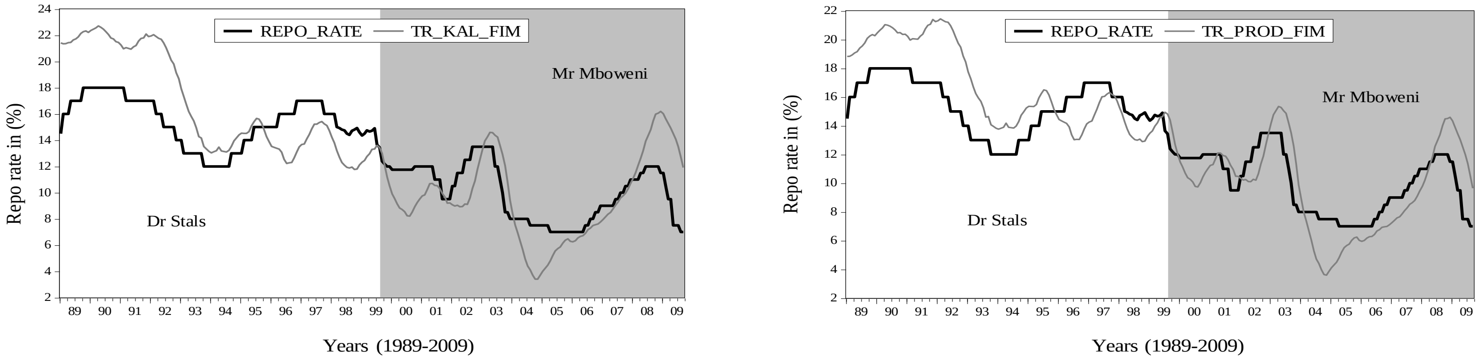
4.7. **The predicted Taylor rule models**

4.7.1. Taylor rule models with the FIM NRIR

The Taylor rule models with the NRIR derived from the FIM predict a repo rate between 11.8 and 22.9 per cent in the Stals governorship. For the Mboweni governorship, the FIM predicts a repo rate within the range of 3.2 to 16.2 per cent. Figure 4.11 below illustrates the predicted repo rates by the various Taylor rule models.

Figure 4.11: <u>Taylor rule model with FIM NRIR</u>





Source: SARB and author manipulation (2015)

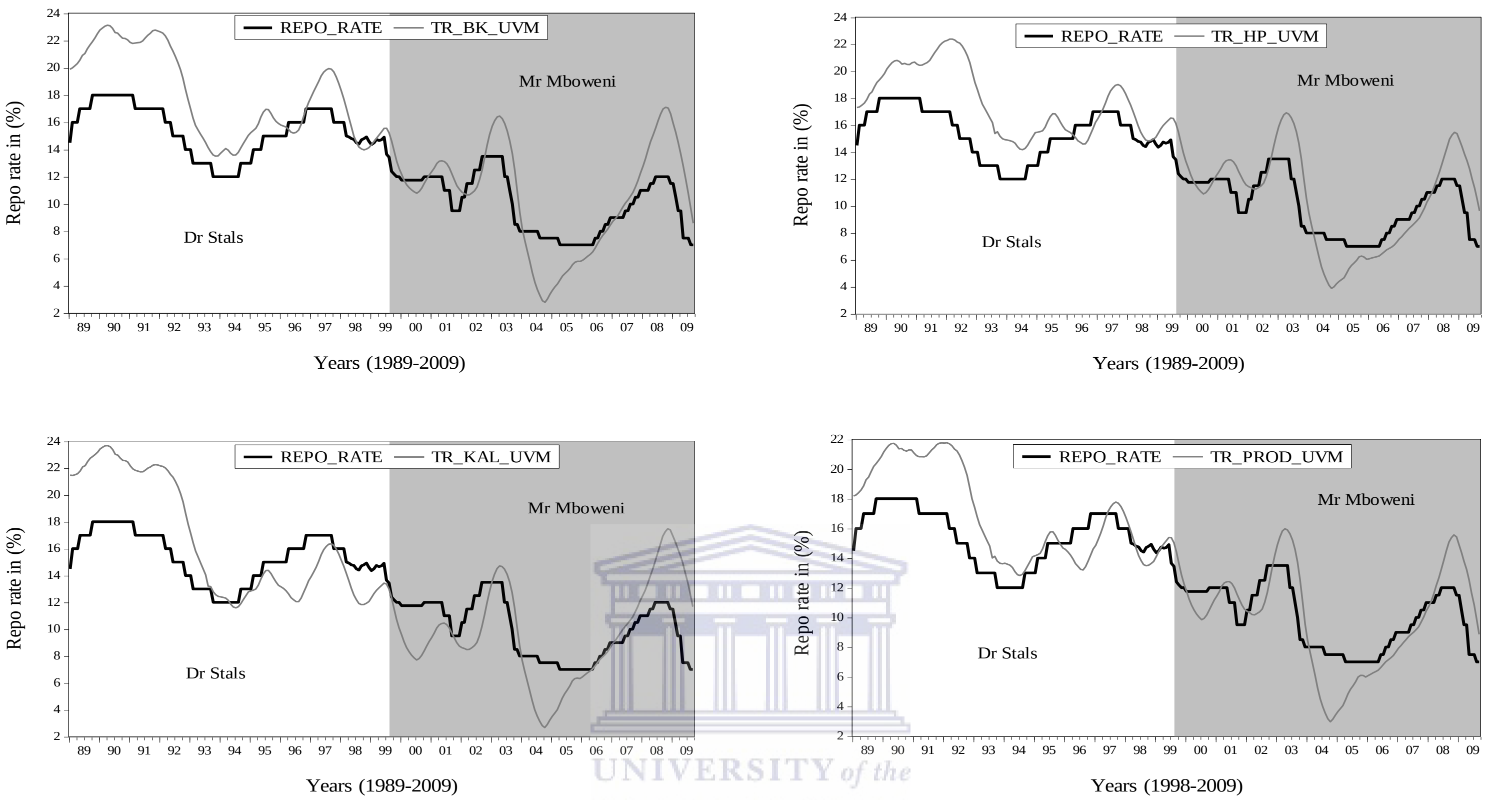
Figure 4.11 above reveals that both Stals and Mboweni often tend to set the repo rate in accordance with the Taylor rule predictions, albeit with noticeable differences in magnitudes. The results reveal that Stals often set the repo rate below the predicted Taylor rules prior to the year 1995. After 1995, Stals governorship reflect mixed outcomes where the Kalman filter and the production function output gap models suggests a repo rate above the predicted whilst the Baxter-King filter and Hodrick-Prescott filter models suggests a repo rate fluctuating close to the predicted.

Over the Mboweni governorship, all four output gap models reveal a repo rate fluctuating close to the predicted models. This suggests that the Mboweni governorship repo rate setting process was more influenced by the developments of inflation and output gap as compared to Stals governorship. More so, over the entire study period, there is evidence of a high correlation between the actual repo rate and the predicted models (see Table 4.8). The Taylor rule with the BK filter output gap reflect a higher correlation coefficient (91 %) with the actual repo rate series as compared to the HP filter, Kalman filter and production function output gap models. This means that a Taylor rule model consisting of the FIM NRIR and either of the four output gaps strongly mimic the policy deliberations of the SARB. Therefore, one can conclude that the output gap and inflation pressures play a major role in the SARB conduct of monetary policy.

4.7.2. Taylor rule models with the UVM NRIR

The Taylor rule models with the UVM NRIR predict repo rates estimates between 11.6 and 23.7 per cent in the Stals governorship. The Mboweni governorship reveals repo rates within the range of 2.7 to 17 per cent. Figure 4.12 below presents the predicted repo rates from the four Taylor rule models and the actual repo rate over the period 1989-2009.

Figure 4.12: Taylor rule model with the UVM NRIR



Source: SARB and author manipulation (2015)

Figure 4.12 above visually shows that both Stals and Mboweni often set the repo rate as suggested by the predicted Taylor rule models, albeit with some variations in magnitudes. Under Stals governorship, the figure markedly show that the repo rate was often set below the predicted from the period of the financial sanctions (1989) up until 1994 for the Kalman filter model and 1995 for the other three models. On the other hand, Mboweni governorship reflects a close movement between the predicted repo rates and the actual repo rate.

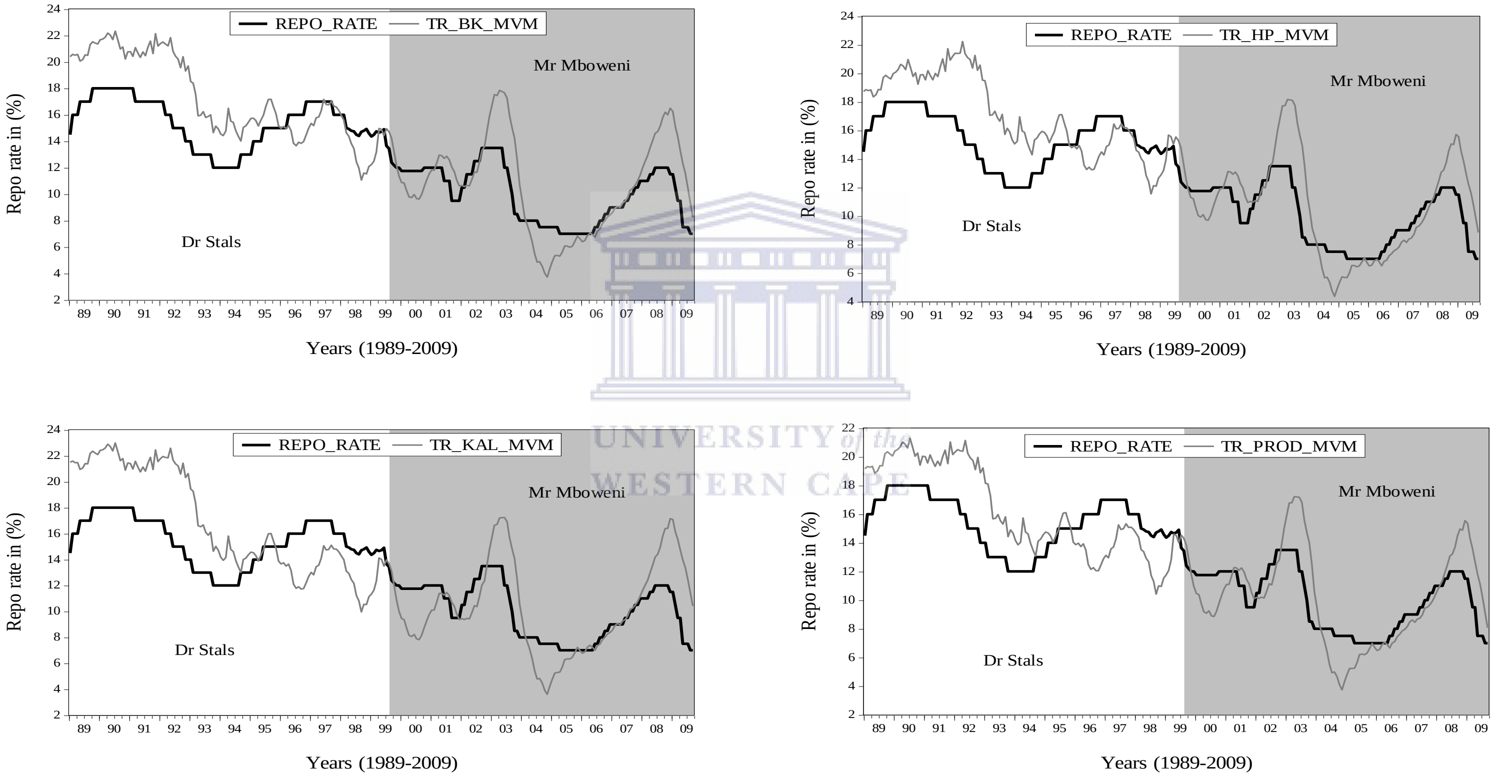
Over the entire study period, models with the UVM NRIR demonstrate a close co-movement between the actual and predicted repo rate series. The Baxter King output gap model outlines the highest correlation coefficient of 92 per cent (see Table 4.8). These high correlation coefficients suggest that monetary policy decisions of the SARB were strongly influenced by both the development of the output gap and inflation rate gap as suggested by the Taylor rule. Therefore, one can conclude that the Taylor rule type model that consists of the univariate

NRIR model and either of the four output gaps mimic well the behaviour of the SARB policy deliberations over the study period.

4.7.3. Taylor rule models with the MVM NRIR

The Taylor rule models with the MVM NRIR predict estimates of the repo rate between 10 and 23 per cent in the Stals governorship. The Mboweni governorship reveals repo rates within the range of 3.6 to 18.1 per cent. Figure 4.13 below outlines the predicted Taylor rule models and the actual repo rate over the period 1989-2009.

Figure 4.13: Taylor rule model with the MVM NRIR



Source: SARB and author manipulation (2015)

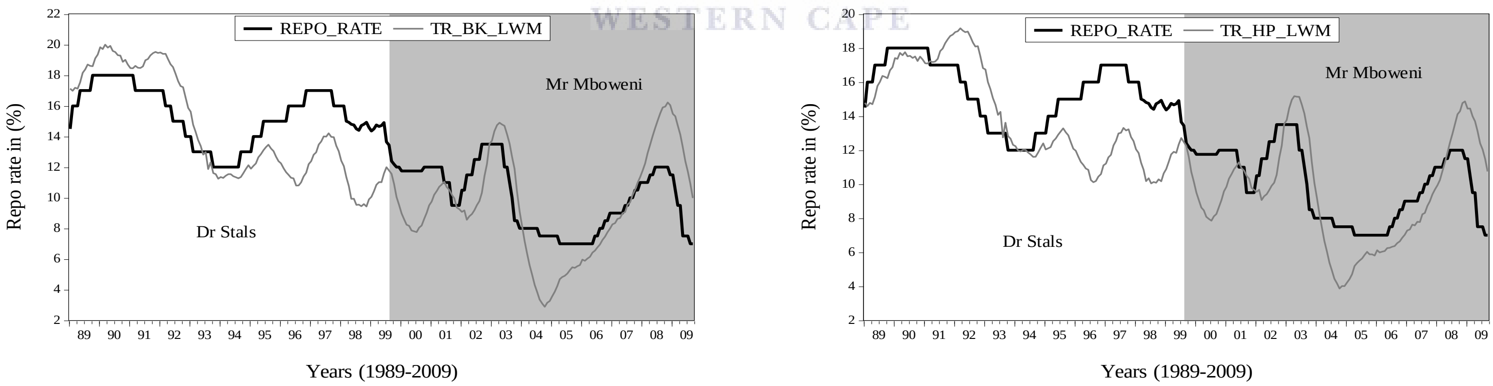
Figure 4.13 visually shows a co-movement between the predicted and the actual repo rate series suggesting that both Stals and Mboweni often set the repo rate in accordance with the Taylor rule model predictions. The results show that Stals governorship often set the repo rate below the predicted prior to 1995, and then above the predicted from 1995 till the end of his tenure. On the other hand, Mboweni governorship reflects a fluctuating close movement between the predicted and the actual repo rate.

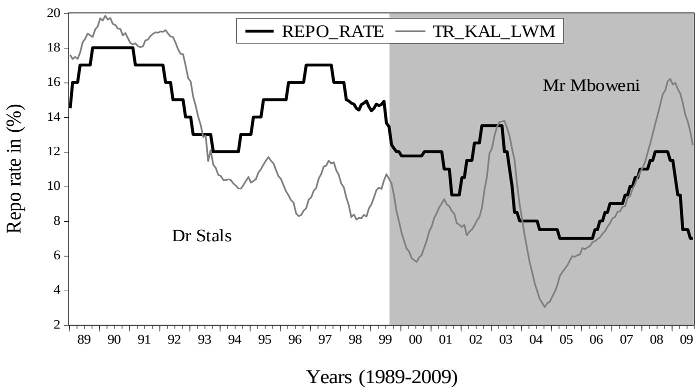
Over the entire study period, models with the MVM NRIR demonstrate a relatively weaker correlation coefficients as compared to the UVM NRIR and FIM NRIR (see Table 4.8), although the coefficients are relatively high. The high correlation coefficients presents evidence that both the output gap and inflation rate gap pressures influenced monetary policy conduct as suggested by the Taylor rule. Therefore, one can conclude that even though the SARB did not explicitly implement a Taylor rule their behaviour strongly mimicked a Taylor rule model consisting of the multivariate NRIR model and either of the four output gaps.

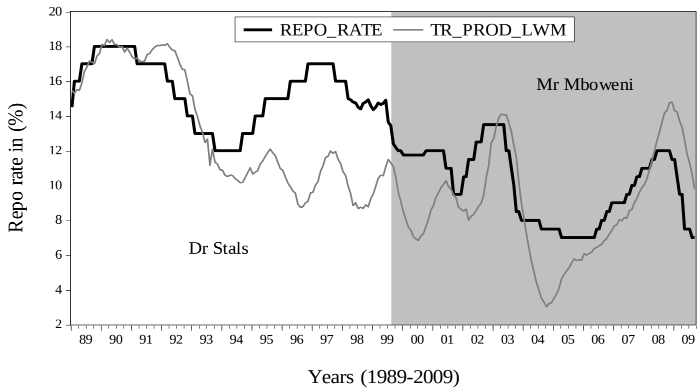
4.7.4. Taylor rule models with the LWM NRIR

The Taylor rule models with the NRIR derived from the LWM predict a weaker correlation between the predicted and actual movements in the repo rate during the entire study period as compared to the other three models (see Table 4.8 below). During Stals governorship, the LWM predicted repo rates that vary between 8.1 and 20 per cent whilst over Mboweni governorship the repo rates vary between 3 and 16.2 per cent. Figure 4.11 below outlines the predicted repo rates from the four Taylor rule models and the actual repo rate over the period 1989-2009.

Figure 4.14: <u>Taylor rule model with the LWM NRIR</u>







Source: SARB and author manipulations (2015)

Over Stals governorship, figure 4.14 reveals an actual repo rate set below the predicted values by the Kalman filter and Baxter-King filter models prior to 1993. On the other hand, the Hodrick-Prescott filter and the production function models show that prior to 1991, the actual repo rate was set above the predicted and thereafter, the rate was set below the predicted till 1993. The period post 1994 till the end of Stals governorship, reflect an actual repo rate set above the predicted for all four models.

During Mboweni governorship prior to 2003, the results show that the actual repo rate was often set above the predicted for all four models. Thereafter, both the actual and predicted rates closely move together often actual being set above the predicted repo rate. Visually, the figure 4.14 suggests that the Mboweni governorship mimicked the Taylor rule more often as compared to the Stals governorship. In addition, over the entire study period the high correlation coefficients from LWM NRIR models indicate that the behaviour of the SARB monetary policy conduct was influenced by inflation and output gap as suggested by the Taylor rule.

4.7.5. Correlations between actual and predicted repo rates

The evidence from Table 4.8 reveals a strong positive co-movement between the actual and predicted repo rates, and all the estimated coefficients were statistically significant at 5 per cent level of significance. This implies that the Taylor rule model mimic strongly the decision-making process of the SARB when making changes to the repo rate over the study period. However, the inflation and output gap degree of influence differs with the model used to estimate the NRIR and the output gap. Table 4.8 below summarises the correlation coefficients between the predicted and actual repo rates.

Table 4.8: <u>Summary of the predicted and actual repo rate correlation</u>

Taylor rule model with	FIM NRIR	UVM NRIR	MVM NRIR	LWM NRIR
BK output gap	0.91 (34.92)**	0.92 (38.11)**	0.86 (27.40)**	0.79 (20.55)**
HP output gap	0.89 (30.69)**	0.90 (33.77)**	0.84 (24.74)**	0.77 (19.07)**
Kalman output gap	0.81 (22.97)**	0.82 (22.20)**	0.78 (20.04)**	0.66 (14.03)**
Prod output gap	0.88 (29.71)**	0.89 (32.30)**	0.83 (24.06)**	0.74 (17.43)**

BK= Baxter-King filter, HP = Hodrick-Prescott filter, Kalman = Kalman filter, Prod = production function model, NRIR= Natural Real Interest Rate, FIM = Financial Indicators Model, UVM = Univariate Model, LWM = Laubach and Williams (2003) Model, Estimated coefficients are not in parenthesis and their t-statistics are in parenthesis and ** = 5 % level of significance.

The Taylor rule models with the NRIR derived from the univariate model (UVM) reveals a high degree of influence on the actual repo rate followed by the FIM, MVM and the least being the LWM. On the other hand, models derived from the Baxter-King filter output gap show a higher degree of influence on the actual repo rate. The Kalman filter output gap models reflect the lowest degree of influence as compared to the other output gaps applied in hypothesis testing.

4.7.6. Conclusion on the predicted Taylor rule models

There is no *a priori* reason for assuming that the SARB used a specific combination of output gap and NRIR estimation procedures as discussed in Section 1.1. This analysis therefore estimated Taylor rule models using combinations of four output gaps and four natural real interest rates. The evidence from the estimated Taylor rule models suggests a strong positive correlation between the predicted and actual repo rate albeit by different degrees. This means all the forms of the estimated Taylor rule models suggested that monetary policy decisions of the SARB were influenced by the inflation rate gap and the output gap pressures over the study period, albeit by different degrees.

The predicted results from the UVM reflect that there was a higher degree of association, relative to the other models, between the predicted Taylor rule rate and the actual repo rate over the study period. This suggests that the behaviour of the SARB was sufficiently structured and influenced by inflation and output gap pressures. Therefore, the Taylor rule model mimics well the policy deliberations of the SARB. Given the unstable macroeconomic and political environment in the country, as well as the change of governorship with a clearly demonstrated change in monetary policy stance during the study period, it is not surprising that the repo rate tended to be relatively volatile. The SARB had to deal with volatile conditions amidst great uncertainty.

Therefore, a correlation of 82 per cent to 92 per cent between the UVM predicted repo rates and the actual repo rate indicates that the Taylor rule model mimics the monetary policy deliberations of the SARB, even though they may not formally have implemented a Taylor rule model. This means that both the inflation and output gap pressures influenced the SARB monetary policy decisions over the study period. More so, the results suggest that the Mboweni governorship mimicked the SARB policy decisions more often than the Stals governorship.

4.8. **Chapter conclusion**

This chapter provided an empirical evaluation of whether the SARB in its inflation targeting framework considered output gap as well as inflation rate gap pressures as suggested by the Taylor rule model. The results suggest that the SARB, while formulating its discretionary monetary policy, implicitly, or at least without making it public, their behaviour was sufficiently structured and influenced by the inflation and output gap pressures. Therefore, the Taylor rule does a good job of mimicking the policy decisions of the SARB. The best, from all estimated Taylor type models, in mimicking the policy deliberations of the SARB is the estimated Taylor rule model with the UVM NRIR, and an output gap derived from the Baxter-King filter. These conclusions were achieved by applying a simple multiple linear econometrics technique.

As a result of the unobservable characteristic of potential output, different approaches were used in the derivation of the output gap. The study adopted four approaches namely Hodrick-Prescott filter, Kalman filter, Baxter band-pass filter and the production function approach (see Section 4.3). This made it more likely to identify the 'hidden' consideration of the output gap by the SARB. It also contributes to a deepening of an understanding of the Taylor rule and to the avoidance of biased estimates.

The sharp fall in production implies a deteriorating output gap (moving from a positive to a negative). The consequence of this sharp drop in output is reflected by a negative output gap in the early 1990s. Furthermore, Section 4.4 focussed on the NRIR which is another unobserved variable of the Taylor rule model. Four approaches to derive the NRIR were adopted. These approaches reveal varying trends in the NRIR. Generally, the Stals governorship shows a stable increasing NRIR whilst the Mboweni governorship reflects a gradual downward trend in the NRIR.

Cointegrating relationships are important as they provide a broader understanding of the dynamics as well as the interrelationships of variables in a system. In order to ensure robust results as well as to avoid the problem of spurious regression results the Taylor rule variables were tested for stationarity (see Section 4.5). The results from the ADF and the KPSS unit root tests indicate that the variables used in the Taylor rule hypothesis testing were stationary after first differencing. The Engle-Granger approach was applied in the study to test for cointegrating relationships (see Section 4.6). The findings reflected evidence of cointegrating relationships in the Taylor rule model variables.

After concluding that there was evidence of long-run cointegrating relationships in the data, the error correction models were estimated. The results show that the SARB considered the output gap[18] (see Section 4.7). It is possible that the unstable macroeconomic and political environment in the country exerted pressure on the SARB policy makers to consider output gap pressures in setting the repo rate. The illustrations of the estimated Taylor rule model predictions against the actual repo rate reflect different degrees of influence from the output gap and inflation rate gap pressures on the setting of the repo rate by the SARB.

The predicted results from the Taylor rule model with UVM NRIR and the four output gaps reveal correlation coefficients between 82 per cent and 92 per cent with the actual repo rate. These coefficients are highly significant. This indicates that even though the SARB did not explicitly implement a Taylor rule, their behaviour was sufficiently structured and influenced

[18] The results need to be interpreted with caution due to the failure to achieve normality.

by developments of inflation and output gaps over the study period. Therefore, the Taylor rule model does a good job of mimicking the policy deliberations of the SARB.

CHAPTER FIVE
CONCLUSION

Monetary policy authorities face a variety of uncertainties in their day-to-day policy decision-making process. This is exacerbated by the assumption that the model variables can be measured reliably. Although there is more uncertainty involved in the measurement of the NRIR and the level and rate of growth of potential output, the Taylor rule model still offers a good yardstick with which to evaluate the historical monetary policy stances of the central bank.

The precise estimation of potential output is important in the evaluation of the Taylor rule hypothesis. However, the uncertainty about whether the potential trend is deterministic or stochastic led to the development of various approaches to approximate the level of potential capacity utilisation in an economy. Four different approaches were adopted in analysing the Taylor rule hypothesis. The Kalman filter and production function approaches tend to display a more deterministic trend as compared to the Hodrick-Prescott and Baxter-King approaches. The Hodrick-Prescott approach imposes a small penalty to the trend that results in a potential trend very close to the actual output.

The uncertain characteristic of potential output is passed on to the estimated output gaps. Economists have only been able to identify the existence of a trend and a cycle for GDP. Its dynamics had not been precisely identified and it is still an issue of debate. The output gap reflects inflationary pressures in the economy. The estimated output gaps from the four approaches differ, but they follow the same trend. They suggest changes in the output gap similar to Bosch and Ruch’s (2012) reference points of the South African business cycle. The PF method and the Kalman filter approaches reflect a negative output gap from 1991 to 2006 whilst the BK and HP approaches shows an alternating output gap over the same period.

Apart from being a determinant in the Taylor rule, the NRIR is a good benchmark measure of the historical policy stance. It is also characterised by uncertainty. In the Stals governorship, all the estimated approaches demonstrate an increasing trend in the estimated NRIR. However, prior to 1994 political transition all NRIR estimates reflect a relatively stable trend. During the Mboweni governorship, all approaches reflect a general downward trend in the NRIR trend. However, the period around 2003 indicates a slight increase in the NRIR, except the UVM, thereafter a gradual decline.

Economic theory suggests that there is a one to one negative relationship between the real rate gap and the output gap. The LWM and the FIM natural real interest rate estimates revealed statistically significant negative relationships with the estimated output gaps, albeit relatively lower than one. On the other hand, the UVM and the MVM estimates indicated statistically significant positive relationship.

The real interest rate gap from FIM NRIR reveals that from 1989 until the political transition monetary policy in South Africa was relatively accommodative, and for the rest of the 1990s it was more restrictive excluding the period of the Asian crisis (1997-98). The majority of the 2000s decade monetary policy was characterised by an accommodative policy stance. On the other hand, the real interest rate gap from LWM NRIR reveals a more restrictive monetary policy over the period of study where the degree of the contractions varies with time.

The real interest rate gap from UVM NRIR reflects three phases of contractionary monetary policy in the Stals era. Whilst, the MVM NRIR show that the SARB had a restrictive monetary policy from 1989 till early 1992 as well as the period post 1994 till the end of Stals governorship. Both the MVM and UVM NRIR show that the Mboweni's tenure is characterised by two phases of contractionary monetary policy.

The estimated Taylor rule models reveal a positive co-movement between the actual and predicted repo rates. This implies that a form of the Taylor rule model mimics well the central banks' decisions regarding changes in the repo rate. The degree of influence differs with the NRIR estimate that is used in the Taylor rule model. The univariate model Taylor rule predictions indicate a higher degree of correlation with the changes in the repo rate given the four output gaps applied. The Taylor rule with the NRIR derived from the Laubach and William's model reveals a low degree of correlation with the actual repo rate.

The predicted results from the UVM suggest that there was a significantly high degree of association between the predicted Taylor rule policy rate and the actual repo rate over the study period. A correlation of 82 per cent to 92 per cent (statistically significant), between the UVM predicted repo rate, indicates the strength of such a possible correlation. It lends weight to the conclusion of this thesis that even though the SARB did not explicitly attempt to implement a Taylor rule, their behaviour was sufficiently structured and influenced by the developments of both inflation and the output gap. This means the Taylor rule does a good job of mimicking the SARB's monetary policy decisions over the study period.

REFERENCE LIST

Aadland, D. 2005. Detrending time aggregated data. *Journal of Economic Letters*. **89** (3): 287-293.

Adema, Y. 2003. A Taylor rule on the Euro area based on the quasi real time data. Amsterdam: *Netherlands Bank Research Department Memorandum,* No 738.

Aguiar, A. & Martins, F. M. M. 2005. Growth cycles in XXth century European industrial productivity: unbiased variance estimation in a time-varying parameter model. Porto: *University of Porto Working Paper,* No 144.

Alogoskoufis, G. & Smith, R. 1991. On error correction models: specification, interpretation, estimation. *Journal of Economic Surveys*. **5** (1): 97-128.

Archibald, J. & Hunter, L. 2001. What is the neutral real interest rate and how can we use it? *Reserve Bank of New Zealand Bulletin*. **64** (3): 15-38.

Arnon, A. 2011. *Monetary theory and policy from Hume and Smith to Wicksell: Money, credit and the economy*. New York: Cambridge University Press.

Asso, P. F., Kahn, G. A. & Leeson, R. 2007. The Taylor rule and the transformation of monetary policy. Kansas City: *The Federal Reserve Bank of Kansas City Economic Research Working Paper,* No 07-11.

Azevedo, J. V. 2011. A multivariate band pass filter for economic time series. *Journal of the Royal Statistical Society*. **60** (1): 1-30.

Ball, L. M. 1999. Policy rules for open economies. In Taylor, J. B. 1999. *Monetary policy rules*. Chicago: University of Chicago Press.

Barker, F. 2007. *The South African labour market: Theory and practice*. 5th ed. Pretoria: Van Schaik Publishers.

Barro, R. J. & Gordon, D. B. 1983. Rules, discretion and reputation in a model of monetary policy. *Journal of Monetary Economics*. **12** (1). 101-121.

Basdevant, O., Bjorkstein, N. & Karagedikli, O. 2004. Estimating a time varying neutral real interest rate for New Zealand. Wellington: *Reserve Bank of New Zealand Discussion Paper Series,* No 2004/01.

Baxter, M. & King, R. G. 1995. Measuring Business cycles approximate band-pass filters for economic time series. Cambridge: *National Bureau of Economic Research Working Paper Series,* No 5022.

Belke, A. & Klose, J. 2012. Modifying the Taylor reaction function in the presence of the zero-lower-bound: Evidence from the ECB and the FED. Berlin: *German Institute of Economic Research Discussion Paper,* No 1218.

Bernhardsen, T. & Gerdrup, K. 2007. The neutral real interest rate. Oslo: *Norges Bank Monetary Policy Department Economic Bulletin*. **78** (2): 52-64.

Bierens, H. J. 1994. *Topics in advanced econometrics: Estimation, testing, and specification of cross section and time series models.* Cambridge: Cambridge University Press.

Blanchard, J. O. & Fisher, S. 1993. *Lectures on macroeconomics*. Cambridge: MIT Press.

Blanchard, O. J. & Watson, W. M. 1986. Are business cycles all alike? In Gordon, R.J. (Ed.) *The American business cycle: continuity and change*. Chicago: University of Chicago Press. 123-180.

Blignaut, Z., Farrel, G., Munyama, V. & Rangasamy, L. 2009. A note on the trimmed mean measure of core inflation in South Africa. *South African Journal of Economics*. **77** (4). 538 – 553.

Boamah, I. M. 2012. Taylor rule and monetary policy in Ghana. *International Journal of Economics and Finance*. **4** (7). 15-21.

Bomfim, A. N. 2001. Measuring equilibrium real interest rate: what can we learn from yields on indexed bonds. Washington, DC: *Federal Reserve Board Working Paper,* No 53.

Bosch, A. & Ruch, F. 2012. An alternative business cycle dating procedure for South Africa. Pretoria: *South African Reserve Bank Working Paper,* No 12/06.

Boshoff, W. 2010. Band-Pass filters and the business cycle analysis: high frequency and medium term deviation cycles in South Africa and what they measure. Stellenbosch: *University of Stellenbosch Department of Economics Working Paper*, No 200.

Brooks, C. 2008. *Introductory econometrics for finance.* New York: Cambridge University Press.

Bruggemans, C. 2008. Taylor rule flags rate cuts potential. *First National Bank Weekly Comment.* 24 January. [online]. Available http://www.finsolnet.atradys.com/.../FNB/ Weekly/Comment 20080124.pdf.

Bryan, F. M. & Cecchetti, G. S. 1993. Measuring core inflation. Cambridge: *National Bureau of Economic Research Working Paper Series,* No 8333.

Bryant, R. C., Hooper, P. & Mann, C. L. 1993. *Evaluating policy regimes: New Research in Macroeconomics*. Washington, DC: The Brookings Institution Press.

Buckle, A. R., Kim, K., Kirkham, H., McLellan, N. & Sharma, J. 2002. A structural VAR model of the New Zealand business cycle. Wellington: *New Zealand Treasury working paper*, No 02/26.

Burger, P. & Marinkov, M. 2006. The South African Phillips curve: How applicable is the Gordon Model? *South African Journal of Economics*. **74** (2). 172-189.

Burns, A. F. & Mitchell, W. C. 1946. *Measuring business cycles*. New York: NBER Press.

Cabanillas, G. L. & Ruscher, E. 2008. The great moderation in the euro area: What role have macroeconomic policy played? Brussels: *European Commission Economic and Financial Affairs Economic Paper,* No 331.

Canova, F. 1998. Detrending and business cycle facts. *Journal of Monetary Economics*. **41**: 475-512.

Casteleijn, A. J. H. 2001. South Africa's monetary policy framework. Pretoria: *Paper Presented at the Conference on Monetary Policy Frameworks in Africa at South African Reserve Bank*. September 17-19.

Chatfield, C. 2000. *Time series forecasting*. New York: Chapman and Hall CRC Press.

Cheng, M., Chung, L. & Yu, I. 2011. On the estimation of the output gap of Hong Kong. Hong Kong: *Hong Kong Monetary Policy Occasional Paper,* No 03/2011.

Clarida, R., Galí, J. & Gertler, M. 2000. Monetary policy rules and macroeconomic stability: theory and some evidence. *Quarterly Journal of Economics.* **115** (3): 147-180.

Clark, P. K. 1987. The cyclical component of the US economic activity. *The Quarterly Journal of Economics*. **102** (4): 797-814.

Clark, T. E. & Kozicki, S. 2004. Estimating equilibrium real interest rate in real time. Frankfurt: *Deutsche Bundesbank Studies of the Economic Research Centre Discussion Paper,* No 32/2004.

Claus, I., Conway, P. & Scott, A. 2000. The output gap: measurement, comparisons and assessment. Wellington: *Reserve Bank of New Zealand Research Paper,* No 14.

Clements, M. 2004. *Explaining and forecasting the US federal funds rate: A monetary model for the US*. New York: Palgrave MacMillan.

Comert, H & Epstein, G. 2011. Inflation targeting in South Africa: friend or foe of development? *Economic History of Developing Regions*. **26** (S1): 94-113.

Cuaresma, J. C., Gnan, E. & Ritzberger-Gruenwald, D. 2003. Searching for the natural real interest rate on Euro area perspective. Vienna: *Oesterreichische Nationale Bank Working Paper,* No 84.

Das, S., Gupta, R., Kanda, T. P., Tipoy, K. C. & Zerihun, F. M. 2012. Real interest rate persistence in South Africa: Evidence and implications. Pretoria: *University of Pretoria Department of Economics Working Paper Series,* No 2014-04.

Davidson, R. & MacKinnon, J. G. 2003. *Econometric theory and methods*. Oxford: Oxford University Press.

Davis, S. J. & Kahn, J. 2008. Interpreting the Great Moderation: Changes in the volatility of economic activity at the macro and micro levels. Cambridge: *National Bureau of Economic Research Working Paper,* No 14048.

De Angelis, C., Aziakpono, M & Faure, P. 2005. The transformation of monetary policy under the repo system in South Africa: An empirical analysis. Durban: *Paper Presented at Biennial Conference of the Economic Society of South Africa*. September 7-9.

De Brouwer, G. 1998. Estimating output gaps. Sydney: *Reserve Bank of Australia Economic Research Department Discussion Paper*, No 9809.

Desai, M. 1979. *Applied Econometrics.* New Delhi: McGraw-Hill.

Dolado, J. J., Gonzalo, J. & Marmol, F. 2001. Cointegration. In Baltagi, B. H. 2001. *A companion to theoretical econometrics*. Berlin: Blackwell Publishers.

Du Plessis, S. & Smit, B. 2005. Economic growth in South Africa since 1994. Stellenbosch: *University of Stellenbosch Economic Working Paper*, No 1/ 2006.

Du Plessis, S. 2014. Targeting core inflation in emerging market economies. Stellenbosch: *University of Stellenbosch department of economics and the Bureau for economic research Working Paper,* No 23/14.

Du Plessis, S. A. 2004. Stretching the South African business cycle. *Journal of Economic modelling*. **21**: 685-701.

Du Plessis, S., Du Rand, G. & Kotze, K. 2015. Measuring core inflation in South Africa. Cape Town: *Economic Research Southern Africa Working Paper,* No 503.

Du Plessis, S., Smit, B. & Sturzenegger, F. 2007. Identifying aggregate supply and demand shocks in South Africa. Stellenbosch: *University of Stellenbosch Economic Working Paper, No 11/07*.

Du Toit, C.B. & Moolman, E.H. 2003. Estimating potential output and capacity utilisation for the South African economy. *South African Journal of Economics*. **71** (1): 96-118.

Ellyne, M. & Veller, C. 2011. What is the SARB's inflation targeting policy, and is it appropriate? Munich: *Munich Personal RePec Archive Paper,* No 42134.

Enders, W. 2004. *Applied econometric time series*. New York: John Wiley & sons Inc.

Engle, R. F. & Granger, C.W. 1987. Co-integration and error correction: Representation, estimation and testing. *Econometrica*. **55**: 251-276.

Epstein, G. 2003. Alternatives to inflation targeting monetary policy for stable and egalitarian Growth: A brief research summary. Amherst: *University of Massachusetts Political Economy Research Institute Working Paper,* No 62.

Epstein, G. 2007. Central banks as agents of employment creation. New York: *Department of Economic and Social Affairs Working Paper*, No 38.

Ericsson, N. R. & MacKinnon, J. G. 1999. Distribution of error correction tests for cointegration. Washington, DC: *Board of Governors of the Federal Reserve System International Finance Discussion Paper*, No 655.

Espinosa-Vega, M. A., Smith, D. B. & Chong, K. Y. 2000. Barriers to international flow: when, why, how big and for who? Atlanta: *Federal Reserve Bank of Atlanta Working Paper*, No 2000-16.

Fourie, F. C. V. & Burger, P. 2009. *How to think and reason in macroeconomics*. 3rd ed. Cape Town: Juta Academic Press.

Frankel, J. 2013. The death of inflation targeting. [online]. Available http://www.economics. utoronto.ca/gindart/2012-05-16 the death of inflation targeting.

Fredderke, J. W. & Schaling, E. 2005. Modelling inflation in South Africa: A multivariate cointegration analysis. *South African Journal of Economics*. **73** (1). 79-92.

Fuentes, R. & Gredig, F. 2007. Estimating the Chilean natural rate of interest. Santiago: *Central Bank of Chile Working Paper*, No 448.

Garnier, J. & Wilhelmsen, R. B. 2005. The natural real interest rate and the output gap in the euro area: a joint estimation. Frankfurt: *European Central Bank Working Paper Series,* No 546.

Garratt, A., Lee, K., Pesaran, M. H & Shin, Y. 2006. *Global and national macro econometric modelling: A long-run structural approach*. London: Oxford University Press.

Geldenhuys, J. & Marinkov, M. 2007. Robust estimation of Okun's coefficient for South Africa. Bloemfontein: *University of the Free State Department of Economics Working Paper*, No 55.

Giammariolli, N. & Valla, N. 2003. The natural real interest rate in the Euro area. Frankfurt: *European Central Bank Working Paper Series*, No 233.

Gilbert, C. L. 1986. Practioners corner: Professor Hendry's econometric methodology. *Oxford Bulletin of Economics and Statistics*. **48** (3): 283-307.

Gonzalez, L. A. A. & Vera, A. P. 2001. Monetary policy, Taylor rule and instability. *Metroeconomica*. **53** (1): 1-24.

Goyal, A. 2008. The natural interest rate in emerging markets. Mumbai: *Indira Gandhi Institute of Development Research Working Paper*, No 2008-014.

Granger, C. W. J. & Lee, T. H. 1990. Multi-cointegration. In Fomby, T. & Rhodes, G. J. Jr. (Eds). *Advances in econometrics: Cointegration, spurious regression and unit roots*. 8 77-84. London: JAI Press.

Granger, C. W. J. & Newbold, P. 1974. Spurious regression in econometrics. *Journal of econometrics*. **2.** 110-120.

Greene, W. H. 2003. *Econometric analysis*. 5th ed. Upper Saddle River: Pearson Education Inc.

Guay, A. & St-Amant, P. 1997. Do the Hodrick-Prescott and Baxter-King filters provide a good approximation of the business cycle? Montreal: *Universite du Quebec a Montreal Centre for Research on Economic Fluctuation and Employment Working Paper*, No 53.

Gujarati, D. N. 2009. *Basic econometrics*. 5th ed. Singapore: McGraw Hill.

Hafer, R. W. 2001. What remains of monetarism? Atlanta: *Federal Reserve Bank of Atlanta Economic Review*. **86** (4): 13-33.

Harris, R. I. D. 1995. *Using cointegration analysis in econometric modelling*. London: Prentice hall.

Harvey, A. C. & Peters, S. 1990. Estimation procedures for structural time series models. *Journal of forecasting*. **9** (2). 89-108.

Harvey, A. C. & Proietti, T. 2005. *Readings in unobserved components models: Advanced texts in econometrics*. New York: Oxford University Press.

Harvey, A. C. 1993. *Time series models*. Cambridge: MIT Press.

Harvey, A. C. 2000. Trend Analysis. Cambridge: University of Cambridge faculty of economics and politics. *Manuscript*.

Harvey, A. C. 2011. Modelling the Phillips curve with unobserved components. *Journal for Applied Financial Economics*. **21**: 7-17.

Hendry, D. F & Juselius, K. 2000. Explaining Cointegration Analysis: Part 1. *The Energy Journal, International Association for Energy Economics*. **21** (1): 1-42.

Hendry, D. F & Juselius, K. 2001. Explaining Cointegration Analysis: Part II. Copenhagen: *University of Copenhagen Department of Economics Discussion Paper,* No 00-20.

Hodrick, R. & Prescott, E. 1997. Post-war US business cycle: An empirical investigation. *Journal of Money, Credit and Banking*. **29**. 1-16.

Hylleberg, S., Engle, R. F., Granger, C. W. J. & Yoo, B. S. 1990. Seasonal integration and cointegration. *Journal of Econometrics*. **44** (1-2). 215-238.

IMF, 2014. Perspectives on global real interest rates. In World Economic Outlook: Recovery strengthens remains uneven. Washington, DC: *International Monetary Fund world economic and financial surveys*. April.

Judd, J. P. & Rudebusch, G. D. 1998. Taylor's Rule and the Fed 1970-1997. San Francisco: *Federal Reserve Bank of San Francisco Economic Review*. **98** (3): 3-16.

Justiniano, A. & Primiceri, G. E. 2010. Measuring the equilibrium real interest rate. Chicago: *Federal Reserve Bank of Chicago Economic Perspectives,* No 1Q/2010.

Kabundi, A. 2009. Synchronisation between South Africa and the US: A structural dynamic factor analysis. *South African Journal of Economics*. **77** (1). 1-27.

Kahn, B. & De Jager, S. 2011. An assessment of inflation targeting and its application in South Africa. *Economic History of Developing Regions*. **26** (S1): 72-93.

Kahn, B. & Farrell, G. N. 2002. South African real interest rates in comparative perspective: theory and evidence. Pretoria: *South African Reserve Bank Occasional Paper*, No 17.

Kannan, P., Rabanal, P. & Scott, A. 2009. Monetary and macroprudential rules in a model with house price booms. Washington, DC: *International Monetary Fund Working Paper*, No 09/251.

Karagedikli, O. & Plantier, L. C. 2004. Estimating the output gap: a Kalman filter approach. Melbourne: *Econometric Society 2004 Australasian Meetings*, No 210.

Kaunermann, G., Krivovokova, T. & Semmler, W. 2011. Filtering time series with penalised splines. *Studies in Nonlinear Dynamics and Econometrics*. **15** (2): 1-26.

Kemp, H. 2012. Estimating potential output for South Africa: a production function approach. Stellenbosch: Bureau for Economic Research. Unpublished research paper.

Klein, N. 2011. Measuring the potential output of South Africa. Washington, DC: *International Monetary Fund Working Paper*, No 11/2.

Knedlik, T. 2004. The MCI as a monetary policy guide in a small, open emerging market economy. *The South African Journal of Economics*. **72** (2): 366-384.

Kohn, D. L. 2007. *John Taylor Rules*. Federal Reserve Bank of Dallas speech on John Taylor's contribution to monetary theory and policy. [online]. Available http://www.federalreserve.gov/newsevents/speech/kohn20071012a.htm.

Koopman, J. S., Harvey, A. C., Doornik, J. A. & Shepard, N. 2009. *Structural time series analyser and modeller and predictor: STAMP 8.2*. London: Timberlake Consultants Ltd.

Kydland, E. K. & Prescott, C. E. 1977. Rules rather than discretion: The inconstancy of optimal plans. *The Journal of political Economy*. **85** (3). 473-492.

Larsen, J. D. J. & McKeown, J. 2004. The information content of empirical measures of the real interest rate and output gaps for the United States. London: *Bank of England Working Paper*, No 224.

Laubach, T. & Williams, J. C. 2003. Measuring the natural real interest rate. *Review of Economic Studies*. **85** (4): 1063-70.

Levin, A. T., Wieland, W. & Williams, J. C. 1999. Robustness of simple monetary policy rules under model uncertainty. In Taylor, J. B. (Ed). *Monetary policy rules*. Chicago: University of Chicago Press. 263-299.

Lombardi, M. J. & Sgheri, S. 2007. (UN) Naturally, low? Sequential Monte Carlo tracking of the US Natural interest rate. Frankfurt: *European Central Bank Working Paper*, No 794.

Lutkepohl, H., Saikkonen, P. & Trenkler, C. 2001. Maximum eigenvalue versus trace tests for the cointegrating rank of a VAR process. *Econometrics Journal*. **4**: 287-310.

Maddala, G. S. & Kim, I. M. 1998. *Unit roots cointegration and structural change*. New York: Cambridge University Press.

Maddala, G.S. 1977. *Econometrics*. New York: McGraw Hill.

Mahadeva, L. & Robinson, P. 2004. Unit root testing to help model building. London: *Centre for Central Banking Studies Bank of England Handbook in Central Banking*, No 22.

Manrique, M. & Marques, J. M. 2004. An empirical approximation of the natural rate of interest and potential growth. Madrid: *Bank of Spain Working Paper Series*, No 41.

Marcus, G. 2014. Fourteen years of inflation targeting in South Africa and the challenges of a changing mandate. Pretoria: *Opening address by Gill Marcus, governor of the South African reserve bank at the Biennial conference of the bank*. October 30-31.

Mboweni, T. T. 2000. Monetary policy. Stellenbosch: *Business conference of the Bureau for Economic Research address by the Governor of the South African bank.* 17 November.

Mills, T. C. 1990. *Time series techniques for economists*. Cambridge: Cambridge University Press.

Mishkin, F. S. 2001. Inflation targeting. Cambridge: *National Bureau of Economic Research Working Paper*, No 7618.

Mohr, P. & Fourie, L. 2004. *Economics for South African students*. 4th ed. Pretoria: Van Schaik Publishers.

Morrison, G. W. & Pike, D. H. 1977. Kalman filter applied to statistical forecasting. *The Institute of Management Sciences*. **23** (7). 768-774.

Naraidoo, R. & Paya, I. 2012. Forecasting monetary policy rules in South Africa. *International Journal of forecasting*. **28**. 446-455.

Naude, W. 2009. The financial crisis of 2008 and the developing countries. Finland: *United Nations University-World Institute for Developing Economic Research Discussion Paper*, No 2009/01.

Ndahiriwe, K. & Naraidoo, R. 2010. Financial assets, linear and non-linear policy rules. An in sample assessment of the reaction function of the South African Reserve Bank. *Journal of Economics studies*. **39** (2). 161-177.

Ndahiriwe, K. & Naraidoo, R. 2011. Evaluating the forecasting performance of linear and nonlinear monetary policy rules for South Africa. Munich: *Munich Personal RePEc Archive Paper*, No 40699.

Ndahiriwe, K. & Naraidoo, R. 2012. The opportunistic approach to monetary policy and financial market conditions. *Journal of Applied Economics*. **45** (18). 2537-2545.

Neely, C. J. & Rapach, D. E. 2008. Real interest rate persistence: Evidence and implications. *Federal Reserve Bank of St Louis Review*. **90** (6): 609-41.

Neiss, K. S. & Nelson, E. 2001. The real interest rate gap as an inflation indicator. London: *Bank of England Working Paper*, No 130.

Nelson, C. R., Zivot, E. & Morley, J. 2002. Why are Beveridge-Nelson an unobserved component decomposition of GDP so different. [online]. Available *https://research.stlouisfed.org/conferences/moconf/papers/morley.pdf*.

Nxedana, S. 2009. A growing output gap. Johannesburg: *First National Bank commercial banking research, 1 April.*

Okun, A. M. 1962. Potential GNP and its measurement and significance. *American Statistical Association proceedings of the business and economics statistics section*, 98-104.

Orphanides, A. & William, J. 2002. Robust monetary policy rules with unknown natural rates. *Brookings paper on Economic Activity*. **2002** (2). 66-118. Washington, DC: Brookings Institute Press.

Orphanides, A. 2007. Taylor Rule. Washington, DC: *Finance and Economics Discussion Series Division of Research & Statistics and Monetary Affairs Federal Reserve Board,* No 18.

Osterholm, P. 2003. Testing for cointegration in misspecified systems: A Monte Carlo study of size distortions. Uppsala: *Uppsala University Department of Economics Working Paper*, No 2003:21.

Pybus, T. 2011. Estimating the UK's historical output gap. London: *Office for Budget Responsibility Working Paper,* No 1.

Rangasamy, L. 2009. How persistant is South Africa's inflation. Pretoria: *South African Reserve Bank Working Paper*, No 115.

Reid, M. & Du Plessis, S. 2010. Loud and clear? Can we hear when the SARB speaks? Stellenbosch: *University of Stellenbosch Working Paper*, No 11/10.

Roberts, J. M. 2001. Estimates of the productivity trend using time varying parameter techniques. *The B.E Journal of Macroeconomics.* **1** (1): 1-32.

Rossouw, J. & Padayachee, V. 2011. Reflecting on ninety years of intermittent success: The experience of the South African Reserve Bank with inflation since 1921. *Economic History of Developing Regions*. **26** (S1): 20-38.

Rossouw, J. 2011. A selective reflection on the institutional development of the South African Reserve Bank since 1921. *Economic History of Developing Regions*. **26** (S1): 3-19.

Ruch, F. & Bester, D. 2011. Towards a measure of core inflation using singular spectrum analysis. Pretoria: *South African Reserve Bank Working Paper*, No 12/07.

Ruch, F., Balciar, M., Modise, M. P. & Gupta, R. 2015. Forecasting core inflation: The case of South Africa. Pretoria: *University of Pretoria Economic Department Working Paper*, No 2015-43.

Rudebusch, J. & Svensson, L. E. O. 1998. Policy rules for inflation targeting. In Taylor, J. B. ed. *Monetary policy rules*. Chicago: University of Chicago Press.

Sauer, S. & Sturm, J. E. 2003. Using Taylor rule to understand ECB monetary policy. *CESIFO Institute for Economic Research Category 6: Monetary policy and International Finance Working Paper*, No 1110.

Scacciavillani, F. & Swagel, P. 2002. Measures of potential output: an application to Israel. *Journal of Applied Economics*. **34** (8): 945-957.

Smal, M. M. & De Jager, S. 2001. The monetary transmission mechanism in South Africa. Pretoria: *South African Reserve Bank Occasional Paper,* No 16.

Smit, B. W. & Burrows, L. 1999. Estimating potential output gaps for the South African economy. Stellenbosch: *University of Stellenbosch Economics Working Paper,* No 5.

Sorenson, B. E. 1997. *Cointegration*. [online]. Available http://www.uh.edu/~bsorense/ ec7395 2005.html.

South African Reserve Bank. 2007. Interest rates and how they work. Pretoria: *South African Reserve Bank Fact Sheet,* No 8.

South African Reserve Bank. 2010. Introduction to central banking (ICB) 2010. Pretoria: *South African Reserve Bank College Publication*.

Statistics South Africa, 2013. Gross Domestic Product: Annual estimates 2003-2013, Regional estimates 2003-2013 and third quarter 2013. Pretoria: *Stats SA Statistical Release Third Quarter 2013 P0441*.

Stock, J. H. & Watson, M. W. 1998. Median unbiased estimator of coefficient variance in a time varying parameter model. *Journal of the American Statistical Association*. **93** (441): 349-358.

Stock, J. H. & Watson, W. M. 2001. Vector autoregressions. *The Journal of Economic Perspective*. **15** (4): 101-115.

Svensson, L. E. O. 1999. Inflation targeting as a monetary policy rule. *Journal of Monetary Economics*. **43**: 607-654.

Svensson, L. E. O. 2002. What is wrong with Taylor Rule? Using judgement in monetary policy through targeting rules. Cambridge: *National Bureau of Economic Research Working Paper*, No 9421.

Taylor, J. B. 1993. Discretion versus policy rules in practice. London: *Carnegie-Rochester Conference Series on Public Policy*. **39**: 195-214.

Taylor, J. B. 1999. A historical analysis of monetary policy rules. *National Bureau of Economic Research Working Paper*, No 7419.

Taylor, J. B. 2009. *Getting off track: How government actions and interventions caused, prolonged and worsened the financial crisis*. California: Hoover Institution Press.

Taylor, J. B. 2010. Getting on track: Macroeconomic policy lessons from the financial crisis. *Reserve Bank of St Louis Review*. **92** (3): 165-176.

Tolulope, A. O. & Ajilore, T. 2013. Inflation targeting monetary policy rule in Nigeria: Estimates of the policy reaction function. *International Journal of Economics and Finance*. **5** (7). 139-144.

Travaglini, G. 2010. The US dynamic Taylor rule with multiple breaks 1984-2001. Munich: *Munich Personal RePEc Archive Paper*, No 3416.

Van der Merwe, E. J. 2004. Inflation targeting in South Africa. Pretoria: *South African Reserve Bank Occasional Paper*, No 19.

Venter, J. C. 2009. Business cycles in South Africa dating the period 1999-2007. Pretoria: *South African Reserve Bank Quarterly Bulletin*. ***253**: 61-69*.

Vitek, F. 2006. An unobserved component model of the monetary transmission mechanism in a small open economy. Munich: *Munich Personal RePec Archive Paper*, No 800.

Wicksell, K. 1898. *Interest and prices: A study of the causes regulating the value of money*. Melbourne: MacMillan and Company.

Wicksell, K. 1907. The influence of the rate of interest on prices. *Economic Journal.* XVII. 213-220.

Wintr, L., Guarda, P. & Rouabah, A. 2005. Estimating the natural interest rate for the euro area and Luxembourg. Luxembourg: *Banque Central du Luxembourg Cahier D'etudes Working Paper*, No 15.

Woglom, G. 2003. How has inflation targeting affected monetary policy in South Africa. *South African Journal of Economics*. **71** (2). 1-27.

Woodford, M. 2001. The Taylor rule and the optimal monetary policy. *The American Economic Review*. **91** (2): 232-237.

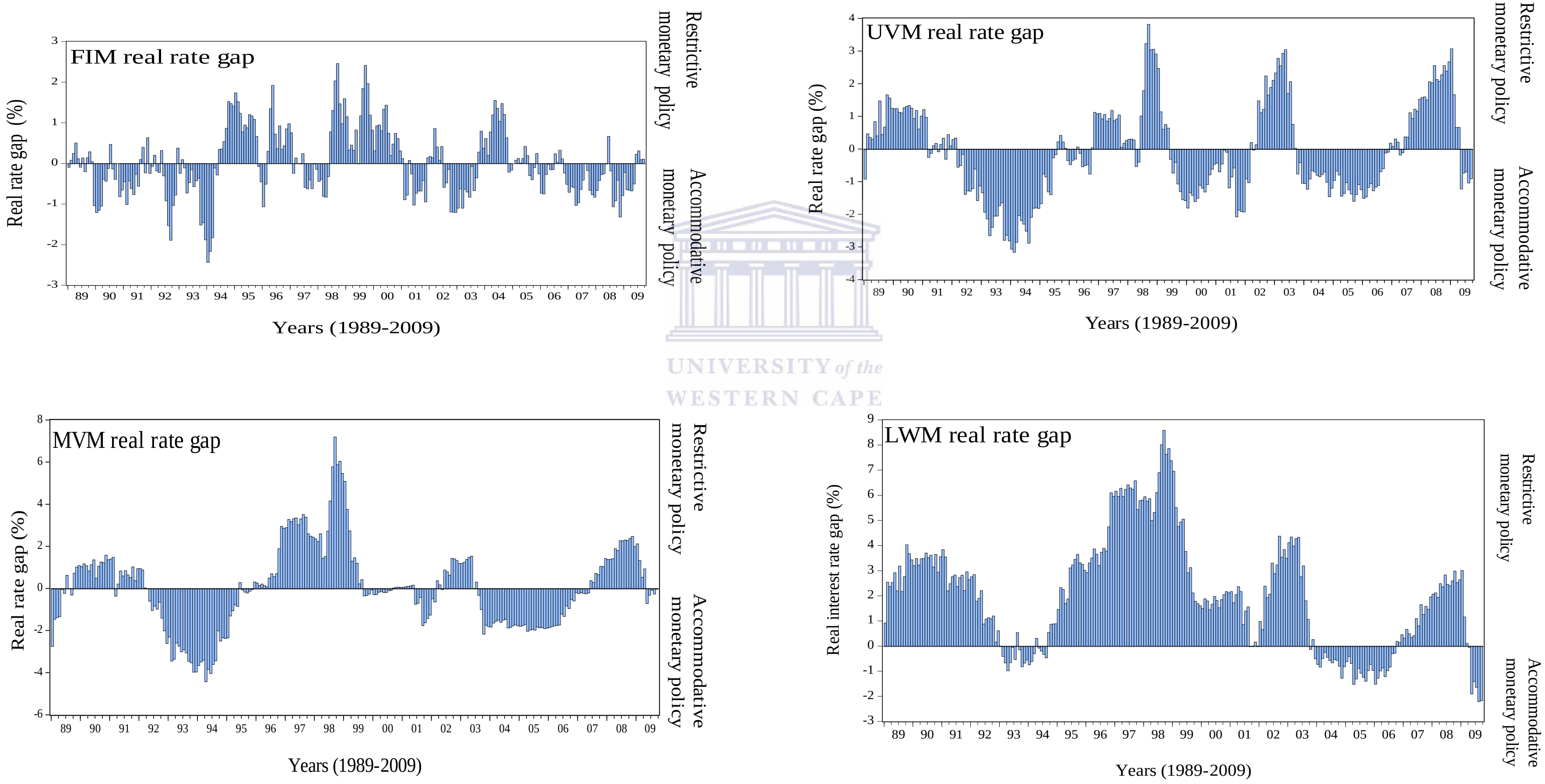
Woodford, M. 2003. *Interest and Prices: Foundation of a theory of monetary policy*. Princeton: Princeton University Press.

Woodridge, J. M. 2005. *Introductory econometrics: a modern approach*. 3rd ed. New York: Thomson Printers.

APPENDICES

APPENDIX 1:

Figure A1: Real interest rate gaps



APPENDIX 2

MacKinnon (1991) linked the critical values for particular test to a set of parameters of n equation of the response surface as illustrated by the equation below:

$$C(\rho) = \varnothing_\infty + \varnothing_1 T^{-1} + \varnothing_2 T^{-2}$$

where $C(\rho)$ is the critical value, T is the sample size and n is number of variables. The appropriate $\varnothing_\infty, \varnothing_1, \varnothing_2$ are selected based on the number of regressors (excluding the constant and trend) that lie between $1 \le n \le 6$. Based on the above formula the Table A2 summarises the critical values applied in the hypothesis testing.

Table A1: MacKinnon critical values.

Critical value	-4.354229417	-3.77665845	-3.476909256
	1% level	5% level	10% level
n	3	3	3
T	249	249	249
ϕ_∞	-4.2981	-3.7429	-3.4518
ϕ_1	-13.79	-8.352	-6.241
ϕ_2	-46.37	-13.41	-2.79

Decision rule: reject the null of no cointergration at the 1%, 5% and 10% level of significance if the t-value associated with ADF test statistic is more negative than -4.35, -3.77 and -3.47 respectively.

APPENDIX 3

Table A2: Breusch -Godfrey Serial Correlation test results

Taylor rule model with	*Critical chi-square at 95% level of significance*	*Observation * R-squared*	*Decision on the null hypothesis of no autocorrelation*
BK output gap and FIM NRIR	5.99	4.65 (0.0977)	Accept
BK output gap and UVM NRIR	5.99	0.04 (0.9776)	Accept
BK output gap and MVM NRIR	5.99	1.58 (0.4530)	Accept
BK output gap and LWM NRIR	5.99	2.95 (0.2277)	Accept
HP output gap and FIM NRIR	5.99	0.91 (0.6319)	Accept
HP output gap and UVM NRIR	5.99	4.17 (0.1242)	Accept
HP output gap and MVM NRIR	5.99	4.94 (0.0843)	Accept
HP output gap and LWM NRIR	5.99	2.03 (0.3624)	Accept
PF output gap and FIM NRIR	5.99	2.47 (0.2900)	Accept
PF output gap and UVM NRIR	5.99	2.52 (0.2826)	Accept
PF output gap and MVM NRIR	5.99	5.10 (0.0779)	Accept
PF output gap and LWM NRIR	5.99	2.04 (0.3603)	Accept
KF output gap and FIM NRIR	5.99	1.70 (0.4273)	Accept
KF output gap and UVM NRIR	5.99	2.75 (0.2521)	Reject
KF output gap and MVM NRIR	5.99	2.14 (0.3426)	Accept
KF output gap and LWM NRIR	5.99	3.10 (0.2117)	Accept

*Decision rule: If the estimated observation *R-squared value is less than the critical chi-square value then accepts the null hypothesis of no serial correlation of the second order (chi-square (2)). Values in parenthesis are p-values.

Table A3: Jacque-Bera normality test results

Taylor rule model with	*Skewness*	*Kurtosis*	*JB statistic*
BK output gap and FIM NRIR	0.06	4.52	24.10
BK output gap and UVM NRIR	0.07	4.67	28.83
BK output gap and MVM NRIR	0.20	4.76	33.50
BK output gap and LWM NRIR	0.03	5.02	42.09
HP output gap and FIM NRIR	-0.06	5.39	59.11
HP output gap and UVM NRIR	0.04	5.49	63.51
HP output gap and MVM NRIR	0.12	5.50	64.36
HP output gap and LWM NRIR	0.11	5.66	73.30
PF output gap and FIM NRIR	0.02	5.18	48.75
PF output gap and UVM NRIR	0.05	5.31	54.92
PF output gap and MVM NRIR	0.02	5.59	68.84
PF output gap and LWM NRIR	0.13	5.78	80.80
KF output gap and FIM NRIR	-0.20	5.49	65.43
KF output gap and UVM NRIR	0.04	5.23	50.87
KF output gap and MVM NRIR	0.09	5.70	75.16
KF output gap and LWM NRIR	0.00	5.88	84.84