# University of the Witwatersrand

# INFLATION, GROWTH AND MONETARY POLICY IN SOUTH AFRICA: APPLICATION OF NON-LINEAR MODELS

By

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## DECLARATION

I declare that this dissertation is my own unaided work, except where acknowledged. The dissertation is submitted for the degree of Doctor of Philosophy in Economics, University of the Witwatersrand, Johannesburg. It has not been submitted to this university or any other university for any other degree or examination.

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Signed ______________________

Date: 25 May 2018

## DEDICATION

I dedicate this dissertation to my understanding wife, Shylet for her unconditional support during these many years of research and to our precious son, Nhlanhla, for the joy he brought to our life. I am also grateful to my parents, siblings and friends for their love, guidance and encouragement.

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## ABSTRACT

This thesis intends to shed new light on the conduct of South Africa's central bank behavior. The thesis analyses the monetary policy conduct and the use of non-linear rules in South Africa. Furthermore, it scrutinizes the applicability of non-linear rules in characterizing the monetary policy behaviour in South Africa. Over and above the introductory chapter, the thesis comprises five main independent chapters, namely: chapters 2, 3, 4, 5, and 6. Chapter 7 cover conclusions.

Chapter 2[1] determines the applicability of a nonlinear Taylor rule in characterizing the monetary policy behavior of the South African Reserve Bank (SARB), using a logistic smooth transition regression approach. The evidence suggests the nonlinear Taylor rule is the most appropriate model to describe the monetary policy conduct of the South African Reserve Bank.

In Chapter 3, nonlinear models are used to analyse the nonlinear relationship among monetary policy, economic activity and financial instability, which is an extension of the previous chapter (Chapter 2). Two models (threshold regression and smooth transition) were used to analyse the role of financial condition in the interest setting by monetary authorities. The findings indicate that there is an inflation threshold level of 6.2 percent above, which the central bank adjusts its interest rate to maintain price stability. The results provide enough evidence that the monetary policy followed by the South Africa Reserve Bank (SARB) can be described by a nonlinear Taylor rule.

The thesis extends the analysis to determine the differential effects of inflation on GDP growth based on the estimated inflation. The purpose is to show that inflation is detrimental to economic growth at elevated levels. As a consequence, chapter 4 identifies the threshold effect of inflation on economic growth in South Africa. The estimated threshold model reveals that in South Africa, there is a non-linear relationship between inflation and economic growth. This implies that above the threshold level, inflation has a negative statistically significant effect on economic growth. These results may help policymakers in maintaining

[1] The original version of this paper was published in the African Development Bank as a working paper no:113, by Ncube M, and Tshuma,M,M., in 2010. In this chapter, we used a longer sampling period ranging from 1975Q1-2016Q1

low inflation, which is below the threshold level to mitigate its negative effect on economic growth.

Chapter 5 examines the effect of inflation variation on financial depth-growth relationship using a smooth transition regression model. The findings show that financial development and economic growth are non-linearly related with an increase in inflation beyond the threshold (at 4.3 percent) negatively impacting on economic growth. Therefore, financial development has a positive impact on economic growth when inflation is below the threshold of 4.3 percent, though above the threshold there is a negative relationship between financial development and economic growth.

Chapter 6 examines the exchange rate pass through effect to headline CPI inflation, producer price inflation and import price inflation in South Africa. The analysis of exchange pass through effect is relevant in the context of South Africa as decisions of monetary policy makers take into account changes in domestic prices emanating from exchange rate adjustments. For the purposes of analysis, this chapter estimates a Threshold Vector Autoregression (TVAR) to capture switches between the low and high inflation regimes implied by the theoretical literature with inflation rate as a transition variable. Using nonlinear impulse response functions, this chapter evaluate the dynamics implied by the threshold model. Findings reveal that prices (headline CPI inflation, producer price inflation and import price inflation) react strongly to a positive one unit exchange rate shock both below and above the threshold level of the inflation rate.

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# CHAPTER 1: INTRODUCTION

This thesis is comprised of five independent chapters more and above the introduction and conclusion. The chapters are self-contained and their topics are interrelated, making it easier for readers to follow the thesis in its entirety. All the chapters deal with several aspects of monetary issues in South Africa and may be of interest to other countries or regions. More specifically, the chapters look at the ability of nonlinear models to capture asymmetries or nonlinearities that cannot be accommodated by linear models.

Each of the chapters focus on various aspects of monetary policy conduct and they are based on nonlinear model. The binding aspect that cut across all the chapters is the nonlinear model estimation of monetary policy issues. Each of the chapters has its own structure and analytical framework. The first two chapters look at whether the monetary policy conduct of the SARB can be described by nonlinear models taking into consideration exchange rate and financial condition which leads to the augmentation of the simple Taylor rule [2](Taylor 1993). The rest of the thesis focuses on different issues related to monetary economics and policy using nonlinear models, for instance how policy changes in response to uncertainties.

South Africa, an emerging market economy, provides an excellent case study for this thesis. The country possesses features of industrialised and emerging market economies and has a developed financial sector. However, there are several economic challenges encountered by South Africa, such as, stagnation of real GDP per capita post the global financial crisis period; slow productivity growth; an increasing unemployment rate from already extraordinarily high levels; and very high inequality.[3] Despite good macroeconomic policies or frameworks, South Africa remains a country where there is marginal decline in poverty, inequality is extremely high, production and trade patterns have not shifted from the relative predominance of raw materials exports and the importation of high value added manufactures (Bhorat et al 2015). Consequently, there has been consistent criticism of inflation targeting by various role players since its adoption. Plessis (2014) argues that there is an apparently persistent gap between the practice of inflation-targeting central banks and the academic consensus on the need to target core rather than headline inflation in an inflation-targeting

[2] The Taylor rule assumes that central banks account for inflation and output gaps when establishing their policy rates(Taylor 1993)
[3] UN-WIDER 2016. Growth and development policy -New data, new approaches, and new evidence

regime. Also, Cosatu has argued that the focus on inflation targeting by monetary authorities has led to an overemphasis on monetary stability at the cost of growth and development, and it reduces flexibility in dealing with exogenous shocks to the economy (Kabundi and Ngwenya 2011). However, the view by Cosatu appears not to be true, as focus on achieving price stability does not necessarily mean that the SARB is not concerned with economic growth and employment.

There is so much critique of the inflation targeting framework that is been utilised by South Africa like other emerging market economies. For instance, critics of inflation targeting argue that the inflation that monetary authorities are trying to curb is imported. Thus, raising interest rates is regarded as a blunt instrument to an essentially supply driven inflation. Even Stiglitz (2008), notes that even the global oil and food prices were to rise at a moderate rate than now bringing down overall inflation rate to lower levels require markedly falling prices elsewhere.

Across all the chapters of the thesis, South Africa is used as a case study to show that empirical macroeconomic analysis can provide reliable results only when one is not challenged by data issues of a particular country and period. A cross country analysis encounters challenges in terms of striking a balance between model selection, technique and data that are appropriate for a particular country. On one hand there is need to adopt a uniform approach that permits comparability of the results.

Research studies on this issue, such as by Jawadi et al (2011), reveal that there are a few studies focusing on monetary policy rules in emerging markets (Brazil, Russia, India, China and South Africa-BRICS). In particular, there is a shortage of studies investigating whether the monetary authority reacts to changes in financial markets, in monetary conditions, in the foreign exchange sector and in the commodity price. It appears monetary authorities in emerging market economies are likely to react to other indicators that are typically neglected in the analysis for industrialised countries. In addition, monetary authorities in different countries are likely to adopt different monetary policies taking into consideration their domestic challenges as there is heterogeneity associated with emerging economies. The heterogeneity in monetary policy determinants for the various countries can be explained by the fact that the financial liberalization, financial and money market developments across countries are not similar. The findings of Jawadi et al (2011) point out that there is strong evidence that the monetary policy followed by Central Banks in the BRICS exhibits asymmetry and nonlinearity. There are different major drivers of such nonlinear conduct of monetary policy in BRICS countries, such as, considerations about economic growth (in Brazil and Russia), inflation (in India and China) and stability of financial markets (in South Africa).

Fry et al (1996) argue that monetary policy in emerging markets has increasingly shifted towards inflation targeting and marked-based instruments. In addition, Mishkin (2000), in last couple of years' monetary policy experience, has witnessed extreme episodes of monetary instability, swinging from very high inflation to financial instability. Lately, the Taylor rule has been augmented to take into consideration some of the indicators that play an important role in emerging markets. For instance, the simple Taylor rule has been extended to include exchange rate (Filosa (2001); Mohanty and Klau (2005); Devereux et al. (2006); Batini et al. (2009)), which supports the fear of floating hypothesis, Mehrotra and Sánchez- Fung (2011) show that McCallum-Taylor specifications [4]with an interest rate instrument and a nominal income gap target perform better than benchmark Taylor rules in describing monetary policy in inflation targeting emerging market economies.

Recently, the use of nonlinear models to estimate the monetary policy behaviour has become popular and it is now a common approach used in empirical economics. For instance, Malikane and Mokoka (2014) evaluate the contribution of each of these components (i.e labour share, output gap and supply shock variables) of real marginal cost as driving forces for inflation. In their study, they assumed a nonlinear input–output technical relation in which labour and non-labour inputs enter in production as complements in order to derive a broad measure of real marginal cost. Their results reveal that supply shock variables dominate the output gap and the labour share in driving inflation dynamics.

Furthermore, there are other several studies that have been used to estimate and forecast economic variables using nonlinear models. Qin and Enders (2008), Martin and Milas (2004), Schaling (2004), Ncube and Tshuma (2010), Kasai and Naraidoo (2012), Naraidoo and Paya

[4] See Razzak,W,A.,2003. Is the Taylor Rule Really Different from the McCallum Rule?, Contemporary economic policy, vol 21, Issue 4, pg 445-457

(2012) and Baaziz et al (2013) among others have conducted research focusing on the nonlinear Taylor rule. The studies, using different approaches indicate that the non-linear Taylor rules are better in explaining the monetary policy reaction functions of the central banks than the linear versions. This is the justification why the thesis has also chosen to approach the study using the same approach.

A central bank may engage in a nonlinear model depending on whether its loss function is symmetric or asymmetric. There are varying conditions in which the nonlinear rule can be applied. Firstly, a nonlinear rule is appropriate to use when there is an asymmetric loss function in which different weights are assigned on positive and negative inflation and output gaps (Castro 2011). Secondly, if the trade-off between inflation and the output gap show signs of nonlinearities, using a linear model will give misleading results that will impart a bias to inflation. As a result, systematic mistakes in monetary policy may be encountered by using linear models (Arghyrou et al 2003). Thirdly, empirical studies show that on average nonlinear models tend to outperform the simple linear specification in terms of its ability to track the actual interest rate. However, there is less literature on nonlinear Taylor models as Castro (2011) points out that only recent studies took into account asymmetries or nonlinearities in the analysis of monetary policy. Nonetheless, in some countries (for example the United Kingdom) Castro (2011) indicates that the linear Taylor rule alone appears to have failed to explain the interest rate setting behaviour.

Taylor and Davradakis (2006) suggest that although nonlinearities in the Taylor rule can result from either nonlinearity in the macroeconomic structure of an economy or asymmetry in the central bank’s preferences. It is highly likely that both the presence and the interaction of these in the economy will amplify the degree of nonlinearity in the policy rule. According to Cukierman (2004) the asymmetric central bank goals result in nonlinear policy rules though the economic structure is linear.

There is a vast body of theoretical and empirical literature on the conduct of monetary policy in many emerging market economies (such as Brazil, Russia, China, India and South Africa) around the world. South Africa’s monetary policy seems to have evolved over the years. Casteleijn (2001) locates the conduct of monetary policy in five broad categories and this is shown in the Table 1 below.

**Table 1: Evolution of Monetary policy in South Africa**

| **Years** | **Monetary Policy Framework** |
|---|---|
| 1960–1981 | Liquid asset ratio-based system with quantitative controls over interest rates and credit |
| 1981–1985 | Mixed system during transition |
| 1986–1998 | Cost of cash reserves-based system with pre-announced monetary targets (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: Casteleijn (2001).

South Africa adopted its first informal inflation targeting approach to monetary policy in March 1998 when an inflation target range was set between 1 to 5 percent (Casteleijn 2001). South Africa went on to formally adopt inflation targeting monetary policy on 23 February 2000, when the Ministry of Finance announced an inflation target in the range of 3 to 6 percent (De Waal and Van Eyden 2014).

Inflation targeting remains the main monetary policy of the South African Reserve Bank (SARB) to date and the range is between 3 to 6 percent, which was adopted since 2000(SARB 2016). The inflation targeting framework is characterised by a public announcement of the official target range of inflation rates over time. The target rates are set by the South African Reserve Bank through consultative process with government and National Treasury. The process therefore only gives the Central Bank the sole responsibility of choosing the monetary policy tool to use in order to achieve the inflation target. The aim is to increase monetary policy transparency and accountability (Van der Merwe 2004).

The adoption of inflation targeting has yielded several benefits, such as minimising the inflation volatilities achieving price stability, as well as the conduct of policy that managed to minimise both anticipated and unanticipated deviations on inflation (SARB 2010). A counter argument to this approach is that monetary policy paid insufficient attention to the potential impact of the build-up of financial vulnerabilities prior to the financial crisis. Events following the financial crisis also demonstrated that financial shocks are costly as their effects are often too rapid for policy to offset easily.

In addition, another mandate of the SARB is to ensure a stable financial system. Ultimately, there is need to examine if the monetary policy implemented by SARB takes into consideration financial stability, thus how it deals with financial instability. Currently, there is an ongoing debate as to whether the central bank should focus only, on inflation and output stabilisation at the expense of assets prices and other financial variables that may have implications on the economy.

The inflation targeting approach of South Africa is forward looking and based on inflation expectations and thus a specific target for inflation has to be met within a predetermined time. A credible monetary policy anchors inflation expectations of future inflation to influence price and wage setting decisions, (Naraidoo and Gupta 2010). Monetary authorities use the repo rate, which has direct effects on other variables such as other interest rates, the exchange rate, money and credit, other assets prices and decision on spending and investment within the South African economy, (Smal and Jager 2001).

It is essential to understand the effects of monetary policy and what monetary policy can and cannot achieve as this enables monetary authorities to establish the most suitable for monetary policy. The monetary authorities in South Africa use interest rates such as repo rate to achieve price stability which has implication on expectations of the economic agents about the future course of real activity in the economy, and the confidence with which those expectations are held. For instance monetary authorities can hike repo rates with an intention of lowering inflation. This could be interpreted by different economic agents as an indication that authorities anticipate the economy to grow at a faster rate than previously anticipated, thereby, increasing the expectations of future growth and confidence in general.

Since the SARB is mainly concerned about achieving price stability, it is important for monetary authorities to understand the form and the scale in which nominal exchange rate changes are passed through to domestic prices. This is because the exchange rate is one of determinants of inflation. In the context of the global imbalances, it is necessary for the SARB to have knowledge of the Exchange Rate Pass-Through (ERPT) since it determines the level of real exchange rates, and a key determinant of the adjustment pattern of the balance of payments.

The trade liberalisation that occurred in the 1990's in South Africa as well as globalisation contributed to instability within South Africa. This made it difficult for the SARB to achieve price stability, thus ensuring that inflation rate is within the 3-6 percent band, as well as facilitating the creation of employment opportunities. This could be partially attributed to the negative impact of globalization on the prices of commodities. Therefore, when a country gets exposed to the global world it finds it challenging to respond to international shocks. The shocks make it difficult for monetary authorities to implement or conduct monetary policy using policy rules to respond to the shocks. For instance, the global financial crisis and oil price increases might reduce the effectiveness of monetary policy in South Africa in responding to economic shocks.

Subsequent to adopting the inflation targeting policy, the monetary authorities have been battling with maintaining inflation rate to be within the 3-6 percent target range. Statistical figures from the SARB reveal that after the adoption of inflation targeting a record low inflation rate of 0.21 percent was registered in January 2004. By July 2008 however, the inflation rate had reached a peak of 13.7 percent. This portrays an increasing inflation trend that can be attributed to a number of factors inclusive of rising food, oil and other commodity prices over a period of strong global demand and economic growth.

Since the adoption of inflation rate targeting policy, there has been a great concern on the effectiveness of monetary policy to curb inflation in South Africa. The effectiveness of the repo rate as a policy instrument to control the level of inflation has been widely criticised not only in the South African context but also internationally (see for example Bernanke and Woodford, 1997 and Mishkin, 2002). The critics have argued that most of the time, the annual inflation rate in South Africa has been outside the 3-6 percent inflation target band. Thus, the use of the repo rate as tool to curb inflation rate increase led to an acceleration of its trend rather than subduing it. Furthermore, the critics point out several issues ranging from a substantial lag for monetary policy changes to affect inflation, to the inability of the policy instrument to effectively affect inflation level.

This thesis contributes to current monetary policy debates through identifying how quickly interest rates move from a low to a high interest rate regime in the context of emerging markets. The thesis provides an analytical framework, which will potentially help policy makers in their decision making. Empirical evidence shows that high inflation (beyond a certain threshold) is costly or detrimental to economic growth, hence policy makers intend to achieve price stability. Furthermore the research intends to alert policy makers to the fact that economic variables are subjected to sudden abrupt changes as monetary policy tends to be relaxed during recession compared to expansions. The outcomes of the research will be more beneficial to policymakers in emerging markets as it provides recent evidence on non-linear models using the latest available data though it applies the concept and methodology used in developed countries. Thus, policymakers from emerging countries will make their decisions on the basis of evidence from emerging markets rather than on evidence from advanced countries as this will be more relevant, taking into account the current global economic condition such as the financial crisis.

The thesis has seven chapters with five chapters mainly focusing on empirical analysis while the other two chapters are introduction and the conclusion. The empirical analysis is organized in way that Chapter 2 and 3 focuses on examining the monetary policy conduct of the SARB using nonlinear models, such as, the smooth transition regression model and threshold autoregressive model. Chapter 2 analyses the augmented forward looking Taylor rule that incorporates foreign interest rate and exchange rate, whereas Chapter 3 looks at nonlinear Taylor rules in the context of South Africa taking into consideration the financial index as an important variable in the determination of interest rates. Chapter 4 deals with the investigation of the relationship between inflation and economic growth in the context of South Africa using nonlinear model, the smooth transition regression. Chapter 5 examines the effect of inflation variation on the nonlinear financial depth - growth nexus in South Africa using a smooth transition regression model. Chapter 6 employs a threshold vector autoregressive (TVAR) methodology to establish whether there is a nonlinear relationship and whether the nonlinear relationship permits for significant effects of exchange rate effects on inflation in the different regimes. Chapter 7 provides the research conclusions.

# CHAPTER 2: MONETARY POLICY CONDUCT BASED ON THE NONLINEAR TAYLOR RULE: EVIDENCE FROM SOUTH AFRICA[5]

## 2.1 Introduction

This Chapter analyses whether the central bank's monetary policy can be described by linear or nonlinear Taylor rule. Furthermore, the Chapter examines the applicability of a nonlinear Taylor rule in characterizing the monetary policy behavior of the South African Reserve Bank, using a logistic smooth transition regression approach.

Many studies have investigated the use of Taylor rules to analyse the monetary policy conduct internationally (i.e. Castro 2011, Petersen 2007). However, there have been few studies carried out for emerging markets possibly due to the lack of interest in emerging market economies. Studies undertaken by Petersen (2007), Castro (2011) and Cukierman (2004) mainly focus on nonlinear models in developed economies, such as, the United States (US) and United Kingdom (UK). Notably, there is a gap within emerging markets. In particular, South Africa presents an opportunity for the utilization of nonlinear models to characterise the behaviour of the Reserve Bank using interest rate functions. Interest rate reaction functions have normally been formulated using the linear Taylor rule.

The Taylor rule spells out that the interest rate adjusts in accordance to the deviation of inflation from its target and real output from potential output. It also assumes that in the US, for instance, the federal funds rate is raised by 1.5 percent points for each 1 percent point increase in inflation (Taylor 1993). Furthermore, an increase in the interest rate of that magnitude would raise real interest rates and help cool off the economy, thus reducing inflationary pressures. According to Taylor (1993), the rule also assumes that interest rates are reduced by 0.5 percent point for each 1 percent point decline in real GDP below its potential. Such a reduction in the interest rate helps to mitigate a (growth cycle) recession and maintain price stability.

Findings by Castro (2011) point that there has been an increase in the usage of nonlinear models as central banks tend to have asymmetric preferences in their loss functions. This implies that weights assigned to negative and positive output gap and inflation could be

[5] The original version of this paper was published in the African Development Bank as a working paper no:113, by Ncube M, and Tshuma,M,M., in 2010. In this chapter, we used a longer sampling period ranging from 1975Q1-2016Q1.

different. With the current dominance of financial instability (such as the one caused by the financial crises), the central bank tends to behave differently in the manner it adjusts its reaction functions to respond to economic booms and slumps. Furthermore, Castro (2011) shows that the failure by the US and UK to incorporate financial conditions in their monetary policy rule could have exposed them to the financial crises.

The behavior of interest rate has been characterized by the use of smooth transition regression models, for example, logistic smooth transition regression. This theoretical approach has been used extensively by Terasvirta and Anderson (1992). In their study, Terasvirta and Anderson (1992) argue that the Smooth Transition Regression (STR) model is regarded as a regime switching model, whereby the transition from one regime to another occurs smoothly. The model requires the identification of a transition variable. The transition variable indicates a point where a change from a low regime to a high regime takes place. The point of inflection is referred to as the threshold level. The chapter uses a grid search method to identify threshold levels as well as the speed of adjustment of the transition variable.

This research study allows the identification of an inflation threshold that assist in the assessment of the appropriate inflation levels and informs adjustment of policy settings by monetary authorities. In addition, this study fills policy gaps by enabling the derivation of inflation thresholds that can assist policy makers to disseminate monetary policy decision to the public. The use of nonlinear models enables policy makers to understand that policy responses are influenced by the existence of inflation regimes.

The chapter contributes to current monetary policy debates through identifying how quickly interest rates move from a low to a high interest rate regime, estimating in the context of emerging markets. In addition, it identifies, as well as demonstrates the existence of threshold level of the transition variable for decision making. This shows the importance of nonlinear models in describing how different the central bank responds to a positive as opposed to negative inflation or output gap to drive them towards the required targets.

A number of studies have estimated the monetary policy reaction function for South Africa using nonlinear models, such as, Ncube and Tshuma (2010), Kasai and Naraidoo (2012), Naraidoo and Paya (2012) and Baaziz et al (2013). This research approach differs from those of the above mentioned authors in the context of South Africa in various respects. Unlike in other studies, this thesis has included foreign interest rates as one of our underlying variables to analyse the applicability of the nonlinear Taylor rule. This is because policy reactions are increasingly affected by the international environment as opposed to setting interest rates according to national conditions. This chapter employs the smooth transition model whereby the transition from one regime to another occurs smoothly. The movement from one regime to the other is usually determined by the inflation threshold. Yet in a study by Baaziz et al. (2013), output gap is a chosen threshold variable that governs the movement from one regime to another. Compared to other existing studies this chapter covers a longer sample period by using data from 1975Q1 to 2016Q1.

In this study, two sampling periods are analysed, the full sample period (1975Q1-2016Q1), and reduced sample starting in 2000Q1 known as the inflation targeting period. The results show that the monetary policy behaviour of the SARB is described by a nonlinear forward looking Taylor rule. This is consistent with the results of Naraidoo and Paya (2012) in the case of the SARB that supports the existence of nonlinearity in the monetary policy conduct of the SARB.

Using a smooth transition regression model, this study finds that there is an inflation threshold of 6.5 percent, above which SARB reacts aggressively by adjusting interest rate to ensure price stability. Overall the results of this study suggest that the nonlinear Taylor rule holds for the SARB’s policy reaction function, which is in sharp contrast to previous findings that linear Taylor rule best describes the SARB’s monetary behaviour. The significant coefficients of the main underlying variables such as inflation, output gap, REER, foreign interest rates show that monetary authorities take these factors into consideration when setting interest rate rules, and that these variables have explanatory power for the interest rate decisions. The results show that a nonlinear Taylor rule may be more appropriate to explain the behaviour of the monetary policy. Thus, the adoption of a nonlinear specification (instead of the linear), would lead to a better fit for the South African Central Bank.

The remaining parts of the chapter are organized as follows: Section 2 focuses on the literature. Section 3 presents the methodology applied. Section 4 provides the data. In section 5 results are presented. Section 6 concludes.

## 2.2 Literature review

This section reviews literature on linear Taylor rule and goes further to discuss the non-linear Taylor rule. The Taylor rule stipulates how the central bank should adjust the nominal interest rates according to the output gap [6]and inflation rate. The original Taylor rule assumes that the response of interest rates to economic conditions is linear and time invariant.

Furthermore, the original Taylor rule does not incorporate the effects of the exchange rate, which plays an important role in shaping the environment, as it was formulated for a closed economy. However, this Chapter intends to adapt or expand the original Taylor rule by including the real effective exchange rate term as an additional variable on South Africa, an open economy. The inclusion of an additional term will enable us to analyze how the interest rate responds to real exchange rate changes. Similarly, Taylor (2000) points out that there exist a relationship between interest rate and the exchange rate through capital markets.

The Taylor rule is useful as it provides an analytical framework which helps central banks in their decision making process. However, Taylor (1993) cautions central banks not to blindly implement the Taylor rule but to use their discretion in applying it, depending on the different situations that prevail. Using simple Taylor rule in presence of asymmetries will yield misleading findings.

Empirical literature outlines the problems associated with the original Taylor rule. Firstly, the Taylor rule mainly depends on estimated variables (i.e. output gap and real interest rates) that are difficult to measure in reality though they are robust conceptually. Secondly, Adema (2003) points out that it is problematic to measure an accurate level of the equilibrium real interest as this variable tends to vary over time. In addition, the original Taylor rule has been criticized for its dependence on ex post data [7]and the output gap data is unknown with precision in reality unless possibly some years later. Thirdly, it is difficult to identify the most appropriate measure of potential output which is used in the calculation of the output gap. In fact, output estimates are likely to vary over time due to the revision of data.

[6] Output gap can be defined as the amount of actual output by which it exceeds (falls short) potential output.
[7] This data could be different from the actual data available when the central bank set the policy rate.

Research studies reveal that some authors have challenged the assumptions underpinning linear models such as the existence of a quadratic loss function. Woglom (2003) points out that the estimation of the original Taylor rule for the US Fed did not incorporate the interest rate smoothing term though nowadays, different central banks include the lagged interest rate to show their interest rate smoothing preferences. Furthermore, the original Taylor rule fails to incorporate the effects of the exchange rate which plays an important role in economic development. Olmedo (2002) has questioned the assumptions on the basis that policymakers will not incorporate the state of business cycles when conducting monetary policy. In fact, Olmedo (2002) argues that the behavior of the central bank over the business cycle is asymmetric.

A central bank may engage in a nonlinear Taylor rule, depending on whether its loss function is symmetric or asymmetric. Firstly, a nonlinear rule is appropriate to use when there is an asymmetric loss function in which different weights are assigned on positive and negative inflation and output gaps. Secondly, if the tradeoff between inflation and the output gap show signs of nonlinearities, using a linear model will give misleading results that will impart a bias to inflation. As a result, systematic mistakes in monetary policy may be encountered by using linear models.

Thirdly, empirical studies show that on average, nonlinear models tend to outperform the simple linear specification in terms of its ability to track the actual interest rate. Yet, there is less literature on nonlinear Taylor models. As Castro (2008) points out, only recent studies took into account asymmetries or nonlinearities in the analysis of monetary policy. Nonetheless, in some countries (e.g. United Kingdom) Castro (2008) indicates that the linear Taylor rule alone appears to have failed to explain the interest rate setting behavior.

Furthermore, Taylor (2006) suggests that although nonlinearities in the Taylor rule can result from either nonlinearity in the macroeconomic structure of an economy or asymmetry in the central bank's preferences, it is highly likely that both the presence and the interaction of these in the economy will amplify the degree of nonlinearity in the policy rule. Lastly, Cukierman (2004) argues that asymmetric central bank objectives lead to nonlinear policy rules even if the economic structure is linear.

### 2.2.1 Causes of asymmetry

A nonlinear interest rate reaction function may result from asymmetry in the central bank's preferences pertaining to the weight assigned to deviation of inflation from target and real GDP from potential output. Furthermore, different arguments have been brought forth with regard to the sources of asymmetry in Central bank behavior. For instance, Olmedo (2002) suggests that asymmetry may arise due to the fact that monetary authorities are to some extent under political pressure since they are accountable to elected political officials for their decisions. In fact, Cukierman (2003) indicates that the central bank may be more averse to recessions as opposed to expansions. Similarly, Blinder (2000) argues that in some instances central banks succumb to political heat when it tightens pre-emptively to avoid higher inflation as opposed to when it eases pre-emptively to avoid higher unemployment.

According to Bruinshoofd and Candelon (2004), asymmetry could arise due to different phases of the business cycle (i.e. whether there is an economic expansion or contraction). Therefore, during an expansionary phase, monetary authorities may be aggressive on inflation, whereas the stabilization of output receives a larger weight in downturns. However, Olmedo (2002) purports that asymmetry may arise due to uncertainty in the effects of monetary policy on the economy that leads the central banker to be more cautious.

### 2.2.2 Evidence on Nonlinear Taylor rule

Petersen (2007) attempts to estimate nonlinearities in the Taylor rule using smooth transition regression model. He finds that the US Federal Reserve switched from a linear model in the period 1960-1979 to a nonlinear threshold type model over the period 1985-2005. Petersen (2007) concluded that the Federal Reserve Bank changed its short term interest rate once inflation (transition variable) reached an inflation threshold of 3.55 percent. The research used inflation rate and output gap as explanatory variables only in a nonlinear Taylor rule equation. In this study, real effective exchange rate and interest rate smoothing terms are added following Ball (1999) suggestion that the Taylor rule for open economies are adjusted to incorporate the real exchange rate.

Castro (2011) analyses whether the central banks also target financial variables and assets prices information, in addition to inflation and output gap targets. Furthermore, he analyzes whether the central banks follow a linear or nonlinear Taylor rule. His study uses monthly data for three central banks namely, the United States Federal Reserve (Fed), the Bank of England (BOE) and the European Central Bank (ECB). Using a smooth transition regression model to estimate non linearities in the Taylor rule, the results show that only the federal reserve of the United States appears to have followed a linear Taylor rule. On the contrary, the Bank of England and the European Central Bank follow a nonlinear Taylor rule.

## 2.3 Econometric Methodology

In this section, this study seeks to find out the appropriate specification of the monetary policy reaction function of the central bank to capture nonlinearity. A simple linear Taylor rule is estimated. Thereafter, the study focuses on nonlinear specifications

### 2.3.1 Linear model

The linear Taylor rule can be specified following Taylor (1993) who put forward the following rule to characterize the implementation of monetary policy in the US:

$$i_t^* = r + \pi_t + \emptyset(\pi_t - \pi^*) + \beta y_t \quad (1)$$

where $i_t^*$ is the target short term interest rate, $r$ is the long run equilibrium real interest rate, $\pi_t$ is the inflation rate, $\pi^*$ is the target inflation rate and $y_t$ is the measure of the output gap. $\emptyset$ indicates the sensitivity of interest rate policy to deviations in inflation from target, and $\beta$ indicates the sensitivity of interest rate to output gap. The coefficients of inflation rate and output gap are expected to have positive signs. If inflation rate or output gap increases, the central bank will respond by raising interest rates.

Castro (2011) points out that in reality, central banks target expected inflation not past or current inflation. Thus, Clarida et al. (1998) propose the use of a forward-looking version of the Taylor rule that permits the central bank to take various relevant variables into account when forming its inflation forecasts. Therefore, according to Clarida et al. (1998, 2000), the central bank's desired level for interest rate ($i_t^*$ ) depends on the deviation of expected inflation $k$ periods ahead from its target value and the expected output gap.

Following Clarida et al (1999, 2000) a forward looking Taylor rule is used:

$$i_t^* = i^* + \beta\big(E\big(\pi_{t,k}\big|\Omega_t\big) - \pi^*\big) + \gamma E(x_t|\Omega_t), \quad (2)$$

where $i_t^*$ is the desired value of the short term nominal interest rate, $i^*$ is, by construction, the desired nominal rate when both inflation and output are at their target levels, $\pi_{t,k}$ denotes the percent change in the price level between periods $t$ and $t+k$, $\pi^*$ is the target for inflation, $x_t$ is a measure of the output gap [8]in period $t$. $E$ is the expectation operator, and $\Omega_t$ is the information set at the time the interest rate is set.

Taylor and Davradakis(2006) indicate that the forward-looking Taylor rule nests the simple interest rate rule originally proposed by Taylor (1999a,b) if either inflation or the cross product of inflation and output gap are sufficient proxies for expected inflation. In addition, Clarida et al (1999, 2000) point out that the forward-looking specification allows the central bank to consider a broad array of information (beyond lagged inflation and output) to form beliefs about the future condition of the economy.

The Taylor principle suggest that monetary policy can be stabilizing if $\beta > 1$ and the coefficient on the output gap $(\gamma)$ should be positive i.e $\gamma > 1$. According to Castro (2011), this implies that when $\beta > 1$ the central bank increases the real interest rate in response to higher inflation, which is considered as a stabilizing effect on inflation. However, interest rate rules characterised by $\beta \leq 1$ and $\gamma \leq 1$ are likely to be destabilizing or, at best, accommodative of shocks to the economy.

Following Clarida et al (1998) and Rudebush (2002) among others, this study augments the baseline specification by introducing the lagged interest rate that takes into account the inertia of monetary policy. Thus it is assumed that the actual nominal interest rate, $i_t$ adjusts towards the desired rate as follow:

$$i_t = pi_{t-1} + (1-\rho)i_t^* + v_t \quad (3)$$

where $\rho$ is a parameter measuring the degree of smoothing of interest rate changes and the interest rate $i_t^*$ is given by equation(2), $v_t$ is an exogenous interest shock with zero mean. According to Clarida et al (2000), the central bank adjusts the interest rate each period to eliminate a fraction $(1-\rho)$ of the gap between its current target level and some linear

[8] Output gap defined as the percentage deviation of actual GDP from its potential level.

combination of its past values. Thus, equation (3) indicates the partial adjustment of the interest rate to the target $i_t^*$.

Castelnuovo (2003) notes that a higher estimated degree of partial adjustment reveal the presence of interest rate smoothing. The central bank may want interest rates to adjust slowly to avoid uncertainties, maintain its credibility and financial stability, as financial markets are likely to excessively react to policy changes leading to financial instability.

Combining equations (2) and (3) the following policy reaction function is obtained:

$$i_t = \alpha_0 + \alpha_1 i_{t-1} + \alpha_2 \pi_{t,k} + \alpha_3 x_t + \epsilon_t \quad (4)$$

where $\alpha_0 = (i^* - \beta\pi^*)(1-\rho), \alpha_1 = \rho, \alpha_2 = \beta(1-\rho), \alpha_3 = \gamma(1-\rho)$ and $\epsilon_t = (1-\rho)\{\beta\left(E\left(\pi_{t,k}\middle|\Omega_t\right) - \pi_{t,k}\right) + \gamma(x_t - E(x_t|\Omega_t))\} + v_t$.

Svensson (2003) suggests an extension of the Taylor rule by incorporating the exchange rate in a rule designed for small open economies. Similarly, Baaziz et al (2013) argues taking into consideration the importance of exchange rate especially in the context of a small open economy, it is widely agreed to introduce it as an explanatory variable in the Taylor rule. According to Ball (1999) the introduction of the exchange rate into Taylor rule leads to an improvement in macroeconomic performance in terms of stabilizing inflation and the output gap. The exchange rate plays a vital role in the transition mechanism of structural shocks to monetary policy (Baaziz et al, 2013).

The Taylor rule is augmented by the introduction of the exchange rate. In the context of South Africa, Baaziz et al (2013) suggest that the inclusion of the exchange rate is in line with the goals of the South African Central Bank (SARB) that emphasise the maintenance of financial and price stability.

Nonetheless, the introduction of the exchange rate [9]is in line with the goal of the South Africa central bank that entails achieving and maintaining price and financial stability.
The model thus becomes:

[9] Real effective exchange rate is used as proxy for exchange rate

$$i_t = \alpha_0 + \alpha_1 i_{t-1} + \alpha_2 \pi_{t,k} + \alpha_3 x_t + \alpha_4 q_t + \in_t \quad (5)$$

where $q_t$ refers to the REER and $\alpha_4$ is the coefficient of the reaction of the central bank in response to a change in REER

Therefore, equation (5) indicates the reaction of nominal interest rate to inflation, output gap and the real effective exchange rate with an interest rate smoothing term

Following Guney (2016), the model is extended in this study to include the US Treasury bill rate as one of the explanatory variables. Due to its importance for the global economy, foreign interest rates are approximated by the US rates. This variable enables us to control for the influence of the US interest rate on South African interest rate movement. In addition, it allows us to capture the policy stance of advanced countries.

### 2.3.2 Nonlinear model

This section intends to respond the question of whether the SARB's monetary policy behaviour can be described by a linear or a nonlinear monetary rule. Therefore, in this study the specification and estimation of the forward looking nonlinear Taylor rule follows Castro (2011).

It is inappropriate to use the simple linear Taylor rule when the central banks preferences are asymmetric. According to Castro (2011), a nonlinear Taylor rule is appropriate to use as it enlightens the behavior of monetary policy when the central bank is assigning different weights to negative and positive inflation and output gaps in its loss function. Kesriyeli et al (2004), suggest that the failure to incorporate interest rate dynamics in the development of literature of nonlinear monetary policy rules may lead to model misspecification.

Castro (2011) outlines the aspects under which inflation and output may result in asymmetric interest rate responses by a central bank. He points out that inflation exhibits a more rapid increase over the business cycle and thus a positive deviation relative to a slower reduction in inflation and associated negative deviation below its target. Similarly, output may exhibit a short and rapid reduction relative to its trend, however long and smooth recoveries. As a result, a central bank may respond asymmetrically to different types of inflation and output deviations relative to their targets.

A number of studies show that different nonlinear time series models such as Markov-switching, artificial neural networks and smooth transition regression (STR) have been used to determine the behavior of the central banks. Swanson (1995) has utilized the artificial neural networks (ANN) nonlinear model to assess the information in the term structure due to its flexibility and simplicity. In addition, this model has performed well in various empirical applications where linear models have been unsuccessful. However, Petersen (2007) indicates that although ANN models can fit the data, they fail to give an economic explanation for the observed nonlinear behavior. Furthermore, some researchers such as Petersen (2007) have criticized the Markov-switching model on the basis that it assumes that the regime switches are exogenous and it fails to provide economic intuition behind the nonlinear policy behavior. Van Dijk (2001) points out that smooth transition regression (STR) models permit for only two regimes that is from low inflation regime to a high inflation regime. Similarly, Petersen (2007) uses STR as it permits regression coefficients to adjust gradually from one regime to another and it gives an economic reasoning for observed nonlinear behavior. Smooth transition models offer the advantage of allowing for more complex dynamics compared to a standard discrete threshold model [10]since they allow for smooth adjustment between two regimes. Therefore, following Bruggermann and Riedel (2011), this study introduces a smooth transition regression model that permits smooth changes in the reaction function of the SARB.

#### 2.3.2.1 Smooth transition regression model

A smooth transition regression model[11] is used in this Chapter to explain the nonlinear behavior as it enables monetary policy to evolve over time. Additionally, Cukierman (2007) points out that smooth transition regression models permit short term nominal interest rate to react marginally to expected output and inflation gaps and to adjust smoothly over the range of the reaction function. Similarly, Kesriyeli et al (2004) use the smooth transition regression model to examine the possibility of both nonlinearity and structural change in the interest rate functions of the US, UK and Germany. They find that during the 1980s there were changes in

[10] A set of different linear autoregressive (AR) models, with regime switches occurring due to the movement of threshold variable(s) with respect to fixed threshold(s)

[11] See Terasvirta (1998), van Dijk et al (2002) and Terasvirta (2004).

the reaction function coefficients for the UK and US. Furthermore, the assumption of constant interest rates overtime has been criticized because it leads to model misspecification.

Following Terasvirta (2005), the standard smooth transition regression model can be derived as follows:

$$i_t = \acute{\emptyset} z_t + \acute{\theta} z_t G(\gamma, c, s_t) + u_t, \quad t = 1, \dots, T, \qquad (6)$$

and the logistic function of order one is considered as follows,:

$$G(\gamma, c, s_t) = (1 + exp\{-\gamma(s_t - c)\})^{-1}, \quad \gamma > 0, \qquad (7)$$

where $z_t = (\acute{w}_{t,}\acute{x}_t)'$ is the vector of explanatory variables,$w_t = (1, y_{t-1}, \dots, y_{t-p})'$ and $x_t = (x_{1t}, \dots, x_{kt})'$ is a vector of strongly exogenous variables. The parameters $\emptyset = (\emptyset_0, \emptyset_1, \dots, \emptyset_m)'$ and $\theta = (\theta_0, \theta_1, \dots, \theta_m)'$ represent $((m+1) \times 1)$ parameter vectors in the linear and non-linear parts of the model, respectively. Furthermore, the disturbance term is $iid$[12] with zero mean and constant variance, $u_t \sim iid(0, \sigma^2)$. Terasvirta (2005) shows that the transition function $G(\gamma, c, s_t)$ is continuous and bounded between zero and one and is a function of the transition variable $s_t$. According to Castro (2011), as the transition variable moves towards negative infinity, the transition function gets closer to zero. However, as the transition variables approaches positive infinity, the transition function gets closer to one. The transition function increases monotonically as a function of $s_t$ and the slope parameter $\gamma$ indicates the smoothness of the transition from one to another and $c$ is the location parameter that determines where the transition occurs.

There are several ways to define the transition function. For example, one may consider a logistic STR model (noted LSTR1 model), where the transition-function is assumed to be a logistic function of order one:

$$G(\gamma, c, s_t) = (1 + exp\{-\gamma(s_t - c)\})^{-1}, \quad \gamma > 0, \qquad (8)$$

The function is a monotonically increasing function of $s_t$, the slope parameter $\gamma$ indicates the smoothness of the transition between regimes, and the location parameter $c$

[12] Independent and identically distributed random variable.

determines where the transition occurs.

The STR model is equivalent to a linear model with stochastically time-varying coefficients and as so, it can be rewritten as:

$$i_t = [\acute{\emptyset} + \acute{\theta} G(\gamma, c, s_t)]z_t + u_t, \tag{9}$$
$$\Leftrightarrow \; i_t = \acute{\xi} \; z_{t\,,} \quad t = 1, \ldots, T$$

As $G(\gamma, c, s_t)$ is continuous and bounded between zero and one, the combined parameters,$\xi$, will fluctuate between $\emptyset$ and $\emptyset + \theta$ and change monotonically as a function of $s_t$. Thus, if $G(\gamma, c, s_t)$ is close to one then the parameters will allow the model to characterize the linear and nonlinear part. However, if $G(\gamma, c, s_t)$ close to zero then the parameters only characterize the linear part. The more the transition variable moves beyond the threshold, the closer $G(\gamma, c, s_t)$ will be to one and closer to the parameters $\xi$ will be to $\emptyset + \theta$, similarly the further $s_t$ approaches the threshold, $c$ , the closer the transition function will be to zero and closer the parameters $\xi$ will be to $\emptyset$ .

A monotonic transition may not be a satisfactory alternative; one can also use the quadratic logistic STR model (or LSTR2 model):

$$G(\gamma, c, s_t) = \; [1 + exp\{-\gamma(s_t - c_1)(s_t - c_2)\}]^{-1} \tag{10}$$

Where $\gamma > 0,$ $c = \{c_1, c_2\}$ and $c_1 \geq c_2$ . As Martin and Milas (2004) suggest, central banks may consider not a simple numeric and rigid target for inflation but a band or an inner inflation regime, where inflation is considered under control and, consequently, the reaction of the monetary authorities will be different from a situation where inflation is outside that regime. This transition function is symmetric about $(c_1 + c_2)/2$ and asymmetric otherwise, and the model becomes linear when $\gamma \rightarrow 0$ .

This study also looks at the case of the exponential STR model (also known as ESTR model). This corresponds to the situation where the transition function is exponential, that is ;

$$G(\gamma, c, s_t) = \; [1 + exp\{-\gamma(s_t - c)^2\}]^{-1} \qquad \gamma > 0, \tag{11}$$

This corresponds to the particular case of the LSTR2 model where $c_1 = c_2$. Thus, the transition function is symmetric. This specification enables to capture the behaviour of monetary policy in the extreme regimes (when central bank define their policies according to economic, financial and commodities variables) as well in the central regime for which monetary authorities are more independent. Even though several tests enable the choice between exponential and logistic models, the first specification is invariably used for financial data than logistic one.

Castro (2011) suggests that in the estimation of the nonlinear model, it is important to test whether the behaviour of monetary policy in a particular country can be really described by a nonlinear Taylor rule. This implies testing linearity against the STR model [13].The null hypothesis of linearity is $H_0: \gamma = 0$ against $H_0: \gamma > 0$. However, neither the logistic smooth transition model with one threshold value nor the model with two threshold values are defined under this null hypothesis; they are only defined under the alternative. Teräsvirta (1998) and van Dijk et al. (2002) show that this identification problem can be solved by approximating the transition function with a third-order Taylor-series expansion around the null hypothesis. This approximation yields, after some simplifications and re-parameterisations, the following auxiliary regression:

$$i_t = \beta_0' z_t + \beta_1' \tilde{z}_t s_t + \beta_2' \tilde{z}_t s_t^2 + \beta_3' \tilde{z}_t s_t^3 + \varepsilon_t^* \qquad t = 1, \dots, T, \qquad (12)$$

where $\varepsilon_t^* = \varepsilon_t + \acute{\theta} z_t R(\gamma, c, s_t)$, with the remainder $R(\gamma, c, s_t)$, and $z_t = (1, \check{z}_t')'$ , where $\check{z}_t$ is a $(h \times 1)$ vector of explanatory variables. Moreover, $\beta_j = \gamma \check{\beta}_j$, where $\check{\beta}_j$ is a function of $\theta$ and $c$. The null hypothesis of linearity becomes $H_{01}: \beta_1 = \beta_2 = \beta_3 = 0$ against the alternative $H_{11}: "at\ least\ one\ \beta_j \neq 0, j = 1,2,3"$. An LM-test can be used to investigate this hypothesis because under the null,$\varepsilon_t^* = \varepsilon_t$. The resulting asymptotic distribution is $\chi^2$ with $3\,h$ degrees of freedom under the null. If linearity is rejected, this study can proceed with the estimation of the nonlinear model. But, which transition function should be employed? The decision between a logistic smooth transition function with one

[13] These tests require that the errors are uncorrelated with the regressors and the threshold variable. In addition, the original regressors and threshold variables need to be stationary.

threshold value or with two threshold values can be made from the following sequence of null hypotheses based on the auxiliary regression.

Terasvirta (2006) points out that if $\gamma$=0, the transition function $G(\gamma, c, s_t)$=0.5 and the model becomes linear. Thus the LSTR nests a linear model. However, when $\gamma \rightarrow \infty$, the LSTR model approaches a threshold regression model with two regimes with equivalent variances. From above this study identifies an existing gap in testing the non-linear Taylor rule in South Africa.

## 2.4 Data

In South Africa, monetary policy primarily focuses at the inflation objective, thus it seeks to achieve price stability. Since February 2000, the SARB has been adopting an inflation targeting policy, though an inflation target band of 3-6 percent was set in 2002. Basically, the Reserve Bank has used the interest rate as its main tool to achieve its monetary policy goal. Interest rate changes have effects on aggregate expenditure (such as investment, consumption) which eventually influences the level of inflation. In the face of shocks, the Reserve bank responds by adjusting its interest rate to maintain stability within the economy. Notably, monetary policy implemented in South Africa is forward looking, as it takes approximately between 18 to 24 months for the effects of interest rate adjustment to be fully passed on inflation.

The South African monetary policy has gone through several regimes since the early 1960's. Similarly, Aron and Muellbauer (2007), provide a brief history about the evolution of monetary policy in South Africa. It appears there were three monetary policy phases namely: liquid asset ratio system, cash reserve system and monetary accommodation. The liquid asset ratio system had quantitative controls on credit and interest rates, notably this system was used until the early 1980s. However, following various changes due to displeasure with the liquid asset ratio system, a cash reserve system was adopted. Aron and Muellbauer (2007) point that pre-announced monetary targets were utilized at the beginning of 1986, to be attained by indirectly changing interest rates. Lastly, a system of monetary accommodation was adopted in the early 1998, which used daily tenders of liquidity through repurchase transactions.

Ortitz and Sturzenegger (2007) examine the performance of monetary policy since 1960. They find that monetary policy has been steady, overtime. It appears the South African Reserve Bank (SARB) has been placing a larger weight on inflation as it is its primary target. Nonetheless, the weight on output gap has been improving while there has been a less focus on the exchange rate.

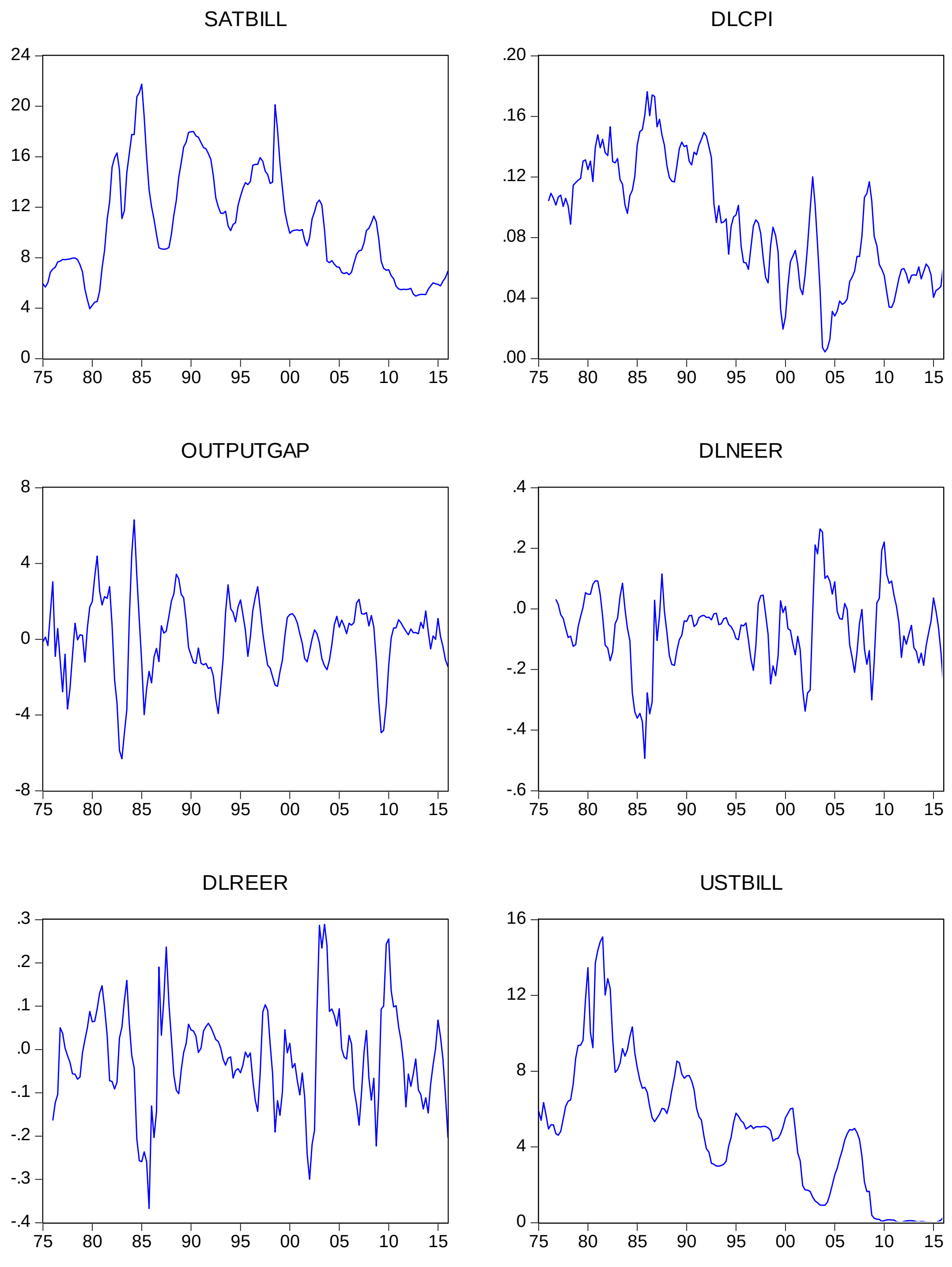
This study employs the original Taylor rule which stipulates how the central bank can adjust its nominal interest rates in response to deviations of inflation from its target level. Furthermore, the US real interest is added to the nonlinear Taylor rule in this study to check for the robustness of the results. Following Peterson (2007) and Castro (2011), a smooth transition model is used to examine the possible changes in monetary policy in this study. The advantage of this model is that it offers an economic reasoning for nonlinear behavior unlike the Markov-Switching model.

The chapter uses quarterly (Q) data from 1975 Q1 to 2016 Q1 for South Africa. The quarterly data is derived from the International Financial Statistics (IFS). The start and end dates of the sample was determined by data availability at the timing of writing this chapter. The five variables used in this chapter to estimate both the linear and nonlinear Taylor rules are the South Africa Treasury bill rate, inflation rate, output gap, and the real exchange rate and US Treasury bill rate. The Treasury bill rate is the rate at which short term securities are traded or issued in the market. On the other hand, the inflation rate refers to the indices reflecting cost of acquiring a fixed basket of goods and services by an average consumer. The Treasury bill rate is used as the nominal interest rate expressed as a percent points deviation. The Inflation rate is measured by the change in Consumer Price Index (CPI) whereas output gap is derived from the logarithm of real Gross Domestic Product (GDP)[14] using the Hodrick- Prescott (HP) filter[15]. The output gap is defined as the difference between actual output and potential output.[16] Njuguna et al (2005) points out that it is flexible in tracing the distinctiveness of the variations in trend output. Further, this method of estimating the output gap is favored as less data is required and it gives stationary output gap over a variety of smoothing values. However, it has been criticized for its failure to give economic interpretation and it creates ambiguities.

[14] See Njuguna et al (2005) for more detail.
[15] See Sarikaya et al (2005) for a discussion on the derivation of HP Filter, its strengths and weakness
[16] Following Nikolsko-Rzhevskyy (2009) argument of unavailability of real time data, this study estimates output gap using real GDP data.

The inflation rate is calculated by taking logarithms of the quarterly CPI index and subtracting the lagged logarithm of CPI from the current logarithm of CPI. Similarly, the real exchange rate is calculated by taking the difference between logarithms of lagged quarterly real effective exchange rate and current logarithm of real effective exchange rate. In line with Woglom (2003), we use real effective exchange rate as an approximation of the real exchange rate. Kesriyeli et al (2004) defines the real effective exchange rate index as nominal effective exchange rate adjusted for relative movements in national prices.

**Figure 1: Plot of variables**




Notes: DLCPI-inflation rate, DLNEER-change in nominal effective exchange rate DLREER-change in real effective exchange rate, OUTPUTGAP-output gap derived using HP filter, SATBILL- South Africa Treasury bill, and USTBILL-USA Treasury bill. Data obtained from the International Financial Statistics (IFS).

Figure 1 shows the series for inflation rate, South Africa Treasury bill rate, output gap and change in real effective exchange rate, change in nominal effective exchange rate and US

Treasury bill rate for the period from 1975:1 to 2016:1. These series indicate some volatility, with real effective exchange and nominal effective exchange rates being the most unstable series. As can be seen from Figure 1, inflation has been high and volatile before 2000, as South Africa had not yet formally adopted inflation targeting monetary framework. The US Treasury bill rate has exhibited a largely continuous downtrend during the period under review.

**Table 2: Descriptive statistics**

| Variables | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| $i_t$ | 158 | 10.683 | 4.276 | 3.960 | 21.750 |
| $\pi_t$ | 158 | 0.090 | 0.041 | 0.004 | 0.176 |
| $y_t$ | 158 | -0.024 | 1.993 | -6.308 | 6.300 |
| $rx_t$ | 158 | -0.017 | 0.115 | -0.367 | 0.289 |
| $i^f_t$ | 158 | 4.780 | 3.595 | 0.020 | 15.090 |

Notes: it =interest rate; πt =inflation rate; yt =output gap; rxt = real effective exchange rate and ift – foreign interest rate, SD-standard deviation. Source: IFS Online Database

Table 2 provides a summary of the descriptive statistics (i.e. mean, median) for the variable used in the estimation of both linear and nonlinear models.

### 2.4.1 Stationarity tests

Recent research studies outline various unit root and stationarity tests that can be relied upon. These include for example, the Augmented Dickey-Filler test statistic, Ng-Perron, Elliott-Rothenberg-Stock (for highly persistent data) and Kwiatkowski, Phillips, Schmidt, Shin (KPSS 1992) stationarity test. However, this Chapter uses Ng-Perron and KPSS tests. Petersen (2007) suggests that the former has exceptional size properties and KPSS test is used for robustness check of the results. Granger and Terasvirta (1993) point out that prior to using nonlinear models, it is essential to undertake a linearity test. Moreover, before the use of the linearity tests and of the STAR models, stationary time series are required. Consequently, the tables below show the results of KPSS and Ng-Perron tests.

**Table 3: Ng Perron test results**

| *Series* | $i_t$ | $\pi_t$ | $y_t$ | $rx_t$ | $i^f t$ |
|---|---|---|---|---|---|
| $H_0$: unit root | -2.136 | -1.553 | -4.616 | -1.870 | -1.193 |
| Asymptotic critical values:1 percent | 2.58 | -2.58 | 2.58 | -2.58 | -2.58 |
| Asymptotic critical values:5 percent | -1.98 | -1.98 | -1.98 | -1.98 | -1.98 |
| Decision at 5 percent Reject | Yes | No | Yes | Yes | No |

Notes: it =interest rate; πt =inflation rate; yt =output gap; rxt = real effective exchange rate; ift – foreign interest rate

Source: IFS Online Database

In Table 3, the Ng- Perron unit root test rejects the null hypothesis of unit root for almost all the series at 5 percent significance level except for inflation rate and foreign interest rate. This indicates that the treasury bill, real effective exchange rate and output gap are stationary. The test indicates inflation rate and foreign interest rate variables are integrated of order one. However, it is expected that the price level to be integrated of order one and inflation rate to be integrated of order zero (i.e. I(0)). This will imply that inflation rate is stationary. These results suggest border stationarity, which some unit root tests such as Ng Perron test cannot determine.

**Table 4: KPSS stationarity test results**

| *Series* | $i_t$ | $\pi_t$ | $y_t$ | $rx_t$ | $i^f t$ |
|---|---|---|---|---|---|
| $H_0$: stationarity | 0.427 | 1.139 | 0.018 | 0.031 | 1.191 |
| Asymptotic critical values:1 percent | 0.739 | 0.739 | 0.739 | 0.739 | 0.739 |
| Asymptotic critical values:5 percent | 0.463 | 0.463 | 0.463 | 0.463 | 0.463 |
| Decision at 5 percent Reject | No | Yes | No | No | Yes |

Notes: $i_t$ =interest rate; πt =inflation rate; $y_t$ =output gap; rxt = real effective exchange rate; $i^f$t – foreign interest rate

Source: IFS Online Database

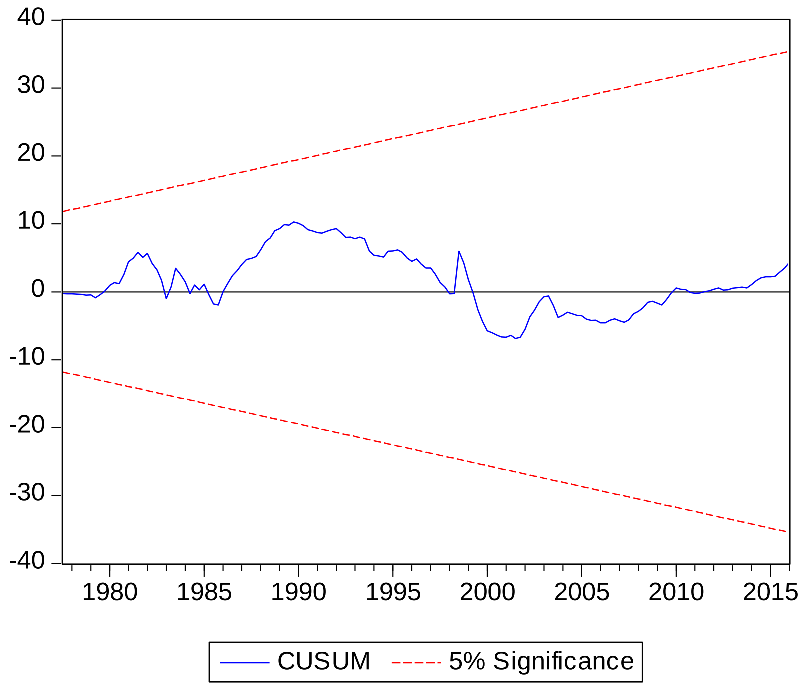
Table 4 shows that the KPSS test fails to reject the null hypothesis of stationarity for the interest rate, output gap and real effective exchange rate at 5 percent significance level. On the other hand, we are able to reject the null hypothesis of stationarity for inflation rate and foreign interest rate. This indicates that the inflation rate and foreign interest rate are non-stationary, whereas output gap, real effective exchange rate and interest rate are stationary. The inflation rate and foreign interest rate are integrated of the order one, consequently first differencing can be used to make these series stationary. Yet, output gap, interest rate and real effective exchange rate are I(0).

### 2.4.2 Parameter stability analysis

Different appropriate econometric methods have been used to identify any structural breaks over the full sample period (1975:Q1 to 2016:Q1. This is in line with the view of Yilmazkuday (2008) who argues that researchers should avoid relying on certain assumptions to determine the structural break dates. Instead, they should allow the data to identity such breaks. A number of techniques can be used to test for coefficient instability namely CUSUM test, CUSUM of Squares, Chow test and Recursive coefficients estimates. Woglom (2003) suggests that CUSUM test is executed on the basis of the out of sample forecasting power of the regression with estimation done over more and more sampling periods.

Following Brown et al (1975), the CUSUM test for the linear Taylor rule is performed In this study, initially, the parameters are assumed to be constant overtime, although this is highly unlikely in reality. If parameters tend to change in between two periods of time it is an indication of a structural break. We find that a structural break occurred in 1979Q1, 1982Q1, 1984Q1, 1985Q3, 1994Q1, 1998Q2, 1999Q4, 2003Q1 and 2009Q1. This coincided with South Africa's debt moratorium of 1985, East Asian crisis, Dotcom bubble burst and 9/11 US attacks and global financial crisis. The findings of Nell (2006) confirmed the structural change that occurred around 1985 and attributed it to the debt standstill. During the structural break-point, South Africa was given a debt moratorium by Western countries. This is confirmed by the results of the CUSUM test presented in Figure 2. The vertical axis is unit less and the horizontal axis shows the movement of the Cusum overtime.

**Figure 2: Parameter test results (Cusum test)**



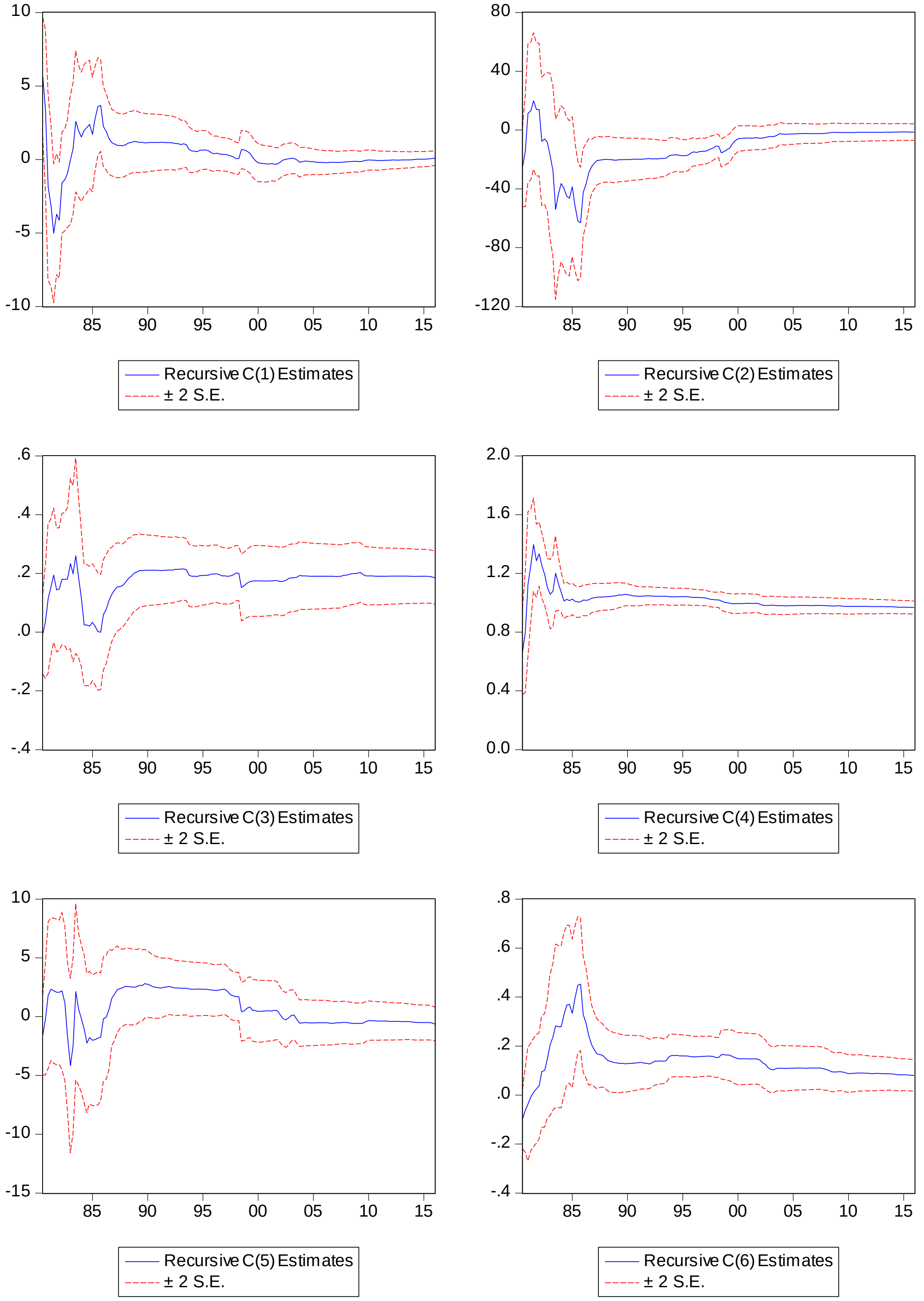

Source: IFS Online Database

The result in Figure 2 shows that the CUSUM moves away from zero and cross the confidence bands around the following periods; 1984Q1, 1998Q2, 2003Q1 and 2009Q1. Hence, we conclude that there is coefficient instability during this period. Some of the structural breaks identified are difficult to justify in terms of economic events and using dummy variables to deal with breaks yields insignificant results from estimations, thus there are not reported. Consequently, the linear Taylor rule has been used as the bench mark specification and smooth transition regression models to test for the existence of nonlinearities in the Taylor rule.

Figure 3, shows the recursive estimates of the simple Taylor rule.[17] The recursive estimates of all the variables (i.e. inflation, output gap and real effective exchange) are very volatile indicating coefficient instability. The recursive estimates reveal that overtime there is a fall in the coefficient series for the constant term though the coefficient series appear to be rising before stabilizing around zero.

[17] Recursive C(1), C(2), C(3) and C(4) represent the constant, coefficient estimate of inflation, output gap and real effective exchange respectively.

**Figure 3: Recursive coefficients estimates for Taylor's rule**




Source: IFS Online Database

Overall, there was instability around the 1980's as shown in Fig 3, though thereafter the coefficients stabilized.

### 2.4.3 Linearity test

The linearity test is used to determine whether nonlinearity exists within the model or not. The rejection of null hypothesis implies that a nonlinear model can be used. Furthermore, this test facilitates the determination of a transition variable and the nonlinear model (LSTR1 or LSTR2) to be used.[18] The null hypothesis of linearity can be formulated as follows, $H_0$: $\beta_1=\beta_2=\beta_3=0$ and the alternative hypothesis $H_1$: $\beta_1\neq\beta_2\neq\beta_3\neq0$. The null hypothesis is tested, using a LM-test regression. In fact, the asymptotic distribution obtained is chi-squared having3$h$ degrees of freedom. So, when nuisance parameters exist under the alternative hypothesis, a regression based on Taylor approximation expansion around the null hypothesis is employed.

The logistic smooth transition requires a suitable transition variable to be chosen amongst competing variables. The variable with the smallest p-value (this variable has the strongest test rejection), is then chosen as a transition variable. Sarantis (1992) confirms this and recommends that one should calculate the p-values for all F tests of different equations. The better LSTR model has the lowest p-value. Granger and Terasvirta (1993) warn that strict application of this sequence of tests is likely to result in wrong conclusions being made. This possibly arises from the higher order terms of the Taylor expansion used in deriving these tests being disregarded.

The linearity test results presented in Table 5 indicate that the inflation rate is the best transition variable. Our results reveal that inflation is selected as the transition variable on basis of the F2 statistic that has the lowest p-value in comparison to the F3 and F4. Therefore, switching between regimes is controlled by the inflation. According to the results in Table 4, LSTR1 is preferred to LSTR2. This is consistent with Petersen’s (2007) identification of a transition variable. Petersen (2007) identifies and uses the inflation rate as a threshold variable. However, unlike Petersen (2007) we added the interest rate smoothing variable in our model.

[18] LSTR1 represents one transition variable with one threshold value. LSTR2 represents transition variable with two thresholds.

**Table 5: Testing linearity against the STR results**

| | F | F4 | F3 | F2 | suggested model |
|---|---|---|---|---|---|
| **models without US real rates** | | | | | |
| Transition variable | | | | | |
| $i_{t-1}$ | $2.20 \times 10^{-5}$ | $3.55 \times 10^{-1}$ | $9.54 \times 10^{-1}$ | $3.28 \times 10^{-2}$ | Linear |
| $\pi_{t*}$ | $5.55 \times 10^{-4}$ | $6.60 \times 10^{-1}$ | $1.49 \times 10^{-1}$ | $3.15 \times 10^{-5}$ | LSTR1 |
| $y_t$ | $1.22 \times 10^{-3}$ | $1.73 \times 10^{-2}$ | $4.43 \times 10^{-1}$ | $2.17 \times 10^{-3}$ | LSTR1 |
| $rx_t$ | $2.49 \times 10^{-2}$ | $2.31 \times 10^{-1}$ | $7.14 \times 10^{-1}$ | $3.13 \times 10^{-3}$ | LSTR1 |
| **models with US real rates** | | | | | |
| Transition variable | | | | | |
| $i_{t-1}$ | $6.65 \times 10^{-3}$ | $2.30 \times 10^{-1}$ | $9.28 \times 10^{-1}$ | $2.11 \times 10^{-4}$ | LSTR1 |
| $\pi_{t*}$ | $1.09 \times 10^{-6}$ | $9.91 \times 10^{-3}$ | $2.16 \times 10^{-2}$ | $2.88 \times 10^{-5}$ | LSTR1 |
| $y_t$ | $3.04 \times 10^{-5}$ | $2.99 \times 10^{-3}$ | $5.47 \times 10^{-2}$ | $1.94 \times 10^{-3}$ | LSTR1 |
| $rx_t$ | $2.95 \times 10^{-2}$ | $9.29 \times 10^{-2}$ | $4.28 \times 10^{-1}$ | $2.57 \times 10^{-2}$ | LSTR1 |
| $i^f t$ | $5.31 \times 10^{-3}$ | $4.15 \times 10^{-1}$ | $8.64 \times 10^{-3}$ | $2.92 \times 10^{-2}$ | LSTR2 |

Note: This table presents the linearity test results against the LSTR nonlinearity. This table reports the results of the test of linearity against the LSTR nonlinearity. All numbers in this table are p-values associated with the test. All p-values are lower than 1 percent; hence, linearity is strongly rejected in all cases. F refers to the test of linearity against LSTR, whereas F2, F3 and F4 allow us to select the adequate LSTR model among LSTR with one threshold (LSTR1) and LSTR with two thresholds (LSTR2). $i_t$ =interest rate; $\pi_t$ =inflation rate; $y_t$ =output gap; $rx_t$ = real effective exchange rate and $i^f_t$ – foreign interest rate. Source: IFS Online Database

## 2.5 Results and Discussion

### 2.5.1 Estimation results of Linear Taylor rule

Table 6 presents the estimation results of linear Taylor rule specifications. The results of the simple Taylor rule [19]estimation are presented in column (I). The response coefficients are significantly different from zero at 5 percent with the exception of output gap, which enters the model negatively, implying that they are significant. These coefficients are less than one though they are significant violating the stability condition for the Taylor rule. These results are consistent with the findings of Baaziz et al. (2013). Furthermore, the model's explanatory power as measured by its $R^2$ is low at 0.094. This might reflect the omission of relevant variables in the simple Taylor rule, such as international dependencies in the interest rate

[19] Without allowing for either a forward looking behaviour of the central bank or interest rate smoothing

setting of central banks. The results show that the simple model fails to capture the reaction of the SARB to inflation rate. This is consistent with the findings of Castro (2011) for the case of ECB, which he argues that the ECB's monetary policy is not characterised by a basic linear Taylor rule.

In column (II) of Table 6, results of the augmented Taylor rule by the lagged interest rate are presented, which significantly and positively influences the actual monetary policy followed by the central bank. The coefficient of all estimated variables ( such as  inflation,  lagged interest rate ) except output gap have expected signs and are significant at 5 percent level. Overall, the inclusion of the lagged interest rate improves the fit of the model as shown by a higher $R^2$.

Column (III) of Table 6 presents the results of the linear Taylor rule augmented by both REER and lagged interest rate. The results show that inflation, lagged interest rate and REER coefficients are significant at the 1 percent level. The results for the linear interest rate rule which has been augmented by foreign interest rate[20], lagged interest rate and REER are presented in Column (IV) of Table 6 that shows a significant reaction of the SARB to REER, foreign interest rate and lagged interest rate. However, inflation and outputgap enter the model insignificantly. It appears the external influences captured by the US Treasury bill have some important role in the domestic interest rate setting which is consistent to the findings of Bruggermann and Riedel (2011) for the case of the Bank of England.

[20] As policy reactions are increasingly affected by the international environment as opposed to setting interest rates  according to national conditions

**Table 6: Estimates of the linear monetary rule**

| Parameters | (I) | (II) | (III) | (IV) |
|---|---|---|---|---|
| α | 0.076*** | -0.005 | -0.004 | -0.003 |
| | (0.008) | (0.003) | (0.003) | (0.003) |
| Ø | 0.284*** | 0.068*** | 0.070*** | 0.020 |
| | (0.087) | (0.023) | (0.022) | (0.029) |
| β | -0.004 | 0.001 | 0.001 | 0.001 |
| | (0.003) | (0.001) | (0.001) | (0.001) |
| ρ | | 1.004*** | 0.993*** | 0.982*** |
| | | (0.024) | (0.024) | (0.023) |
| ϑ | | | -0.021*** | -0.023*** |
| | | | (0.008) | (0.008) |
| ω | | | | 0.001*** |
| | | | | (0.000) |
| $R^2$ | 0.873 | 0.939 | 0.942 | 0.944 |
| DW statistic | 0.158 | 1.375 | 1.411 | 1.421 |
| N(no: of observations) | 130 | 130 | 130 | 130 |

Notes: α, ø, β, ρ, ϑ and ω refer to the constant, inflation, output gap, lagged interest rate, REER and the foreign interest rate respectively. Standard errors are in brackets following each regression coefficient. ***, **, * represent the 1 percent, 5 percent and 10 percent significance level respectively at which the null hypothesis is rejected, Source: IFS Online Database

### 2.5.2 Estimates of the linear and nonlinear monetary rule

Besides using the full sample period (1975Q1-2016Q1), we include a reduced sample starting in 2000Q1 as the inflation targeting period following Naraidoo and Paya (2012). This enables us to analyse the behaviour of the SARB pre and post inflation targeting period.

The results show that the SARB makes a drastic change in its interest rate decision, from a low interest rate regime to a high interest regime, when inflation goes beyond the threshold level of 6.5 percent,[21] which reveals the existence of two regimes. Thus, the nonlinear model presented in Table 7 reports the response of monetary policy rule to inflation, output gap, foreign interest rate and REER depending on whether inflation is above or below an estimated inflation threshold of 6.5 percent.

[21] However, this is well above South Africa's inflation target band of 3-6 percent.

The results of the estimated models presented in Table 7 shows that the parameters of the interest rate rule appear to change over time. For example, according to the nonlinear model, the SARB did respond to both inflation and output gap aggressively above the threshold level pre and post the inflation target period as the coefficients of inflation and output gap are larger in the upper regime compared to the lower regime though there are insignificant in the upper regime.

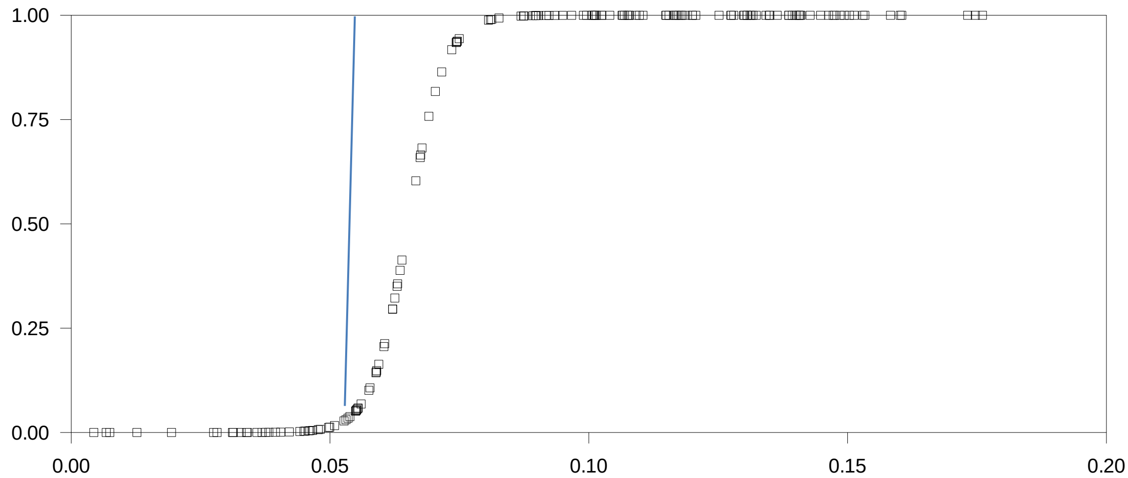
**Table 7: Model estimates**

| | Linear model | | Nonlinear model | |
|---|---|---|---|---|
| | 1975-2016 | 2000-2016 | 1975-2016 | 2000-2016 |
| Variable | ( I) | ( II) | (III) | ( IV) |
| | | | **Lower regime** | |
| Constant | 0.077*** | 0.036*** | 0.096*** | 0.064*** |
| | (0.008) | (0.005) | (0.009) | (0.005) |
| Inflation | 0.070 | 0.569*** | -0.742*** | -0.092 |
| | (0.114) | (0.076) | (0.263) | (0.115) |
| output gap | -0.006** | -0.019*** | -0.024** | -0.019*** |
| | (0.003) | (0.007) | (0.011) | (0.005) |
| real effective exchange rate | -0.083*** | 0.043*** | -0.104*** | 0.010 |
| | (0.030) | (0.016) | (0.031) | (0.019) |
| USs tbill | 0.003*** | 0.006*** | 0.003*** | 0.532*** |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| | | | **Upper regime** | |
| Inflation | | | 0.086 | 0.264 |
| | | | (0.304) | (0.343) |
| output gap | | | 0.017 | 0.004 |
| | | | (0.012) | (0.013) |
| Threshold | | | 0.065*** | 0.070*** |
| | | | (0.003) | (0.002) |
| speed of transition | | | 286.749 | 507.633 |
| DW stats | 0.173 | 0.481 | 0.322 | 0.937 |
| N(no: of observations) | 130 | 55 | 130 | 55 |
| $R^2$ | 0.886 | 0.972 | 0.378 | 0.820 |

Notes: Standard errors are in brackets following each regression coefficient. ***, **, * represent the 1 percent, 5 percent and 10 percent significance level respectively at which the null hypothesis is rejected, us tbill represents the US treasury bill rate. Source: IFS Online Database

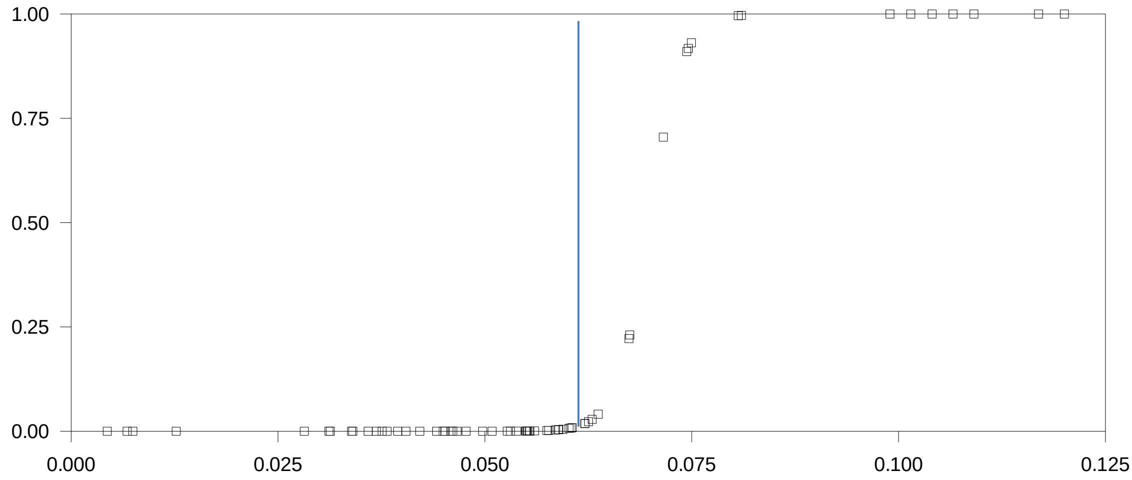
Almost all the variables namely, the inflation rate, output gap, foreign interest rate and real effective exchange enter significantly in the linear model during the inflation targeting period. However, inflation effect is lower than one, therefore failing to satisfy the taylor principle that a one percentage increase in inflation leads to more than one percentage increase in the real interest rate, this is consistent with the findings of Naraidoo and Paya(2012), Woglom(2003) and Naraidoo and Gupta(2010) in the case of South Africa. In the non-model only the output gap is insignificant though other variables enter significantly during the period before inflation targeting.

**Figure 4: Transition variable parameter (1975Q1-2016Q1)**




Note: the solid line denotes the threshold level .Source: IFS Online Database

**Figure 5: Transition variable parameter (2000Q1-2016Q1)**




Note: the solid line denotes the threshold level. Source: IFS Online Database

Figure 4 and 5 illustrates the smoothness of the adjustment parameter from one to regime to another for the whole sample and inflation targeting period respectively. The figures display a slow adjustment from one regime to another. Basically, this indicates the existence of a special regime that applies only to unusual economic conditions, in response to which the central bank change its usual policy conduct.

## 2.6 Conclusion

Using quarterly data from 1975 to 2016 to analyse the movement of the nominal short term interest rate for the South African Reserve Bank (SARB), this study reveals that the non-linear Taylor rule holds. These results conclude that SARB monetary policy behavior can be appropriately described by a nonlinear Taylor rule. Therefore, based on the whole sample period this study finds that there is a threshold level of inflation of 6.5 percent at which the behavior of the central bank changes.

Overall our results suggest that the nonlinear Taylor holds for the SARB's policy reaction function, which is in sharp contrast of previous findings that linear Taylor rule best describe the SARB's monetary behaviour. The results show that a nonlinear Taylor rule may be more appropriate to explain the behaviour of the monetary policy and thus the adoption of a nonlinear specification instead of the linear one would lead to a better fit of the South African Central Bank. The results of this paper have policy implications. The results suggest that policy makers in their decision making need to take into account uncertainties. Thus, the use of interest rate (either aggressively or not) to achieve price stability by policy makers should be informed by inflation regimes (high inflation or low regime) or economic cycles (i.e. boom or recession).

Further research should focus on including an extra nonlinear additive term on the nonlinear Taylor model to improve the results. Non- linear Taylor rules have opened up debates on the monetary policy conduct of central banks. The monetary policy in general has become central due to the recent financial crisis. It is therefore important to incorporate financial conditions in monetary policy rule in the light of current financial crisis.

# CHAPTER 3: DO FINANCIAL CONDITIONS PLAY A ROLE IN THE MONETARY POLICY RULE IN SOUTH AFRICA?

## 3.1 Introduction

This Chapter intends to examine the role of financial conditions in the determination of interest rate setting by the SARB given that since the global financial crisis; there has been more emphasis on financial stability across the world. As Guney (2016) points out, post the global financial crisis, several central banks across the globe have started to focus on financial stability. In addition, the analysis will focus on whether SARB has followed or adopted a nonlinear Taylor rule with or without financial condition as it is inappropriate for monetary authorities to employ a simple Taylor rule in context of uncertainties.

There are a few studies (i.e.by Kasai and Naraidoo, 2012) that have looked at nonlinear Taylor rules in the context of South Africa. The study by Kasai and Naraidoo (2012) takes into consideration the financial index[22] as an important variable in the determination of interest rates. However, this chapter differs from Kasai and Naraidoo (2012) as the transition from one regime to the other is controlled by inflation not output. Unlike Kasai and Naraidoo (2012) who are interested in understanding the South African Reserve Bank's (SARB) response of monetary policy to inflation during different business cycles(i.e recessions and booms), this chapter intends to determine whether monetary policy authorities pay close attention to financial stability when setting policy rates.

There has been debate on whether the traditional or original Taylor rule best describes the behaviour of central banks when they respond to uncertain economic events. For example, Naraidoo and Paya (2012) indicate that over the last couple of years, the general benchmark of monetary policy rules has been intensely debated as recent economic events such as the global economic crisis have led to the focus on the performance of certain assets (i.e. stock, house prices) and central banks have been concerned about maintaining financial stability.

Over the past years, most central banks in both developed and developing countries have focused on achieving price stability, which is regarded as their primary objective. A number of studies have been undertaken on interest rate functions. Research studies (e.g. by

[22] It is proxy for financial condition

Cukierman and Muscatelli (2008) reveal that monetary policy authorities have utilized short-term rate of interest as a policy instrument when minimising linear combinations of the quadratic deviations of inflation and of output from their respective targets (the inflation and the output gaps).

Other research studies (such as by Goodhart, 2006; Borio and Drehmann, 2009), reveal that the global financial crisis has presented new challenges for central bank authorities. In particular, the operationalization of issues related to financial stability for monetary-policy decision making. Thus, following the 2008 global financial crisis, policy makers, academics and market analysts realised the need to improve their understanding of financial conditions so as to achieve financial stability. In the context of South Africa, the central bank has emphasised its role towards ensuring maintenance and attainment of a stable financial system. Furthermore, the SARB seeks to achieve price stability which is its primary objective through inflation targeting framework. However, since the 2007/8 global crisis the SARB has placed too much emphasis on achieving and maintaining financial stability. Similarly, Baxa et al (2013) argue that the recent financial crisis has intensified the interest in exploring the interactions between monetary policy and financial stability.

There has been a debate on whether central banks should respond to financial instability without clear consensus being reached. For instance, Mishkin (2008) argues that it is difficult to identify asset price bubbles and in instances where they are identified, their response to interest rates is far from certain. Whereas, De Grauwe (2007) points out central banks cannot avoid taking more responsibilities beyond inflation targeting hence financial asset prices should be targeted as well. Recent economic events reveal that sudden and sharp swings in financial and credit markets can have a potentially large impact on the macroeconomic outlook. Such economic shocks may not be captured by simple linear rule due to the complexities in conducting monetary policy. Thus, a non-linear specifications of the Taylor rule could be better in explaining the monetary policy reaction functions of the central banks (e.g. Qin and Enders, 2008; Martin and Milas, 2004; Schaling, 2004) as central bank could have asymmetric preferences.

A nonlinear Taylor rule should better represent the monetary policy behaviour of the central bank in instances whereby monetary authorities are assigning different weights to negative and positive inflation and output gaps in its loss function. Current studies have begun to consider nonlinear models or asymmetries in the analysis of monetary policy. To the researchers' knowledge, only Martin & Milas (2004), Petersen (2007), Castro (2011), Kasai & Naraidoo (2012), and Naraidoo and Paya (2012) have seriously examined models that allow for a smooth transition from a state of high inflation to a state of low inflation (and vice-versa) in the context of the Taylor rule. The smooth transition regression models appear to provide a better framework to explain nonlinear policy behavior because they allow for endogenous regime switches compared to other model such as Markov-switching model. These models provide economic intuition to understand the nonlinear policy behavior of the central bank and they assist in terms of explaining why and when the central bank has changed its policy rule.

Previously, it was assumed that the monetary authorities' response to inflation and output is constant overtime whatever the state of economy (Kasai and Naraidoo, 2012). However, current debates (i.e. Walsh 2009) on the behaviour of central banks reveal that there are other additional objectives over and above inflation and output stabilization. Hence, in this chapter the augmented nonlinear Taylor rule that entails a regime switching model is employed, which allows for a smooth movement from one regime to another.

This Chapter contributes to recent debates on the conduct of central banks in event of economic shocks and to a larger body of literature focusing mainly on the role played by financial condition index in the interest rule setting by monetary authorities. To best of the researchers' knowledge, there is no study that has used both techniques in the case of South Africa. This study intends to determine if the results are not influenced by different techniques. Recent research (e.g. by Castro 2011) reveals that the central bank can have asymmetric preferences (i.e. it might assign different weights to expected negative and positive inflation and output gaps in its loss function).

The results of this study reveal that nonlinearities exist in the data and that the preferred model specifications are the threshold (TAR) regression and smooth transition regression (STR) where inflation is used as a transition variable. Therefore, inflation determines the changes of parameters in the model. Furthermore, the results reveal that the SARB takes into consideration information contained in some financial variables when deciding on interest rate, though it plays a less important role. Our results indicate that the dynamics of the interactions among monetary policy, financial markets and economic activity change considerably as the economy moves from one phase of the inflation regime to another and linear models cannot fully capture the nonlinear nature of those interactions.

Overall, the results provide enough evidence that the monetary policy followed by the South African Reserve Bank (SARB) can be described by a nonlinear Taylor rule in line with Castro 2011's findings on the European Central Bank. In addition, the results of this Chapter suggest that monetary authorities do take into consideration financial condition index when determining interest rates.

The remainder of the Chapter is organised as follows: Section 2 presents the brief review of the Taylor rule. Section 3 summarises the theoretical model. Section 4 describes the econometric methodology. Section 5 discusses the data. Section 6 presents the results. Section 7 presents robustness analysis. Section 8 summarises the main conclusions.

## 3.2 Literature Review

This section briefly reviews the literature on the traditional Taylor rule and goes further to discuss the non-linear Taylor rule highlighting the main contributions that motivate the analysis presented in this Chapter.

The Taylor rule stipulates how the central bank should adjust the nominal interest rates according to the output gap and inflation rate. The original Taylor rule assumes that the response of interest rates to economic conditions is linear and time invariant. However in practice, when central banks set interest rate, they take into account all readily available information. Hence, some researchers, for instance Clarida et al. (1998; 2000), propose the utilisation of a forward-looking type of Taylor rule by central banks so as to target expected variables as opposed to past or actual values. Thus, it permits central banks when undertaking their forecasts to take into account several relevant variables The authors show the advantages of using such an approach to analyse the policy behavior for central banks(i.e. the Federal Reserve Bank).

The original linear Taylor rule has been augmented in order to model and understand the conduct of monetary policy by central banks in several countries. For instance, Clarida et al (1998) has added the lagged interest term to model the interest rate behaviour. Guney (2016) argues that in more open economies exchange rate plays an important role to describe the state of the economy besides relying on output gap and inflation. In a similar vein, Svensson (2003) suggested an augmentation of the standard Taylor rule by adding exchange rate in a rule meant for a small open economy. Some studies, for example (Albulescu et al, 2013) indicate that the standard Taylor rule has been augment by adding financial, banking and external instability aggregate indicators. In addition Naraidoo and Paya (2012) point out that in last couple of years there has been intense debate on the suitability of the benchmark or traditional Taylor rule in the context of recent economic events that have turned attention of monetary authorities on the behaviour of certain assets prices (such as house prices, stock prices and exchange rate) and also as a result of the concern of central banks with regard to the maintenance of financial stability.

There are a few studies that mainly focus on the relationship between the monetary-policy stance and financial stability. However, they do not arrive at a consensus on whether a monetary-policy rule should include some measure of financial stability (Baxa et al 2013). Since the global financial crisis of 2007, concerns have been raised pertaining to financial instability. There has been considerable debate as to whether the central banks should focus on financial stability in addition the common objectives such as price stability and output stabilisation. However until recently, there has been no consensus on this intensively debated issue. Kafer (2014) points out that since the financial crisis,[23] the traditional policy rules might not be sufficient if the central banks place more emphasis on financial stability than what is currently represented in inflation and output.

Castro (2011) analyses whether the central banks also target financial variables and assets prices information, in addition to inflation and output gap targets. Furthermore, he analyzes whether the central banks follow a linear or non-linear Taylor rule. His study uses monthly data for three central banks namely, the United States Federal Reserve (Fed), the Bank of England (BOE) and the European Central Bank (ECB). Using a smooth transition regression model to estimate non linearities in the Taylor rule, the results show that only the Federal Reserve of the United States appears to have followed a linear Taylor rule. On the contrary, the Bank of England and the European Central Bank follow a non-linear Taylor rule.

[23] US subprime crisis and European sovereign debt crisis

Asymmetries can be characterized through a nonlinear macroeconomic model, or nonlinear central bank preferences. Thus, one can unravel asymmetries using either a linear or nonlinear policy rule. As a result, you can characterize asymmetry using a linear rule, for example you may find that a central bank allocates a larger weight to output contractions/recessions as compared to output expansions/booms. That is there is a greater fear for recessions as compared to booms. Such has been evident in an analysis by Surico (2007).

## 3.3 Theoretical model

The theoretical model used in this study is based on the approach utilized by Surico (2007). The model uses the new-Keynesian structure assessed by Clarida et al. (1999) and allows the monetary authority to have asymmetric preferences with regard to its objectives or targets. Specifically, the monetary authority is allowed to be more averse to negative deviations of the actual output from the potential output and to positive deviations of the inflation rate from the inflation target. The presence of these types of asymmetries constitutes the explanation for possible nonlinear responses of the monetary policy interest rate to inflation and output fluctuations.

### 3.31 Economic structure

Following Clarida et al (1999), this study characterizes the behaviour of the economy using a stylized forward looking new Keynesian and sticky prices framework (Cukierman and Muscatelli (2008) by the following equations:

$$x_t = -\varphi(i_t - E_t\pi_{t+1}) + E_t x_{t+1} + g_t, \quad (1)$$

$$\pi_t = \theta x_t + \beta E_t \pi_{t+1} + u_t, \quad (2)$$

Where $x_t$ is the output gap, $\pi_t$ is the inflation rate , $E_t x_{t+1}$ and $E_t\pi_{t+1}$ are the expected values for the output gap and for inflation conditional on the information available in period $t$, $i_t$ is the nominal interest rate, $g_t$ is the demand shock, $u_t$ is a cost shock and $\varphi$, $\theta$ and

$\beta$ are positive parameters[24]. According to Cukierman and Muscatelli (2008) the innovations $g_t$ and $u_t$ are mutually and temporally independent white noise processes whose reallisations are not forecastable on the basis of information available to the Central Bank prior to period $t$.

Over the last decade, literature reveals Taylor rules or reaction functions have been estimated on the basis of short-term interest rate as a linear function of the (currently expected) future values of the inflation and of the output gaps(Cukierman and Muscatelli,2008). These linear reaction functions are obtained when the expected value of a loss function that is quadratic in the inflation and output gaps is minimized, subject to a linear economic structure.

### 3.3.2 Policy objectives

The central bank makes monetary policy decisions before the realization of the economic shocks $g_t$ and $u_t$ and before variables within the system are determined (Surico 2007). According to Surico (2007), the central bank is faced with a challenge of choosing the interest rate at the beginning of period $t$ conditional upon the information available at the end of the previous period. Thus, the goal of the central bank is to minimize:

$$E_{t-1} \sum_{\tau=0}^{\infty} \delta^{\tau} \quad L_{t+\tau} \qquad (3)$$

Subject to equations (1) and (2), where $\delta$ is the discount factor and $L$ stands for the period loss function.

Following Surico (2007), the monetary authority's loss function at time $t$, $L_t$, is written as follows:

$$L_t = \frac{e^{[\alpha(\pi_t-\pi^*)]}-\alpha(\pi_t-\pi^*)-1}{\alpha^2} + \lambda \left[\frac{\boldsymbol{e^{(\gamma x_t)}-\gamma x_t-1}}{\boldsymbol{\gamma^2}}\right] + \frac{\mu}{2}(i_{\boldsymbol{t}} - i^*)^{\mathbf{2}} \qquad \mathbf{(4)}$$

Where $\lambda$ and $\mu$ represent the central bank's aversion towards output fluctuations around potential and towards interest rate level fluctuations around the target $i^*$. The policy preference towards inflation stabilization is normalized to one and therefore $\lambda$ and $\mu$ are

[24] See, for example Clarida et al (1999) for detailed step by- step derivations

expressed in relative terms. The inflation target is $\pi^*$, yet the parameters $\alpha$ and $\gamma$ capture any asymmetry in the objective function of the monetary authorities.

The linex specification (4) was proposed by Varian (1974) and Zellner (1986) taking into consideration the Bayesian econometric analysis, while Nobay and Peel (2003) were the pioneers of its introduction in the optimal monetary policy studies. According to Surico (2007), this functional form differs from the quadratic objective in that policy makers are allowed to treat differently positive and negative deviations of inflation and output from the target.

Surico (2007) suggests that a negative value of $\gamma$ shows that ceteris paribus, output contraction relative to the potential level is weighted more severely than an output expansion of the same magnitude. Thus, whenever $x_t < 0$ the exponential component of the loss function (4) dominates the linear component whereas the opposite is observed for $x_t > 0$. In the case of $\alpha$, its value will be positive if monetary authorities are paying particular attention to overshooting $\pi$* as opposed to undershooting. This implies that low inflation relative to the target is less costly than high inflation. However, it should be noted that the linex specification (4) does not prevent $\alpha$, from being negative, which corresponds to a case in which the risk of deflation outweighs the risk of inflation.

As a special case, the linex function nests quadratic form in which both $\alpha$ and $\gamma$ tend towards zero,(4) is reduced to the symmetric parameterization:

$$L_t = \frac{1}{2}\left[(\pi_t - \pi^*)^2 + \lambda x_t^2 + \mu (i_t - i^*)^2\right] \qquad (5)$$

Following Surico (2007), the optimization problem (3) is solved under discretion, since no endogenous state variable enters the model, thus the intertemporal problem reduces to a sequence of static optimization problems. This entails choosing the instrument $i_t$ in each period so as to minimize

$$E_{t-1}\left(\frac{e^{[\alpha(\pi_t-\pi^*)]} - \alpha(\pi_t - \pi^*) - 1}{\alpha^2}\right) + \lambda E_{t-1}\left[\frac{e^{(\gamma x_t)} - \gamma x_t - 1}{\gamma^2}\right] + \frac{\mu}{2}(i_t - i^*)^2 + F_t$$

subject to $\pi_t = kx_t + f_t$ and $x_t = -\varphi i_t + g_t$, where $F_t \equiv E_{t-1}\sum_{\tau=1}^{\infty}\delta^{\tau}L_{t+\tau}$, $f_t \equiv \theta E_t\pi_{t+1} + \varepsilon_t^s$ and $g_t \equiv E_t x_{t+1} + \varphi E_t\pi_{t+1} + \varepsilon_t^d$ are taken as given reflecting the fact that the monetary authorities cannot directly manipulate expectations. Hence, the first order condition is presented as follows:

$$-E_{t-1}\left(\frac{e^{[\alpha(\pi_t-\pi^*)]}-1}{\alpha}\right)k\varphi - E_{t-1}\left(\frac{e^{(\gamma x_t)}-1}{\gamma}\right)\lambda\varphi + \mu(i_t - i^*) = 0 \tag{6}$$

This describes the optimal, potentially nonlinear response function of the central bank to shocks within the economy. Thus equation (6) nests the linear form as a special case and when both $\gamma$ and $\alpha$ tend towards zero, Surico (2007) shows that the reduced reactions function: becomes an implicit interest rate rule:

$$-k\varphi E_{t-1}(\pi_t - \pi^*) - \lambda\varphi E_{t-1}(x_t) + \mu(i_t - i^*) = 0 \tag{7}$$

This feature is attractive as it produces a joint restriction on policy makers' preferences that can be formally tested for. The parameters a and g are indeed crucial for the analysis of optimal monetary policy not only because they introduce an asymmetric motive in the central bank objective function but also because, more importantly, they make nonlinear an otherwise conventional policy rule. This suggests that the hypothesis of symmetric central bank preferences can simply be tested by evaluating the functional form of the interest rate reaction function as the latter would correspond to testing whether the structural parameters a and g are significantly different from zero.

## 3.4 Estimation of Taylor rules

### 3.4.1 Linear Taylor rule

The original Taylor rule proposed by Taylor (1993) could be presented as follows:

$$i_t^* = r + \pi^* + \alpha(\pi_t - \pi^*) + \beta x_t \tag{8}$$

where $i_t^*$ is the desired short term interest rate, $r$ is the long run equilibrium real interest rate, $\pi_t$ is the inflation rate, $\pi^*$ is the target inflation rate and $x_t$ is the output gap[25]. Thus $\alpha$ indicates the sensitivity of interest rate policy to deviations in inflation from the target and parameter $\beta$ indicates the sensitivity of interest rate to the output gap. However, according to Castro (2011), when the economy reaches equilibrium, the deviation of inflation and output

[25] The deviation of real GDP from potential output

from their target values is zero. Ultimately, the target nominal interest rate ($i_t^*$) becomes the sum of the equilibrium real rate ($r$ ) plus the target value of inflation. The coefficients of inflation rate and output gap are expected to have positive signs. If inflation rate or output gap increases the central bank will respond by raising interest rate.

Bec et al (2000) note that the nominal interest rates can be regarded as automatic stabilizers as they enable the central bank to meet its target levels. Furthermore, the Taylor rule is useful as it provides an analytical framework which helps central banks in their decision making process. However, Taylor (1993) cautions central banks not to blindly implement the Taylor rule but to use their discretion in applying it, depending on the different situations that prevail. It appears that in practice, central banks target expected inflation as opposed to past or current inflation (Castor 2011). Hence, Clarida et al (1998, 2000) propose the utilisation of the forward looking Taylor rule that permits monetary authorities to take into consideration several variables when forming inflation forecasts. In line with Clarida et al (1998, 2000) the central bank's target interest rate ($i_t^*$) is expressed as follows;

$$i_t^* = \omega + \alpha\left(E_t\left[\pi_{t+p}\middle|\Omega_t\right] - \pi^*\right) + \beta E_t\left[x_{t+p}\middle|\Omega_t\right], \tag{9}$$

where $= r + \pi^*$ , $E_t\left[\pi_{t+p}\middle|\Omega_t\right]$ and $E_t\left[x_{t+p}\middle|\Omega_t\right]$ are the inflation rate and output gap expected to materialize in period $t + p$ and $t + p$ given all the information available.

In addition, in reality the central bank adjusts interest rates gradually such that the actual rate converges to the desired rate through a partial adjustment mechanism in line with Clarida et al (1998, 2000):

$$i_t = pi_{t-1} + (1 - \rho)i_t^* \tag{10}$$

Inserting equation (10) into 9 and adding an exogenous interest rate yields the following:

$$i_t = (1 - \rho)\left\{\omega + \alpha\left(E_t\left[\pi_{t+p}\middle|\Omega_t\right] - \pi^*\right) + \beta E_t\left[x_{t+p}\middle|\Omega_t\right]\right\} + \rho i_{t-1} + \mu_t \tag{11}$$

Following Cukierman and Muscatelli (2008), this study adds and subtracts $\alpha E_t[\pi_{t+p}|\Omega_t]$ and $\beta E_t[x_{t+p}|\Omega_t]$

and rearranging:

$$i_t = (1-\rho)\{\widetilde{\omega} + \alpha\pi_{t+p} + \beta x_{t+p}\} + \rho i_{t-1} + \varepsilon_t \quad (12)$$

where $\widetilde{\omega} = \omega - \alpha\pi^*$ and the error term, $\varepsilon_t$, is linear combination of the forecast errors of inflation and of the output gap, and of the interest rate control error.

The original Taylor rule fails to incorporate the effects of the exchange rate which plays an important role in economic development. Svensson (2003) suggests the extension of the traditional Taylor rule by adding the exchange rate to the model designed for small open economies.

The model becomes:

$$i_t = (1-\rho)\{\widetilde{\omega} + \alpha\pi_{t+p} + \beta x_{t+p} + \theta q_{t+p}\} + \rho i_{t-1} + \varepsilon_t \quad (13)$$

where θ and $q_{t+p}$ represent the coefficient of reaction of the monetary authorities to a change in exchange rate and proxy for exchange rate respectively.

This study has adds the financial conditions index [26]to the traditional rule to take into account other variables that might influence the interest rate setting by monetary policy authorities (Castro, 2011). Thus, the model can be expressed as follows:

$$i_t = (1-\rho)\{\widetilde{\omega} + \alpha\pi_{t+p} + \beta x_{t+p} + \theta q_{t+p} + \vartheta f_{t+p}\} + \rho i_{t-1} + \varepsilon_t \quad (14)$$

Where $f_{t+p}$ is the financial condition index.

[26] This study undertook a correlation test between the change in nominal effective exchange rate and the financial condition index and the result show a negative correlation of a small magnitude(-0.394)

Following Castro (2011), in order to estimate equation (14), this study considers a reduced form:

$$i_t = \emptyset_0 + \emptyset_1 \pi_{t+p} + \emptyset_2 x_{t+p} + \sigma q_{t+p} + \delta f_{t+p} + \rho i_{t-1} + \varepsilon_t \qquad (15)$$

where new vector of parameters are related to the former as follows:

$$(\emptyset_0, \emptyset_1, \emptyset_2, \sigma, \varphi)' = (\omega, \alpha, \beta, \theta, \vartheta)'$$

Thus, given the estimates of the parameters obtained from (15), the implied estimates of $\omega, \alpha, \beta, \theta \ and \ \vartheta$ can be recovered and their respective standard errors.

### 3.4.2 Nonlinear Taylor rule

The augmented monetary policy rule given by equation (15) assumes that monetary authorities respond symmetrically to inflation rate, real (or nominal) exchange and financial conditions deviations from their targeted levels. However, this does not apply in reality. Many recent studies (e.g. Castro 2011 and Baaziz et al (2013) argue that the responses of monetary authorities are asymmetric and change with economic conditions reflecting the various business cycles or inflation regimes

Nonlinearities in the Taylor rule can arise in various ways. For instance, Taylor and Davradakis (2006) point out that they may result from an irregularity in the central bank's preferences or a nonlinear macroeconomic structure of the economy. Consequently, it is inappropriate to use the simple linear Taylor rule when the central banks preferences are asymmetric. Furthermore, Castro (2011) argues that a nonlinear Taylor rule is appropriate to enlighten the behavior of monetary policy when the central bank is assigning different weights to negative and positive inflation and output gaps in its loss function.

To analyse the behaviour of the SARB in the context of uncertainties, this study employs two techniques, namely: the smooth transition regression model (STR) and threshold regression model (TAR). As such, uncertainties may not be captured by simple linear rule due to the complexities in conducting monetary policy. In addition, this study seeks to determine if the results are not influenced by different techniques. The smooth transition regression model allows an economic indicator to switch between two distinct regimes smoothly rather than a sudden jump from one to the other. The threshold model can be regarded as an extension of autoregressive models, allowing for the parameters changing in the model according to the value of an exogenous threshold variable. Compared to smooth transition regression models, the threshold model can better capture abrupt or aggressive adjustments of interest rates in response to inflation or any other explanatory variable entering the model.

### 3.4.2.1 Smooth transition regression model

Smooth transition models (STR) allow parameters to adjust slowly from one regime to another capturing the smoothness of regime switching in monetary policy reaction function. Following Terasvirta (1993, 1996), STR model can be defined as follows for the nonlinear Taylor rules:

$$i_t = \alpha' z_t + \delta' z_t G(\gamma, c, s_t) + \varepsilon_t, \tag{16}$$

where $z_t$ denotes the vector of explanatory variables, $i_{t-1}$, $\pi_t$ and $x_t$. Vectors $\acute{\varepsilon}$ and $\gamma$ include the parameters vectors in the linear and nonlinear parts of the equation respectively. The disturbance term $\varepsilon_t$ is assumed to be $iid$[27] with zero mean and constant variance, $u_t \sim iid(0, \sigma^2)$.

The transition function $G(\gamma, c, s_t)$ is continuous and bounded between zero and one and is a function of the transition variable $s_t$. The transition variable moves towards negative infinity, the transition function gets closer to zero. As the transition variables approaches positive infinity, the transition function gets closer to one. The transition function increases monotonically as a function of $s_t$ and the slope parameter $\gamma$ indicates the smoothness of the transition from one to another and $c$ is the location parameter that determines where the transition occurs.

[27] Independent and identically distributed random variable.

The transition function can be written in two ways; the logistic smooth regression model and the exponential smooth transition model. A logistic STR model has the following transition function:

$$G(\gamma, c, s_t) = [1 + exp\{-\gamma(s_t - c)\}]^{-1}, \quad \gamma > 0 \qquad (17)$$

This function is monotonically increasing function of transition variable $s_t$, the slope parameter $\gamma$ indicates how smoothly the transition occurs between regimes, yet $c$ is the location parameter that determines where the transition occurs.

The exponential STR model (ESTR) has the following transition function:

$$G(\gamma, c, s_t) = 1 - exp\,[-\gamma(s_t - c)^2] \qquad \gamma > 0, \qquad (18)$$

This corresponds to the particular case of the LSTR2 model where $c_1 = c_2$. Thus, the transition function is symmetric. This specification enables us to capture the behaviour of monetary policy in the extreme regimes (when central bank define their policies according to economic, financial and commodities variables) as well in the central regime for which monetary authorities are more independent. Even though several tests enable the choice between exponential and logistic models, the first specification is invariably used for financial data than logistic one.

### 3.4.2.2 Threshold Model

This analysis also considered the Threshold Autoregressive (TAR) model that was originally formulated by Tong (1978) and was recently modified by Hansen (1999; 2000). Thus, to check the existence of the inflation threshold effect, the following equation was used:

$y_t = \vartheta_1' x_t + u_{1t}$ , $\quad q_t \leq \gamma$..........................................................................................(22)

$y_t = \vartheta_2' x_t + u_{2t}$ , $\quad q_t > \gamma$.. (23)

where $q_t$ represent the threshold variable, divides observed values in two regimes or classes (Hansen 1999) on the basis of whether the threshold variable is larger or smaller than the

threshold value $\gamma$ . $y_t$ and $x_t$ denote the dependent variable and a vector of control variables (interest rate, inflation rate, output growth , change in nominal effective exchange, financial condition index rate) . $u_{it}$ represents an error term. Since the threshold value is an unknown parameter, it cannot be estimated using a simple OLS (Munir and Mansur (2009)). Rather, it should be estimated jointly with other parameter of the model (Tsionas and Christopoulos (2003)). Notably, Munir and Mansur (2009) point out that the model estimates equation (22) if the threshold variable is smaller than the threshold parameter. In the same way, if the threshold variable is greater than the threshold parameter, the model estimates equation (23).
A binary variable could be defined as follows; $d_t(\gamma) = \{q_t \leq \gamma\}$ where $\{.\}$ is the indicator function, with $d = 1$ if $q_t \leq \gamma$ occurs or $d = 0$ otherwise, and setting $x_t(\gamma) = x_t d_t(\gamma)$, thus equation (22) and (23) can be written a single equation as follows:

$$y_t = \vartheta' x_t + \delta' x_t(\gamma) + u_t \tag{24}$$

where $\vartheta = \vartheta_2, \delta = \vartheta_1 - \vartheta_{2,}$ and $\vartheta, \delta, and\, \gamma$ are the regression parameters to be estimated. Thus, the sum of squares errors as a result of estimating the regression parameters is presented as follows:

$$S_1(\gamma) = e_t{}^{\wedge}(\gamma)' e_t{}^{\wedge}(\gamma) \tag{25}$$

Following Chan and Hansen's arguments (see Chan (1993) and Hansen (2000)), the threshold value is hereby estimated using OLS. Thus, the sum of squared residuals are minimised as function of the expected threshold value. Hence the optimal threshold level value is presented as follows;

$$\gamma^{\wedge} = argmin S_1(\gamma) \tag{26}$$

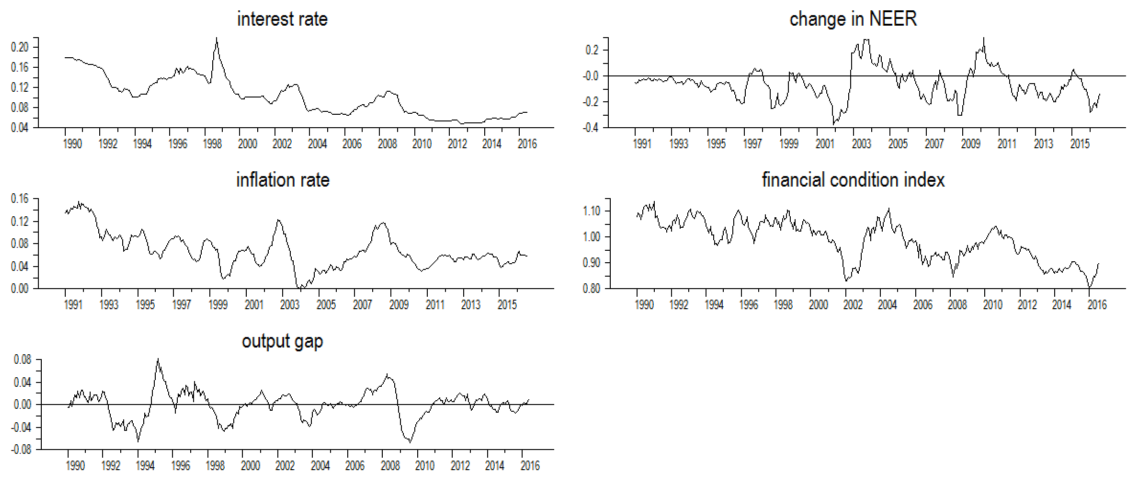
Conditional on $\gamma^{\wedge}$, the regression equation is linear in $\vartheta$ and $\delta'$, yielding the conditional OLS estimates of $\vartheta^{\wedge}(\gamma)$ and $\delta^{\wedge}(\gamma)$ by regression of dependent variable on control variables
Hansen (1999) argues that is important to determine whether there is a threshold effect or not. Thus, the null hypothesis of no threshold effect ($H_0: \beta_1 = \beta_2$ ) is tested against an alternative hypothesis where threshold effect is present ($H_1: \beta_1 \neq \beta_2$).

## 3.5 The Data

This study uses monthly (M) data, mostly sourced from the South African Reserve Bank (SARB) and Quantec database. The sample covers the period from 1990M1 to 2016M8. The following variables have been used namely, nominal interest rate, output, inflation rate, nominal effective exchange rate (NEER), real effective exchange rate (REER), and financial index. Different measures of exchange rate namely, NEER and REER are used in different estimations. The 3-month Treasury bill rate measures the nominal interest rate. The Inflation rate is measured by the annual change in consumer price index (CPI). The manufacturing production growth is used as proxy for output in this study. The output gap is derived from the logarithm of manufacturing production growth using the Hodrick- Prescott (HP) filter. Output gap captures the economic behaviour (Castro 2011). Following Castro (2011), the financial conditions index has been utilised to capture all the important economic information found in financial variables. Central banks can use a financial condition index (weighted index) to acquire particular economic relevant information rather than targeting particular asset prices or financial variable (Castro 2011).

Movements of all variables over time are illustrated in Figure 6. As shown in Figure 6, movements in inflation are closely mirrored by the interest rate, the dynamics, of which closely follow those of the inflation rate. Inflation is on a downward trajectory for the period before 2001. It appears that this period of declining inflation was not only experienced in South Africa, but also in other developed and emerging market economies, even those that had not adopted inflation targeting framework. During 2001 and 2007, high levels of inflation were recorded which could be attributed to exchange rate shocks. The rand depreciated in 2001 following the implementation of changes to the foreign exchange market system by monetary authorities (SARB). The global financial and economic crisis that occurred in 2007 led to the depreciation of the rand. The change in nominal effective exchange rate and financial index display some volatility over the period.

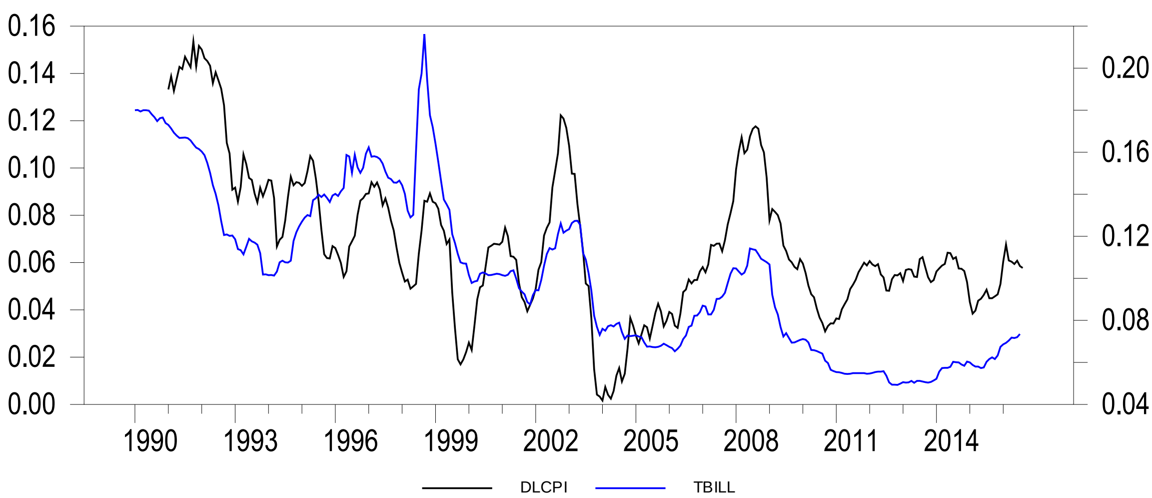
**Figure 6: Plots of main variables**




Source: SARB and Quantec database

South Africa, like other countries, has been exposed to global inflation movements and policy trends. Figure 7 illustrates the link between inflation rates and interest rates from 1990 to 2015. The movements in inflation are closely mirrored by interest rates, thus increases in inflation rate is closely followed by interest rate hikes or increase. Since 1990 inflation has been generally downward trending (as is global inflation), although there have been significant spikes during 2001 and late 2007.

**Figure 7: Link between inflation and interest rate**




Notes: dlcpi, tbill represent inflation and interest rate respectively. Source: SARB and Quantec database

Table 8 below illustrates the descriptive statistics of all variables, in particular the mean, standard deviation, minimum and maximum values, skewness, kurtosis, jarque bera. The financial condition index has the highest standard deviation value indicating that it is the most volatile variable with both the minimum and maximum growth rate exceeding 65 per cent. All the three exchange rate measures show that the exchange rates deviate from their means by 15-21 per cent, which is higher than deviations of inflation, expected inflation and interest rates. The output gap has shown less variability and the average represents close to 0 per cent over the period under study and the mean inflation rate is 6.8 per cent. The Jarque-Bera test for normality rejects the assumption of normality for all variables in the study.

**Table 8: Descriptive statistics**

| | Tbill | dlneer | Dlcpi | output gap | Fci |
|---|---|---|---|---|---|
| Mean | 10.111 | -0.052 | 0.068 | 0.000 | 98.931 |
| Median | 10.160 | -0.052 | 0.062 | 0.002 | 100.117 |
| Maximum | 21.620 | 0.288 | 0.154 | 0.131 | 113.414 |
| Minimum | 4.930 | -0.375 | 0.002 | -0.096 | 83.229 |
| Std. Dev. | 3.724 | 0.121 | 0.032 | 0.027 | 7.100 |
| Skewness | 0.437 | 0.283 | 0.563 | -0.195 | -0.342 |
| Kurtosis | 2.309 | 3.488 | 3.170 | 6.176 | 2.067 |
| Jarque-Bera | 15.273 | 6.873 | 15.933 | 125.822 | 16.459 |
| Probability | 0.000 | 0.032 | 0.000 | 0.000 | 0.000 |

Notes: tbill, dlneer, dlcpi, output gap and fci represent interest rate, change in nominal effective exchange rate inflation, output gap and financial condition index respectively. Source: SARB and Quantec database

It is important to check for the stationarity of the considered time series to deal with the problem of spurious regression. Various unit roots tests are shown in Table 9 such as the Augmented Dickey Fuller (ADF), Kwiatkowski-Phillips-Schmidt-Shin (KPSS), and Phillips-Person test (PP). The ADF and PP tests reject the null hypothesis of unit root for nominal interest rate, nominal effective exchange rate and financial conditions index at the 1 percent significance level. Consequently, inflation rate and output gap series are stationary. However, the KPSS test cannot reject the null hypothesis that the variables being tested are stationary. Therefore, there is need to difference the variable when estimating.

**Table 9: Unit root test**

| Variables | ADF | PP | KPSS |
|---|---|---|---|
| DLCPI | -3.135** | -3.067** | 0.786*** |
| TBILL | -2.204 | -2.036 | 1.661*** |
| OUTPUT GAP | -4.364*** | -8.947*** | 0.024*** |
| LNEER | -0.779 | -0.611 | 1.932*** |
| FCI | -2.469 | -2.258 | 1.430*** |

Notes: dlcpi, tbill, output gap, lneer and fci represent inflation, interest rate, output gap, nominal effective exchange rate and financial condition index respectively. Source: SARB and Quantec database

## 3.6 Empirical Results

The models require the identification of a transition variable. This variable will indicate a point where a change from a low regime to a high regime takes place. This point of inflection is referred to as the threshold level. In this Chapter, we have used the grid search method to identify threshold levels as well as the speed of adjustment of the transition variable. For both the threshold model and smooth transition model inflation has been selected as the transition variable on basis the lowest p-value. Thus, inflation controls the switching between regimes.

The analysis begins with the estimation of the linear augmented Taylor rule given by equation (15). Thereafter, we estimate the nonlinear models(TAR and STR) and a comparison of these model is undertaken which is useful as it can indicate if there exist substantial differences in the estimates of the policy rule parameters of the three models which can result in wrong inferences about the objectives of the monetary policy authorities.

### 3.6.1 Linear and Threshold estimation results

Table 10 reports the parameter estimates of the linear model and the estimates of the threshold effect. The results indicate that the coefficient of inflation is statistically significant at all conventional significance and expected signs of coefficients of inflation (positive) and output gap are obtained in line with other studies. This shows that to a larger extent the estimated model seems to be reasonable though output gap is insignificant. This implies that perhaps excess demand pressures are absent. Our results are consistent with Castro (2011) whose findings support evidence of a nonlinear Taylor rule for the European Central Bank, as we find that the central bank reacts to financial conditions (see Table 10) as it has a significant coefficient. We find that some of the variables are significant at the conventional levels, for instance the interest rate smoothing term enters both the linear and threshold model significant at 1 percent level.

**Table 10: Estimates of linear and threshold autoregressive Taylor rules**

| | **LINEAR** | | **THRESHOLD** | | | |
|---|---|---|---|---|---|---|
| | | | **Upper regime** | | **Lower regime** | |
| **Parameter** | (I) | (II) | (III) | (IV) | (V) | (VI) |
| **Constant** | -0.005 | -0.283** | -0.214*** | 0.001 | -0.314*** | -0.028*** |
| | (0.006) | (0.018) | (0.025) | (0.007) | (0.033) | (0.009) |
| **Inflation** | 0.001 | 0.567*** | 0.392*** | 0.007 | 0.126*** | 0.064*** |
| | (0.011) | (0.038) | (0.063) | (0.016) | (0.072) | (0.029) |
| **output gap** | 0.043*** | 0.103*** | 0.160*** | 0.046*** | -0.153 | 0.013 |
| | (0.010) | (0.043) | (0.047) | (0.011) | (0.103) | (0.023) |
| **Dlneer** | -0.008*** | -0.095** | -0.074*** | -0.003 | -0.130*** | -0.016*** |
| | (0.003) | (0.011) | (0.016) | (0.004) | (0.017) | (0.004) |
| **financial index** | 0.007 | 0.344*** | 0.296*** | 0.004 | 0.377*** | 0.026*** |
| | (0.006) | (0.019) | (0.025) | (0.008) | (0.031) | (0.010) |
| **tbill(-1)** | 0.975*** | | | 0.953*** | | 0.995*** |
| | (0.013) | | | (0.019) | | (0.019) |
| **threshold** | | | 0.062 | 0.062 | 0.062 | 0.062 |
| **log-likelihood** | | | 384.648 | 603.902 | 373.622 | 590.310 |
| **$R^2$** | 0.986 | 0.727 | 0.595 | 0.976 | 0.525 | 0.977 |
| **N(no: of observations)** | 296 | 296 | 296 | 296 | 296 | 296 |

Notes: Standard errors are in brackets following each regression coefficient. ***, **, * indicate the statistical significance and the rejection of null hypothesis at 1 percent, 5 percent and 10 percent. tbill (-1) represents the lagged interest rate, dlneer represents change in nominal exchange rate, threshold represents threshold estimate Column 1, 4, 6 presents estimates with lagged interest included in the model. Source: SARB and Quantec database

### 3.6.2 Smooth transition results

Table 11 presents the results of the Taylor rule estimates (both linear and nonlinear model). In the case of the linear model, inflation, financial index effects are statistically insignificant though the output gap and exchange rate effects are statistically significant. The inflation effect in both the linear model and nonlinear model fails to satisfy the Taylor principle. The principle says that nominal interest rate should rise more than one to one increase in inflation rate. Several research studies such as Naraidoo and Gupta (2010), Woglom (2003) reveal similar results of the inflation effect being lower than one in the case of South Africa. This reveals that perhaps the accommodative behaviour of the central bank in using interest rate in response to inflation shocks.

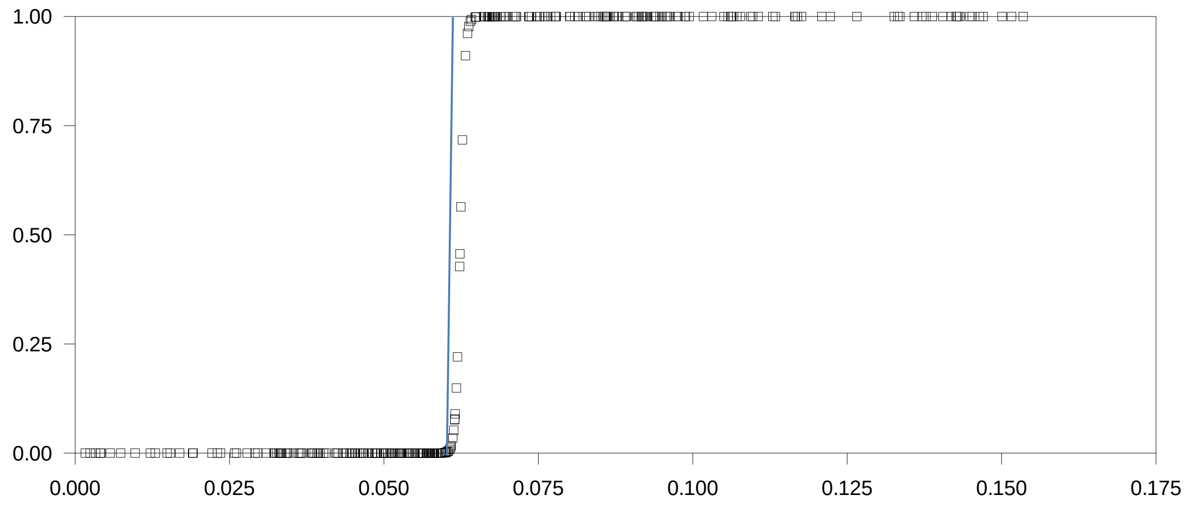
**Table 11: Estimated model results**

| Variable | Linear model | | Nonlinear model | |
|---|---|---|---|---|
| | (I) | (II) | (III) | (IV) |
| | | | Lower regime | |
| **Constant** | 0.001 | -0.005 | -0.251*** | -0.346*** |
| | (0.001) | (0.006) | (0.025) | (0.022) |
| **Inflation** | -0.003 | 0.001 | 0.357*** | 0.794*** |
| | (0.011) | (0.011) | (0.108) | (0.066) |
| **output gap** | 0.041*** | 0.043*** | 0.106*** | 0.082*** |
| | (0.010) | (0.010) | (0.032) | (0.036) |
| **Dlneer** | -0.007*** | -0.008*** | -0.086*** | -0.087*** |
| | (0.002) | (0.003) | (0.013) | (0.013) |
| **financial index** | | 0.007 | 0.318*** | 0.398*** |
| | | (0.006) | (0.023) | (0.021) |
| **tbill(-1)** | 0.986*** | 0.975*** | | |
| | (0.009) | (0.013) | | |
| | | | Upper regime | |
| **Inflation** | | | 0.020 | -0.086 |
| | | | (0.129) | (0.125) |
| **financial index** | | | | -0.168 |
| | | | | (0.033) |
| **Threshold** | | | 0.062*** | 0.089*** |
| | | | (0.001) | (0.002) |
| **speed of transition** | | | 1414.371 | 891.595 |
| **DW stats** | 1.197 | 1.183 | 0.120 | 0.171 |
| **N(no: of observations)** | 296 | 296 | 296 | 296 |
| **$R^2$** | 0.986 | 0.986 | 0.745 | 0.759 |
| **Log-likehood** | | | 754.195 | 762.663 |

Notes: Standard errors are in brackets following each regression coefficient. ***, **, * indicate the statistical significance and the rejection of null hypothesis at 1 percent, 5 percent and 10 percent. Tbill (-1) represents the lagged interest rate, dlneer represents change in nominal exchange rate, threshold represents threshold estimate. Source: SARB and Quantec database

The estimated results of the specifications in Table 11 indicate the existence of two regimes (high and low inflation regimes). Thus the results show the effects of inflation, outputgap, financial index and exchange rate on interest rates in a high or low inflation regime. Inflation is selected as the threshold variable due to the weight that Reserve Bank places on it. The first column reports estimates without the financial index in the high regime and the estimated inflation threshold of 6.2 percent is obtained. The speed of adjustment from one regime to another is illustrated by a transition graph in Figure 8. Inflation has positive effects on interest rate both in lower and upper regime, indicating that following inflation increases, the monetary authorities respond by hiking interest rate. The results show that the effect of inflation and financial conditions in the high regime is smaller than in the lower regime in contrast with the findings of other studies which could be attributed to the issue of specifications and the variables that have included in the model.

**Figure 8: Transition variable parameter**




Note: the solid line denotes the threshold level. Source: SARB and Quantec database

In this analysis, the financial condition has been added on the higher regime, as presented in Table 11(column 5), to see if we can get different findings. Similar results were obtained (i.e. inflation enters the model positively and significant in lower regime, though it is insignificant in the upper regime), although the inflation threshold is 8.9 percent. The results presented in

Table 11 show that the central bank favours an asymmetric response depending on whether inflation is above or below the threshold.

Overall, the results provide enough evidence that the monetary policy implemented by the South African Reserve Bank (SARB) can be described by a nonlinear Taylor rule in line with Castro 2011's findings on the European Central Bank. The results of the nonlinear model reveal that the SARB takes into consideration information contained in some financial variables when deciding on interest rate, though it plays a less important role. Hence, the augmented nonlinear Taylor rule best describes the SARB's behaviour as a policy rule.

The two nonlinear models (TAR and STR) considered in this chapter have the same inflation threshold values (6.2 percent). The results reveal an inflation threshold that is outside of the 3-6 percent inflation targeting band. Furthermore, on the basis of the log-likehood values (presented in Table 10 and 11) the smooth transition model is preferred in terms of overall fit in line with the findings of Tsionas and Christopoulos (2003).

## 3.7 Robustness analysis

For robustness analysis, we have estimated both models (threshold and smooth transition regression) without the financial condition index to see its effect on the overall results. The estimated models without the financial condition index are presented in Table 12. According to Table 12, an inflation threshold of 6.2 percent is obtained for both the smooth transition model and threshold autoregressive model which is the same as for the models that incorporate the financial condition index. However, most of the variables are insignificant for both the TAR and STR models indicating that the financial condition index play an important in the policy rule setting.

**Table 12: Estimates of nonlinear models**

| | TAR | | STR |
|---|---|---|---|
| | **Upper regime** | **Lower regime** | |
| Variable | | | |
| | | | **Lower regime** |
| Constant | 0.079*** | 0.081*** | 0.080 |
| | (0.009) | (0.007) | (0.005) |
| Inflation | 0.488*** | -0.148 | -0.137 |
| | (0.088) | (0.168) | (0.131) |
| output gap | 0.051 | -0.093 | -0.244 |
| | (0.064) | (0.147) | (0.162) |
| real effective exchange rate | -0.017 | -0.037* | -0.020 |
| | (0.021) | (0.022) | (0.017) |
| financial condition index | | | |
| | | | **Upper regime** |
| Inflation | | | 0.622*** |
| | | | (0.155) |
| output gap | | | 0.288*** |
| | | | (0.163) |
| Threshold | 0.062 | 0.062 | 0.062*** |
| | | | (0.001) |
| speed of transition | | | 1960.005 |
| log-likelihood | 332.837 | 321.481 | 683.8153 |
| $R^2$ | 0.192 | 0.019 | 0.519 |
| N(no: of observations) | 296 | 296 | 296 |

Notes: Standard errors are in brackets following each regression coefficient. ***, **, * indicate the statistical significance and the rejection of null hypothesis at 1 percent, 5 percent and 10 percent. Source: SARB and Quantec database

## 3.8 Conclusion

In this Chapter, additional evidence to the existing literature of nonlinearities in the conduct of SARB monetary policy has been provided. It has been demonstrated that nonlinear models (both threshold regression and smooth transition regression) fit the data better than its linear counterpart. This implies that linear models (i.e simple Taylor rules) are inappropriate to capture interest rates setting asymmetries between times when the inflation rate is below or above the 6.2 percent threshold. The results of the estimated models reveal that the SARB reacts to the main variables under both regimes (upper and lower regime). Using both techniques (TAR and STR), we find that results are not influenced by different techniques, as we get similar results.

Nonlinear models such as the STR, TAR provide alternative approaches to tracking the movement of interest rate overtime. This Chapter reveals that monetary policy authorities pay close attention to financial stability when establishing interest rate which is consistent to Kasai and Naraidoo (2012) findings. The empirical findings suggest that the central bank change their usual policy conduct in response to unexpected economic shocks in the context of a special regime. The existence of uncertainty within the economy makes it difficult to rely on simple Taylor rules to track the behaviour of monetary authorities in the context structural changes as linear models fail to consider these changes which may yield biased results. Hence, recent studies indicate that monetary authorities take into account issues of asymmetry when deciding on the appropriate policy rule.

In addition, the results show that the SARB takes into consideration information contained in some financial variables when deciding on interest rate, though it plays a less important role. This is consistent with the findings of Naraidoo and Paya (2012) for case of the SARB and Castro (2011) in the case of European Central Bank where he argues that the Eurozone was less vulnerable to the recent credit crunch. In conclusion, we strongly believe that this study contributes to existing literature on the analysis of monetary policy of South Africa using nonlinear models.

# CHAPTER 4: INFLATION DYNAMICS AND ECONOMIC GROWTH IN SOUTH AFRICA

## 4.1 Introduction

In this Chapter, we investigate the existence of the inflation threshold level in the inflation-growth nexus for South Africa is investigated. It is important for policy makers to determine the point of inflection which is referred to as the threshold level as this will inform the policy rate setting in response to abrupt economic shocks. For instance, understanding that high inflation (beyond a certain threshold) is costly or detrimental to economic growth is critical, as policy makers intend to achieve price stability in an inflation targeting economy. Thus, this research intends to alert policy makers to the fact that economic variables are subjected to sudden abrupt changes as monetary policy tends to be relaxed during recession compared to expansions.

Therefore, in the context of South Africa (an inflation targeting economy) it is essential to establish the inflation threshold beyond which inflation becomes detrimental on output growth. The monetary authorities will be informed by the threshold level in determining the appropriate policy rate so as to achieve price stability, which could be less than the threshold level of inflation. Thus as, the Monetary Policy Committee (MPC) seeks to ensure that inflation remains within the 3 to 6 percent inflation band, they need to be mindful of the implications of their policy actions on economic growth. Hence, it is important to understand the difficult choices that need to be made in terms of inflation and output trade-off.

We use the logistic smooth transition regression model to assess the relationship between inflation and economic growth. To our best knowledge, there seems to be no study that has used nonlinear models to investigate the relationship between inflation and economic growth in the context of South Africa. Notably, research studies reveal that there is no strong consensus pertaining to the inflation-growth relationship as it depends on the threshold effects that are hard to accurately identify (Rousseau and Wachtel, 2002).

Over the past years, a number of countries have adopted price stability as their primary goal on the premise that high inflation is an undesirable outcome (Fountas, 2010). From a theoretical perspective, there exists some uncertainty as to how inflation impacts on economic activity. The relationship between economic growth and inflation is one of the most debated macroeconomic issues and remains a controversial issue in theoretical and empirical research. For instance, there has been debate between structuralists and monetarists, with the former asserting that inflation is important for economic growth yet the latter view inflation as harmful to economic growth. Bhar and Mallik (2010) reveal that economists are divided pertaining to the relationship between inflation and economic growth. Notably, in a number of studies, economists have found varying results ranging from positive, negative and or no relationship. Fountas et al (2006) point out that in some cases the relationship is negative, though in other instances it has been found to be positive. On the other hand, Kearney and Chowdhury (1997) did not find any causal relationship between inflation and economic growth in a sample of 70 countries between 1960 and 1989. Mallik and Chowdhury (2001) examined the relationship between growth and inflation in four South Asian countries and found that growth has a significant positive effect on inflation. The general consensus is that growth is significantly and negatively related to inflation. Over the past two decades of empirical studies, the contour of an inverse connection between inflation and economic growth across countries has begun to emerge (Fountas et al (2006)).

Some studies(i.e Vaona, 2012; Ocran, 2007; Hodge, 2006; Fischer, 1993) have found these variables are negatively related while others for instance Mallik and Chowdhury( 2001) have concluded that positive relationship exists between them yet others found no relationship (i.e Erbaykal and Okuyan, 2008; Faria and Carneiro, 2001). However, a growing number of research studies (i.e Sarel, 1996; Ghosh and Phillips, 1998; Khan and Senhadji, 2001; Rousseau and Wachtel, 2002; Burdekin et.al, 2004; Pollin and Zhu, 2005; Omay and Kan, 2010; Phiri, 2010; Leshoro, 2012) have recently focused on the non-linearity of the inflation-growth nexus, as well as inflation-finance relationship.

Further, this debate takes into account the following issues namely; the direction of causality and the nature of the relationship if it does exist. Kydland and Prescott (1990) based their debates on the real business cycle theories[28]and believed that inflation negatively impacts on economic growth. Basically, the inverse relationship between inflation and growth is believed to be caused by supply shocks and not demand shocks, which remains debatable.

Bhar and Mallik (2010) reveal that economists are divided pertaining to the association between inflation and economic growth. Notably, in a number of studies, economists have found varying results ranging from positive, negative and or no relationship. Fountas et al (2006) report that in some instances, the relationship between inflation and economic growth is negative, though in others it has been found to be positive. On the other hand, Kearney and Chowdhury (1997) did not find any causal relationship between inflation and economic growth in a sample of 70 countries between 1960 and 1989. Mallik and Chowdhury (2001) examined the relationship between growth and inflation in four South Asian countries and found that growth has a significant positive effect on inflation.

According to Okun (1971) and Friedman (1977), the influence of high inflation on economic activity occurs through its effect on inflation uncertainty. This implies that if for some reasons high inflation does not lead to inflation uncertainty, it is unlikely that the negative relationship between inflation and economic growth would be observed. Notably, the general consensus is that growth is significantly and negatively related to inflation. Over the past two decades of empirical studies, the contour of an inverse connection between inflation and economic growth across countries has begun to emerge (Fountas et al 2006).

Currently, it appears there is no consensus pertaining to the point beyond which further increases in inflation become harmful to economic growth. Pollin and Zhu (2005) indicate that although the inflation growth relationship is of great importance for macroeconomic theory and policy, there is nothing close to a professional consensus as to what the empirical evidence tells us about this relationship. Yet, Hodge (2005) asserts that although there is no consensus on the level above which inflation negatively affects economic growth, the general

[28] Theory of fluctuations based on the classical dichotomy that nominal variables (such as the money supply and the price level) do not affect real variables (such as output and employment) and business cycles are driven by technology shocks (real shocks).

finding by various researchers is that countries maintaining low inflation enjoy higher economic growth in comparison to countries that allow inflation.

Results of this study show that there is a threshold of approximately 4 percent. These results have policy implications taking into account the need for price stability. This research investigates the relationship between inflation and growth in the context of South Africa. Its approach differs from other studies[29] in that it looks at an emerging market economy using time series data. A threshold model is used to estimate the inflation-growth nexus in order to enhance the policy makers' ability to maintain macroeconomic stability. Further, this research fills the research gap on the relationship between inflation and economic growth in South Africa.

Thus, the findings of this research are important in guiding policymakers in the design and implementation of policies that promote economic growth whilst fostering price stability.

The Chapter is outlined as follows. Section 2 presents the discussion on inflation and growth in South Africa. Section 3 provides the inflation economic growth transmission mechanism. Section 4 reports on the Methodology and Data. Section 5 reports and discusses the empirical results. Final Section 6 offers concluding remarks and draws some policy implication.

## 4.2 Inflation and growth in South Africa economy

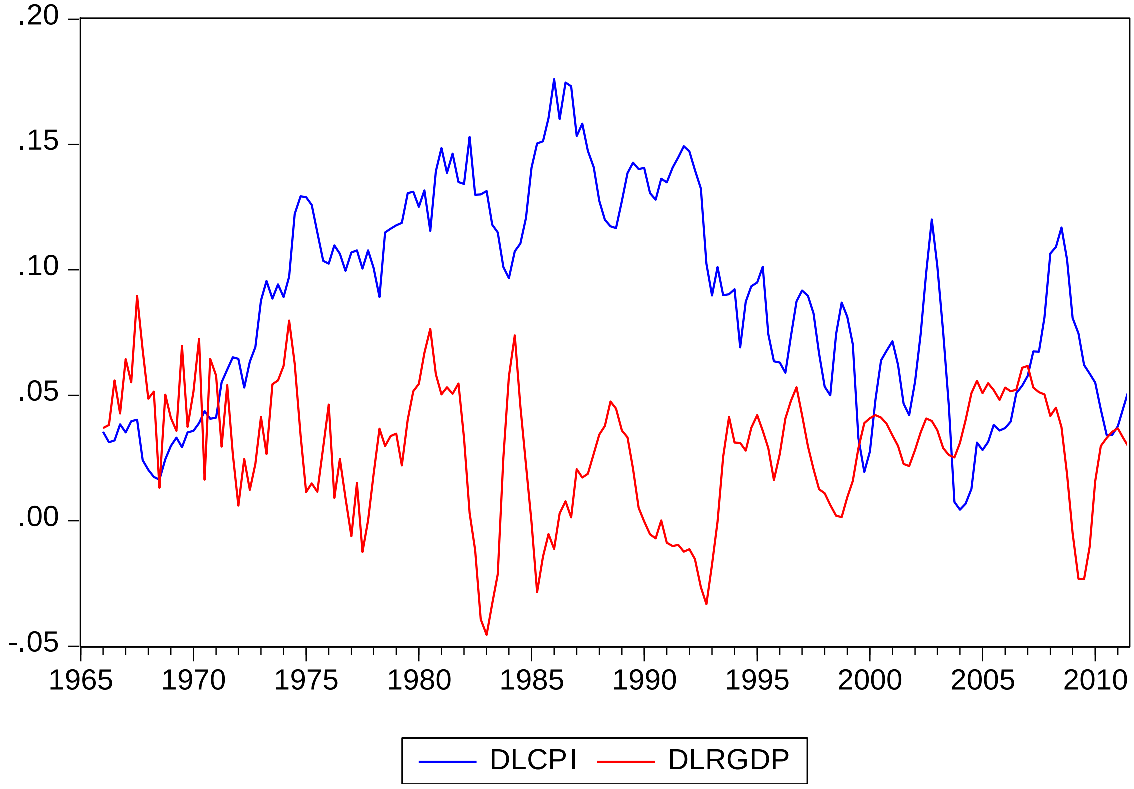
Several studies have been undertaken mainly focusing on the relationship between inflation and economic growth in South Africa. These papers include among others Pretorius & Smal (1994), Schaling (1999), Nell (2000), Hodge (2002), Fedderke & Schaling (2005), Burger & Du Plessis (2006), Burger & Marinkov (2005), Hodge (2006), Nell (2006) and Hodge (2009). Models were estimated ranging from Phillips' traditional view to expectations-augmented and New-Keynesian specifications. Notably these papers strictly looked at the relationship

[29] For instance Omay and Kan (2010).

between inflation and economic growth or output using linear models that fail to capture nonlinearities.

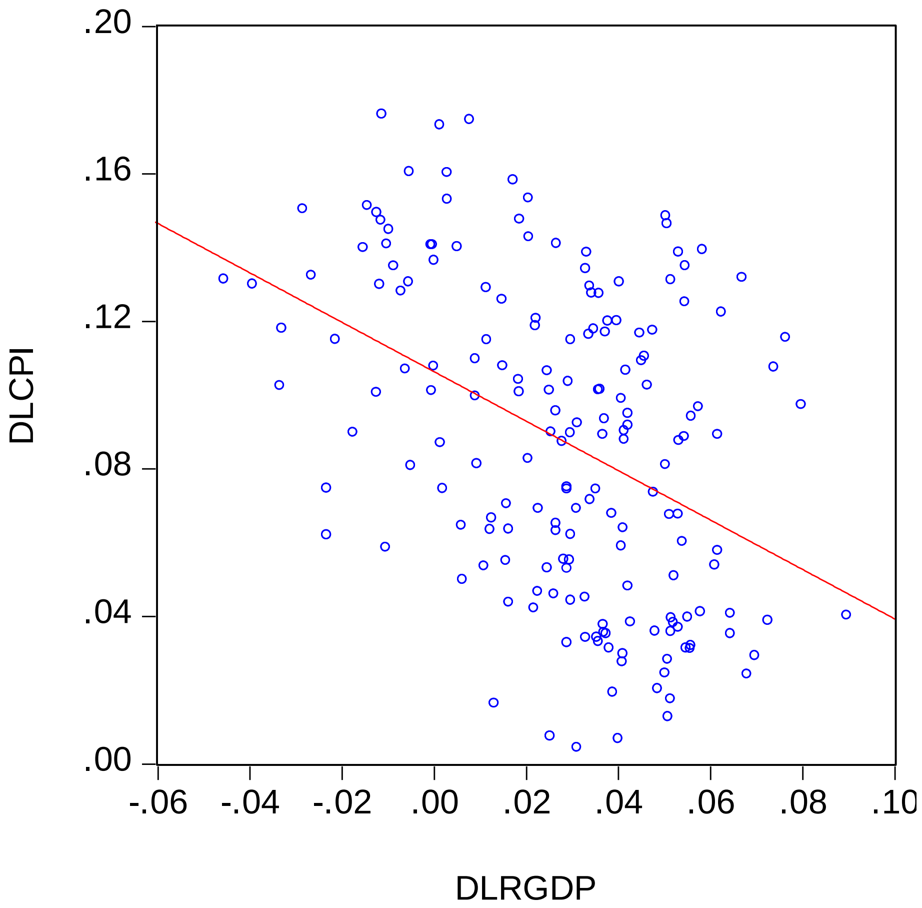
The relationship between inflation and real GDP growth rate in South Africa is illustrated in Figure 9. The data on GDP growth and inflation reveal a negative trend. In periods of high inflation, economic growth has been low and vice versa. High inflation rates and lower economic growth of approximately 15 percent were recorded in the 1980s and 1990s which could be attributed to the escalating cost of apartheid (Hodge 2006). Following the adoption of the inflation targeting framework, inflation and economic growth were less volatile. Notably, the impact of inflation on economic growth is not instantaneous but occurs with lag. When inflation rate is at peak, economic growth will be low.

**Figure 9: Inflation and Real GDP growth rate**




Notes: DLCPI– inflation rate and DLRGP represents the GDP growth rate. Source: SARB and Quantec database

**Figure 10: Scatter plot of Inflation and Economic growth**



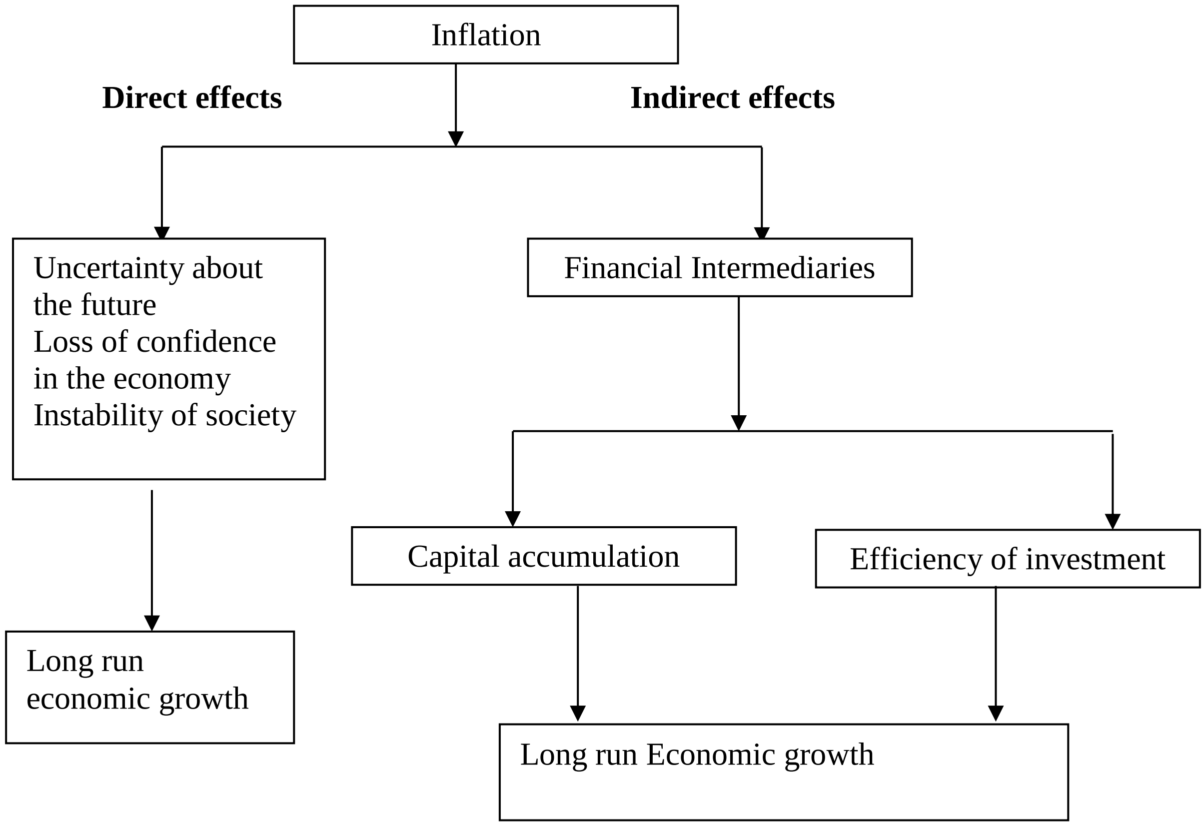

Notes: DLCPI– inflation rate and DLRGP represents the GDP growth rate. Source: SARB and Quantec database

Figure 10 indicates the presence of correlation between inflation and economic growth. The coefficient of correlation is found to be -0.41 indicating a partially strong but negative relationship between the two variables.

## 4.3 Transmission mechanism from Inflation to Economic growth

Inflation can affect economic growth both directly and indirectly through various channels as shown in Figure 11. Inflation may indirectly affect economic growth through the inflation uncertainty, which affects intra-temporal and inter-temporal resource allocation (Fountas and Karanasos, 2007; Fountas et al, 2006). Misallocation of resources occurs when inflation affects interest rates and relative prices under conditions of nominal rigidities. Grier and Grier (2006) argue that the effect of inflation on economic growth is indirectly nonlinear, given the strong and negative impact of uncertainty on output growth. In this study, we focus on the direct effect of inflation on economic growth.

**Figure 11: Relationship between inflation and economic growth**




Source: Li (2006)

A study by Friedman (1977) on the causal effect of inflation on its uncertainty revealed that higher inflation leads to greater uncertainty and lower output growth. Thus, higher average inflation negatively impacts on output growth. Fountas et al (2006) point out that inflation uncertainty increases the uncertainty pertaining to future returns of investment projects. This implies that investors will be likely to delay investment in long term projects which ultimately lowers investment levels and output growth. Similarly, theoretical literature reveals that inflation increases result in credit tightening which eventually lowers investment and economic growth (Burdekin et al 2004).

Grier and Grier (2006) indicate that higher average inflation is detrimental to output growth due to its effect on inflation uncertainty. Fountas and Karanasos (2007) point out that inflation may indirectly impact on output growth through the inflation uncertainty link. Friedman (1977) shows that an increase in inflation is likely to cause an erratic policy response by monetary authorities. Therefore, this can lead to more uncertainty about the future rate of inflation. The Friedman hypothesis points out that inflation uncertainty negatively impacts on output or economic activity as it distorts the price mechanism, which promote or facilitate the efficient and effective allocation of resources. In fact, it generates economic inefficiencies and lowers economic growth (Fountas and Karanasos, 2007). According to Fountas and Karanasos (2007), at high levels of inflation the public is subjected to increasing uncertainty about future inflation as it is unknown which policymaker will be in office in the next period and consequently what response to the high inflation rate will be. Notably, in the presence of low inflation such uncertainty does not exist.

Grier and Grier (2006) suggest that depending on the assumption underlying an economic model, the association between inflation and growth can either be positive, none or negative. Okun (1971) and Friedman (1977) suggest that increased uncertainty reduces the informativeness of the price movements and hinders long term contracting, thus potentially lowering growth. Ozdemir and Fisunoglu (2008) assert that higher inflation uncertainty has a negative causal effect on real growth. Similarly, an increase in inflation reduces accumulated wealth, which leads to an increase in current savings, investment and growth.

## 4.4 Methodology and Data

### 4.4.1 The Smooth Transition Regression Model

Smooth transition regression (STR) models belong to the class of the nonlinear models. Generally STR models, try to explain asymmetry in rising and falling samples or effects of a process and model. STR models may contain $n$ different regimes, these regimes depend on the threshold parameter $c$ and specific threshold variables $(s_t)$.In the case of a two regime STR model, one of the regimes can represent a linear AR component, while the other regime can represent a nonlinear AR component. Combining the linear and nonlinear component forms a nonlinear process.

A brief outline of the modelling cycle is provided, starting with the specification of a linear AR model of order (p), followed by testing the null hypothesis of linearity against the alternative LSTR or ESTR nonlinearity. If linearity is rejected, the appropriate transition variable $s_t$ and the form of the transition function $G(\gamma, c, s_t)$ using grid search procedures can be selected. Then, the parameters in the selected LSTR or ESTR are estimated. This is followed by evaluation of the model using diagnostic tests and impulse response analysis. Where necessary, the model is modified. This model could be utilised for descriptive or forecasting purposes. Notably, we will introduce dummy variables to deal with the problem of outliers.

The smooth transition regression model is explored in this section, which permits for the smooth movement from one regime to another. Boehm (2008) suggests that the derivation of smooth transition regression models can be considered as an extension of the switching regression models to incorporate smooth transitions between parameter regimes. According to Mourelle and Cancelo (2009), smooth transition regression models are mostly chosen as opposed to other models such as Markov switching model or self-excited threshold autoregressions (SETAR) for various reasons. Firstly, they are easy to interpret and are locally linear, a continuum of intermediate regimes is allowed. Secondly, the flexibility of the model permits the description of a wide range of nonlinear behaviours. Thirdly, they perform well in capturing cyclical behaviour in macroeconomic variables such as unemployment, consumption and industrial production. Lastly, the parameterisation of smooth transition regression models allows for capturing different types of behaviour that a linear model fails to characterise in a suitable manner.

This analysis follows a nonlinear approach that belongs to the smooth transition autoregressive by Terasvirta (1994, 1998). According to Boehm (2008), $y_t$ and $x_t$ can be regarded as the endogenous variable and vector of explanatory variables respectively, hence the smooth transition model can be presented as follows:

$$y_t = \varphi x_{\hat{t}} + \theta' x_t G(\gamma, c, s_t) + e_t \tag{1}$$

where $y_t$ indicates real economic growth and $x_t = (1, x_{k-1}, \ldots \ldots x_{kt-1-d})$ with d lags of variables vector k (comprising of inflation rate, terms of trade, growth rate of investment, growth rate of money supply). Terasvirta et al (2005) suggest that $\varphi = (\varphi_0, \varphi_1, \dots \varphi_p)'$ and $\theta = (\theta_0, \theta_1, \dots \theta_p)'$ are parameter vectors and $e_t \sim IID(0, \sigma^2)$. $G(.)$ is the transition function that is continuous and bounded between 0 and 1, satisfying two extreme regimes defined by $G = 0$ and $G = 1$; $c$ is the location parameter, sometimes referred to as the switch-point between regimes and $\gamma$ is the slope parameter determining how rapid the transition is and shows the speed of transition between 0 and 1, $e_t$ is a white noise residual with variance $\sigma^2$. Equation (2) can be rewritten in the same way as by Terasvirta et al (2005):

$$y_t = \{\varphi + \theta G(\gamma, c, s_t)\}' x_t + e_t \ ,$$

This indicates that the smooth transition model can be interpreted as a linear model with stochastically time varying coefficients$\varphi + \theta G(\gamma, c, s_t)$. The logistic transition function $G(.)$ is bounded between 0 and 1 depicted as $0 \leq G \leq 1$ and $\gamma > 0$

$$G(\gamma, c, s_t) = (1 + \exp(-\gamma(s_t - c)))^{-1} \ , \qquad \gamma > 0 \tag{3}$$

Terasvirta (1994) assert that (2) and (3) jointly define the logistic smooth transition regression model (LSTR).In this study, we focus on the LSTR model with one transition variable, though in some instances multiple transition variables have been used. Bruinshoofd and Candelon (2005) indicate that the LSTR specification nests the two regime switching regression for $\gamma \to \infty$. In some cases, the LSTR model is extended by the inclusion of time trend $t$ as the transition variable. However, this issue is not pursued in this study. Instead, we are interested in using the linear model as a benchmark in testing the relevance of the LSTR model. As $\gamma \to 0$, the LSTR tends to a linear model with a coefficient $\varphi + \theta/2$ yet the model becomes a two regime threshold autoregressive (TAR) model with $c_1$ as the threshold value when $\gamma \to 1$ (Terasvirta et al, 2005). Terasvirta (2006) points out that if $\gamma$=0, the transition function $G(\gamma, c, s_t)$=0.5 and the model becomes linear. Thus the LSTR nests a linear model. However, when $\gamma \to \infty$, the LSTR model approaches a threshold regression model with two regimes with equivalent variances.

Terasvirta (1994) proposed another function which is non-monotonic as the monotonic transition may not be always successful in applications

$$G(\gamma, c, s_t) = 1 - \exp(-\gamma(s_t - c)^2), \qquad \gamma > 0 \tag{4}$$

Combining (1) and (4) give rise to the exponential smooth transition regression(ESTR). This transition function is symmetric at $s_t = c$ and has the same shape at low and moderate values of the slope parameter $\gamma$

In dealing with the problem of an LM type linearity test, Luukkonen et al (1988) built an LM type statistic using the third order Taylor approximation of the transition function as follows:

$$G(\gamma, c, s_t) \equiv \alpha_0 + \alpha_1 s_t + \alpha_2 s_t^2 + \alpha_3 s_t^3 + V(\gamma, c, s_t) \tag{5}$$

where $V$is a remainder and $\alpha_j, j = 0,1,2,3$ are constant. Then substituting (4) into (2) yields

$$y_t = x_t'\varphi + (x_t s_t)'\beta_1 + (x_t s_t^2)'\beta_2 + (x_t s_t^3)'\beta_3 + e_t^* \qquad (t = 1, \dots, T) \tag{6}$$

where $e_t^* = e_t + (x_t'\theta)V(\gamma, c, s_t)$. The LM test of linearity assesses $H_0\colon \beta_j = 0, j = 1,2,3$ against $H_1$: at least one $\beta_j \neq 0$. The statistic ($\mathcal{L}$) associated with this test has the following form:

$$\mathcal{L} = \sigma^2 (\textstyle\sum_{t=1}^{T} e^{\wedge}{}_t\, w_t)'(M^{\wedge}{}_{11} - M^{\wedge}{}_{10} M_{00}^{\wedge-1} M^{\wedge}{}_{01})^{-1} \left(\sum_{t=1}^{T} w_t\, e_t^{\wedge}\right), \tag{7}$$

where $w_t = (x_t s_t, x_t s_t^2, x_t s_t^3)', M_{00}^{\wedge} = \sum_{t=1}^{T} x_t^{\wedge} x_t', M_{01}^{\wedge} = \sum_{t=1}^{T} x_t^{\wedge} w_t', \ M_{10}^{\wedge} = \sum_{t=1}^{T} w_t^{\wedge} x_t'$ and $M_{11}^{\wedge} = \sum_{t=1}^{T} w_t^{\wedge} w_t'$. Luukkonen et al (1988) indicate that under the null $\mathcal{L} \rightarrow \chi^2(3p)$ where $p = k\, X\, (m + 1) + 1$ indicates the number of explanatory variables. In the empirical part of the Chapter we use an F approximation to $\mathcal{L}$ with $3p$ and $T - 4p - 1$ degrees of freedom.

### 4.4.2 Threshold Model

Tong (1978) was the first to develop Threshold Autoregressive (TAR) model which were further modified by Tong and Lim (1980) and Tong (1983). TAR models seek to describe a given stochastic process by a piecewise linear autoregressive model, where the determination of whether each of the models is active or not depends on the value of a known variable, called the threshold variable. Tong (2011) has provided a detailed historical background and motivation that resulted in the introduction of the threshold models in time series analysis as well as a systematic account of the development of these models in past thirty years. The TAR models are simple and easy to understand, but rich enough to generate complex nonlinear dynamics. For example, it can be shown that the TAR models can have limit cycles and thus be used to model periodic time series, or produce asymmetries and jump phenomena that cannot be captured by a linear time series model.

In spite of the simplicity of the TAR model form, there are many free parameters to estimate and variables to choose when building a TAR model, and this has hindered its early use. Recently, however, much progress has been made with regard to specification and estimation of TAR models.

Following Tong (2015) a TAR model of order $p$ can be presented as follows:

$$X_t = \beta_1' \omega_{t-1} I(X_{t-d} \leq r) + \beta_2' \omega_{t-1} I(X_{t-d} > r) + \varepsilon_t, \qquad (8)$$

where $\omega_{t-1} = (1, X_{t-1}, \dots, X_{t-p})'$, $I(.)$ is the indicator function , $\beta_1$ and $\beta_2$ are (column) vectors of coefficients, and $\varepsilon_t$ is a real valued martingale difference with respect to some increasing sequence of $\sigma$-fields generated by $\{(X_j, \varepsilon_j): j \leq t\}$. In this instance, $p \geq 1$ and $d > 0$ are integers temporarily assumed known, and $r$ is an unknown real constant that is assumed to lie in the bound subset of the reals$[r, \bar{r}]$. For simplification, let $= max\{p, d\}$, $y = (X_{q+1}, \dots, X_n)'$, $\varepsilon = (\varepsilon_{q+1}, \dots, \varepsilon_n)'$, and $I(r) = (a_{ij})(n-q)x(p+1)$ with $a_{ij} = I(X_{q+i-d} \leq r)$. It should be noted that the row elements of the matrix $I(r)$ are identical. Tong (2015) suggests that the sample could be as follows$\{x_{1,}, \dots, x_{n,}\}$. Thereafter, the TAR model can be rewritten (now replacing $X_j$ by the observations$x_j$, all $j$) as

$$y = X_1(r)\beta_1 + X_2(r)\beta_2 + \varepsilon, \qquad (9)$$

where $X_1(r) \equiv X * I(r)$ and $X_2(r) \equiv X * \{I(\infty) - I(r)\}$ with $X$ being an $(n-q)x\ (p+1)$ matrix, whose *i*th row is $(1, x_{q+i-1}, \dots, x_{q+i-p})$. '*' denotes the Hadamard product of matrices. Denote the parameter vector $(\beta_1', \beta_2', r)'$ by $\theta$ and its true value by $\theta_0$. The TAR model is linear in $\beta_1$'s and least squares estimation gives the square error function.

$$S_n(r) = y'y - y'X_1(r)\left(X_1(r)'X_1(r)\right)^{-1}X_1(r)'y - y'x\,X_2(r)\left(X_2(r)'X_2(r)\right)^{-1}X_2(r)'y, \quad (10)$$

from which the least squares estimate of $r$ is obtained by

$$\hat{r} = arg\ min_{r \in [r, \bar{r}]} S_n(r) \quad (11)$$

where $S_n = y'y - y'X(X'X)^{-1}X'y$. Tong (2015) assumes that $\{\varepsilon_t\}$ and $\{X_t\}$ are both strictly stationary and ergodic, $EX_t^2 < \infty$ and $X_t$ has a continuous density that is positive on real line.

The modelling of the threshold autoregressive model (TAR) comprises of five steps namely: specifying a linear model, testing linearity against a TAR model and there after the threshold variable is selected, number of thresholds are determined, the model is estimated and lastly the estimated model is evaluated.

### 4.4.3 Data Analysis

Here, the relationship between inflation and economic growth is estimated using quarterly data covering the period 1961 to 2011[30]. The data is obtained from the International Monetary Fund's 'International Financial Statistics' and the South African Reserve Bank. The data comprise inflation computed as the difference of CPI index, growth rate of GDP, growth rate of investment and growth rate of terms of trade. All the variables have been transformed to natural logs in order to minimise the variance and to linearise the variables (Erbaykal and Okuyan 2008).

[30] Post 2011, results were not converging due to possible a number of instabilities which could be attributed to high global economic uncertainty and turbulence. Thus, the time periods after 2011 are excluded in this study.

#### 4.4.3.1 Descriptive Statistics

Descriptive statistics in Table 13 provide a summary of the variables that have been used in the study. The Table shows that the average growth rate of real GDP was 2.803 percent between 1965 and 2011, with maximum and minimum of 8.964 percent and -4.556 percent, respectively. During the same period, average inflation was approximately 8.755 percent with maximum and minimum of 17.606 percent and 0.436 percent respectively.

**Table 13: Descriptive statistics for variables**

| | DLRGDP | DLCPI | DLM2 | DLINVS | DLTOT |
|---|---|---|---|---|---|
| Mean | 2.803 | 8.755 | 13.786 | 9.558 | -0.351 |
| Maximum | 8.964 | 17.606 | 31.834 | 31.785 | 15.993 |
| Minimum | -4.556 | 0.436 | 0.233 | -11.217 | -14.033 |
| Std. Dev. | 2.575 | 4.211 | 6.221 | 7.803 | 5.302 |
| Skewness | -0.478 | -0.004 | 0.220 | 0.060 | -0.166 |
| Kurtosis | 2.872 | 1.936 | 2.905 | 3.128 | 3.409 |
| Observations | 183 | 183 | 183 | 183 | 183 |

Note: DLRGDP- real GDP growth rate, DLCPI-inflation rate, DLM2- growth rate of money, DLINVS-growth rate of investment and DLTOT-growth of terms of trade. Source: SARB and Quantec database

#### 4.4.3.2 Stationarity Test

Before estimating the logistic smooth transition model it is advisable to investigate the stochastic properties of the variables to be used in the analysis. This implies checking for the level of stationarity in series using unit root tests. According to Munir and Mansur (2009) stationarity tests are undertaken to make certain that variables utilised in regression are not subjected to spurious regression.

In this study, the Augmented Dickey-Fuller (ADF) unit root test and Kwiatkowski-Philips-Schmidt-Shin (KPSS) stationarity test were utilized for level of stationarity. The ADF is based on the null hypothesis of unit root or non stationarity while the KPSS is based on the null of stationarity. Table 14 presents the stationarity test results for the following variables namely; real GDP growth rate, inflation rate, growth rate of investment, growth of money supply and growth rate of terms of trade. The results indicate that inflation is non-stationary using ADF test. This is in sharp contrast with KPSS test results that suggest that inflation is stationary. In case of the growth rate of investment using both the ADF and KPSS test, the results show that growth rate of investment is stationary, due to the failure to reject the null hypothesis at the 0.05 level.

**Table 14: Stationarity tests**

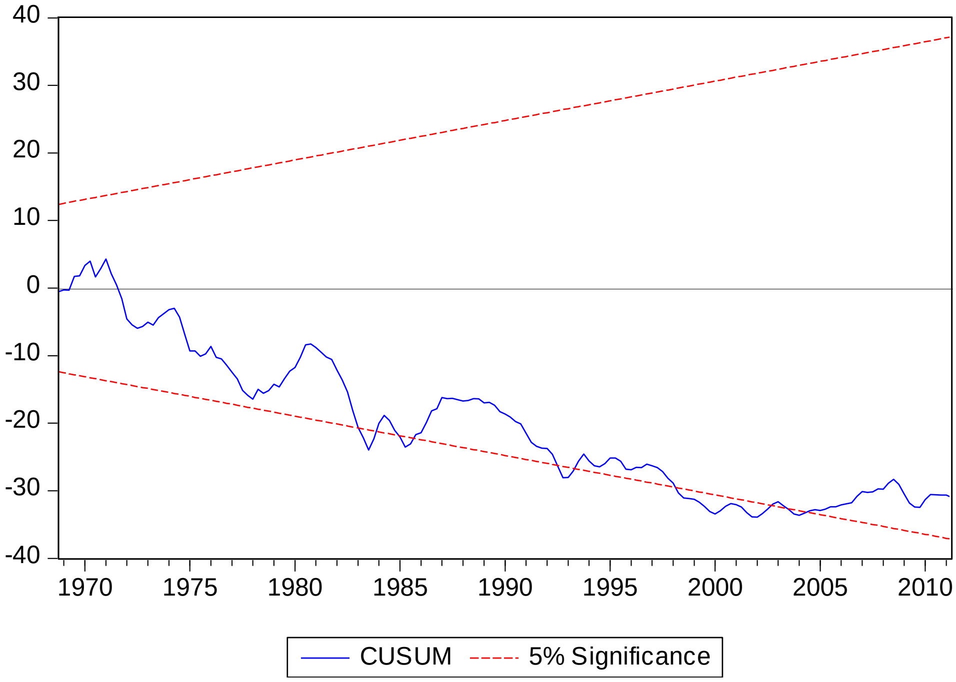
| | DLCPI | DLINVS | DLTOT | DLM2 | DLRGDP |
|---|---|---|---|---|---|
| ADF | -1.846 | -4.441*** | -4.898*** | -4.795** | -3.627** |
| KPSS | 0.401 | 0.077 | 0.556 | 0.173 | 0.247 |
| : | | | | | |

Note: ***, **and * indicate significant at 1 percent, 5 percent and 10 percent levels respectively, DLRGDP- real GDP growth rate, DLCPI-inflation rate, DLM2- growth rate of money, DLINVS-growth rate of investment and DLTOT-growth of terms of trade. ADF denotes Augmented Dickey-Fuller unit root test and KPSS denotes Kwiatkowski-Philips-Schmidt-Shin stationarity test. Source: SARB and Quantec database

### 4.4.3.3 Structural Stability Test

Various methods can be implemented to test the structural stability for instance, the CUSUM test, Recursive, Chow test. Figure 12 shows that the CUSUM moves away from zero and crosses the confidence bands. Using Bai Perron, six break points have identified as follows: 1971:01, 1994:04, 2000:02, 2005:02 and 2007:02. Hence, it is concluded that there is coefficient instability during the period 1965-2011. In addition, time dummy variables have been generated to deal with various structural breaks. However, the coefficients of dummy variables are insignificant hence there are not reported in the estimation.

**Figure 12: Stability-CUSUM test**




Source: SARB and Quantec database

### 4.4.3.4 Granger causality test

A number of models have come up with different hypotheses to analyse the relationships amongst variables though these models have not managed to establish the variables cause and effect relationships between them. Nonetheless, Granger (1969) is regarded the pioneer of the cause and effect analysis. He defined the lead and lag relations on the basis of the role of predictability using twin factors of vector autoregressive models (VARs) to find variables causal relationship. The Granger causality test assumes that two series $X_t$ and $Y_t$ define message set as follows:

$$X_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} X_{t-1} + \sum_{i=1}^{k} \alpha_{2i} Y_{t-1} + \varepsilon_{1t} \tag{13}$$

$$Y_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} X_{t-1} + \sum_{i=1}^{k} \beta_{2i} Y_{t-1} + \varepsilon_{2t} \tag{14}$$

Four coefficients are test to determine the relationships amongst variables as follows;

(i) $\alpha_{2i} \neq 0$ and $\alpha_{1i} = 0$: This means that $Y$ leads $X$ or $X$ lags $Y$

(ii) $\beta_{1i} \neq 0$ and $\beta_{2i} = 0$: This means that $X$ leads $Y$ or $Y$ lags $X$

(iii) $\alpha_{2i} = 0$ and $\beta_{1i} = 0$: This means that both variables are independent

(iv) $\alpha_{2i} \neq 0$ and $\beta_{1i} \neq 0$: This means that both variables are interactive of each other and have feedback relationship.

Pair wise Granger Causality test is employed to investigate the causal relations between inflation rate, real growth rate, growth rate of money, growth rate of investment and growth of terms of trade. In this study, five variables have been examined which are inflation rate, real growth rate, growth rate of money, growth rate of investment and growth of terms of trade. The results presented in Table 15 show that there a bi-directional causality between inflation and real economic growth as we fail to reject the null hypothesis. The results reveal that the growth rate of money Granger caused growth rate of investment and inflation rate. The growth of terms of trade Granger caused the growth rate of money. In addition, real growth rate Granger caused the growth rate of investment On the other hand all other variables were independent to each other; inflation with growth rate of investment, growth of terms of trade with growth rate of investment, and real growth rate with growth rate of money, inflation rate with growth of terms of trade, all are independent.

**Table 15: Pair wise granger causality**

| Null Hypothesis | Obs | F-test | Prob. |
|---|---|---|---|
| DLM2 does not Granger Cause DLINVS | 181 | 7.186 | 0.001 |
| DLINVS does not Granger Cause DLM2 | | 0.641 | 0.528 |
| DLCPI does not Granger Cause DLINVS | 181 | 1.114 | 0.330 |
| DLINVS does not Granger Cause DLCPI | | 0.438 | 0.646 |
| DLRGDP does not Granger Cause DLINVS | 181 | 8.813 | 0.000 |
| DLINVS does not Granger Cause DLRGDP | | 1.047 | 0.353 |
| DLTOT does not Granger Cause DLINVS | 181 | 0.552 | 0.577 |
| DLINVS does not Granger Cause DLTOT | | 0.680 | 0.508 |
| DLCPI does not Granger Cause DLM2 | 181 | 0.677 | 0.509 |
| DLM2 does not Granger Cause DLCPI | | 4.894 | 0.009 |
| DLRGDP does not Granger Cause DLM2 | 181 | 2.139 | 0.121 |
| DLM2 does not Granger Cause DLRGDP | | 0.763 | 0.468 |
| DLTOT does not Granger Cause DLM2 | 181 | 3.059 | 0.050 |
| DLM2 does not Granger Cause DLTOT | | 0.339 | 0.713 |
| DLRGDP does not Granger Cause DLCPI | 181 | 2.952 | 0.055 |
| DLCPI does not Granger Cause DLRGDP | | 5.808 | 0.004 |
| DLTOT does not Granger Cause DLCPI | 181 | 0.256 | 0.774 |
| DLCPI does not Granger Cause DLTOT | | 0.872 | 0.420 |
| DLTOT does not Granger Cause DLRGDP | 181 | 0.429 | 0.652 |
| DLRGDP does not Granger Cause DLTOT | | 0.431 | 0.651 |

DLRGDP- real GDP growth rate, DLCPI-inflation rate, DLM2- growth rate of money, DLINVS-growth rate of investment and DLTOT-growth of terms of trade. Source: SARB and Quantec database

## 4.5 Empirical Results

The results of the relationship between inflation and economic growth are presented in Table 16. Column (I) and (II) shows the results of linear regression without threshold. The results reveal that only the inflation rate and growth rate of investment enter the model significantly at the 1 percent level. The linear regression model results as presented in column (I) and (II) of Table 16 indicate that inflation is negatively related to economic growth.

A threshold variable that divides the observed values in two regimes (for instance, the upper and lower regime is obtained following Hansen (1999). Lee and Wong (2005) suggest that this entails testing the null hypothesis of the linear model against the alternative hypothesis of the two regime model (low inflation and high inflation regimes). The inflation rate is utilised as the threshold variable in this study. Column (III) and (IV) illustrates threshold model result in the upper regime yet column (V) and (VI) indicate the lower regime result of the threshold model. The estimated inflation threshold value is 4.1 percent.

The results indicate that there exists a nonlinear relationship between inflation and growth and the threshold level of inflation is 4.1 percent. There is negative relationship between inflation and growth for inflation rates above the threshold level, though below the threshold level inflation appears to be positively related to economic growth. In the lower regime inflation rate enters the model positively and insignificantly. This shows that monetary authorities are mainly concerned with inflation increases in the higher regime as it harms economic growth. An increase in the rate of inflation by 1 percent, while remaining above the threshold, leads to a reduction of growth by approximately 0.2 percent.

**Table 16: Estimates of linear and threshold autoregressive models**

| | LINEAR | | THRESHOLD | | | |
|---|---|---|---|---|---|---|
| | | | Upper regime | | Lower regime | |
| **Parameter** | (I) | (II) | (III) | (IV) | (V) | (VI) |
| **constant** | 0.034*** | 0.035*** | 0.021*** | 0.020*** | 0.041*** | 0.046*** |
| | (8.040) | (8.871) | (3.736) | (3.506) | (5.287) | (4.425) |
| **Dlcpi** | -0.300*** | -0.291*** | -0.203*** | -0.213*** | 0.120 | 0.074 |
| | (-7.909) | (-8.247) | (-4.197) | (-4.152) | (0.487) | (0.289) |
| **Dlinvs** | 0.145*** | 0.153*** | 0.177*** | 0.168*** | 0.034 | 0.053 |
| | (6.523) | (8.383) | (8.806) | (6.778) | (0.885) | (1.140) |
| **Dltot** | 0.001 | 0.004 | 0.038 | 0.035 | -0.090 | -0.088 |
| | (0.035) | (0.134) | (1.174) | (1.046) | (-1.560) | (-1.499) |
| **dlm2** | | 0.019 | | 0.021 | | -0.051 |
| | | (0.631) | | (0.618) | | (-0.740) |
| **threshold** | | | 0.041 | 0.041 | 0.041 | 0.041 |
| **log-likelihood** | | | 366.462 | 366.659 | 103.475 | 103.790 |
| **$R^2$** | 0.735 | 0.736 | 0.673 | 0.674 | 0.926 | 0.927 |

Notes: t-statistics are presented in brackets, ***, **, * represent the 1 percent, 5 percent and 10 percent significance level respectively at which the null hypothesis is rejected. DLRGDP- real GDP growth rate, DLCPI-inflation rate, DLM2- growth rate of money, DLINVS-growth rate of investment and DLTOT-growth of terms of trade. Source: SARB and Quantec database

The empirical results of the smooth transition model are reported in Table 17. Column (I) of Table 17 presents the results of the baseline model. Columns (II),(III) and (IV) are used for robustness checks. The results obtained indicate that inflation rate has a positive impact on economic growth in the lower regime as it enters the model positively and significantly across all the columns. However, the results obtained for the upper regime show a different picture as the impact of inflation on growth is significantly different. In fact, the level of inflation rate influences the magnitude and sign of the inflation coefficient. The results show that the threshold level of inflation for economic growth in the South African economy is 3 percent (as shown in Figure13). Figure 13, illustrates that the transition from low inflation to the high inflation regime occurs smoothly overtime.

The results show that under high inflation regime, inflation increases have detrimental effects on growth. However, in the low inflation regime when inflation is below 3 percent, the extra inflation does not hurt the economic growth. Thus on average a 1 percent increase in inflation in South Africa results in a 1.8 percent increase in economic growth. In the case of inflation above the threshold level, a 1 percent increase in inflation leads to a 2 percent decrease in economic activity. Following Tsionas and Christopoulos (2003), on the basis of the log-likehood values (presented in Table 16 and 17) the smooth transition model is preferred in terms of overall fit.

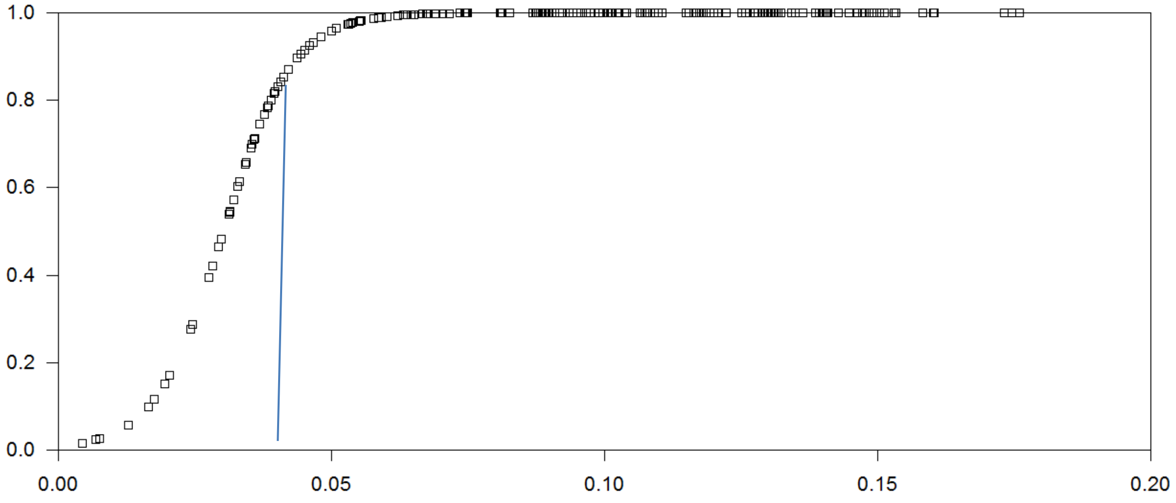
These empirical findings have essential policy implications as they indicate that above the threshold level of 3 percent inflation is harmful rather than being a stimulator of growth. This implies that it is important for the central bank to maintain lower inflation rates as it leads to higher output growth. In the context of South Africa, higher inflation is likely to hinder economic growth through its effect on the investment rate. Thus higher inflation will lower the rate of investment which in turn will adversely lower output growth. Overall, these findings have strong policy implications for South African central bank to continue maintaining inflation within the inflation target band of 3-6 percent so as achieve sustainable economic growth.

**Table 17: Smooth transition regression results**

| **Variable** | Dependent variable: dlrgdp | | | |
|---|---|---|---|---|
| | (I) | (II) | (III) | (IV) |
| | | **lower regime** | | |
| **Constant** | 0.003 | 0.010 | 0.009 | 0.003 |
| | (0.367) | (1.165) | (1.096) | (0.302) |
| **Dlcpi** | 1.847* | 1.835** | 1.778* | 1.812* |
| | (1.862) | (1.979) | (1.951) | (1.834) |
| **Dlinvs** | 0.163*** | 0.155*** | 0.148*** | 0.158*** |
| | (9.384) | (9.060) | (6.355) | (6.623) |
| **dlcpi(t-1)** | | -0.322*** | -0.325*** | |
| | | (-2.758) | (-2.776) | |
| **Dltot** | 0.014 | 0.010 | 0.008 | 0.012 |
| | (0.455) | (0.336) | (0.254) | (0.396) |
| **dlm2** | | | 0.015 | 0.011 |
| | | | (0.510) | (0.380) |
| | | **Upper regime** | | |
| **Dlcpi** | -2.033** | -1.712* | -1.661* | -2.004*** |
| | (-2.087) | (-1.857) | (-1.831) | (-2.067) |
| $c_1$ | 0.030*** | 0.031*** | 0.032*** | 0.030*** |
| **Γ** | 159.761 | 167.604 | 168.059 | 159.318 |
| **N(no: of observations)** | 182 | 182 | 182 | 182 |
| **R 2** | 0.754 | 0.762 | 0.762 | 0.754 |
| **log likelihood** | 466.898 | 467.457 | 467.457 | 466.971 |

Notes: t-statistics are presented in brackets, ***, **, * represent the 1 percent, 5 percent and 10 percent significance level respectively at which the null hypothesis is rejected,. $\gamma$ is the slope parameter and $c_1$ represents the threshold level. DLCPI-inflation rate, DLM2- growth rate of money, DLINVS-growth rate of investment and DLTOT-growth of terms of trade. Source: SARB and Quantec database

**Figure 13: Transition variable parameter**




Note: the solid line denotes the threshold level. Source: SARB and Quantec database

## 4.6 Conclusion

Using quarterly data, this study examined the presence of inflation threshold level for South Africa. The interesting result found from this study is that there is nonlinear relationship between inflation and economic growth in the South African economy. Further, the study reveals that the threshold level of inflation for economic growth is 4 percent. However, these results are in contrast with Hodge's (2005) findings which showed no evidence to support the view that inflation and growth are nonlinearly related over the medium to long term in South Africa. According to this study's results, a rate of inflation below the threshold level has a positive statistically significant effect on economic growth, although above the 4 percent level this positive relationship becomes negative.

On the basis of these research findings, it is advisable for policy makers to maintain inflation below the 4 percent threshold level. Policy makers need to realise that an increase in inflation beyond the threshold level is detrimental to economic growth. The results have implications for monetary policy makers who desire to achieve low inflation all meant to impact positively on economic growth. Indeed, it has implications on the inflation targeting band of 3 percent-6 percent set by the South Africa Reserve Bank. The 4 percent inflation threshold is within the 3-6 percent inflation band. This implies that the upper limit of 6 percent in the band is already high enough and does not need to be revised upwards. Overall, the policy implication drawn from this study is that it is essential to maintain inflation below the threshold level in South Africa as this promotes positive growth.

# CHAPTER 5: THE EFFECTS OF INFLATION ON THE FINANCIAL DEPTH-GROWTH NEXUS IN SOUTH AFRICA: A SMOOTH TRANSITION REGRESSION MODEL

## 5.1 Introduction

This Chapter is important as it examines existing literature on nonlinearity in the finance growth relationship and provides a better understanding of that relationship to various economic agents. The results from this Chapter will assist policy makers to take into account inflation levels when discussing issues of financial reforms. In addition, the Chapter identifies as well shows the existence of threshold levels of the transition variable for decision making.

The analysis provides an analytical framework which helps policy makers in their decision making, as empirical evidence shows that high inflation is costly or detrimental to the financial development- economic growth link, hence policy makers intend to achieve price stability. Several research studies (i.e Eggoh, 2012) reveal that the real sector can be affected either direct or indirect by inflation. Inflation leads to increases in transactions and information costs, and then impedes efficient resource allocation by obscuring the signals resulting from price changes. Eggoh (2012) points out that under circumstances characterized by imperfection of the information about prices, economic agents will be reluctant to enter contracts; this penalizes investment and inhibits economic growth. Thus, in inflationary environments, financial institutions are not willing to embark on long-term financing that promotes economic growth because of the greater stock return variability and tends to maintain liquid portfolios. Furthermore, higher inflation volatility discourages financial intermediaries as high inflation rate results in less predictability and increase economic uncertainty. The opposite is true in a low inflationary environment.

It is important to understand the relationship between inflation and financial development in the context of emerging market economies (i.e South Africa). For South Africa to move up to a higher economic growth path, it needs to maintain low inflation rate in order to create the conditions for sustainable growth. In instances where inflation adversely affects financial development anti-inflationary policy can be utilised to lower inflation.

This research intends to alert policy makers to the fact that economic variables are subjected to sudden abrupt changes as monetary policy tends to be relaxed during recession compared to expansions. This Chapter will be more beneficial to policymakers in emerging markets as it provides recent evidence on nonlinear models using the latest available data. There seems to be no study that has examined the effect of inflation variation on the nonlinear financial depth- growth relationship in South Africa using a smooth transition regression model. Thus there is a need to undertake such a study to see if similar results could be obtained as in studies that have been conducted in advanced economies. With this type of analysis, it is possible to estimate the inflation threshold level and identify two inflation regimes, low and high inflation (Villavicencio and Mignon 2011), hence the smooth movement from one regime to another is determined by the inflation variable.

A number of central banks across the world aim to achieve high and sustainable levels of economic growth at low levels of inflation rate which is regarded as the main macroeconomic objective. Over the last decade, there has been considerable debate pertaining to the relationship between inflation and economic growth. Lee and Wong (2005), point out that the question of the existence and nature of the relationship between inflation, economic growth and financial development has been in discussion over a long period of time without any consensus. Khan and Senhadji (2003) suggest that a consensus has been reached among economists pertaining to the role of financial markets in economic development.

Research studies reveal mixed results pertaining to the link between the three variables namely; financial development, economic growth and inflation. Lee and Wong (2005) indicate that inflation negatively impacts on medium and long term growth, thus it discourages investment and productivity growth (see Barro (1991), Fischer (1993), Bullard and Keating (1995)). In a related application, Bruno and Easterly (1998), Boyd et al (2001) reveal that inflation negatively impacts on financial depth. Azariadis and Smith (1996) and Hyubens and Smith (1999) argue that inflation prevents economic growth through its negative impact on the financial development. Boyd et al (2001) reveal that there exists a strong nonlinear and negative relationship between inflation and financial sector development. Thus, the financial sector performance is weak for economies with inflation rates above the 15 percent level. According to King and Levine (1993), Diamond and Dybvig

(1983), Levine (1997), financial development plays a vital role in the growth process. Recently, the relationship between finance and economic growth has received so much attention from various academics. However, there is no general consensus among various researchers as to whether inflation is detrimental to economic development (Bhusal and Silpakar 2011).

Eggoh (2012) points out that the analysis of the relationship between financial development and economic growth dates back to Schumpeter (1911). He indicated that in terms of economic development, the banking sector plays a vital role, by selecting which organisation or companies have a better chance of succeeding in terms of the innovation process. Over the last two decades, some studies have shown that economic growth and financial development are not positively related. Khan and Senhadji (2001) reveal that inflation negatively affects economic growth both in the medium and long term.

There are a number of studies analysing the relationship between financial depth [31]and economic growth. Some studies suggest that there is robust positive relationship between financial development and economic growth. Similarly, Iqbal and Nawaz (2009) point out that the existence and nature of relationship between inflation and economic growth and the channels through which it affects real economic activities has been the subject of considerable interest and debate due to inconclusive results.

This Chapter differs from the following studies that were undertaken by Hodge (2006), Phiri (2010), Leshoro (2012) and Seleteng et al (2013) in that a smooth transition regression model is used to estimate inflation threshold level on time series data with a sampling period ranging from 1960 to 2012. This is a different econometric technique utilised to identify the existence of inflation threshold in the relationship (Huang et al 2010).

The rest of the Chapter is organised as follows: Section 2 offers the review of empirical evidence. Section 3 discusses the theoretical framework. Section 4 reports data and

[31] The level of development of financial markets

methodology. Section 5 reports and discusses the empirical results. Finally section 6 offers some concluding remarks and draws some policy implications.

## 5.2 Literature review

Fischer (1993) noted the existence of a non-linear relationship between inflation and economic growth, thus at low rates of inflation, there is a positive link between inflation and long run economic growth, though at higher inflation rates there is a negative relationship.

Haslag and Koo (1999) examined the relationship between inflation and financial repression. Their results indicated that financial development and inflation are negatively correlated, though an increase in inflation rate beyond the threshold level leads to a positive relationship. Huang et al (2010) analysed the finance-growth relationship to determine whether it relied on different levels of inflation. In fact, they assessed a threshold effect on the finance-growth link. The results indicated inflation threshold levels of between 7.31 and 7.69 percent. Thus, the impact of finance on growth is negative or insignificant when inflation exceeds this threshold level. Furthermore, in their study they also focused on the threshold effect on the relationship between financial development and productivity growth. Thus, if the inflation rate exceeds the threshold of approximately 8 percent, there is an insignificant influence of financial development on productivity.

Deida and Fattouh(2002) and Rioja and Valev(2004a) indicated a weak or insignificant relationship between financial development and economic growth at a low level of per capita income and a positive relationship at high levels of per capita income. Thus, their results reveal that financial development is significant in countries with high income levels. Rioja and Valev (2004b) pointed out that financial development has reached a certain size threshold, thus it presents a strong positive impact on economic growth, though below the threshold level, the effect is uncertain. Similarly, Rousseau and Watchel (2002) indicate the presence of the threshold effect in the finance and growth relationship though inflation rate is the transition variable used for the period between 1960 and 1995 across a sample of 84 countries. In their analysis they used rolling panel regression approach and results showed that inflation threshold for the finance-growth relationship exists between 6 percent and 8 percent and finance has insignificant effects on economic growth when inflation increases beyond the threshold level.

Empirical studies such as those by King and Levine (1993) and Levine et al (2000) found a strong relationship between economic growth and financial development. Khan and Senhadji (2003) point out that there has been a lot of empirical and theoretical work undertaken pertaining to the role that financial markets play in promoting development and economic growth. The findings of Khan and Senhadji (2003) indicate that the effect of financial development on growth is positive though the size of the effects differs as per the various indicators of financial development.

Christopoulos and Tsionas (2004) results reveal that the relationship between financial depth and economic growth remains unclear. Further, Christopoulos and Tsionas(2004) reveal that some research studies for instance King and Levine(1993a,b), Khan and Senhadji (2000) and Levine et al (2000) using panel and cross country data established positive effects on output growth by financial development taking into consideration other determinants of growth as well as for potential biases caused by simultaneity, omitted variables.

In some instance, researchers have been able to identify a point of inflexion beyond which inflation is detrimental to economic growth. Research studies have been able to find inflation threshold levels below which the impact of inflation on economic growth is positive and insignificant and while above that level, it is negative and significant. Notably, evidence presented by various empirical studies reveals different results from one country to another. For instance, Eggoh (2012) assessed how inflation variations impact on the link between financial development and economic growth using a panel smooth threshold regression for 71 industrialised and developing economies for the period ranging from 1960-2004. Her results indicated that there is a nonlinear relationship between economic growth and financial development. Eggoh(2012)'s result revealed that there is an inflation threshold of 20 percent, beyond which increases in inflation lead negatively to or have no effect on economic growth by financial development. Yet below the 10 percent inflation threshold there is a positive impact of finance on economic growth or output.

Fischer (1993), using panel data, acknowledged the existence of a positive relationship between long run growth and inflation at low levels of inflation and a negative one following inflation increase. A number of research studies, for instance by Hyubens and Smith (1999), Gylfason and Herbertsson (2001), Bose (2002), as well as Rousseau and Wachtel (2002), have highlighted inflation levels as a key factor impacting on the relationship between financial development and growth. Lee and Wong (2005) argue that there are empirical findings revealing that financial development enhances economic growth under a low or moderate inflation rate. However, under a high inflation environment, financial development does not have any significant impact on economic growth. Lee and Wong (2005) indicate that in an inflationary environment there is high uncertainty and information asymmetry pertaining to investment projects. Thus following inflation increases, it becomes costly to transact as well as acquire information which directly negatively impacts on economic growth.

Khan et al (2006) indicate that there exist threshold levels of inflation of between 3-6 percent and in instances whereby inflation rates exceed the threshold level; further increases in inflation negatively affect financial development.

Huang et al (2010) investigates the existence of an inflation threshold in the finance-growth relationship using the Caner and Hansen's (2004) instrumental variable threshold regression approach. The latter found that there exists a significant inflation threshold in the finance-growth relationship. Notably, below the inflation threshold financial development positively impacts on economic growth, and yet above which financial development effect on growth is insignificant.

## 5.3 Theoretical Framework

Following the framework of Odedokun (1996), we use the neo classical aggregate production function which comprises of financial development as an input as in Eq. (1) given below:

$$Y_t = f(L_t, K_t, F_t, Z_t). \tag{1}$$

where $Y_t$ denotes aggregate output ; $L_t$ denotes labour force; $K_t$ denotes capital stock; $F_t$ denotes financial development level; $Z_t$ denotes the vector other factors that can be regarded as the inputs in the aggregate production process

Linearizing Eq. (1) and re-arranging the resulting expression, the following growth equation is obtained as illustrated below in Eq.(2):

$$\dot{Y_t} = \beta_0 + \beta_1\dot{L_t} + \beta_2\dot{K_t} + \beta_3\dot{F_t} + \beta_4\dot{Z_t} + u_t. \tag{2}$$

where $\dot{Y_t}$, $\dot{L_t}$, $\dot{K_t}$, $\dot{F_t}$ and $\dot{Z_t}$ respectively represent real GDP growth rate, labour force growth rate, investment rate, financial development index, and other factors and $u_t$ denotes the error term.

This study includes export growth rate ($\dot{EX_t}$) and inflation rate $\dot{P_t}$ to incorporate other factors that influence economic growth, following the empirical approach of Beck et al.(2000) and Christopoulos and Tsionas(2004).

Thus, the equation becomes:

$$\dot{Y_t} = \vartheta_0 + \vartheta_1\dot{L_t} + \vartheta_2\dot{K_t} + \vartheta_3\dot{F_t} + \vartheta_4\dot{EX_t} + \vartheta_5\dot{P_t} + \dot{u_t}. \tag{3}$$

$\vartheta_1$ and $\vartheta_2$ are positive coefficients according to the growth theory, given that capital stock and labour force positively impact real output.

## 5.4 Data and Methodology

### 5.4.1 Data Analysis

This study uses annual time series data on financial development and macroeconomic indicators for South Africa over the period 1960-2012[32]. Data was extracted from the IMF, World Bank's World Development Indicators database. The following variables are used in this analysis namely growth of real GDP, inflation, population growth, investment growth, export growth and growth of financial development. Calderon and Liu, (2003) argue that financial development cannot be captured by a single measure; instead three commonly

[32] Post 2012, results were not converging due to possible a number of instabilities which could be attributed to high global economic uncertainty and turbulence. Thus, the time periods after 2012 are excluded in this study

utilised measures of financial development are used in this Chapter. The first measure is the ratio of liquid liabilities to GDP (M3 as a percent of GDP). Other measures are domestic credit provided by banking sector (percent of GDP) and domestic credit to private sector (percent of GDP). Notably, this measure segregates credit issued to the private sector, as opposed to credit issued to the public sector and also eliminates credits issued by the central bank. The variables used in this Chapter were derived as follows: Economic growth is measured as annual percentage growth of GDP at constant prices. Labour force growth is proxied by population growth that is in turn calculated as the annual growth of population size. Inflation is measured as annual percentage change of average consumer price index. Investment is measured as gross capital formation as percent GDP. Real export growth is computed as the annual growth rate of real exports of goods and services.

#### 5.4.1.1 Descriptive statistics

The descriptive statistics of sample data indicate that the average value of growth rate of GDP is 3 percent, with maximum and minimum of 8.89 percent and -2.137 percent, respectively and inflation has an average value of 9.1 percent, with maximum and minimum of 18.655 percent and 1.385 percent, respectively and growth rate of population has an average value of 2.0 percent. Investment has an average value of 3.9 percent while M3 as a share of GDP and growth rate of exports have average values of 53.1 percent and 2.4 percent respectively as shown in Table 18.

**Table 18: Descriptive analysis**

*Descriptive statistics*

| Variables | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| GDP growth rate | 47 | 2.996 | 2.502 | -2.137 | 8.896 |
| Inflation | 47 | 9.113 | 4.481 | 1.385 | 18.655 |
| Growth rate of population | 47 | 2.026 | 0.490 | 0.962 | 2.597 |
| M3 as percent of GDP | 47 | 53.053 | 6.637 | 38.680 | 61.872 |
| Domestic credit to private sector( percent of GDP) | 47 | 94.644 | 33.212 | 55.600 | 161.980 |
| Domestic credit provided by banking sector( percent of GDP) | 47 | 119.203 | 38.539 | 76.353 | 195.335 |
| Investment as  percent of GDP | 47 | 3.881 | 7.478 | -17.506 | 16.276 |
| Growth rate of Exports | 47 | 2.430 | 5.121 | -19.542 | 10.938 |

Source: International Financial Statistics (IFS) and World Development Indicators

Table 19 presents the correlation between various variables. Investment as a percentage of economic growth is negatively related to inflation, M3 as a percentage of GDP and population growth, though it is positively related to export growth. Inflation is positively related to population growth and M3 as a percentage of GDP, however it negatively relates to export growth. The financial ratios are correlated amongst themselves and for this reason, they are experimented with one at a time.

**Table 19: Correlations**

| | Inv | Infl | llmgdp | dcpgdp | dcbgdp | pop | Exp | gdp |
|---|---|---|---|---|---|---|---|---|
| Inv | 1.000 | | | | | | | |
| Infl | -0.436 | 1.000 | | | | | | |
| Llmgdp | -0.097 | 0.154 | 1.000 | | | | | |
| Dcpgdp | 0.174 | -0.417 | -0.778 | 1.000 | | | | |
| Dcbgdp | 0.191 | -0.434 | -0.829 | 0.986 | 1.000 | | | |
| Pop | -0.326 | 0.434 | 0.747 | -0.708 | -0.781 | 1.000 | | |
| Exp | 0.115 | -0.193 | -0.094 | 0.173 | 0.138 | 0.045 | 1.000 | |
| Gdp | 0.658 | -0.486 | 0.070 | -0.013 | 0.003 | -0.138 | 0.192 | 1.000 |

Notes: inv denotes Investment as percent of GDP, infl-inflation rate, llmgdp denotes liquid liabilities(M3) as percent of GDP, dcbgdp denotes- domestic credit provided by banking sector( percent of GDP), dcpgdp represents domestic credit to private sector( percent of GDP) , pop denotes population growth, exp- exports growth and GDP denotes growth of GDP. Source: International Financial Statistics (IFS) and World Development Indicators

Augmented Dickey-Fuller (ADF) test is used to test the stationarity of the series, with null hypothesis suggesting that there is a unit root. Table 20 shows the result of ADF test for all series. Real GDP growth rate, growth rate of exports, and investment to GDP ratio are all stationary at level while M3 as percent of GDP, inflation, population growth rate are non-stationary at level and become stationary at first difference.

**Table 20: Stationarity test**

*Test for Non-stationarity of variables*

| Variables | Level | | | First Difference | | |
|---|---|---|---|---|---|---|
| | No Trend | With trend | Result | No Trend | With trend | Result |
| Rgdp | -4.92 | -4.83 | Stationarity | | | |
| Infl | -1.76 | -1.85 | Non-Stationarity | -6.1 | -6.34 | Stationarity |
| Pop | -0.73 | -1.67 | Non-Stationarity | -5.43 | -5.47 | Stationarity |
| Llmgdp | -1.1 | -4.89 | Non-Stationarity | -5.69 | -5.63 | Stationarity |
| Dcpgdp | 1.08 | -2.24 | Non-Stationarity | -5.70 | -5.77 | Stationarity |
| Dcbgdp | 1.08 | -2.32 | Non-Stationarity | -7.60 | -7.88 | Stationarity |
| Inv | -4.67 | 4.62 | Stationarity | | | |
| Exp | -5.6 | -5.6 | Stationarity | | | |

Notes: inv denotes Investment as percent of GDP, infl-inflation rate, llmgdp denotes liquid liabilities(M3) as percent of GDP, dcbgdp denotes- domestic credit provided by banking sector( percent of GDP), dcpgdp represents domestic credit to private sector( percent of GDP) , pop denotes population growth, exp- exports growth and rgdp denotes real growth of GDP. Source: International Financial Statistics (IFS) and World Development Indicators

### 5.4.1.2 Structural breaks

A series of methods can be used to test the structural stability for instance, the CUSUM test, Recursive, Chow test. In this Chapter, we used the Bai and Perron test, and identified 4 break points as follows: 1974:01, 1983:01, 1993:01, and 2002:01.[33] Thus, we can conclude that there is parameter instability during the period 1965-2011.

### 5.4.1.3 Granger causality test

Pair wise Granger Causality test is employed to examine the causal relations between inflation rate, investment, domestic credit provided by banking sector and domestic credit to private sector, liquid liabilities, population growth and exports growth. The results presented in Table 21 show that there is a bi-directional causality between domestic credit provided by banking sector and domestic credit to private sector as the null hypothesis cannot be rejected. In addition, there is a bi-directional causality between domestic credit to private sector and liquid liabilities as there is a failure to reject the null hypothesis.

[33] Tests results are available and can be provided upon request

The results reveal that domestic credit provided by banking sector Granger caused population growth, liquid liabilities and inflation rate. The domestic credit to private sector, Granger caused the inflation rate, population growth, and export growth. Inflation Granger caused investment and export growth. In addition, real growth rate Granger caused the growth rate of investment. Population growth Granger investment and liquid liabilities Granger caused population growth. On the other hand all other variables were independent to each other; investment with domestic credit provided by banking sector, investment with domestic credit to private sector, investment with export growth, population growth with export growth, and liquid liabilities with export growth, population growth with liquid liabilities, liquid liabilities with inflation rate, population growth with inflation, all are independent.

**Table 21: Pair wise granger causality**

| Null Hypothesis | Obs | F-test | P-value |
|---|---|---|---|
| DCPGDP does not Granger Cause DCBGDP | 45 | 4.14911 | 0.023 |
| DCBGDP does not Granger Cause DCPGDP | | 7.54159 | 0.0017 |
| EXGROWTH does not Granger Cause DCBGDP | 45 | 0.18403 | 0.8326 |
| DCBGDP does not Granger Cause EXGROWTH | | 6.54929 | 0.0035 |
| INFL does not Granger Cause DCBGDP | 45 | 0.59641 | 0.5556 |
| DCBGDP does not Granger Cause INFL | | 4.6226 | 0.0156 |
| GFCFG does not Granger Cause DCBGDP | 45 | 0.68261 | 0.5111 |
| DCBGDP does not Granger Cause GFCFG | | 1.22878 | 0.3035 |
| POPGROWTH does not Granger Cause DCBGDP | 45 | 1.32567 | 0.277 |
| DCBGDP does not Granger Cause POPGROWTH | | 7.24106 | 0.0021 |
| LLMGDP does not Granger Cause DCBGDP | 45 | 0.61223 | 0.5471 |
| DCBGDP does not Granger Cause LLMGDP | | 3.74565 | 0.0323 |
| EXGROWTH does not Granger Cause DCPGDP | 45 | 0.08514 | 0.9185 |
| DCPGDP does not Granger Cause EXGROWTH | | 7.31902 | 0.002 |
| INFL does not Granger Cause DCPGDP | 45 | 0.50869 | 0.6051 |
| DCPGDP does not Granger Cause INFL | | 4.67651 | 0.015 |
| GFCFG does not Granger Cause DCPGDP | 45 | 0.34811 | 0.7081 |
| DCPGDP does not Granger Cause GFCFG | | 0.74382 | 0.4818 |
| POPGROWTH does not Granger Cause DCPGDP | 45 | 1.24065 | 0.3001 |
| DCPGDP does not Granger Cause POPGROWTH | | 5.09898 | 0.0107 |
| LLMGDP does not Granger Cause DCPGDP | 45 | 5.52503 | 0.0076 |
| DCPGDP does not Granger Cause LLMGDP | | 3.10438 | 0.0558 |
| INFL does not Granger Cause EXGROWTH | 45 | 7.25826 | 0.002 |
| EXGROWTH does not Granger Cause INFL | | 0.87783 | 0.4235 |
| GFCFG does not Granger Cause EXGROWTH | 45 | 1.56626 | 0.2214 |
| EXGROWTH does not Granger Cause GFCFG | | 0.09025 | 0.9139 |
| POPGROWTH does not Granger Cause EXGROWTH | 45 | 0.03647 | 0.9642 |

| | | | |
|---|---|---|---|
| EXGROWTH does not Granger Cause POPGROWTH | | 1.64915 | 0.205 |
| LLMGDP does not Granger Cause EXGROWTH | 45 | 0.67377 | 0.5155 |
| EXGROWTH does not Granger Cause LLMGDP | | 0.18193 | 0.8343 |
| GFCFG does not Granger Cause INFL | 45 | 0.15675 | 0.8554 |
| INFL does not Granger Cause GFCFG | | 6.46778 | 0.0037 |
| POPGROWTH does not Granger Cause INFL | 45 | 1.83468 | 0.1728 |
| INFL does not Granger Cause POPGROWTH | | 1.03705 | 0.3638 |
| LLMGDP does not Granger Cause INFL | 45 | 1.02385 | 0.3684 |
| INFL does not Granger Cause LLMGDP | | 0.45529 | 0.6375 |
| POPGROWTH does not Granger Cause GFCFG | 45 | 2.80303 | 0.0726 |
| GFCFG does not Granger Cause POPGROWTH | | 0.59951 | 0.5539 |
| LLMGDP does not Granger Cause GFCFG | 45 | 0.86144 | 0.4302 |
| GFCFG does not Granger Cause LLMGDP | | 0.39717 | 0.6748 |
| LLMGDP does not Granger Cause POPGROWTH | 45 | 2.76206 | 0.0752 |
| POPGROWTH does not Granger Cause LLMGDP | | 0.22819 | 0.797 |

GFCFG denotes Investment as percent of GDP, INFl-inflation rate, LLMGDP denotes liquid liabilities(M3) as percent of GDP, DCBGDP denotes- domestic credit provided by banking sector( percent of GDP), DCPGDP represents domestic credit to private sector( percent of GDP) , POPGROWTH denotes population growth, EXGROWTH - exports growth. Source: International Financial Statistics (IFS) and World Development Indicators

### 5.4.2 The Smooth transition regression model

Following Terasvirta (1998), the smooth transition regression model could be presented as follows:

$$y_t = \emptyset z_{\hat{t}} + \vartheta z_t G(s_t , \gamma, c) + \varepsilon_t \tag{4}$$

where $y_t$ indicates real economic growth and $z_t = (w_t', v_t')$ represents a vector of regressors that incorporates the exogenous variables, $v_t(1, v_{1t}, \ldots, v_{kt})$ and the lagged dependent variable is presented as follows: $w_t(y_{t-1}, \ldots, y_{t-p})$. Baaziz et al (2013) suggest that

$\emptyset = (\emptyset_0, \emptyset_1, \ldots, \emptyset_n)$ and $\vartheta = (\vartheta_0, \vartheta_1, \ldots, \vartheta_m)$ represent $((n+1) * 1)$ and $((m+1) * 1)$ parameter vectors in the linear and nonlinear parts of the model, respectively.

and $\varepsilon_t \sim IID(0, \sigma^2)$. $G(\gamma, c, s_t)$ is the transition function bounded between 0 and 1 and it depends on the transition variable $s_t$, the location parameter $c$ [34], the slope parameter, $\gamma$ is determining how rapid the transition is and shows the speed of transition between 0 and 1, $\varepsilon_t$ is a white noise residual with variance $\sigma^2$.

The logistic smooth transition regression (LSTR) is regarded as a common choice for the transition variable and the exponential smooth transition (ESTR) is an alternative specification (Cheikh 2012). The LSTR is presented as follows:

$$G(s_t, \gamma, c) = [1 + \exp\{-\gamma(s_t - c)\}]^{-1} \qquad (5)$$

where parameter $c$ is the threshold between two extremes regimes (such as the upper and lower regime). According Cheikh (2012), different values would be taken by non-linear coefficients depending on whether the transition variable is below or above the threshold. Therefore, the parameters $\emptyset + \vartheta G(s_t, \gamma, c)$ change monotonically as a function of the transition variable $s_t$ from $\vartheta$ to $(\emptyset + \vartheta)$. Thus, as $(s_t - c) \to -\infty$, $G(s_t, \gamma, c) \to 0$ and the coefficients correspond to $\emptyset$. In case whereby $(s_t - c) \to +\infty$, the transition function $G(s_t, \gamma, c) \to 1$ and the coefficients become $(\emptyset + \vartheta)$. If $s_t = c$, $G(s_t, \gamma, c) = {}^1/_2$ and coefficients will be $\left(\beta + {}^{\vartheta}/_{2}\right)$.

Terasvirta (1994) proposes three steps to be followed in generating an LSTR model such as specification, estimation and evaluation. Specification is the first stage that begins with setting up a linear model for the analysis. The second part of specification entails testing for nonlinearity, selecting the appropriate $s_t$ and deciding on the most appropriate form of the transition function such as logistic or exponential specification. According to Terasvirta (1994) for the purpose of choosing the appropriate transition variable $s_t$ and the most suitable form of the transition function among LSTR1[35], LSTR2[36] and ESTR model, a linearity test has to be conducted.

[34] Sometimes referred to as the switch-point between regimes
[35] A model with a single transition variable
[36] A model with two transition variables

Furthermore, Luukkonen et al. (1988) reveals the existence of the identification problem in the specification above, as the model is only identified under the alternative of nonlinearity. Baaziz (2013), indicates that the parameters $c$ and $\vartheta$ are nuisance parameters and are not present under the null of linearity. According to Teräsvirta (1998) the identification problem can be avoided by approximating the transition function with a third Taylor expansion around $= 0$ . Following, Luukkonen et al. (1988) the reparametrization and rearrangement results in the following regression:

$$y_t = \beta_0' z_t + \beta_1' \tilde{z}_t s_t + \beta_2' \tilde{z}_t s_t^2 + \beta_3' \tilde{z}_t s_t^3 + \varepsilon_t^* \tag{6}$$

where $\varepsilon_t^* = \varepsilon_t + \acute{\theta} z_t R(\gamma, c, s_t)$, with the remainder $R(\gamma, c, s_t)$, and $z_t = (1, \check{z}_t')'$ , where $\check{z}_t$ is a $(h \times 1)$ vector of explanatory variables. Moreover, $\beta_j = \gamma \check{\beta}_j$, where $\check{\beta}_j$ is a function of $\theta$ and $c$. The null hypothesis of linearity becomes $H_{01}: \beta_1 = \beta_2 = \beta_3 = 0$ against the alternative $H_{11}: "at\ least\ one\ \beta_j \neq 0, j = 1,2,3"$. An LM-test can be used to investigate this hypothesis because under the null, $\varepsilon_t^* = \varepsilon_t$. The resulting asymptotic distribution is $\chi^2$ with $3\ h$ degrees of freedom under the null. If linearity is rejected, we can proceed with the estimation of the nonlinear model.

The second stage involves estimation of the parameters of the STR model that entails identifying appropriate starting values for the nonlinear estimation and estimating the model. The grid search procedure is used to estimate $\gamma$ and $c$ and attaining good starting values is important in this procedure (Cheikh, 2012). The final stage focuses on the evaluation of the model which utilises various tests for misspecification, such as error autocorrelation, parameter nonconstancy, remaining nonlinearity, ARCH and non-normality.

## 5.5 Empirical Results

The nonlinear model has been estimated using Equation 8 and results are illustrated in Table 22. For robustness, various regressions have been estimated using either of the three measures of financial depth and in some instances adding inflation uncertainty and output uncertainty to determine their influence on the relationship between finance and growth. Across all the regression, the coefficients of inflation on a low inflation regime are positive and significant yet the opposite is true for the high inflation state. These findings indicate that financial development and economic growth are non-linearly related with an inflation threshold beyond which increases in financial development positively impacting on economic growth. The results show that the inflation threshold is at 4.3 percent which is also considered as the inflexion point indicating two inflation regimes- low and high inflation thus the movement from one regime to another is determined by the inflation variable (as shown in Figure 15). Thus, finance positive impacts on economic growth for an inflation level below 4.3 percent and for an inflation rate exceeding 4.3 percent is negatively or not affected by financial development.

In Table 22, most variables with the exception of inflation uncertainty and population growth are significant. As in a recent paper by Eggoh (2012) population growth has an insignificant impact on economic growth. Most of the variables have correct signs and significant at 1 percent, 5 percent though others are significant at 10 percent. This aligns with Eggoh's (2012) results, which indicate that the ratio of government expenditure to GDP, inflation rate have a significant negative effect on economic growth including openness to trade. The results of this study however show a positively significant effect of trade openness on economic growth. In line with Ndou and Gumata (2017), the results presented in this chapter are robust whether inflation in used in logarithm or in level.

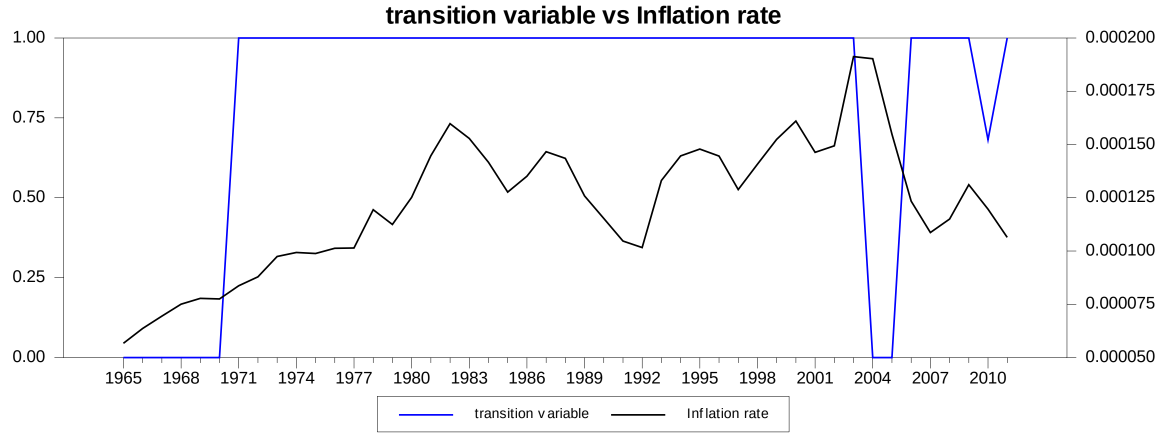
**Table 22: Estimated parameters for the LSTR models**

| Variable | Dependent variable: % Growth rate of Real GDP | | | |
|---|---|---|---|---|
| | (I) | (II) | (III) | (IV) |
| | | **Lower regime** | | |
| **Constant** | -0.080** | -0.064*** | 0.138*** | 0.096*** |
| | (-2.036) | (-2.605) | (3.890) | (3.731) |
| **Inflation** | 0.890** | 0.667 | 0.611*** | 0.693*** |
| | (2.136) | (1.595) | (3.967) | (2.787) |
| **population growth** | -0.870 | -0.320 | -1.320** | -0.387 |
| | (-1.029) | (-0.467) | (-1.809) | (-0.628) |
| **investment rate** | 0.074 | 0.100** | 0.067** | 0.173 |
| | (1.712) | (2.074) | (2.406) | (5.989) |
| **Llmgdp** | 0.179** | 0.141** | 0.004 | |
| | (1.981) | (2.425) | (0.054) | |
| **Trade openness** | 0.102*** | 0.092*** | 0.096*** | |
| | (7.905) | (5.415) | (5.542) | |
| **Government expenditure(annual % growth)** | 0.214*** | 0.196** | | |
| | (2.707) | (2.286) | | |
| **Government expenditure( % of GDP)** | | | -0.655*** | -0.517*** |
| | | | (-7.667) | (-3.571) |
| **dcpgdp** | | | | 0.004 |
| | | | | (0.260) |
| **location parameter** | 0.043 | 0.045 | 0.057 | 0.054 |
| **slope parameter** | 8791.583 | 213.454 | 2816.486 | 435.269 |
| **output growth uncertainty** | -0.009*** | -0.010*** | -0.006*** | -0.007*** |
| | (-4.204) | (-2.759) | (-3.369) | (-3.533) |
| **inflation uncertainty** | 0.003 | | 0.003 | |
| | (0.780) | | (0.768) | |
| | | | **Upper regime** | |
| **Inflation** | -0.999** | -0.744 | -0.584*** | -0.626** |
| | (-2.420) | (-1.861) | (-3.753) | (-2.146) |
| **output growth uncertainty** | 0.007** | 0.007* | | |
| | (2.420) | (1.951) | | |
| **DW stats** | 1.691 | 1.714 | 2.224 | 2.663 |
| **N(no: of observations)** | 47 | 47 | 47 | 47 |
| **$R^2$** | 0.911 | 0.908 | 0.937 | 0.883 |

Notes: Absolute values of t-statistics are in parentheses following each regression coefficient. ***, **, * indicate the statistical significance and the rejection of null hypothesis at 1 percent, 5 percent and 10 percent, dcpgdp represents domestic credit to private sector( percent of GDP) and llmgdp denotes liquid liabilities(M3) as percent of GDP. Source: International Financial Statistics (IFS) and World Development Indicators

In Figure 14, we link the inflation rate to transition variables to illustrate the aspect of monetary policy. Inflation rate is classified as follows; from 1965-1970 there was a low inflation regime, yet there was a high inflation regime for the period ranging from 1971 to 2004. Thereafter, there was low inflation regime from 2004/5 to 2011, which coincided with the adoption of the inflation targeting framework by the South Africa Reserve Bank to maintain price stability. Various central banks respond in different ways to unanticipated shocks to the economy. During an economic crisis such as financial crisis or recession, the monetary policy authorities adopt a moderately loose monetary policy stance[37] and implement a number of measures to promote economic growth and price stability. However, the face of an economic recovery with likely inflationary pressure, the central bank should respond by shifting its monetary policy stance from moderately loose to prudent.

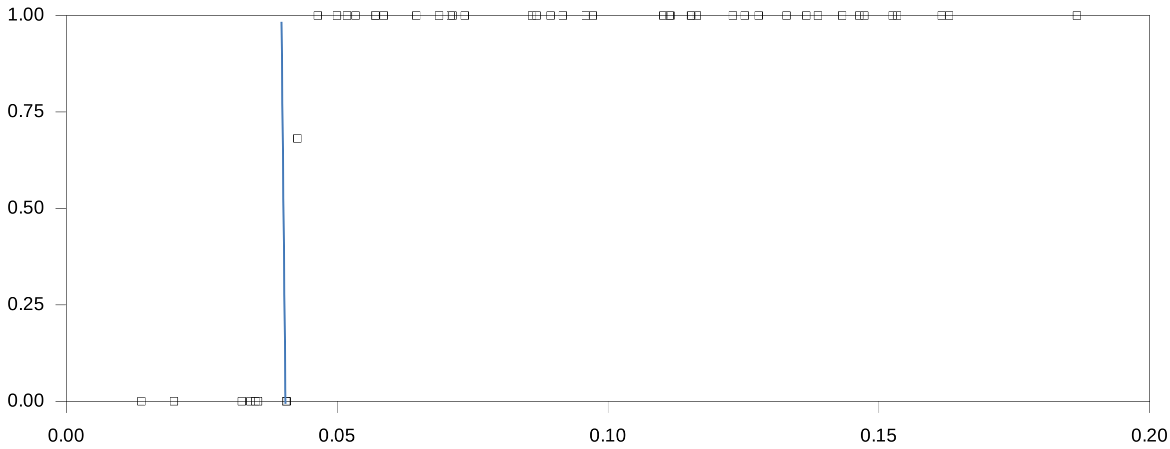
**Figure 14: Transition variable and inflation rate**




Source: International Financial Statistics (IFS) and World Development Indicators

[37] Refers to the contribution made by monetary policy to economic, financial and monetary developments

**Figure 15: Transition variable parameter**




Note: the solid line denotes the threshold level. Source: International Financial Statistics (IFS) and World Development Indicators

## 5.6 Conclusion

This chapter investigated the inflation thresholds beyond which inflation exerts negative effects on the financial depth-growth nexus. We used the smooth transition regression model to examine the effect of inflation variation on financial depth- growth relationship and to test the robustness of results. The results confirm the existence of an inflation threshold in the finance growth relationship. Thus, the results confirm that inflation affects the role of finance on economic growth. The findings provide strong evidence of an inflation threshold in the finance-growth nexus. The results show that the inflation threshold is at 4.3%. Thus, for rates of inflation below the threshold, finance positively and significantly impacts on economic growth, though the effect of finance on economic growth at inflation rates above 4.3% could be negatively.

Thus, these results support the South African Reserve Banks' inflation targeting policy to achieve price stability, hence there is need to ensure that inflation does not exceed the threshold level as it will be detrimental to the finance-growth relationship making it difficult for the economy to achieve sustainable economic activity. This study provides an analytical framework which helps policy makers in their decision making, as empirical evidence shows that high inflation (beyond a certain threshold) is costly or detrimental to the financial development- economic growth link, hence policy makers intend to achieve price stability. In line with Ndou and Gumata (2017), the results presented in this chapter are robust whether inflation in used in logarithm or in level. In terms of policy recommendation, it is ideal for policy intervention to be directed at maintaining inflation rate within the inflation target band of 3-6 percent and preferably below 4.3 percent to support and enhance a sustainable financial deepening and economic growth (Ndou and Gumata, 2017).

# CHAPTER 6: DOES THE EXCHANGE RATE EXHIBIT A NONLINEAR PASS THROUGH EFFECT INTO PRICES IN SOUTH AFRICA? EVIDENCE USING ATHRESHOLD VECTOR AUTOREGRESSION APPROACH

## 6.1 Introduction

This Chapter aims to examine the exchange rate pass through effect to headline CPI inflation, producer price inflation and import price inflation in South Africa. Exchange rate pass through refers to the degree to which exchange rate changes are reflected in the domestic prices. This could be the exchange rate effect on different prices such as consumer prices, producer prices or import prices. The Chapter intends to establish whether there exists a nonlinear relationship and whether the nonlinear relationship permits for significant effects of exchange rate effects on inflation in the different regimes. It is envisaged that the analysis will contribute to existing studies on exchange rate pass through (ERPT) taking into consideration issues of nonlinearity. This will be done by examining not only nonlinearities in ERPT related to the size and the direction of exchange rate changes, but also to import process, the inflation level and output gap.

There are a few studies mainly focusing on nonlinearities in exchange rate despite its relevance or prominence in the context of South Africa. This Chapter conducts a nonlinear time-series analysis for South Africa, employing a threshold vector autoregressive (TVAR) methodology that closely follows Aleem and Lahiani (2014). The threshold vector autoregression (TVAR) model allows for the flexibility of the parameters under differing regimes. The threshold value is determined endogenously, allowing the data to find the value of the inflation rate that maximizes the fit of the model in both regimes.

The extent of exchange rate pass through to inflation remains a well-researched topic. From the South African Reserve Bank (SARB) standpoint, whose primary objective is price stability, it is essential to understand the degree of exchange pass through to domestic prices. The monetary authorities in South Africa have the responsibility of attaining low inflation levels and price stability. Since 2000, the country has adopted inflation targeting framework. This entails monitoring inflation to ensure that it does breach the 3-6 percent inflation target band as well as using interest rates to influence determinants of inflation.

Since the exchange rate movement is regarded as one of the main determinants of inflation it is important for monetary authorities to understand the implications of exchange rate on inflation. According to Ocran (2010), an understanding of the relationship between domestic prices and exchange rate movements assists in the formulation of trade and monetary policy. Previous research has assumed that the long-run relationship between the price level and the exchange rate is symmetric. Further, it has been the view that the transmission of exchange rate changes (be it an appreciation or depreciation) to prices (i.e. domestic prices) is of the same scale or size. However, asymmetries are widely observed in the prices of final goods and they are mostly explained by rigidities, implying that prices are stickier downwards than they are upwards. These rigidities make the hypothesis of a symmetric pass-through unrealistic and too restrictive. In fact omitting asymmetric effects of exchange rates on prices may seriously distort the effects of monetary policies (Delatte and López-Villavicencio, 2012).

A number of research studies mainly focusing on the exchange rate pass through literature have employed models that cannot capture asymmetry or nonlinearity for instance, stationarity vector autoregression(VAR),co-integration and single equation regression(Aleem and Lahiani 2014). However, the existence of nonlinearities or asymmetry in the exchange rate pass through renders linear models as inappropriate techniques. A more realistic approach would be to recognize that the inflationary environment also affects the responses of economic agents to an exchange rate shock. It follows that domestic prices may not respond to an exchange rate shock due to the low and stable inflation. But they respond to the same shocks if the inflation is above its threshold level.

South Africa is one of the important emerging market countries in Africa. Its good macroeconomic policies provide an exemplary for African monetary policy, and a key destination for emerging market capital flows. SA has undergone several economic structural changes in recent decades, enhancing the importance of the exchange rates to import prices link. Hence, this study intends to contribute to existing ERPT literature on developing economies by choosing South Africa as a case study. Empirical research studies (i.e Ndou and Gumata, 2017) reveal that exchange rate pass through has implications for policy makers' decisions pertaining to the policy stance and expected future developments. Hence, it is important for policy research to focus on nonlinearity and asymmetry issues as it informs the decisions of policy makers.

Therefore, the main contribution of this Chapter is to implement a threshold vector autoregression (TVAR) model, to study the exchange rate pass-through to headline CPI inflation, producer price inflation and import price inflation in the context of South Africa. South Africa is a small, emerging and open economy in which exchange rate movements are sensitive to foreign capital flows. Thus, it is essential to understand and analyse the exchange rate pass through in the context of an inflation targeting country such as South Africa in order to be able to manage the country's trade balance So far only a few studies have considered and tested for asymmetry and non-linearity in South Africa. This may arise from menu costs, as exporters only change their prices if the exchange rate change exceeds a certain threshold. Furthermore, investigating the exchange rate pass through in South Africa remains important and it would contribute to our understanding of the factors that affect the value of the exchange rate pass through, and the aggregate process of price determination. The failure to understand the existence of a possible nonlinear behavior in the relationship between exchange rates and prices could affect inflation forecasts. In addition, an incomplete analysis and wrong assumptions about the future path of macroeconomic aggregates could lead to wrong inferences and, consequently, inadequate policies.

Nonetheless a major gap remains unfilled by these South African studies as well as studies from other developing countries, particularly the investigation of the asymmetric adjustment of domestic prices (import, producer and consumer prices) to fluctuations in the exchange rate. It is essential for policy makers to understand the adjustment of domestic prices to exchange rates in a nonlinear manner using regime dependent TVAR approaches as it helps anticipate inflation effects and monetary policy responses differs according to regimes. Our results show stronger positive correlation between the degree of exchange rate pass-through and the domestic prices.

Our results reveal the presence of nonlinearity with two regimes threshold values of exchange rate. In addition, the results show that domestic prices react strongly to a positive one unit exchange rate shock both below and above the threshold level of the exchange rate. Similar to Aleem and Lahiani (2014) technique the threshold values of exchange rate are estimated endogenously. The findings show that domestic prices react strongly to a positive one unit exchange rate shock both below and above the threshold level of the exchange rate

The outline of the rest of the Chapter is as follows. In Section 2, we briefly discuss the related literature. Section 3 provides an overview of South Africa's exchange rate and domestic prices. Section 4 outlines the analytical framework. Section 5 provides a data description. Section 6 presents the results. Section 7 presents the robustness analysis. Concluding remarks are available in Section 8.

## 6.2 Literature review

This Chapter is, thus, similar in spirit to that of Cheikh and Rault (2016). However, the model employed is different because it explicitly allows for possible nonlinearities that may exist over time. In recent years, there has been a growing interest in developing countries with regard to the investigation of ERPT. For instance, Aron et al (2014) reveal that in recent years, the growing trend of empirical analysis on ERPT in developing countries has been observed. Several studies have been undertaken (Mihaljek & Klau 2001; Rowland 2004; Nogueira 2007; Bussière & Peltonen 2008; Karoro et al. 2009; Omisakin 2009; Parsley 2010; Ocran 2010; Masha & Park 2012; Aron et al. 2014) on exchange rate related issues. Others are on ERPT to import, producer or consumer prices. There is also a mixture of analysis at both disaggregate and aggregate price level. However, most of these studies have not introduced possible nonlinearities in the estimation of pass through effects. Consequently, and considering the variability of the results obtained thus far, the empirical evidence is not conclusive and the estimates of pass through effects are not uniform.

### 6.2.1 Nonlinearities in exchange rate pass-through

Several research studies have been undertaken analysing ERPT mainly focusing on nonlinear models. For instance, Nogueira and Leon-Ledesma (2008) investigated the empirical evidence on ERPT into inflation for a set of developing and industrialised countries. They provided compelling evidence of nonlinear ERPT. Their findings show that the nature of nonlinearity varies with the magnitude of the exchange rate variation, the output gap, the inflation rate and with a measure of macroeconomic stability.

Shintani et al. (2009) analysed the relationship between the ERPT and inflation using smooth transition autoregressive (STAR) models. The author's findings prove the Taylor's hypothesis and point out, that the declines in the ERPT could be attributed to lower inflation during the 1980s and 1990s.

Wickremasinghe and Silvapulle (2004) examine the exchange rate pass-through to import prices of manufactured goods in Japan using asymmetric unit root tests, cointegration tests and asymmetric models. Notably, the authors' findings revealed the presence of an asymmetric pass-through, with a weak pass through to import prices following depreciation yet a strong pass through to import prices is experienced as a result of currency appreciation.

Pollard and Coughlin (2003) explore the symmetry in response of import prices in manufacturing to appreciations and depreciations as well as to the size of the change of the exchange rate in the US. Their findings indicate the presence of asymmetry in response of import prices in different industries. However, across industries the authors failed to establish a clear direction of the asymmetry. In conclusion, Pollard and Coughlin (2003) show that pass-through is positively associated to the size of the change in the exchange rate.

Campa et al. (2006) investigate non-linearity in import price adjustment in the European Union, utilising industry-level data. Their findings display strong evidence for the presence of nonlinearities in the adjustment towards long-run equilibrium in certain industries. In addition, the authors' findings revealed the existence of thresholds of no adjustment centred on zero. However, the thresholds appear to be much higher for the commodity industries than for manufacturing.

Using a state-space model, Nogueira and Leon-Ledesma (2010) test the same hypothesis. They argue that exchange rate pass-through (ERPT) into domestic inflation has been declining in many countries following a change in inflation environment during the 1990s. The model used permits ERPT to be time-varying and dependent on the inflation environment. Thus, Nogueira and Leon-Ledesma (2010) estimated the model for 12 industrialised and emerging market economies and tested whether inflation contains significant information about the future evolution of the ERPT. Their findings support evidence of a smooth decline in the impact of exchange rates on domestic inflation, though it contradicts the hypothesis that lower inflation precedes ERPT decline.

### 6.2.2 Empirical studies on South Africa

There are only a few research studies that have been undertaken on the exchange rate pass through in the context of South Africa using nonlinear models although there is more literature on ERPT around the world (Karoro et al 2009). For instance, Aron et al (2014), Nell(2000), Bhundia(2002), SARB(2002), Ocran (2010) have analysed exchange rate pass through phenomenon in South Africa. Most of the studies reveal mixed findings. For example both Bhundia (2002) and Ocran (2010) found that short-run pass-through peaks at 40 percent in the third quarter and after eight months respectively. Razafimahefa (2012) also reports an average of 40 percent pass-through in sub-Saharan Africa. Similarly, using single equations, Aron et al. (2012) establish a pass through into import prices in the range of 44 percent to 55 percent depending on the model.

In the case of South Africa, three noteworthy studies have been conducted by Nell (2000) and Bhundia (2002) respectively. Nell (2000) analysed the inflationary impact of exchange rate depreciation in South Africa. The findings of the study showed that the long-run causes of inflation in South Africa had changed from a demand-pull inflation over the period 1973-1983, to a cost-push cause of inflation since 1987 when a market determined exchange rate had finally stabilised. These studies found that the ERPT is greater on import as compared to consumer prices. This seems to confirm Bhundia's (2002) findings on the channels of ERPT. This is further supported by the studies of Choudri and Hakura (2006) who found that ERPT to the consumer price was only seven per cent after two years in South Africa.

The above was also confirmed by Parsley (2010), who conducted a study which estimated ERPT into consumer goods and services prices, and at the dock. The various authors also found that ERPT was greater on depreciation rather than appreciation of the rand. This shows that asymmetry plays a significant role in South Africa in determining the extent and degree of ERPT. A similar study by the SARB (2001), which investigated the first stage of exchange rate pass-through, found that approximately 78 per cent of an ERPT to import prices in South Africa in the long run and that half of this adjustment occurs in just less than one year

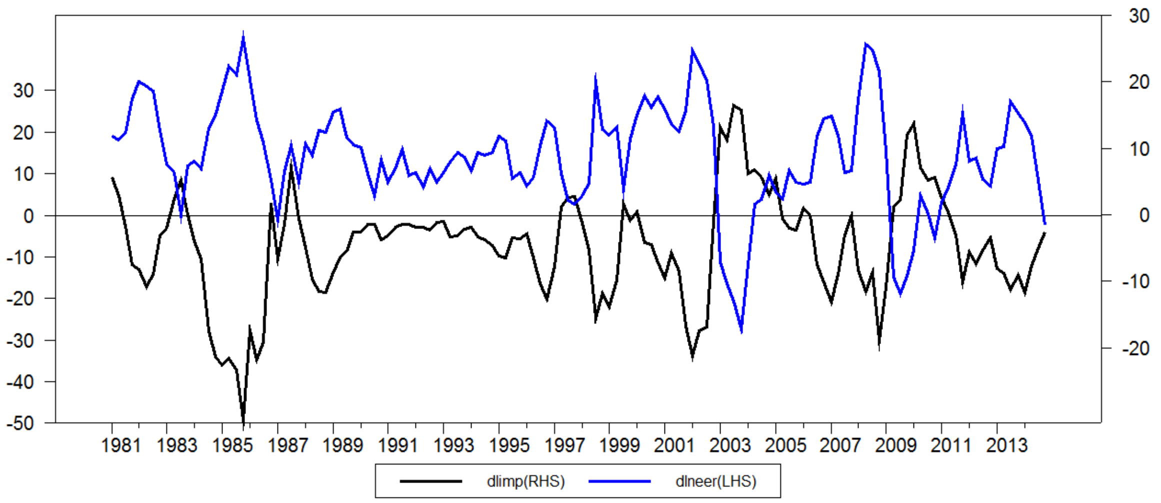
The literature on exchange rate pass through effect in South Africa reveals mixed findings. In a nutshell, most of the studies reviewed in the context of South Africa reveal that the degree of pass-through in South Africa is incomplete. In addition, the results are influenced by the price level aggregation or disaggregation or which stage of the distribution is being analysed. Most of the studies reveal that ERPT to import prices is around 40 percent and 55 percent, while ERPT to producer and consumer prices is below 30 percent and 20 percent respectively

## 6.3 Overview: Exchange rate and domestics prices in South Africa

South Africa formally adopted inflation targeting in 2000. However, over the past years the exchange rate regime has changed from fixed exchange rate system to managed float and lately to flexible exchange rate system. According to Ocran (2010), there appear to be marked differences in the degree of variability between the period of dual exchange rate regime (around 1985-1995) and that of the floating exchange rate (from 1995-present).

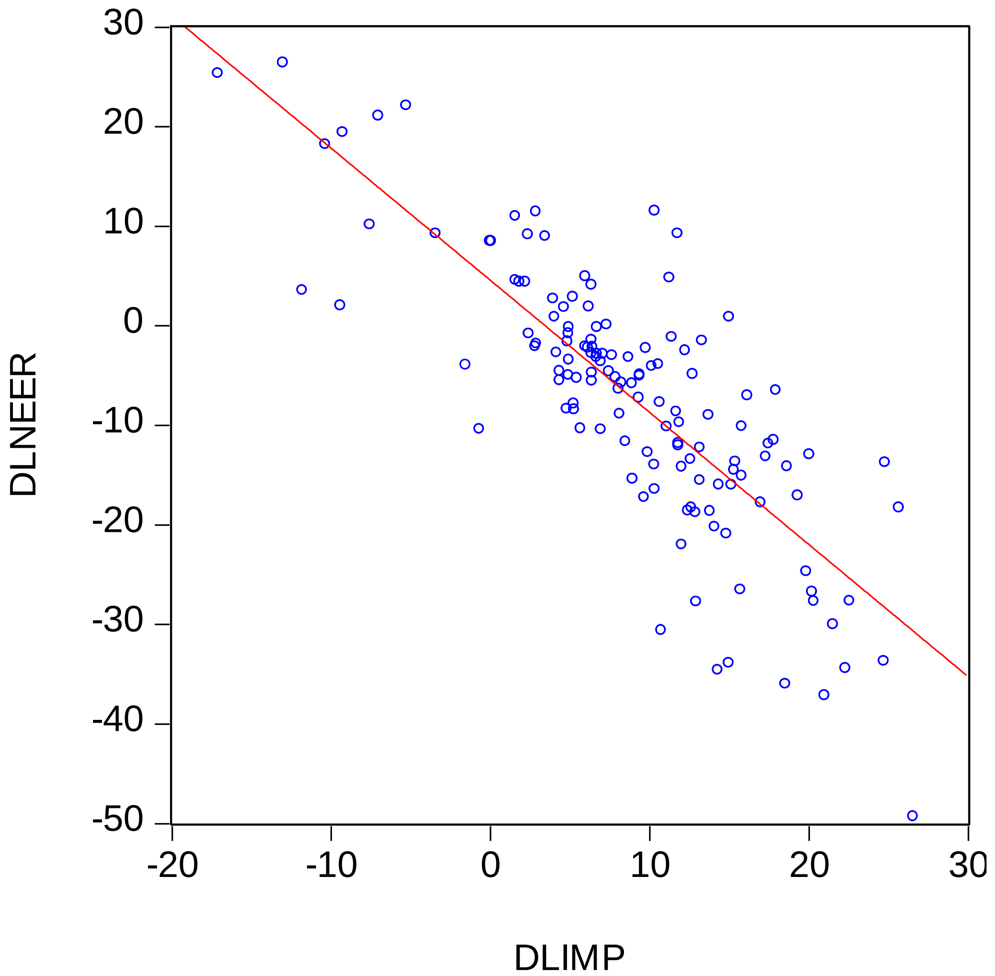
Figure 16 depicts the relationship between exchange rate movement and import prices for the period ranging 1975Q1 to 2014Q4. Thus, there is a negative relationship between exchange rate movements and import prices. This is in line with other research studies for instance; Bhundia (2002) suggests that the rand appreciation results in the reduction of the cost of imported products, ultimately lowering the import prices. However, the rand depreciation results in opposite effects. Similar to Karoro et al (2009), Figure 17 illustrates a downward trend of the nominal effective exchange rate implying a general depreciation in the nominal value of the rand. This shows that although the South African Reserve Bank (SARB) adopted a flexible exchange rate system, the rand remained volatile.

**Figure 16: Nominal effective exchange rate and import prices**




Notes: dlimp denotes import prices and dlneer represents changes in nominal effective exchange rate
Source: Source: IFS Online Database

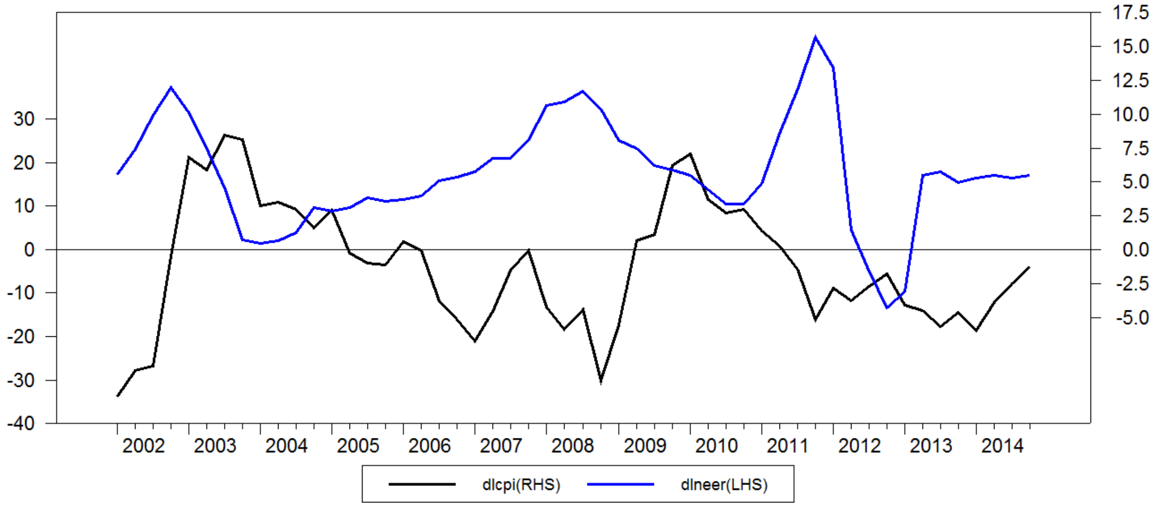
**Figure 17: Scatter plot of exchange rate changes and import price**




Source: IFS Online Database

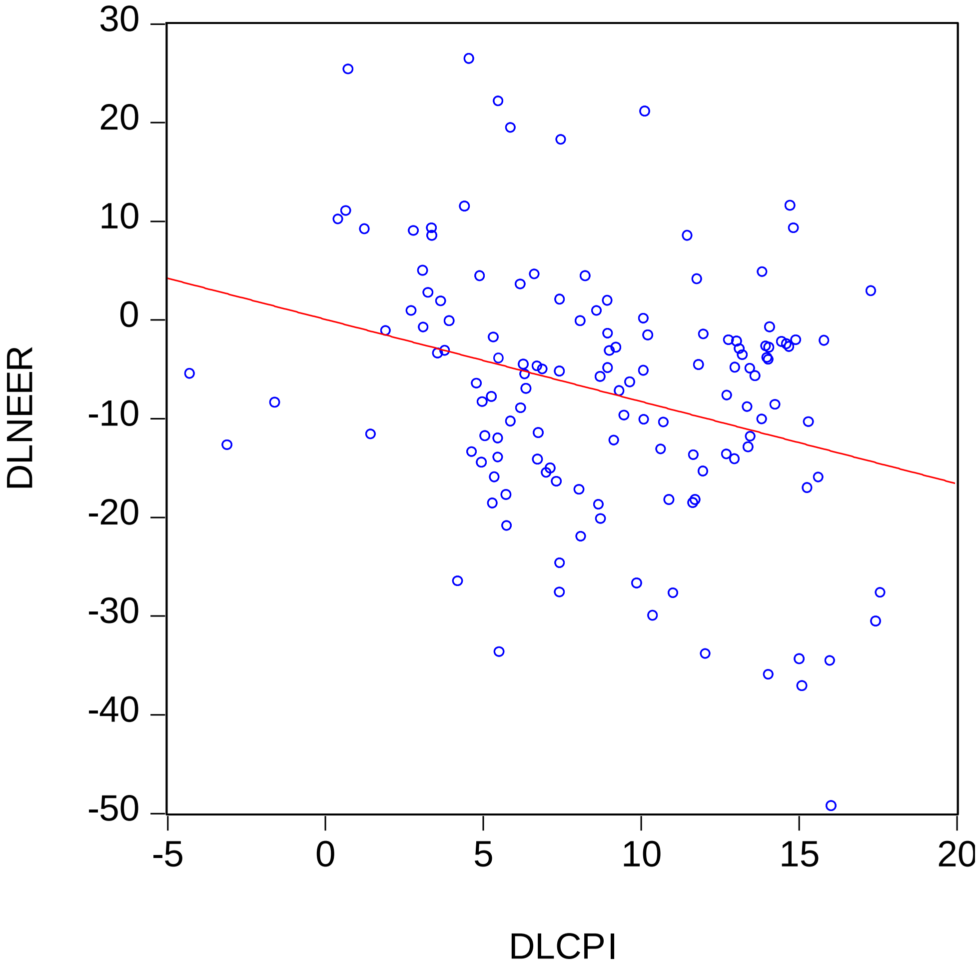
Figure 18 illustrates the relationship between exchange rate movements and consumer price inflation for the period between 2002 and 2014. The graph indicates that over time there has been appreciation and depreciation of the rand of different magnitudes. And there is a negative correlation between exchange rate movements and consumer price inflation, thus when the rand appreciates consumer price inflation is reduced (as shown in Figure 19).

**Figure 18: Percent changes in nominal effective exchange rate and consumer price inflation**




Notes: dlneer represents changes in nominal effective exchange rate, dlcpi represents inflation
Source: Source: IFS Online Database

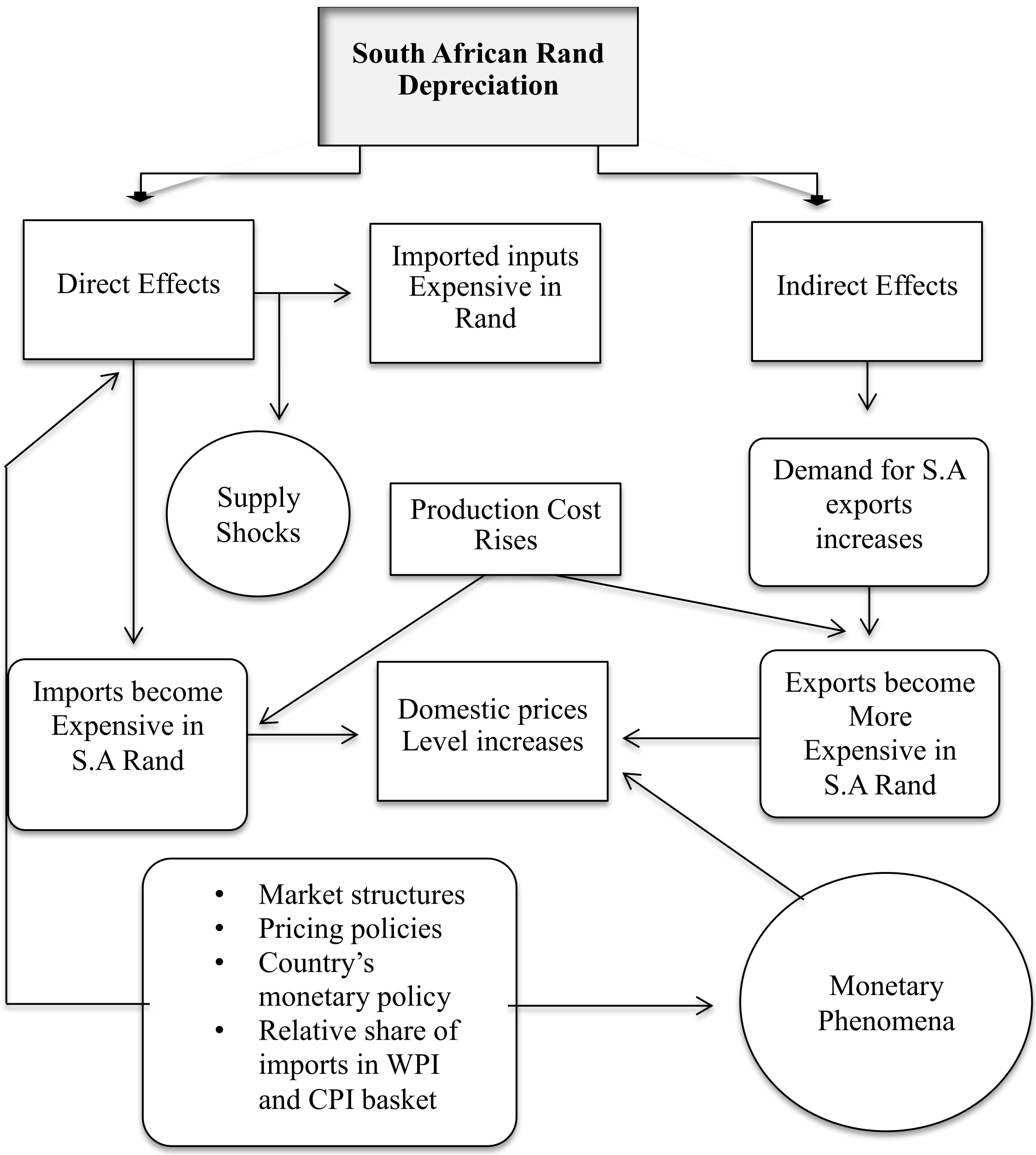
**Figure 19: Scatter plot of exchange rate changes and consumer price inflation**




Source: IFS Online Database

Exchange rate movements can impact on domestic prices through indirect and direct channels (Hyder and Shah 2004). For instance, as illustrated in Figure 20, the exchange rate movement can directly impact on domestic prices through changes in the price of imported finished goods and imported inputs. Thus, as the currency depreciates, it leads to higher import prices. Yet, lower import prices result from appreciation in price taker countries like South Africa. The potentially higher costs of imported raw material and capital goods associated with exchange rate depreciation increase marginal costs and lead to higher prices of domestically produced goods. In case of indirect effect, the exchange rate depreciation affects the net exports, which in turn influence the domestic prices through the change in aggregate demand, putting upward pressure on domestic prices.

**Figure 20:Exchange pass through transmission channels**




Sources: Adapted from Hyder and Shah (2004)

## 6.4 Analytical framework

This section discusses the analytical framework underlying the pass-through relation examined in this Chapter. Following Cheikh and Rault (2016), the model is set in the context of a price-discriminating monopolist, and it is a partial equilibrium. Let us consider a home country that imports a good, $q^m$, from a foreign monopolist. In home, the foreign firm faces competition from a domestic substitute good, $z$. Assuming that home's import demand for this good is weakly separable from other goods in the consumer's utility function, demand in the home country can be expressed follows: $q^m(p^m, p^z, Y^m)$ where $p^m$ denotes the import price of $q^m$ in the domestic currency, $p^z$ is the domestic currency price of $z$ and $Y^m$ is the income or expenditure on all goods in the importing. Similarly, in the foreign firm's domestic market, demand is determined by the local (Foreign) currency price of the good and income (or expenditures on all goods): $q^x(p^x, Y^x)$ where $p^x$ is the foreign currency price of the good and $Y^x$ is the income or expenditures on all goods in other countries.

The production of good $q$ occurs only in foreign country and inputs are allowed to come from both domestic and foreign countries. Therefore, factor prices in the foreign country, $w^*$, will depend on the exchange rate, $e$ expressed as the foreign currency price of the home currency. According to Pollard and Coughlin (2003) the cost of producing the good depends on the total quantity produced, $(Q = q^m + q^x)$, and factor prices: $c(Q, w^*(e))$. Assuming that costs are homogeneous of degree one in factor prices then $c(Q, w^*(e)) = w^*(\text{e})\text{ø}(\text{Q})$. The foreign firm maximizes profits in its own currency, treating $z$ and $Y^m$ as exogenous. Then, the profit maximization problem can be stated as:

$$max \prod_{p^x, p^m} = p^x q^x + e^{-1} p^m q^m - w^*(\text{e})\text{ø}(\text{Q}) \quad (1)$$

The first- order condition with respect to the price in the foreign market, $p^x$ , yields:

$$p^x = q^x + p^x \frac{\delta q^x}{\delta p^x} - w^* \text{ø}' \frac{\delta q^x}{\delta p^x} = 0 \quad (2)$$

with respect to the import price in the importing country, $p^m$, is:

$$p^m = e^{-1} q^m + e^{-1} p^m \frac{\delta q^m}{\delta p^m} - w^* \text{ø}' \frac{\delta q^m}{\delta p^m} = 0 \quad (3)$$

Eq.(2) can be written as:

$$p^x \colon \frac{\delta q^x}{\delta p^x} \left[ p^x \left( 1 - \frac{1}{\varepsilon^x} \right) \right] - w^* \text{ø}' = 0 \quad (4)$$

and Eq(3) as follows:

$$p^m: \frac{\delta q^m}{\delta p^m}\left[e^{-1}p^m \left(1-\frac{1}{\varepsilon^m}\right)\right] - w^*ø' = 0 \quad (5)$$

Where $\varepsilon^i = - \left(\frac{\delta q^i}{\delta p^i}\frac{p^i}{q^i}\right)$ is the elasticity of demand with respect to price for $i = x, m.$

Knowing that markup over marginal cost is defined as $\mu^i = \left(\frac{\varepsilon^i}{\varepsilon^i - 1}\right)$, the first order condition regarding $p^x$ becomes:

$$p^x: \frac{\delta q^x}{\delta p^x}\left[\frac{p^x}{\mu^x} - w^*ø'\right] = 0 \quad (6)$$

and for $p^m$:

$$p^m: \frac{\delta q^m}{\delta p^m}\left[\frac{e^{-1}p^m}{\mu^m} - w^*ø'\right] = 0 \quad (7)$$

Therefore, according to equation(6) and (7), prices in each market can be expressed as:

$$p^x = w^*ø'.\mu^x \quad (8)$$

$$p^m = e.w^*ø'.\mu^m \quad (9)$$

Solving profit maximization yields the standard condition that the price in each market, that is, foreign and domestic, is determined by a market specific markup, $\mu^i$, over common marginal cost, $w^*ø'$. Our primary focus is on equation (9). This equation shows that the import price $p^m$ (which is expressed in the importing country's currency) depends on three factors: the bilateral exchange rate between importer and exporter, the marginal cost, and the markup of price over marginal cost. Note that the exporter's marginal cost and markup may change independently of the exchange rate. For instance, a change in the cost of a locally provided input (in the foreign country) can shift the marginal cost. Also, adjustments in markups may occur in response to changes in variables specific to the importing country, namely, demand conditions $Y^m$ and the price of the competing product $p^z$, so that: $\mu^m = \mu^m(Y^m, p^z)$ .

Cheikh and Rault (2016), argue that in order to estimate the degree of pass-through, it is necessary to isolate the exchange rate effect from other effects, namely the exporter's cost shifter, the importer's demand conditions, and the price of the domestic competitor. Thus, the arguments of the import price presented equation (9) could be simplified through a log-linear regression specification similar to that tested throughout the ERPT literature, namely

$$p_t^m = \beta_0 + \beta_1 e_t + \beta_2 w_t^* + \beta_3 Z_t + \varepsilon_t, \quad (10)$$

where $p_t^m$ is domestic currency import prices, $\varepsilon_t$ is the exchange rate, $w_t^*$ denotes variable representing exporter costs, and $Z_t$ is a vector including demand conditions and competitor prices in the importing country among other control variables, and $\varepsilon_t$ is white noise. According Campa and Goldberg (2005), biased estimates of the pass through coefficient could arise if foreign wages or GDP are correlated with the exchange rates but omitted from the regression.

According to equation (10), the ERPT coefficient is given by coefficient $\beta_1$ is expected to be bounded between 0 and 1. Thus one for one pass through to changes in import prices, known as a complete ERPT, is given by $\beta_1 = 1$ . In this case, exporters let the domestic currency import prices affected by exchange rate fluctuations. However, when exporters adjust their mark-up, a partial or incomplete ERPT occurs and $\beta_1 < 1$ . It is important to note that mark-up setting is in turn influenced by other factors, such as macroeconomic conditions in the importing country. For instance, recent empirical studies gave supportive evidence that pricing strategies of foreign firms depend on the inflation environment in the destination market. Countries with stable and low inflation levels would have their currencies chosen for transaction invoicing, leading to lower pass-through into import prices.

Following Cheikh (2012), it is assumed that pricing strategy of foreign firms depends on importer's macroeconomic environment in a non-linear framework (i.e macroeconomic determinants such as inflation level). The macroeconomic dependence is seen as a firm's strategic decision on how much to translate exchange rate changes given different macroeconomic scenarios in the importing country. In addition, the pass through coefficients are assumed to be nonlinearly related to inflation rate, thus the exchange rate pass through is a non-linear function of the importing country inflation rate. Nonetheless, it appears there is some threshold inflation level which provides two extreme macroeconomic regimes, namely: high and low inflation environment regimes. Therefore, a threshold vector autoregressive model is employed in this study to account for nonlinearities.

### 6.4.1 Threshold Vector Autoregressive (TVAR) model

We use the threshold vector autoregressive model to capture the non-linearity in the exchange rate transmission. A threshold VAR is a simple method to model changing dynamics of a set of variables over two or more distinct regimes. The regimes are determined by a transition variable, which is either endogenous or exogenous (Hansen 1996, 1999, Tsay 1998). In general, it is possible to obtain more than one critical threshold value, but for simplicity on a model with only two regimes is hereby focused upon.

Employing a threshold vector autoregressive (TVAR) model, the nonlinearity in the pass through effect of the exchange rate on domestic prices is analysed following Takatoshi and Kiyotaka (2008). It is assumed that there is some exchange rate changes threshold level ($\gamma_1$), which provides two extreme regimes (Cheikh 2012). The two regime TVAR model is estimated as follows (see Aleem and Lahiani 2014):

$$\boldsymbol{y_t} = \begin{cases} \beta_1 + A_1(L)y_t + \varepsilon_{1t} \;\; if \quad q_t \leq \gamma_1 \\ \beta_2 + A_2(L)y_t + \varepsilon_{2t} \;\; if \quad q_t > \gamma_2 \end{cases} \tag{4}$$

where the vector variables $(y_t)$ consists of the change in oil prices ($\theta_t$ ), the output gap $(g_t)$ , the rate of money growth $m_t$, the nominal effective exchange rate $(s_t)$ and ( $v$), the domestic prices, $q_t$ is the threshold variable, and $\gamma_1$ and $\gamma_2$ are the threshold values. According to Aleem and Lahiani (2014), the output gap captures the effects of the real sector on exchange rate pass-through or the demand side effect (Takatoshi and Kiyotaka, 2008). Money supply is added to capture the effects of monetary policy on inflation. Import price index and producer price index are included to enable the investigation of the effects of shocks at different stages of the pricing chain from imports to retail.

Following Takatoshi and Kiyotaka (2008), a five variable TVAR (baseline model) is set up, which consists of the above mentioned endogenous variables i.e. oil price $(\theta)$, output gap $(g)$, money supply growth $(m)$, nominal effective exchange rate $(s)$ and domestic prices $(v)$.

$$y_t = [\theta \quad g \;\; m \;\; s \quad v\,] \tag{5}$$

We treat the nominal effective exchange rate as the threshold variable in our model. $\beta_i', i = 1 \ldots ,2,$ is a 2 x 1 vector of constants while the lag polynomial $A_i(L) = A_{i1}L \; + A_{i2}L^2 + \cdots +$

$A_{ip}L^{P}$ with a $4 \times 4p$ matrix $A_{ij}, j = 1, 2, \dots, p$; $L$ is the lag operator. A more compact form of the two regime $TVAR(p)$ model is as follows:

$$y_t = \left(\beta_1 + A_{11}(L)y_{t-1} + \cdots + A_{1p}(L)y_{t-p} + \varepsilon_{1t}\right)I(q_t \leq \gamma_1) + \left(\beta_2 + A_{21}(L)y_{t-1} + \cdots + A_{2p}(L)y_{t-p} + \varepsilon_{2t}\right)I(q_t > \gamma_2) \quad (6)$$

where $I(.)$ takes the value 1 if its argument is satisfied and 0 otherwise. Defining $\emptyset = (\beta_1, \beta_2, A_1, A_2, \gamma_1, \gamma_2)$ as the vector of parameter of interest, we use the ordinary least square (OLS) method to minimise the following function:

$$\widehat{\emptyset} = \arg min_{\emptyset} \left(\sum_{t=1}^{T} \begin{pmatrix} y_t - (\beta_1 + A_{11}(L)y_{t-1} + \cdots + A_{1p}(L)y_{t-p} + \varepsilon_{1t})I(q_t \leq \gamma_1) \\ -(\beta_2 + A_{21}(L)y_{t-1} + \cdots + A_{2p}(L)y_{t-p} + \varepsilon_{2t})I(q_t > \gamma_2) \end{pmatrix}\right) \quad (7)$$

Variables for this baseline model (five variables TVAR model) were selected on the basis of these previous research studies by Zaha and Zhang (2013), Takatoshi and Kiyotaka (2008), Hahn (2003), and McCarthy (2000).However, these studies with the exception of Takatoshi and Kiyotaka (2008) use six or seven or eight variable VAR which incorporate import prices (IMP), producer price index (PPI) and consumer price index (CPI) jointly. In case of the baseline model, following Takatoshi and Kiyotaka (2008), each price variable is included one by one and the estimated results obtained from the respective estimations are compared. In line with previous studies, oil prices and the output gap are included to identify supply shocks and capture demand side effects respectively.

A TVAR model is set following Ito and Sato (2008), with the vector of five endogenous variables, $x_t = (dloil_t, ogap_t, dlm1_t, dlneer_t, dlcpi_t)$,′ where $dloil_t$ denotes the growth of oil prices); $ogap_t$, real output gap; $dlm1_t$; money growth rate; $dlneer_t$, a nominal effective exchange rate growth; $dlcpi_t$, consumer inflation rate.

### 6.4.2 Generalized Impulse Response Function (GIRF)

Utilising the standard impulse response analysis was an option for this study. However, according Berument et al (2008,) this method is criticised because the results depend on the orthogonally assumption and they differ with the ordering choice. Thus the generalised impulse response analysis developed by Koop et al (1996) and Pesaran and Shin (1998) was preferred. This method has two advantages over the standard impulse response analysis.

Firstly, it does not presuppose any ordering that may have theoretical implications and it does not rely on the ordering choice of the researcher. Secondly, it provides for a meaningful interpretation of the initial impact of the shocks.

The Generalized Impulse Response Function (GIRF), introduced by Koop et al. (1996) offers a useful generalization of the concept of impulse response to nonlinear models. The GIRF for a specific shock $\varepsilon_t = \delta$ and history $h_{t-1}$ is defined as

$$GIRF\ r(k, \delta, h_{t-1}) = E[r_{t+k} | \varepsilon_t = \delta, h_{t-1}] - E[r_{t+k} | h_{t-1}], \tag{8}$$

for $k = 0, 1, 2, \ldots.$

In the GIRF, the expectation of $\{r_{t+k}\}$ given that a shock $\delta$ occurs at time $t$ is conditioned only on the history and this shock. Thus the problem of dealing with shocks occurring in intermediate time periods is handled by averaging them out. The natural benchmark for the impulse response is then the expectation of $\{r_{t+k}\}$ conditional only on the history, $h_{t-1}$ and the current shock is averaged out as well. It is easily seen that for linear models the GIRF is equivalent to the traditional impulse response function.

However, the GIRF is a function of $\delta$ and $h_{t-1}$ that are realizations of the random variables $\varepsilon_t$ and $\Omega_{t-1}$ and thus a realization of a random variable, defined as;

$$GIRF\ r(k, \varepsilon, h_{t-1}) = E[r_{t+h} | \varepsilon_t, h_{t-1}] - E[r_{t+h} | h_{t-1}], \tag{9}$$

for a particular history $h_{t-1}$ and the GIRF is treated as a random variable in terms of $\varepsilon_{t.}$

It is equally possibly to reverse the roles of the shock and the history by fixing the shock at $\varepsilon_t = \delta$ and defining the GIRF to be a random variable with respect to the history $\Omega_{t-1}$. In general, one might consider the GIRF to be random conditional on particular subsets A and B of shocks and histories respectively, that is, $r(k, A, B)$ . For example, one might condition on all histories in a particular regime and consider only negative shocks.

Since Generalized Impulse Response is invariant to changes in ordering, the results are more robust than those of the orthogonalised impulse response analysis.

Instead of controlling the impact of correlation among residuals, GIRF follows the idea of nonlinear impulse response function and compute the mean impulse response function. When one variable is shocked, other variables also vary as is implied by the covariance. GIRF computes the mean by integrating out all other shocks. The formula of GIRF is derived under the assumption of multivariate normality that might not be true for some empirical applications.

## 6.5 Data

The data are quarterly observations and sourced from International Financial Statistics (IFS) database. The sample period ranges from 1975:1 to 2014:1. Thus, the availability of data determined the beginning of the sample. The exchange rate is measured by the nominal effective exchange rate computed by the IFS. For the measure of domestic economic activity, output gap is used. The Treasury bill rate was used as a proxy for short-term interest rate which is regarded as an alternative monetary policy variable. The money stock is measured by M1 (Jiang and Kim 2013) and the domestic prices are measured by headline CPI inflation (CPI), producer price inflation(PPI) and import price inflation(IMP).These prices are widely used indicator by both financial analysts and policy makers to examine developing price trends. For the computation of the pass through effects, all data series except the interest rates are converted to logarithms and differenced to ensure stationarity.

The output gap is defined by applying the Hodrick Prescott (HP) filter to the natural log of the real GDP. The nominal effective exchange rate is used as a proxy for the exchange rate as it is regarded as more appropriate than utilising other bilateral exchange rates such as the ZAR/USD rate. In this study, a shock to the exchange rate is defined as a positive variation of the exchange rate. Thus, an increase in the exchange rate value represents a nominal appreciation for home country (Aleem and Lahiani, 2014). The rate of inflation is measured by the consumer price index (CPI). The exchange rate affects import prices which in turn affect production costs and consequently the CPI.

**Table 23: Descriptive statistics**

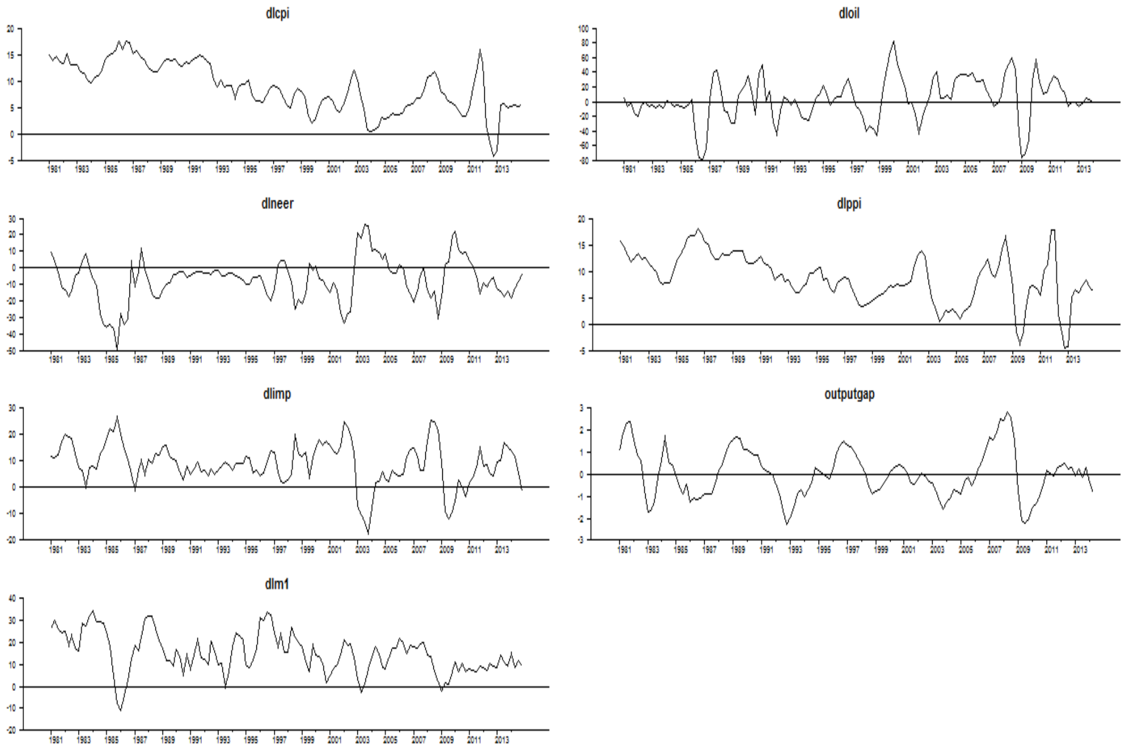
| Variables | Obs | Mean | Std Error | Minimum | Maximum |
|---|---|---|---|---|---|
| DLRGDP | 136 | 2.280 | 2.463 | -4.556 | 7.390 |
| DLCPI | 136 | 8.876 | 4.612 | -4.265 | 17.606 |
| DLPPI | 136 | 8.639 | 4.736 | -4.544 | 18.162 |
| DLM1 | 136 | 14.944 | 9.056 | -11.296 | 34.199 |
| MMKT | 136 | 11.640 | 4.645 | 4.750 | 22.500 |
| TBILL | 136 | 11.373 | 4.184 | 4.953 | 21.750 |
| DLNEER | 136 | -7.324 | 12.990 | -49.307 | 26.400 |
| DLREER | 136 | -2.007 | 12.104 | -36.752 | 28.890 |
| DLIMP | 136 | 8.958 | 7.900 | -17.096 | 26.570 |
| DLOIL | 133 | 3.212 | 29.356 | -77.810 | 82.680 |
| OUTPUTGAP | 136 | 0.036 | 1.092 | -2.287 | 2.825 |

Note: DLRGDP- real GDP growth rate, DLCPI-inflation rate, DLM1- growth rate of money, MMKT-money market rate, TBILL- treasury bill rate, DLNEER- changes in nominal effective exchange rate, DLREER- changes in real effective exchange rate DLIMP- growth of import prices changes in imports, DLOIL- growth of oil prices, OUTPUTGAP- real output gap. Source: IFS Online Database

Table 24 presents the descriptive statistics of all variables, in particular the mean, standard error, minimum and maximum values. Oil price inflation has the highest standard deviation value indicating that it is the most volatile variable with both the minimum and maximum growth rate exceeding 77 per cent. The two exchange rate measures show that the exchange rates deviate from their means by 12 per cent, which is higher than deviations of domestic prices, GDP growth averaged 2.28 per cent. On the other hand, inflation over the period averaged 8.87 per cent, as shown in Table 24.

Figure 21 depicts the time paths of all variables used for analysis over the period 1975Q1 to 2014Q1.

**Figure 21: Plot of variables**




Source: IFS Online Database

### 6.5.1 Stationarity

As a standard practice in time series analysis, time series property is examined to guard against spurious regression. In order to avoid the creation of spurious regression, stationarity of the research variables were first examined in this study. Thus, unit root tests were performed to analyse the time series characteristics of the data. Several tests were used to enhance the robustness of the results, the null hypothesis for the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test is stationarity, yet the null hypothesis in case of Phillips-Perron (PP) tests, and for the Augmented Dickey Fuller (ADF) test, the null hypothesis is that the variable tested is non stationarity. If the PP test and ADF test reject the null hypothesis, yet the KPSS test fails to reject the null hypothesis, the variable is regarded as being stationary. The results summarised in Table 25 reflect that most of the variables are non-stationary for instance, CPI inflation, PPI inflation, money market rate and tbill rate.

**Table 24: Unit root tests results**

| Variables | ADF | PP | KPSS |
|---|---|---|---|
| DLRGP | -2.896** | -3.253** | 0.397*** |
| OGAP | -4.969*** | -3.481*** | 0.042*** |
| DLCPI | -1.106 | -2.426 | 1.119 |
| DLPPI | -1.811 | -2.926** | 0.892 |
| DLM1 | -3.379*** | -3.340** | 0.576 |
| MMKT | -2.214 | -2.189 | 0.981 |
| TBILL | -2.567 | -2.242 | 0.947 |
| DLNEER | -3.847*** | -4.135*** | 0.188*** |
| DLREER | -5.306*** | -4.393*** | 0.041*** |
| DLIMP | -3.657** | -3.077** | 0.266*** |
| DLOIL | 3.830*** | 3.469*** | 0.448*** |

Note: The critical values of the ADF test, PP test and KPSS test are in parentheses. ***, **, * indicate the statistical significance and the rejection of null hypothesis at 1 percent, 5 percent and 10 percent in the case of ADF test and PP test. The variable name is abbreviated as follows: DLRGDP(real output growth), OGAP(real output gap), DLCPI(consumer inflation rate), DLPPI(producer inflation rate), DLM1(money growth rate), MMKT(money market rate), TBILL(tbill rate), DLNEER(nominal effective exchange rate growth), DLREER(real effective exchange rate growth), DLIMP(growth of import prices), DLOIL(growth of oil prices). Source: IFS Online Database

## 6.6 Empirical Results

### 6.6.1 Responses of domestic prices to exchange rate shocks

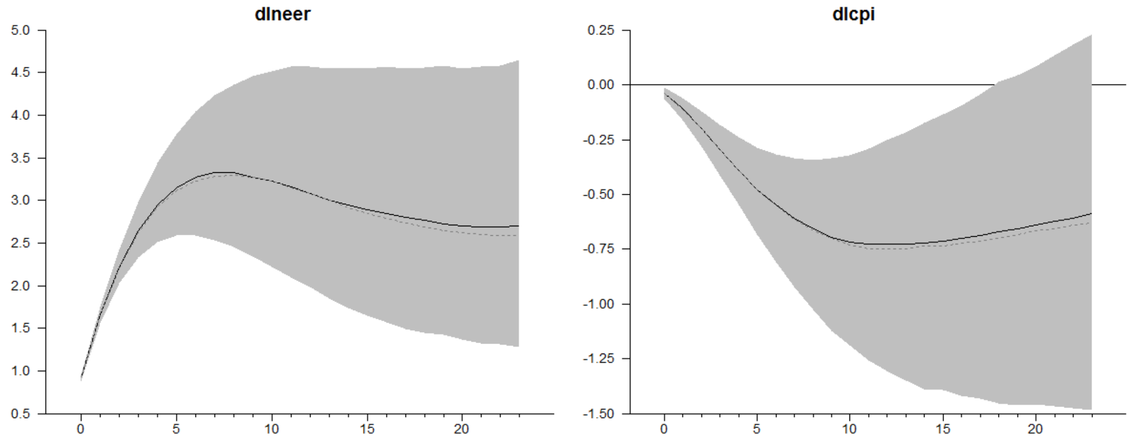
In terms of analysis of the pass through from exchange rate fluctuations and import price inflation to producer price inflation to domestic inflation, two sets of statistics were employed following (McCarthy 1999). The two sets of statistics were the impulse responses and variance decompositions. The impulse responses to the exchange rate shocks are estimated over the twenty four quarter horizon. Thus, they are standardised to correspond to the response to a 1 percent shock in the exchange rate to allow a comparison of the sensitivity to the external factors. In addition, variance decompositions were employed to analyse how much of the variance in domestic prices over this period can be attributed to these external factors.

This section presents the results from TVAR model with the inflation rate acting as a threshold variable as reported below. Firstly, in the case of the baseline model[38] the threshold

[38] TVAR model with five variables

value is 3.206, above this value there is an upper regime and below this value there is a lower regime.

**Figure 22: Response to exchange shock in both regimes**

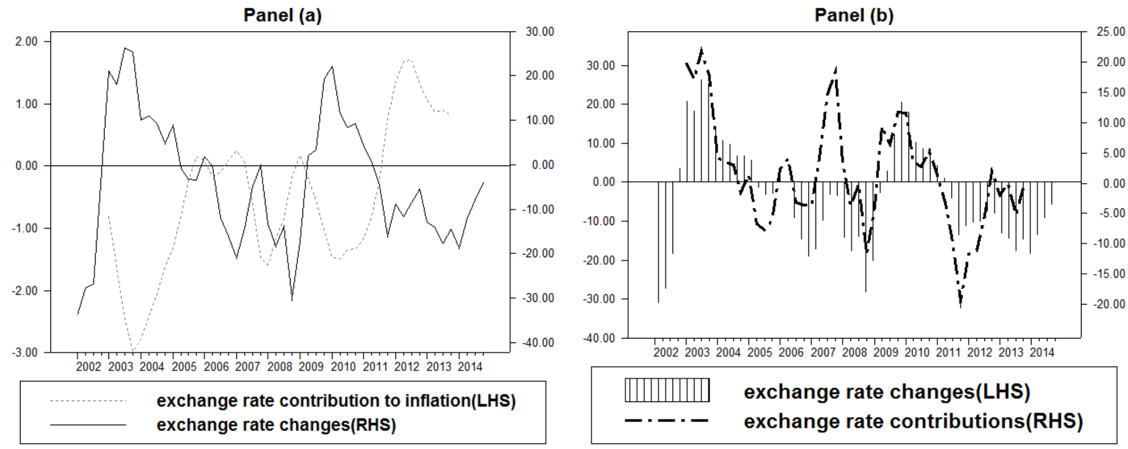



Note: dotted line denotes the high regime and bold line denotes low regime. Source: IFS Online Database

Figure 22 depicts the responses of growth rate of exchange rate and domestic prices to a positive one unit exchange rate shock. A positive one unit exchange rate shock leads to a decrease in domestic prices (i.e. inflation), up to 10 quarters both in the upper and lower regime.

Figure 23 depicts panel (a) and (b), which illustrate the exchange rate changes and exchange rate contribution to inflation and the link between exchange rate changes and exchange rate contributions overtime respectively. According to panel (a), an appreciation of the exchange rate leads to a decline in inflation revealing a negative relationship between inflation and exchange rate. This is consistent with other research studies (McCarthy 2000). Panel (b) indicates that there could be other dominating factors that might have contributed to the exchange rate movements as the exchange rate contribution occurs with a delay. Thus, other factors could have contributed to the exchange rate fluctuation. However, in the case of the exchange rate depreciation, exchange rate contribution kicks in immediately, pulling the exchange rate.

**Figure 23: Exchange rate contribution**




Source: IFS Online Database

### 6.6.2 Transmission along the distribution chain

In line with Takatoshi and Kiyotaka (2008) approach, this section looks at the degree of pass-through from the exchange rate appreciation to three price variables, CPI, PPI, and IMP.

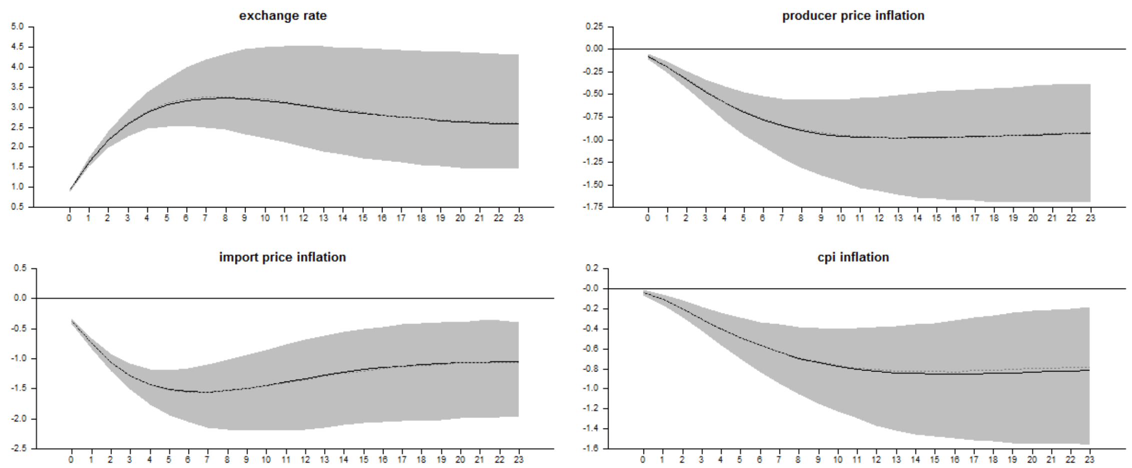
Takatoshi and Kiyotaka (2008) suggest that distribution costs may magnify or dilute the sensitivity of domestic inflation depending on whether domestic distributors actively adjust the distribution margins at different stages of distribution chains in response to external shocks. In order to investigate the effects induced by the change in distribution costs or networks, the five-variable TVAR model is extended to the seven-variable by including three types of domestic prices together in the model. It becomes possible to trace out the response of the three different domestic prices to shocks along the distribution chain, which reflects the effect of changes in distribution costs and networks on CPI inflation.

$$y_t = [\theta_t \quad g_t \quad m_t \quad s_t \quad \mu_t \quad \rho_t \quad \pi_t \quad ]' \tag{10}$$

where $\theta_t$, $g_t$ , $m_t$, $s_t$ represents oil price , output gap, money supply growth, nominal effective exchange rate, and $\mu_t$, $\rho_t$ and $\pi_t$ denote imports, producer price inflation and cpi inflation.

Figure 24 indicates that an exchange rate shock has a negative impact on domestic prices. Notably, the response to the exchange rate appreciation appears to be similar across three prices. In other words, an exchange rate appreciation (South African rand) leads to a decrease in import price, producer price inflation and consumer inflation .This is consistent with Saha and Zhang (2013) analysis of exchange rate depreciation. The negative response to exchange rate shocks by domestic prices in almost all cases indicates that the exchange rate does matter for domestic inflation.

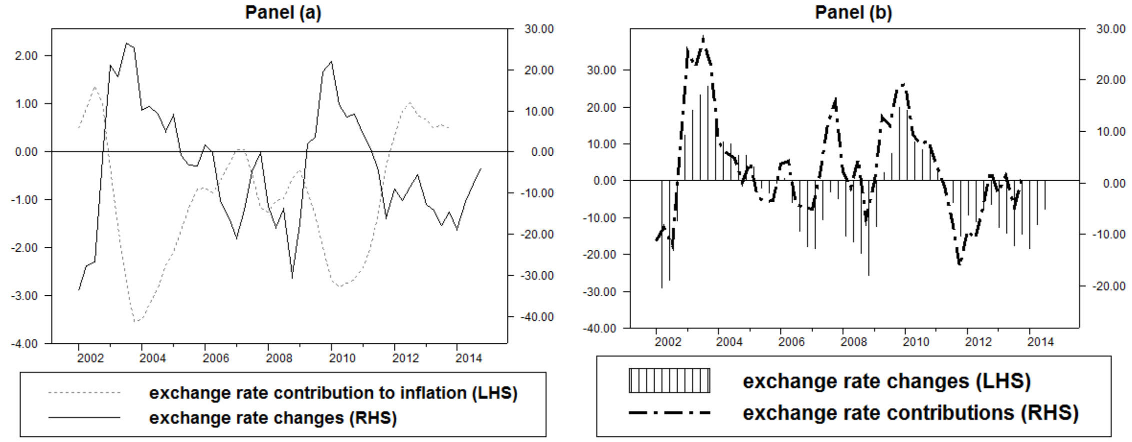
**Figure 24: Response to exchange shock in both regimes**




Note: dotted line denotes the high regime and bold line denotes low regime. Source: IFS Online Database

Panel (a), in Figure 25 presents the negative relationship between the exchange rate changes and exchange rate contributions to inflation overtime. An exchange rate appreciation leads to an inflation decrease which is in line with McCarthy (2000), Takatoshi and Kiyotaka (2008) research studies. According to panel (b), the exchange rate fluctuations were the dominating factor. This implies that other external factors had minimal influence following an exchange rate appreciation. Similarly, in the case of the exchange rate depreciation, exchange rate contribution kicks in immediately, pulling the exchange rate.

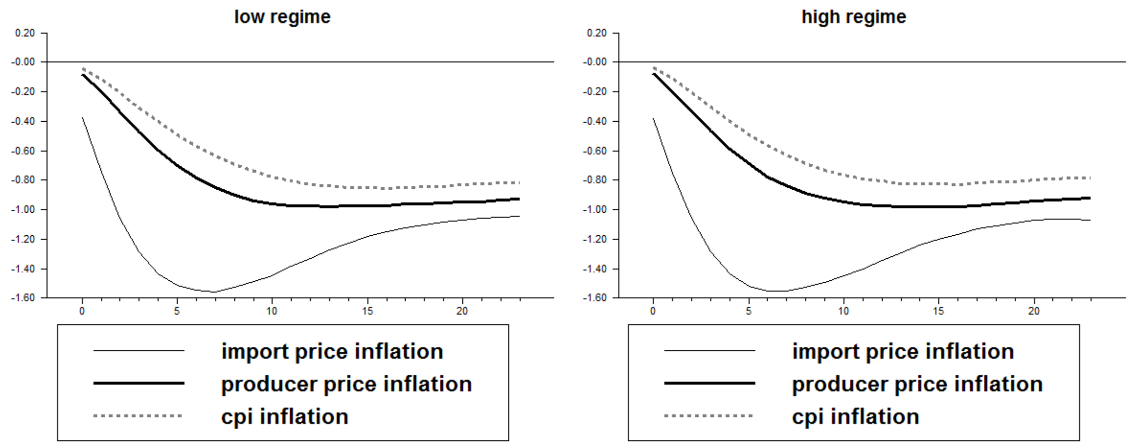
**Figure 25: Exchange rate contribution**




Source: IFS Online Database

Figure 26, indicates that overtime imports decline more than consumer inflation and producer inflation as a result of an exchange rate appreciation both in the high and low regime. This implies that the response of inflation to exchange rate appreciation is the weakest compared to import prices and producer prices inflation.

**Figure 26: Comparison of responses of different domestic prices**




Source: IFS Online Database

### 6.6.3 Variance decomposition

This section presents the variance decomposition analysis. Variance decomposition tells how much of a change in a variable is due to its own shock and how much to other variables. Similarly, Saha and Zhang (2013) argue that variance decompositions examine the fluctuations of each price variables that are due to the exchange rate shocks or other factors.

Although the impulse responses indicate the extent of pass-through to domestic prices, they do not indicate how important these shocks have been in explaining domestic price fluctuations. If the exchange rate shocks in a country are small, then pass-through could be large. Nonetheless, exchange rates would have little influence on domestic inflation. Therefore, to investigate the importance of these external factors, the variance decompositions of the price variables were examined.

Table 26 also presents the generalized variance decomposition. In the case of import prices, exchange rate shocks are important in explaining import price. Thus, for import prices, exchange rate shocks are the next important factor in explaining import price variance, where the share changes from 42 percent to 50 percent. The exchange rate shocks account for about 6.9 percent and 25.6 percent PPI variation. Whereas for cpi inflation variation, exchange rate shocks account for about 2.7 percent and 18.8 percent cpi inflation variation. Overall, the influence of external factors (exchange rate and import prices) on CPI variance is less than it is for PPI.

**Table 25: Generalised variance decomposition**

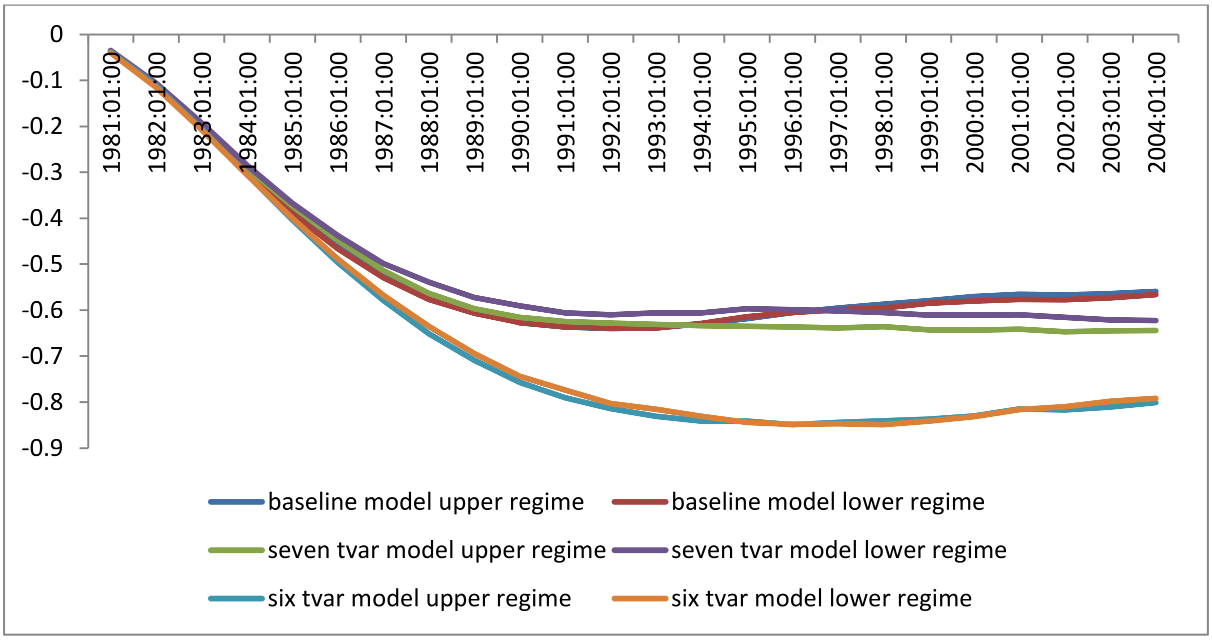
| | Period | S.E | Exchange rate | Import price | PPI | CPI |
|---|---|---|---|---|---|---|
| Exchange rate | 1 | 7.477 | 88.656 | 0.000 | 0.000 | 0.000 |
| | 5 | 11.748 | 79.097 | 0.540 | 0.571 | 0.584 |
| | 10 | 12.604 | 70.679 | 0.606 | 0.605 | 3.826 |
| | 20 | 12.987 | 67.730 | 0.936 | 0.583 | 6.262 |
| Import prices | 1 | 4.370 | 42.636 | 47.895 | 0.000 | 0.000 |
| | 5 | 7.150 | 50.576 | 22.883 | 0.515 | 0.650 |
| | 10 | 7.672 | 45.020 | 20.551 | 0.587 | 4.319 |
| | 20 | 7.900 | 44.117 | 19.755 | 0.574 | 6.275 |
| PPI | 1 | 2.241 | 6.909 | 6.379 | 75.139 | 0.000 |
| | 5 | 4.134 | 24.085 | 3.684 | 47.933 | 1.641 |
| | 10 | 4.603 | 26.557 | 2.999 | 40.550 | 1.910 |
| | 20 | 4.714 | 25.612 | 2.983 | 39.078 | 2.095 |
| CPI | 1 | 1.763 | 2.761 | 3.727 | 44.161 | 45.152 |
| | 5 | 3.521 | 15.918 | 3.000 | 28.637 | 40.340 |
| | 10 | 4.246 | 18.839 | 2.294 | 23.045 | 32.601 |
| | 20 | 4.550 | 17.140 | 2.141 | 21.598 | 28.769 |

Note: PPI- producer inflation, CPI represents consumer inflation, import price-denotes import inflation. Source: IFS Online Database

## 6.7 Robustness

To check for robustness, the baseline model results are compared to the six TVAR and seven TVAR. These models have been set up to analyse the impact of exchange rate shocks on prices (such as headline CPI inflation, producer price inflation and import price inflation). The results are presented in Figure 27. Overall, the results show the exchange rate pass through effect on prices remains unchanged regardless to the number of variables that have been used**.** The results of the generalised impulse responses in this study reveal that IMP, PPI and CPI decrease immediately following a positive exchange rate shock in line with An and Wang (2011) findings. According to An and Wang (2011) this is consistent with the conventional view that a currency appreciation results in a decrease in aggregate prices.

**Figure 27: Comparison of prices for different models**




Source: IFS Online Database

## 6.8 Conclusion

This Chapter investigated the pass-through of exchange rate into domestic prices overtime employing a threshold vector autoregression(TVAR) model that incorporate distribution chain. The results suggest the presence of nonlinearity with two regimes threshold values of inflation rate. Similar to Aleem and Lahiani (2014) technique the threshold values of exchange rate are estimated endogenously. The findings show that domestic prices react strongly to a positive one unit exchange rate shock both below and above the threshold level of the exchange rate. The findings of this study are consistent with the Nogueira and Leon-Ledesma (2008) results that ERPT responds nonlinearly to inflation in South Africa, Mexico, Canada, and the United Kingdom.

The results suggest that policy makers should recommend appropriate policy responses that take into consideration the nonlinearities underlying dynamic responses of nominal and real variables. Policy makers should act cautiously when conducting monetary policy consideration whether the exchange rate is above or below the threshold level as nominal or real variables can respond differently under alternative exchange rate regimes. The evidence presented in this Chapter has policy implications in that monetary authorities should be cautious when assessing the transmission of exchange rate shocks to domestic prices. Delayed or premature policy rate adjustments without enough evidence, understanding of nonlinearities and state contingent dynamics might prove detrimental for achieve low inflation and price stability.

# CHAPTER 7: DISCUSSION, RECOMMENDATIONS AND CONCLUSION

## 7.1 Introduction

This chapter discusses the main findings of the study, presents recommendations and concludes the study. By way of discussion, the chapter also explains its main findings in respect of the policy implications. The chapter advances its theoretical conclusions to contextualize the South African perspective of the implications of the monetary policy from a nonlinear technical analysis.

The conclusion is validated by the research findings that are in line with various scholars that have used the nonlinear Taylor rule in related studies to clearly outline and argue the South African Reserve Banking policy perspective in relation to various factors as discussed in detail across the chapters. The chapter finally recognises the impossibility to exhaust the contentious policy implications in a single study and therefore recommends possibilities for further studies to augment the shortfall.

## 7.2 Discussions of findings

One of the key findings of the study was that a nonlinear Taylor rule best described the monetary policy behaviour of the SARB. In the study examination of whether financial conditions were one of the key determinants of interest rate setting by the SARB, the finding revealed that there was need for policy makers to be cognisant of financial stability in respect of determination or setting interest rate. The study further arrived at a conclusion that monetary policy authority should pay close attention to financial stability when establishing interest rate. On the basis of empirical findings, the study concluded that the central banks changed their usual policy conduct in response to unexpected economic shocks in the context of a special regime.

In the analysis of the findings the study established the challenge on relying on simple Taylor rules to track the behaviour of monetary authorities in the context of structural changes. This challenge was due to the fact that linear models failed to consider structural changes and they could give false or biased results and therefore this uncertainty within an economy made it difficult to completely rely on a Taylor rule mode and as such the issue of uncertainty has policy implications.

One the objectives of the study were to investigate the existence of inflation threshold level in the inflation growth nexus for South Africa. This investigation led to the establishment by the study that there was a nonlinear relationship between inflation and economic growth in the South Africa economy. The investigation further established that a rate of inflation below the threshold level had a statistically positive effect on economic growth, although above the 4 percent level this positive relationship became negative. The contribution of the study could be for policy makers to appreciate that an increase in inflation beyond threshold levels was detrimental to the economic growth.

In addition to the findings, following an investigation of pass-through of exchange rate into domestic prices overtime through the deployment of the threshold vector autoregression (TVAR), results suggested the presence of nonlinearity with two regimes threshold values of inflation rate. The empirical findings further showed that domestic prices react strongly to positive one unit exchange rate shock both below and above the threshold level of the exchange rate.

## 7.3 Relevance of the findings

The results of the study have shown relevance towards a possibility to support the SARB's inflation targeting policy that could achieve price stability. This would be so on the basis of ensuring that inflation did not exceed 4.3 percent in view of the potential to be detrimental to thefinance- growth relationship, which will make it difficult for the South African economy to achieve sustainable economic activity. The study has offered an analytical framework which would be helpful to policy makers in their decision making. This assertion was based on the fact that empirical evidence showed categorically that high inflation was costly or detrimental to the financial development-economic growth link which would assist policy makers to achieve price stability. The study strongly contributes to the body of existing literature particularly on the analysis of the monetary policy of SA through its application of the nonlinear model. The engagement of the findings of this study would help policy makers to develop strong and reliable policies that enhance fundamentals and low inflation as well as attracting foreign capital which would be healthy and good for the South African economy.

## 7.4 Recommendations

On the basis of an investigation and analysis of the performance of the SA economy in relation to the inflation rate over a period of more 30 years, the study recommends that policy makers maintain inflation below the 4 percent threshold level. The study further recommends on the basis of empirical findings that it would be essential for policy makers to maintain the inflation below the threshold level in South Africa in an attempt to promote positive growth. The findings of the study present several policy implications such as the implementation of appropriate policies that take into consideration the nonlinearities that should underlie dynamic responses of nominal and real variables. Given the implications on the economy's performance below or above the threshold level, the study highly recommends policymakers to act cautiously when conducting monetary policy considerations given that nominal or real variables responded differently under alternative exchange rate regimes.

The findings of the study suggest that policy makers should develop strong and reliable policies that enhance fundamentals and low inflation and attract foreign capital. A high growth and low inflation environment will boost credit growth and further enhance economic activity. However, given the volatility of foreign capital experienced during the financial crisis, banks dependent on foreign capital are susceptible to external shocks. The study therefore recommends that monetary authorities be vigilant to foreign capital fuelled credit expansion in view of the nature of the volatility of foreign capital in times of crisis. Furthermore, banks should be encouraged to build an efficient domestic deposit base for sustainable credit growth in the country.

The findings of the study will have significant implications for the monetary authorities in the small and open economy such as South Africa. The significance and importance are derived from the argument that domestic problems faced by developing countries (such as South Africa) are said to be complicated by external factors, which further inhibit and constrain their efforts at economic development.

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