

ANALYSIS OF MONETARY POLICY RULES FOR SOUTH AFRICA

by

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A Thesis

Submitted in fulfilment of the requirements for the Degree

PhD Economics

in the

FACULTY OF ECONOMIC AND MANAGEMENT SCIENCES

at the

UNIVERSITY OF PRETORIA

2011



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
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2011

Doctor of Philosophy Thesis

ANALYSIS OF MONETARY POLICY RULES FOR SOUTH AFRICA

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2011

Declaration

“I declare that the Thesis, which I hereby submit for the degree PhD Economics at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at another university.”

DEDICATION

This thesis is dedicated to

my beloved wife, Niyonsaba Cécile,

my daughter Teta Kasai and

my sons Caleb Kasai and Béni Kasai.

ACKNOWLEDGMENTS

It is with praise and highest honour that I thank God whose amazing grace made this thesis possible.

My deep and sincere gratitude are expressed to my supervisor, Dr Ruthira Naraidoo, who kept telling me that there is always room for improvement. Up-to-date econometric techniques he introduced to me provided a solid foundation for the present thesis. His ideals and concepts will have a remarkable influence on my teaching and research career.

I am grateful to my co-supervisor, Prof Rangan Gupta, for his inspirational way of doing research and for having gone through this work. I am also still indebted to his important guidance at Masters Level which became the cornerstone of my abilities in the field of research.

I owe my most sincere gratitude to Prof Balinda Rwigamba and his wife Marie Louise Nyirashyirambere, whose faith in my abilities, encouragement and continuous support enabled me to stand firm during the completion of the thesis. Their affection to my family when I was abroad has provided a good peace of mind.

I owe my sincere gratitude to my mother in law, Sarah Nyirarwandiko, for her unfailing love and availability for my children. Similarly, my deep gratitude goes to my parents Dismas Rukamata Mpfizi and Béatrice Nyirakararwa who did everything they could to

satisfy my unlimited needs since my first cry. They perfectly accomplished their responsibility as parents. They are wonderful.

I am also grateful to all my Professors and colleagues for providing a warm working environment. Special thanks go to Dr Josine Uwilingiye, who was like a sister to me. I wish her all the best for her new career.

I also express my gratitude to the Rwandan government, whose financial support enabled me to achieve my aspirations for a doctoral degree. My most sincere gratitude is particularly expressed to the Rwandan High Commission based in Pretoria for having perfectly accomplished its responsibility during my stay in South Africa. I always felt at home.

Finally, I would like to offer my regards and blessings to all my entire family and friends for their contribution in making my dreams come true. To my wife Cécile Niyonsaba, when I was abroad for studies you performed quit well, more than I could imagine! Children are well raised, your family in law is proud of you, the house I never left is nice and you kept your very demanding lectureship. There is no single word to express my love and satisfaction. You are perfect!

FINANCIAL ASSISTANCE

“Study loan provided by the Rwandan Ministry of Education in respect of the costs of this study is hereby acknowledged. Opinions or conclusions that have been expressed in this study are those of the writer and must not be seen to represent the views, opinions or conclusions of the Republic of Rwanda.”

ABSTRACT

Besides the introduction and conclusion, this thesis is comprised of six independent chapters. In this thesis we provide an in-sample and out-of-sample assessment of how the South African Reserve Bank (SARB) sets its policy rate, post 2000 inflation targeting regime, in the context of both linear and nonlinear Taylor-type rule models of monetary policy.

Chapter 2 provides the theoretical foundations and the case study discussion. The literature has shown that the Taylor (1993) rule has gone through many modifications since the last decade of the 20th century. The modifications of the Taylor rule include interest rate smoothing, backward and forward looking versions, and nonlinear approximations. Furthermore, there has been increasing debate on whether central banks should respond to asset prices and financial variables. Despite some disagreements, economists seem to agree on the role of the financial market in determining inflation and economic performance. As far as South Africa is concerned, a stable financial system is one of the mandates of the central bank.

Chapter 3 discusses the research methods used in the thesis. First, the chapter provides an overview on the Hodrick-Prescott Filter used to detrend some series. Second, more

focus is oriented on a class of estimators, used in this thesis, called Generalized Method of Moments (GMM) estimators. GMM is important in that it can be applied to several estimation contexts besides the linear model. In fact, GMM can provide a simple alternative to other estimators, especially when it is difficult to write down the maximum likelihood estimator.

Chapter 4 is aimed to provide the source of data, to show the transformation made to some of them and to explore the data for preliminary results. The Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), GLS transformed Dickey-Fuller (DFGLS) and Kwiatkowski, *et. al.* (KPSS) tests suggest that all the series follow a stationary process. The chapter also reveals that the financial conditions index measured as an equal weight average of its components yields a smallest AIC than other alternative suggested herein. Furthermore, the chapter shows that the models that consider coincident business cycle indicator, rather than industrial production, perform better in terms of goodness of fit.

Given the controversial debate on whether central banks should target asset prices for economic stability, chapter 5 investigates whether the SARB pays close attention to asset and financial markets in their policy decisions. The main findings are that the SARB policy-makers pay close attention to the financial conditions index when setting interest rate. In the same chapter, it is also found that nonlinear Taylor rule improves its performance with the advent of the financial crisis, providing the best description of in-sample SARB interest rate setting behaviour. The 2007-2009 financial crisis witnesses an overall increased reaction to inflation and financial conditions. In addition, the financial

crisis saw a shift from output stabilisation to inflation targeting and a shift, from a symmetric policy response to financial conditions, to a more asymmetric response depending on the state of the economy. Although one could have expected that the SARB's response of monetary policy to output during the crisis to increase, the response has dropped significantly. These results show the concern over the high level of inflation observed during the second semester of 2008.

In chapter 6, we test the concept of Opportunistic Approach to monetary policy. The findings support the two features of the opportunistic approach. First, we find that the models that include an intermediate target that reflects the recent history of inflation rather than a simple inflation target improve the fit of the models. Second, the data supports the view that the South African Reserve Bank (SARB) behaves with some degree of non-responsiveness when inflation is within the zone of discretion but react aggressively otherwise. Recursive estimates from the preferred model reveal that overall there has been a subdued reaction to inflation, output and financial conditions amidst the increased economic uncertainty of the 2007-2009 financial crisis.

Chapter 7 compares forecast performance of linear and nonlinear monetary policy rules estimated in the two previous chapters but rewritten in their backward looking versions. Recursive forecasts values are computed for 1- to 12-step ahead for the out-of-sample period 2006:01 to 2010:12. For the nonlinear models we use bootstrap method for multi-step ahead forecasts as opposed to point forecasts approach used for linear models. The aim is to evaluate the performance of three competing models in an out-

of-sample forecasting exercise. Overall ranking reveals the superiority of the nonlinear model that distinguishes between downward and upward movements in the business cycles in closely matching the historical record. As such, forecasting performance tests reveal that the SARB pays particular attention to business cycles movements when setting its policy rate.

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LIST OF ACRONYMS

- AIC : Akaike information criterion.
- AR : Autoregressive.
- CPI : Consumer price index.
- CS : Credit spread.
- CW-t : Clark and West Test.
- DFGLS : Dickey-Fuller Test with Generalized least squares (GLS) Detrending
- DM-t : Diebold and Mariano Test.
- ECB : European central bank.
- EHS : Eichenbaum, Hansen and Singleton.
- ENC-t : Encompassing Test.
- ERSA : Economic Research Southern Africa
- F : Future interest spread.
- FCI : Financial conditions index.
- FCI_{EW} : Financial conditions index measured as an equal weight average of its components.
- FCI_{KAL} : Financial conditions index for which the Kalman Filter algorithm is used to determine the time varying weights of its components.
- FCI_{OLS} : Financial conditions index for which the OLS estimation of the output gap is used to determine the weights of its components.
- GDP : Gross domestic product.

GMM	: Generalised method of moments.
HP	: Hodrick-Prescott.
KPSS	: Kwiatkowski, Phillips, Schmidt, and Shin Test.
LSTAR	: Logistic Smooth Transition Autoregression.
MedSPE	: Median squared prediction error.
MOM	: Method of moments.
MPC	: Monetary policy committee.
MSC	: Moment selection criteria.
MSPE	: Mean squared prediction error.
OAD	: Opportunistic approach to disinflation.
OAMP	: Opportunistic approach to monetary policy.
OLS	: Ordinary least squares
PC	: Phillips curve
PP	: Phillips-Perron
REER	: Real effective exchange rate.
RH	: Real house price.
RS	: Real stock price.
S.E	: Standard error.
SA	: South Africa.
SARB	: South African reserve bank.
SIC	: Schwarz information criterion
STAR	: Smooth Transition Autoregression

UK : United Kingdom.

2SLS : Two-stage least squares.

Chapter 1

Introduction

1.1. Introduction

Theories of rules and discretion have become a *corner stone* in the formulation of monetary policy. Commonly, the Taylor (1993) rule model and its extensions (e.g. Clarida *et al.*, 2000) are used. The rules assume that interest rates relate linearly to the gap between actual and desired values of inflation and output. The purpose of this study is to investigate how the South African Reserve Bank (SARB, hereafter) sets interest rates in the context of both linear and nonlinear policy reaction functions. Given the recent controversial debate on whether central banks should target asset prices for economic stability (see Bernanke and Gertler, 2001; Chadha *et al.*, 2004 and Papademos, 2009), the study investigates whether the SARB pays close attention to asset prices and financial variables in their policy decisions. For instance, one of the SARB's primary goals is to protect the value of the currency and achieve and maintain financial stability. But one of the questions the thesis aims to answer is “how has the SARB reacted to financial variables?” To answer to this question, the Taylor rule is augmented with a financial conditions index that reflects the state of the housing market, the stock market, the real exchange rate and credit risk measures.

In this thesis, the issue of linearity is tested. Indeed, a number of prominent authors have proved that central banks do not (or should not) behave linearly in setting the policy instrument (see Bec *et al.*, 2002; Cukierman, 2002; Huang and Shen, 2002; Nobay and Peel, 2003; and Ruge-Murcia, 2003). Although the specification of a given model should be statistically and theoretically correct, it seems that researchers almost never give the reason they choose for most of the time linear specification. To avoid restrictions on possible nonlinear underlying economic behaviour, this study do not subjectively consider linear specification without any statistical support. As such, this research also intends to develop rival models having different specifications and so the selection of the best model will be based on empirical properties of the data.

It is well known that one of the prime benefits of robust economic models is the predictive accuracy they have. Furthermore, the Reserve Bank's target for the repo rate is one of the most anticipated and influential decisions regularly affecting financial markets and is of interest to economic analysts, economic forecasters and policymakers. As such, this thesis assesses the out-of-sample predictive ability of the alternative monetary policy rules.

1.2. Problem statement

The problem statement is oriented to four perspectives from which research questions will emerge. The first problem statement focuses on whether the flexibility of the central bank has been extended to financial stabilisation. Speaking at the Milken

Institute Forum in September 1999, Dudley the then director of US Economic Research at Goldman Sachs ascertained that they had proposed a Financial Conditions Index (FCI) as another way of assessing whether monetary policy might need to be tightened or not.

According to Dudley (1999), the Goldman Sachs financial conditions index was made up of four variables. The first variable is the three-month LIBOR which was regarded as the primary rate in the interbank market. The second variable is the single A-rated corporate bond yield regarded as being able to capture the rate that private-sector borrowers have to pay in the market. In addition, A-rated corporate bond yield could allow the disclosure of changes in credit spreads. The third variable is the Goldman Sachs Trade-Weighted Dollar Index which was claimed to be close to the Federal Reserve Foreign Exchange Index. The last variable is the stock market variable. The first reason to include the stock market into the FCI was motivated by the recognition of the link it had with interest rate since equity market valuation was affected by changes in monetary policies. The second reason was the linkage between stock market and the real economy.

Similarly, Cecchetti *et al.* (2000) argue that in addition to future inflation and output gap, central banks should target asset prices and they emphasize that a complex rule is always more advisable than a simple Taylor rule. However, the idea to have financial variables as target does not emerge without criticism. For example, Bernanke and Gertler (1999) and Filardo (2001) show their concern about the potential costs of responding to asset price given its volatility relative to their information content¹ while Mishkin and White (2002) suggest that monetary authorities should only be concerned by asset price misalignments when they affect financial stability. By contrast, Borio and Lowe (2002)

¹ To account for economic agents' behavioural changes, due to volatile financial variables, Montagnoli and Napolitano (2005) and Castro (2008) used Kalman Filter algorithm to determine the weight of the variables; a method that allows the weight to change over time.

argued that financial instability could be a serious threat even for central banks with sound and credible economic policies. In fact, financial variables are likely to affect both future inflation and economic activity levels. Therefore, it is assumed that projecting monetary authorities ought to act before the impact of financial variables on inflation and economic activity is experienced. Luüs (2007) describes financial conditions index as a rough indicator for the conduct of monetary policy. As such, economic agents will never turn a blind eye on movements of financial variables.

Despite the above disagreements and fears, economists seem to agree on one thing; the role of financial market in determining inflation and economic performance. In his speech, Mnyande (2010) has confirmed that low inflation, stable currency value, and stable financial systems are bedrock ingredients that form the core of what the South African Reserve Bank does. Therefore, the question I to try to answer in this thesis is whether the SARB reacts to financial fluctuations. In this regard, Reid (2009) reports an interaction between the SARB and financial markets and Du Plessis (2010) suggests that Central Banks should have models that would be sensitive to financial fragility.

Second, it is also worth noting that researchers have recently questioned the linear specification and a nonlinear framework applies if, for instance, the central bank has asymmetric preferences as originally propounded by Nobay and Peel (2003) in the context of linex function. Early works that argued in favour of asymmetric policy rules include Ruge-Murcia (2002, 2004), Dolado *et al.* (2002), Bec *et al.* (2002), Nobay and Peel (2003), Cukierman and Gerlach (2003), Gerlach (2003) and Surico (2004).

Asymmetric preferences are mostly illustrated using the transition logistic function, which is in fact the most popular in the classes of regime switching models. Few works (probably none for the case of South Africa) have considered the output gap as a transition variable. For an early work, Bec *et al.* (2002) shows that depending on the state of the economy, central bankers may adopt a more (less) aggressive reaction to deviations of inflation and output gap from their targeted level.

Third, the theoretical foundations provided by Orphanides and Wilcox (2002) assume that monetary policy is set depending on a ‘zone of inaction’. Corresponding literature suggests that when inflation is within the zone, the focus of the central bank is on output rather than inflation stabilisation (see Orphanides and Wilcox (2002) and a somewhat different theoretical model provided by Minford and Srinivasan (2006) for this same concept). Literature on opportunistic approach clearly explains its two features. The first feature is that monetary policy should move inflation toward an intermediate inflation target which is a function of past inflation rates and the inflation target rather than inflation target itself. The second feature is related to the concept of the zone of discretion for which policymakers are supposed to behave opportunistically by accommodating shocks that tend to move inflation towards the desired level. The interest rate will be raised when inflation is above the zone of discretion and decreased if inflation is below the zone (see Orphanides and Wilcox (2002) for more discussion). In the South African context, asymmetries that could result from the inflation target range of 3-6% framework implemented in 2000 (see Du Plessis *et al.*, 2007 and Burger and Marinkov, 2008) can be described as a necessary condition for an opportunistic

monetary policy but not as a sufficient one. In fact, opportunistic approach to disinflation is a special case of asymmetric monetary policy rule which requires a range of inflation for which the central bank is supposed to behave opportunistically.

Fourth, given the recent in-sample outperformance of nonlinear monetary policy reaction functions, one can expect them to predict better the behaviour of central banks than a simple linear policy rule. However, literature review by Clements *et al.* (2004) suggests that the forecasting performance of nonlinear models is on average not particularly good relative to rival linear models. As far as monetary policy rules are concerned, the concern was evidenced by Qin and Enders (2008) who find that the univariate models forecast better than the Taylor rules, linear and nonlinear. More recently, Naraidoo and Paya (2010) find that semi-parametric model that relaxes the functional form of monetary policy rule outperforms other models especially in long horizon forecasting.

Indeed, myth or reality, the debate highlighted above gives the opportunity to ask questions and formulate some hypotheses of the research. The basic research question emerges as “what is the best specification of the monetary policy rules for South Africa”? This being the main question, our study intends to investigate the topic in various dimensions and raises the following sub questions:

- (1) Has the SARB reacted to financial fluctuations?

- (2) Has the SARB been reacting symmetrically or asymmetrically with respect to its objectives? In other words, how do linear and nonlinear Taylor type rule models compare in-sample?
- (3) Does the SARB follow the opportunistic approach to monetary policy?
- (4) Do the nonlinear Taylor rules dominate standard linear Taylor rules out-of sample?

1.3. Aim and research objectives

According to Jankowicz (2000), a good way of clarifying the purpose of a research is to examine the associated objectives in detail. In this regard, the main objective was set as *to test alternative specifications of the monetary policy rules applied to the South African monthly data.*

The pursuit of this broad objective requires pursuing the following specific objectives:

- (1) To investigate whether the SARB pays close attention to asset prices and financial variables in their policy decisions.
- (2) To test possible nonlinear behaviour of the SARB and particularly nonlinearities controlled by changes in the state of the business cycles.
- (3) To test the opportunistic approach to monetary policy with application to the South African data.
- (4) To determine the best policy rule model in predictive accuracy.
- (5) To propose measures that can enhance monetary policy rules for South Africa.

1.4. Importance of the research

1.4.1. Personal learning experience

This study has given me the opportunity to study interest rates and to investigate the objectives of policymakers in the quest to provide the best description of in-sample and out-of-sample SARB interest rate setting behaviour. It has also developed my ability to produce sound journal articles with advanced conceptual and technical content.

1.4.2. Conceptual interest

In addition to the personal interest, the study is also important in the field of monetary policy. In fact, the study has provided evidences for relatively newly developed concepts on monetary policy rules not covered extensively in the literature.

1.4.3. Specific context of South Africa

In this thesis several empirical approaches are adopted with the aim to identify the best empirical models describing the SARB interest rate setting behaviour and should be of interest to economic analysts, economic forecasters and policymakers, in financial institutions, research organisations and government departments. In fact, the model can guide into measuring the response of the SARB to changes in its objectives. The models can also be used to assess the possible nonlinear response of the central bank over expanding or contracting state of the economy or the nonlinear response of the key policy rate over different inflation regimes. The study is also important in that it provides significant information on how the response coefficients to inflation, output

gap and financial conditions have varied across times and across regimes with the onset of the sub-prime crisis. The predictive power of the alternative models can also guide agents to the behaviour of the most anticipated rates in financial markets. Furthermore, the study has provided valuable contribution to South African monetary policy makers in that it has compiled new insights on the topic of monetary policy rules and so suggestions that can inspire them have been formulated.

1.5. Methodology

One of the definitions of research methodology is the collection of data and the processing thereof within the framework of the research process (Brynard, 1997). According to Bhattacharyya (2003), research methodology deals with research methods and techniques to be used; but its wide scope makes it differ from problem to problem. Therefore, before dealing with research methods and techniques, it is of paramount importance to know the substance of this research.

1.5.1. Type of research

Quantitative analysis has been used to describe the behaviour of the South African Reserve Bank. According to Babbie (2004), quantitative analysis is the numerical representation and manipulation of observations for the purpose of describing and explaining the phenomena that those observations reflect.

1.5.2. Research methods and techniques

In this subsection, research methods and techniques that have guided this study are overviewed in summary. Though the two terms are sometimes confused, research methods concern the *what* is being done while research techniques deal with the *how* it will be done (Jankowicz, 2000).

1.5.2.1. Research methods

By definition research method is “a systematic and orderly approach taken towards the collection and analysis of data so that information can be obtained from those data” (Jankowicz, 2000). Empirical research, which is the context of this study, includes experimental, *ex post facto* and descriptive methods. This thesis uses experimental method which can be thought of as systematic, trial and observation: ‘trial’ because the answer was not known before-hand, ‘observation’ because the results have been carefully observed and recorded, and ‘systematic’ because the research was planned and purposeful.

1.5.2.2. Research techniques

In simple words, Jankowicz (2000) defines research technique as “a step-by-step procedure of gathering and analyzing data”. The thesis being an empirical research, time series data were subjected to statistical analysis. Initially, time series plots and descriptive statistics of the data have made a clear overview in that it is easier to compare and to summarize data. Secondly, unit root characteristics of the data have been performed to

analyse their time series properties. Third, multivariate analyses are performed with the aim to determine robust linear or nonlinear empirical relationships amongst variables and so to determine the best model in predictive accuracy. As such, several steps and sub-steps have been followed:

Step 1: Data collection from the SARB's database.

Step 2: Data transformation where needed.

Step 3: Time series plots.

Step 4: Descriptive statistics of the data.

Step 5: Testing the unit root characteristics of the data.

Step 6: Perform a linear multivariate analysis of the simple Taylor rule.

Step 7: Perform a linear multivariate analysis of the Taylor rule augmented with financial conditions index.

Step 8: Testing nonlinearities controlled by output gap for a Taylor rule augmented with financial conditions index.

Step 9: Perform recursive and rolling estimation of the equations modelled in steps 7 and 8.

Step 10: Testing the opportunistic approach to monetary policy.

Step 11: Perform recursive and rolling estimation of the opportunistic approach modelled in step 10.

Step 10: Obtaining the best functional form in predictive ability amongst the models in steps 7, 8 and 10.

1.5.3. Data collection

1.5.2.1. Obtaining empirical data

According to Rosnow (1999: 81) “quantitative methods are those in which the observed data exist in a numerical form”. This research uses time series data that have been collected from the South African Reserve Bank database.

1.5.2.2. Documentary secondary data

Documentary secondary data include written documents such as notices, correspondence, minutes of meetings, reports to shareholders, diaries, transcripts of speeches and administrative and public records. Written documents can also include books, journals and magazine articles (Saunders *et al.*, 2003:190).

Documentary data provides an insight to the thesis, based on the literature and studies conducted before this one. The approach outfits the study in making clear questions of the problem to be addressed in order to achieve content validity. Books, journal articles and reports on the aspects of monetary policy were consulted and so the research was able to determine the truth about the phenomenon.

1.6. Scope of study

The scope of this study identifies its boundaries in terms of area, time frame and subject. The study uses ‘final’ South African monthly data covering the period

2000M01-2010M12. In terms of subject, the study is limited to monetary policy rules and specifically to the Taylor (1993) rule and its extensions. Given the South African policy framework, alternative policy rules such as the McCallum (1988; 1993) rule and the Friedman's k -percent rule (Friedman, 1960) have not been explored. The McCallum rule can be useful in the case where money stock is the policy instrument (see Burkedin and Siklos, 2008) and the simple Friedman's k -percent rule cannot be formulated with an interest rate instrument (see Orphanides, 2010).

1.7. Limitations of study

The study has some limitations that can be addressed in future research. First, a longer sample period could yield more robust econometric results but the beginning of the sample is constrained by two reasons: (1) the explicit inflation targeting regime started in February 2000, and (2) data for some financial variables are only available since 1999. Another worth mentioning limitation concerns the use of final data. In fact, current literature recommends the use of real data, which are available at the time the central bank makes its decisions. Orphanides (2001) and in particular, Orphanides and van Norden (2002) have shown that empirical estimates of the output gap are subject to significant revisions and therefore the use of real time data is highly warranted for operational usefulness in monetary policy. The absence of real time data for the case of South Africa makes such analysis impossible. It is also worth mentioning that this thesis main aim is to provide an investigation on how the SARB has behaved in-sample and its likely behaviour out-of-sample. Further research is needed to answer questions such as

whether the SARB should target asset prices or do nonlinear Taylor type rule models improve welfare in general. These questions are beyond the scope of this study.

1.8. Structure of the thesis

Chap. 1: Introduction

This chapter gives the broad outline of the study and includes the problem statement, the objectives of the study, the research motivation and the structure of the study is outlined in this section.

Chap. 2: Theoretical foundations and case study discussion

This chapter provides theoretical foundations and empirical evidences on monetary policy rules. Books and journal articles have been consulted to find out how different authors explain theories and/or provide evidences. In addition, this chapter gives an overview of the South African monetary policy. This will help the reader to understand the behaviour of the SARB.

Chap. 3: Research methodology

Chapter three discusses the Generalised Method of Moments (GMM) estimation used in chapters 4 to 7.

Chap. 4: Data analysis and preliminary results

Chapter 4 includes two sections. Section 1 discusses the data and Section 2 provides preliminary results of the extended linear Taylor rule. In fact, given the proliferation of candidate series, Section 2 is aimed to give an empirical evidence and indication of the data to be maintained (or excluded) for further investigations of the monetary policy rule.

Chap. 5: Financial assets, linear and nonlinear policy rules: An In-sample assessment of the reaction function of the South African Reserve Bank

Chapter 5 tests the presence of nonlinearities resulting from the state of the business cycle. Furthermore, recursive and rolling estimations for both linear and nonlinear models are reported with the aim to show how the SARB has behaved before and during the subprime crisis.

Chap. 6: The Opportunistic approach to monetary policy and financial market conditions

Chapter 6 tests the opportunistic approach to monetary policy developed by Orphanides and Wilcox (2002) for which Martin and Milas (2010a) have provided the first empirical evidence using US data.

Chap. 7: Evaluating the forecasting performance of monetary policy rules in South Africa

Chapter seven compares forecast performance of linear and nonlinear monetary policy rules estimated in chapters 4, 5 and 6. Recursive forecasts values are computed for 1- to 12-step ahead for the out-of-sample period 2006:01 to 2010:12. For the nonlinear

models, bootstrapping method is used for multi-step ahead forecasts as opposed to point forecasts approach used for linear models.

Chap. 8: Summary, conclusion and recommendations

The last chapter contains summary, conclusion and policy recommendations of the study.

Chapter 2

Theoretical foundations and case study discussion

2.1. Theoretical foundations: Monetary policy and rules

According to Bordo (2010), “monetary policy is the principal way in which governments influence the macro economy”. Worldwide, the implementation of monetary policy is the responsibility of a central bank which uses its policy instruments, mainly the short-term interest rate or the monetary base, to achieve and maintain low inflation and sustainable development. Existing literature suggest policy makers to set nominal interest rate that minimizes the following central bank’s loss function:

$$L = (Y_t - Y_t^*)^2 + a(\pi_{t+1} - \pi^*)^2 \quad (2.1)$$

Subject to equations (2) and (3) below

$$\pi_t = \pi_{t-1} + b(Y_{t-1} - Y_{t-1}^*) \quad (2.2)$$

$$Y_t - Y_t^* = -c(r_{t-1} - r^*) \quad (2.3)$$

where Y_t is the level of output,

Y_t^* is the potential output,

π_t is the inflation rate,

π^* is the inflation target,

r_t is the real interest rate,

r^* is the equilibrium real interest rate,

a is the relative weight attached to the loss from inflation,

b is a positive parameter that determines how inflation reacts to the output gap
(the slope of the Phillips curve),

Equation (2.1) is the central bank's loss function which assumes an equal concern about positive and negative deviations of inflation and output from target levels. Equation (2.2) is a simple linear expression of the Phillips curve (PC) which shows the relationship between output Y_t and inflation π_t . The equation reveals that output Y_t above its potential level Y_t^* will lead to an increase in inflation above the initial level. In reverse, a negative output deviation will cause inflation to fall below the initial level. Equation (2.3) is the IS curve which shows the relationship between real interest rate and output. The IS curve has a negative slope since a low interest rate leads to a high level of investment and consumption, which in turn implies high level of output. As it can be seen in the system composed of equations (2.1) to (2.3), the assumption of timing is that output can only have effect on inflation the next period and so is the effect of the interest rate (r_{t-1}) on output Y_t . Therefore, the central bank's interest rate at time $t-1$ can only influence output at time t , and inflation at time $t+1$.

The optimal value of Y_t that minimizes L is computed by substituting equation (2.2) into equation (2.1) and by deriving the obtained equation with respect to Y_t as follows:

$$L = (Y_t - Y_t^*)^2 + a[\pi_t + b(Y_t - Y_t^*) - \pi^*]^2$$

$$\frac{\partial L}{\partial Y_t} = 2(Y_t - Y_t^*) + 2ab[\pi_t + b(Y_t - Y_t^*) - \pi^*] = 0$$

with $\pi_t = \pi_{t-1} + b(Y_{t-1} - Y_{t-1}^*)$, we have:

$$\frac{\partial L}{\partial Y_t} = (Y_t - Y_t^*) + ab(\pi_{t+1} - \pi^*) = 0 \quad (2.4)$$

Rearranging the above equation (2.4) we find a inverse relationship between inflation and output with the slope determined by the central bank's inflation aversion, a , and the responsiveness of inflation to output gap (see Polovková, 2009). Equation (2.5) notes that if inflation shoots above its target, the policy maker raises its indirect control (output) via its policy rate to control inflationary pressures.

$$-\frac{1}{ab}(Y_t - Y_t^*) = \pi_{t+1} - \pi_t^* \quad (2.5)$$

From the above, one can write a new system of equations, in which equations (2.2)', (2.3)' and (2.5)' respectively stand for the Phillips curve, the IS curve and monetary policy rule.

$$\pi_t = \pi_{t-1} + b(Y_{t-1} - Y_{t-1}^*) \quad (2.2)'$$

$$Y_t - Y_t^* = -c(r_{t-1} - r^*) \quad (2.3)'$$

$$-\frac{1}{ab}(Y_t - Y_t^*) = \pi_{t+1} - \pi_t^* \quad (2.5)'$$

Substituting (2.2)' in (2.5)' we have

$$\pi_t + b(Y_t - Y_t^*) - \pi^* = -\frac{1}{ab}(Y_t - Y_t^*). \quad (2.6)$$

Based on the information in equation (2.3)' we solve equation (2.6) which gives

$$\begin{aligned} \pi_t + b(-c(r_{t-1} - r^*)) - \pi^* &= -\frac{1}{ab}(-c(r_{t-1} - r^*)) \\ \pi_t - \pi^* &= b(c(r_{t-1} - r^*)) + \frac{1}{ab}(c(r_{t-1} - r^*)) \\ &= c\left(\frac{1}{ab} + b\right)(r_{t-1} - r^*) \end{aligned} \quad (2.7)$$

Pulling the Phillips curve equation (2.2)' into (2.6) we have

$$\pi_{t-1} + b(Y_{t-1} - Y_{t-1}^*) - \pi^* = c\left(\frac{1}{ab} + b\right)(r_{t-1} - r^*)$$

Rearranging further we obtain the following

$$(r_{t-1} - r^*) = c\left(\frac{1}{ab} + b\right)[(\pi_{t-1} - \pi^*) + b(Y_{t-1} - Y_{t-1}^*)]$$

Solving for time t instead of time $t-1$ we have the following equation:

$$(r_t - r^*) = c\left(\frac{1}{ab} + b\right)[(\pi_t - \pi^*) + b(Y_t - Y_t^*)]. \quad (2.8)$$

The optimal interest rate rule in equation (2.8) takes the form of Taylor (1993) rule.

2.1.1. The original Taylor rule

A Taylor rule is by definition, a monetary policy rule that prescribes how much a central bank should adjust its interest rate policy instrument in response to changes in inflation and macroeconomic activity (see Orphanides, 2010). According to Abel and Bernanke (2010), since the Taylor rule was proposed in 1993, it has become common to assume that a central bank follows some type of rule that is similar to it. The original formulation of the Taylor (1993) rule is given by

$$\hat{i}_t = r^* + \pi_t + \alpha_\pi(\pi_t - \pi^*) + \alpha_y(Y_t - Y_t^*) \quad (2.9)$$

where \hat{i}_t is the desired level of nominal interest rate. According to the Taylor rule, both α_π and α_y should be positive. This means that the central bank should reduce the nominal interest rate in response to negative deviations of actual inflation from its target and of output from its potential level. The nominal interest rate is increased when deviations are positive.

The reduced form of the Taylor rule can be written by pulling the constants together and solving the output terms as follows

$$\hat{i}_t = \rho_0 + \rho_\pi \pi_t + \rho_y y_t \quad (2.10)$$

where $\rho_0 = r^* - \alpha_\pi \pi^*$, $\rho_\pi = 1 + \alpha_\pi$, $\rho_y = \alpha_y$ and $y_t = Y_t - Y_t^*$. As a rough rule of thumb, Taylor (1993) set $\alpha_\pi = \alpha_y = 0.5$ and proposed $r^* = 2$ and $\pi^* = 2$ to find the following specification:

$$\hat{i}_t = 1 + 1.5\pi_t + 0.5y_t \quad (2.11)$$

Equation (2.11) suggests that if π raises by 1%, the interest rate should be increased by 1.5%. Although Taylor admits that the coefficient ρ_π of equation (2.10) does not need to be exactly 1.5, his principle is that it has to be larger than 1. This is known as the Taylor principle.

2.1.2. Modified versions of the Taylor rule

2.1.2.1. Dynamic Taylor rule

The trial modifications of the Taylor rule include interest rate smoothing. Early versions of the Taylor rule that allowed the inclusion of lagged interest rate include Clarida *et al.* (1998, 2000), Amato and Laubach (1999), Goodhart (1999), Levin *et al.* (1999) and Woodford (1999, 2003). For a better illustration one can rewrite the reduced form of the original Taylor rule in equation (2.10).

$$\hat{i}_t = \rho_0 + \rho_\pi \pi_t + \rho_y y_t + \varepsilon_t \quad (2.10)'$$

Allowing for interest rate smoothing (see for example Woodford, 2003) we formulate a simple partial adjustment mechanism which relates the actual and target instrument growth:

$$i_t = \rho_i(L)i_{t-1} + (1 - \rho_i)\hat{i}_t \quad (2.12)$$

where, $\rho_i(L) = \rho_{i1} + \rho_{i2}L + \dots + \rho_{in}L^{n-1}$ is an indicator of the degree of smoothing of the instrument. Combining equation (2.10) and (2.12) we have

$$i_t = \rho_i(L)i_{t-1} + (1 - \rho_i)\{\rho_0 + \rho_\pi\pi_t + \rho_y y_t\} \quad (2.13)$$

Equation (2.13) has also been subjected to changes; namely backward and forward looking versions.

2.1.2.2. Backward and forward looking versions

Examples of both backward and forward looking versions of Taylor rule include Rudebusch (2002); Orphanides (2002); Osborn *et al.* (2005), and Dolado *et al.* (2005). See Rudebusch & Svensson (1999), Batini and Nelson (1999); Clarida *et al.* (2000), Orphanides (2001, 2003) and Huang *et al.* (2001) for forward looking versions. It should be noted however that existing studies of the impact of inflation and output on monetary policy use a version of the Taylor (1993) rule that is forward looking. The forward looking version of the Taylor rule can be derived from the New-Keynesian model (see Svensson, 1997, Clarida *et al.*, 1999 and Castro, 2008) as follows:

$$\pi_{t+p} = a_1\pi_{t+p-1} + a_2(Y_{t-1} - Y_{t-1}^*) + \mu_{t+p}^s \quad (2.14)$$

$$(Y_{t+q} - Y_{t+q}^*) = b_1(Y_{t+q-1} - Y_{t+q-1}^*) - b_2(i_t - \pi_{t+p-1}) + \mu_{t+q}^d \quad (2.15)$$

Equation (2.14) is interpreted as an aggregate supply curve (AS curve) or a linear expression of the Phillips curve (PC) which shows the relationship between output Y_t and inflation π_t . As above, the equation shows that output Y_t above its potential level Y_t^* will lead to an increase in inflation above the initial level. In reverse, a negative output deviation will cause inflation to fall below the initial level. Equation (2.15) is the aggregate demand curve (IS curve) which shows that output gap depends on its lagged value and on the real interest rate. The IS curve has a negative slope since a low interest rate leads to a high level of investment and consumption, which in turn implies high level of output. The supply and demand shocks are respectively μ_{t+p}^s and μ_{t+q}^d .

Conditional to the information available at time t , it is assumed that the central bank uses a policy rule to control monetary policy. As such, the central bank chooses a short-term interest rate in order to minimize the following inter-temporal loss function:

$$E_t \sum_{\tau=0}^{\infty} \delta^\tau \left[\lambda_1 (\pi_{t+\tau} - \pi^*)^2 + \lambda_2 (Y_{t+\tau} - Y_{t+\tau}^*)^2 + \lambda_3 (i_{t+\tau} - \bar{i})^2 \right] \quad (2.16)$$

subject to (2.14) and (2.15). The parameter δ ($0 < \delta < 1$) is the inter-temporal discount factor and i^* ($i^* = r^* + \pi^*$) is the long-run equilibrium nominal interest rate. The above central bank's loss function assumes that i_t affects y_t and π_t contemporaneously.

However, Svensson (1997) shows that in practice i_t does not affect y_t and π_t contemporaneously. He suggests a period-by-period static minimisation given by:

$$\min_i E_t \lambda_1 \left[(\pi_{t+\tau} - \pi^*)^2 + \lambda_2 (Y_{t+\tau} - Y_{t+\tau}^*)^2 + \lambda_3 (i_{t+\tau} - i^*)^2 \right] \quad (2.17)$$

The first order necessary condition below is obtained by minimising equation (2.17) subject to equations (2.14) and (2.15)

$$\hat{i}_t = i^* + \beta E_t (\pi_{t+p} - \pi^*) + \gamma E_t (Y_{t+q} - Y_{t+q}^*) \quad (2.18)$$

Allowing for interest rate smoothing of equation (2.12) we have equation (2.19):

$$i_t = \rho_i(L) i_{t-1} + (1 - \rho_i) \left\{ i^* + \beta E_t (\pi_{t+p} - \pi^*) + \gamma E_t (Y_{t+q} - Y_{t+q}^*) \right\} \quad (2.19)$$

where, $\rho_i(L) = \rho_{i1} + \rho_{i2}L + \dots + \rho_{in}L^{n-1}$ is an indicator of the degree of smoothing of the instrument.

2.1.2.3. Asymmetric policy rules

The above Taylor rule model and its extensions assume a linear relationship between interest rate and the gaps between actual and desired values of inflation and output. More recently, however, the focus of the monetary policy literature has been increasingly placed on nonlinear models resulting from either asymmetric central bank preferences (e.g. Nobay and Peel, 2003; Cukierman and Gerlach, 2003; Bec *et al.*, 2002; Orphanides and Wieland, 2000; and Favero *et al.*, 1999) or a nonlinear (convex) aggregate supply or Phillips curve (e.g. Dolado *et al.*, 2005 and Schaling 2004), or still when central banks follow the opportunistic approach to disinflation (Aksoy *et al.*,

2006). Dolado *et al.* (2004) discuss a model which comprises both asymmetric central bank preferences and a nonlinear Phillips curve.

Asymmetric preferences or LINEX preferences departs from the quadratic objective in that policy makers are allowed, but not required, to treat positive and negative deviations of output and inflation from target values differently. This comes from the fact that when the monetary authorities are endowed with inflation and output stabilisation, they may have an inflation bias when inflation overshoots the target and an output bias during productivity declines (Orphanides and Wilcox, 2002). Thus the monetary authorities may behave in ways that reflect asymmetries when confronted by numerous competing objectives. This implies that their responses to inflation and output may be different depending on whether these variables undershoot or overshoot their target values. The monetary authorities may also exhibit zone-like behaviours by penalising more when inflation moves out of the target range and being passive when it is within the target range. Thus an empirical framework that allows for target zones and asymmetries in monetary policy preferences is more relevant to evaluate the monetary authorities' actual practice of monetary policy setting. However, as argued by Orphanides and Wieland (2000), the quantitative evaluations of monetary policy that are based on linear models that use the Taylor (1993) rule and its extensions by Clarida *et al.* (2000) may not fully capture the actual practice of inflation targeting.

Asymmetric preferences result in nonlinear policy rules that can be illustrated using the transition logistic function, which is in fact the most popular in the classes of regime switching models. Departing from the forward looking linear equation (2.19) above, the alternative Logistic Smooth Transition Autoregression (LSTAR) model can be

$$i_t = \rho_0 + \theta M_{1t} + (1 - \theta)M_{2t} + \varepsilon_t \quad (2.20)$$

where $M_{jt} = \rho_{ji}i_{t-1} + (1 - \rho_{ji})(\rho_{j\pi}E_t\pi_{t+p} + \rho_{jy}E_t y_{t+q})$ for $j=1,2$ and the function θ is the probability that the transition variable defined by equations (2.21) to (2.23) will be less than τ percent points from the equilibrium. In model (2.20), the response to interest rate, inflation, output gap and financial conditions index is allowed to differ between regimes. M_{1t} is a linear Taylor rule that represents the behavior of policymakers when the transition variable is below the threshold value τ and M_{2t} is a linear Taylor rule that represents the behavior of policymakers above the threshold level. If $\rho_{1i} = \rho_{2i}$, $\rho_{1\pi} = \rho_{2\pi}$ and $\rho_{1y} = \rho_{2y}$ the model simplifies to the linear Taylor rule in (2.19). The definition of θ depends on the chosen transition variable as follows:

$$\theta = 1 - \frac{1}{1 + \exp[-\gamma^i (E_t i_{t-1} - \tau_i) / \sigma_{(E_t i_{t-1})}]} \quad \text{if } i_{t-1} \text{ is the transition variable;} \quad (2.21)$$

$$\theta = 1 - \frac{1}{1 + \exp[-\gamma^y (E_t y_{t-1} - \tau_y) / \sigma_{(E_t y_{t-1})}]} \quad \text{if } y_{t-1} \text{ is the transition variable;} \quad (2.22)$$

$$\theta = 1 - \frac{1}{1 + \exp[-\gamma^\pi (E_t \pi_{t-1} - \tau_\pi) / \sigma_{(E_t \pi_{t-1})}]} \quad \text{if } \pi_{t-1} \text{ is the transition variable;} \quad (2.23)$$

where $\gamma \geq 0$ is the smoothness parameter which determines the degree of smoothness of the transition from one regime to the other. τ is the threshold between the two regimes. $\theta=0$ and $\theta=1$ denotes that the logistic function changes monotonically from 0 to 1 as the transition variable (i_{t-1}, y_{t-1} or π_{t-1}) increases (see Franses and van Dijk, 2003). As proposed by Granger and Teräsvirta (1993) and Teräsvirta (1994) σ is the standard deviation of the transition variable which serves to make the smoothness parameter γ dimension free.

At this stage it is worth mentioning that Orphanides and Wilcox (2002) have introduced theoretical foundation of a special case of asymmetric preferences known as the opportunistic approach to monetary policy (OAMP). The so-called opportunistic approach can also emerge from equation (2.20) but with a different annotation of θ . In the case of OAMP, θ is the probability of being within the inflation target and can be approximated by the following quadratic logistic function (see, for example, van Dijk *et al.*, 2002)

$$\theta = pr\left\{-\delta \leq E_{t-1}(\pi_{t+p} - \pi_{t+p}^I) \leq \delta\right\} = 1 - \frac{1}{1 + e^{\frac{-\gamma \left[E_{t-1}(\pi_{t+p} - \pi_{t+p}^I + \delta) \right] \left[E_{t-1}(\pi_{t+p} - \pi_{t+p}^I - \delta) \right] \sqrt{\sigma^2}}}{E_{t-1}(\pi_{t+p} - \pi_{t+p}^I)}} \quad (2.24)$$

Where π_t^I is the intermediate inflation and δ the threshold (see chapter 6 for more details on intermediate inflation). The assumption is that the policy maker responds to $E_{t-1}(\pi_{t+p} - \pi_{t+p}^I + \delta)$ when inflation is below the zone of discretion and to $E_{t-1}(\pi_{t+p} - \pi_{t+p}^I - \delta)$ when the inflation is above the zone of discretion.

2.1.2.4. Extended policy rule

In concomitance with the aforementioned Taylor rule modifications, there has also been increasing debate on whether central banks should respond to financial variables and/or asset prices. For example, Clarida *et al*, (2000) extend a forward looking Taylor rule by the inclusion of exchange rate within the model. Other examples include Knedlik (2006) who combines the estimation of the Monetary Conditions Index (MCI) with the theoretic modelling of monetary policy rules for South Africa with the assumption that monetary policy is not only interested in optimal monetary conditions but also in external stability.

Considering the probable role of asset prices and financial variables in policy setting, the central bank's loss function is augmented by a financial index (see Akram and Eitrheim, 2008). Departing from equation (2.1), the reduced form of the loss function is

$$L(\lambda) = V(\pi^*) + \lambda V(y^*) \quad (2.1)'$$

which becomes

$$L(\lambda, \phi) = V(\pi^*) + \lambda V(Y^*) + \phi V(f) \quad (2.25)$$

if augmented by a financial index. $V(\pi^*)$ denotes the variance of actual inflation relative to its target level, π^* ; $V(Y^*)$ denotes the variance of output relative to its equilibrium path, Y^* ; and $V(f)$ is a variance term representing financial instability. The parameters

λ and ϕ are respectively weights attached to output and financial instability. Svensson (1999) stipulates that under a strict inflation targeting regime $\lambda = 0$, while a flexible inflation targeting regime implies that $\lambda > 0$. Therefore, if the same logic is applied to equation (2.25), $\lambda = \phi = 0$ for a strict inflation targeting regime and $\lambda > 0$ and $\phi > 0$ for a flexible inflation targeting regime (see Akram and Eitrheim, 2008).

At this stage, the issue that deserves a particular attention is whether the central bank's flexibility includes financial stabilisation or not. The next section presents an overview on the South African monetary policy and so it sheds some lights on the variables that can be included in the policy rule.

2.2. The South African monetary policy: contextual overview

The aim of this section is to provide a contextual overview by discussing the South African monetary policy. This is important to understand the behaviour of the SARB and interpret empirical results. The information that has been gathered from the SARB's website (www.reservebank.co.za) has served as a baseline for the elaboration of this section. It discusses the background, the mandate, the functions and the monetary policy framework.

2.2.1. Background

The central bank of the Republic of South Africa, called the South African Reserve Bank (SARB), started its operations on the 30th June 1921 in terms of a special Act of Parliament, the Currency and Banking Act, 1920 (Act No. 31 of 1920). The current operations of the SARB are framed in the Constitution of the Republic of South Africa, sections 223 to 225 (1996) and the South African Reserve Bank Act of 1991.

Unlike the majority of central banks worldwide, the SARB has shareholders other than the government. Early 2011, the SARB had 650 shareholders. The total number of issued shares is 2,000,000 but no shareholder can be allowed to hold, or hold in aggregate with his, her or its Associates, more than 10,000 shares (see SARB, 2011a).

2.2.2. Mandate

The South Reserve Bank has the mandate “to achieve and maintain price stability in the interest of balanced and sustainable economic growth in South Africa” (SARB, 2011b). Section 224 of the Constitution (1996) stipulates that “*the Bank, in pursuit of its primary object [sic], must perform its functions independently and without fear, favour or prejudice, but there must be regular consultation between the Bank and the Cabinet member responsible for the national financial matters.*” With such independence, the SARB can use any instruments of monetary policy at its disposal to achieve the entrusted policy goal of price stability. This implies that the SARB has independence to select the instrument but not the independence in the selection of monetary policy goal.

However, the achievement of price stability requires the stability of the financial system and financial markets. In this regard, a revised mandate that includes particular responsibility for financial stability was announced by the Minister of Finance during his budget policy statement held on 27 October 2010. Accordingly, the SARB has established an internal Financial Stability Committee which includes all members of the monetary policy committee expanded by other members.

For instance, one of the SARB's primary goals is to protect the value of the currency and achieve and maintain financial stability. This mandate goes in line with the current literature which provides an increasing debate on the view that a policy rule that addresses inflation and output stabilisation ignoring movements in assets prices and other financial variables may be too restrictive. Among others, De Grauwe (2007) and Papademos (2009) argue that asset prices should be monitored in the conduct of monetary policy. In fact, Papademos (2009) has acknowledged the importance of monitoring asset prices as part of monetary policy. Indeed, he reiterates that ““leaning against the wind” of booming asset prices by raising the policy interest rates would, even in the short to medium term, be compatible with the ECB’s monetary policy strategy aiming at consumer price stability”.

2.2.3. Functions

In addition to the primary function of price stability, the SARB takes the following responsibility:

- *“Ensuring that the South African money, banking and financial system as a whole is sound, meets the requirements of the community and keeps abreast of international development;*
- *Assisting the South African government, as well as other members of the economic community of the southern Africa, with data relevant to the formulation and implementation of macroeconomic policy; and*
- *Informing the South African community and all stakeholders abroad about monetary policy and the South African economic situation.”* (SARB, 2011c).

2.2.4. Monetary policy framework

Between 1960 and January 2000, the SARB has adopted a number of frameworks; namely the exchange-rate targeting, discretionary monetary policy, monetary-aggregate targeting and “informal inflation targeting” announced in August 1999. The South African cabinet approved the proposal of a system of inflation targeting in October 1999, which was formally adopted in February 2000 (see Dykes, 2004 and SARB, 2011d). Since then, the SARB conducts monetary policy within an inflation targeting framework. Monetary policy is conducted and set by the Bank’s Monetary Policy Committee (MPC) with a CPI inflation target ranging from 3 to 6 per cent on a continuous basis. The adjustment of the repo rate (interest charged on the Bank’s refinancing system) is the main mechanism used by SARB for the implementation of monetary policy.

2.3. Conclusion

Chapter 2 has the aim to provide the theoretical foundations and the case study discussion. The literature has shown that the Taylor (1993) rule has gone through many modifications since the last decade of the 20th century. Modified or not, the Taylor rule (1993) can describe not only the inflation targeting regime's component, but also certain other characteristics, such as monetary policy response to business cycles. The trial modifications of the Taylor rule include interest rate smoothing, backward and forward looking versions, and nonlinear approximations. Furthermore, there has been increasing debate on whether central banks should respond to asset prices and financial variables. Despite some disagreements, economists seem to agree on the role of the financial market in determining inflation and economic performance.

As far as South Africa is concerned, a stable financial system is one of the mandates of the central bank. As such, if the Central bank has some responsibility on financial stability, this study investigates whether the SARB has adopted a more flexible inflation-targeting regime which allows a reaction to financial instability. This would be in line with the current literature which provides an increasing debate on the view that a policy rule that addresses inflation and output stabilisation ignoring movements in assets prices and other financial variables may be restrictive.

Chapter 3

Research methodology

3.1. Introduction

In chapter 1, research methodology was defined as being the how of collecting data and the processing thereof within the framework of the research process (Brynard, 1997). As such, research methodology deals with research methods and techniques to be used. According to Jankowicz (2000), research methods deal with *what* is being done while research techniques concern the *how* it will be done. To avoid confusion at this early stage, specific methods and techniques are discussed in corresponding chapters in appropriate ways. Indeed, each specific method or technique is designed to verify at least one of the hypotheses formulated in the thesis and for most of the cases they emerge from a model specification itself. In this chapter, the attention is focused on a class of estimators, used in this thesis, called Generalized Method of Moments (GMM) estimators. However, before discussing the GMM approach, the study provides an overview on the Hodrick-Prescott Filter used to detrend some series.

3.2. The Hodrick-Prescott Filter

The Hodrick-Prescott (1997) filter has been used to separate the cyclical component of some time series such as coincident business cycle and industrial production from their potential levels. Hodrick and Prescott (1997) consider that a series y is composed of a trend s and cyclical component c . As such, the Hodrick-Prescott (HP) filter is a filter that computes the smoothed component s by minimizing the variance of y around s , subject to a penalty that constrains the second difference of s . The illustration is given by

$$\min \sum_{t=1}^T (y_t - s_t)^2 + \lambda \sum_{t=2}^{T-1} ((s_{t+1} - s_t) - (s_t - s_{t-1}))^2$$

where T is the number of observations and λ is the penalty parameter. The value of λ depends on the frequency of the data and the larger the value of λ , the higher is the penalty. Hodrick and Prescott (1997) suggest that $\lambda = 14\,400$ for monthly data is reasonable.

To tackle the end-point problem in calculating the HP trend (see Mise *et al*, 2005a&b), the sample has to be expended on both starting and ending points. With regards to the starting points, this study considers actual data for twelve months prior to 2000. With regard to the ending points, an autoregressive ($AR(n)$) estimation has been applied to the series under decomposition and the AR model is in turn used to forecast additional

observations that have to be added to each of the series before applying the HP filter. The method is applied to the output measure and the components of the financial index (with n set at 4 to eliminate serial correlation). The obtained smoothed representation s (trend) of a given time series is considered to be its potential level. The cyclical component s represents the fluctuations around the long-run pattern. A negative value of the cyclical component indicates that the short-term level of the series is below its potential level, while a positive value indicates that the short-term level is above the potential one.

3.3. Generalized Method of Moments (GMM)

According to Johnston and DiNardo (1997), since Hansen's seminal paper (1982), there has been an extensive use of GMM estimators for two main reasons:

1. *"GMM nests many common estimators, and provides a useful framework for their comparison and evaluation.*
2. *GMM provides a 'simple' alternative to other estimators, especially when it is difficult to write down the maximum likelihood estimator."*

For the specific case of monetary policy rules, GMM is also useful for the estimation of forward-looking reaction function which contains expected values not observable at the moment the central bank makes the decision with respect to interest rate. Furthermore, the method can eliminate a potential simultaneity bias between the instrument and the explanatory variables (see Vdovichenko and Voronina, 2006).

3.3.1. GMM and the traditional Method of Moments (MOM)

The traditional Method of Moments (MOM) is the starting point of GMM estimation. The Method of Moments is based on the idea of estimating a population moment by using corresponding sample moment. The vector of L moment conditions that the true parameters β should satisfy may be written as

$$E[m(y_t, \beta)] = 0; \quad (3.1)$$

where y_t is a vector of variables observed at time t and β is the unique value of a set of parameters that makes the expectation equal to zero. Equation (3.1) should usually satisfy orthogonality conditions between a set of instrumental variables Z_t and the residuals of the equation, $u_t(\beta) = u(y_t, X_t, \beta)$ as follows:

$$E[Z_t u_t(\beta)] = 0; \quad (3.2)$$

where X_t refers to explanatory variables observed at time t . By replacing the moment conditions in equation (3.1) by its sample analogue, the following traditional MOM estimator is found

$$m_T(\beta) = \frac{1}{T} \sum_{t=1}^T Z_t u_t(\beta) = \frac{1}{T} Z' u(\beta) = 0; \quad (3.3)$$

where T is the sample size. The MOM can only yield an exact solution to this equation if the L number of moment conditions is equal to K number of parameter estimates.

However, in general, there are more moment conditions than the number of unknown parameters; ($L > K$). Under such conditions, the alternative approach to deal with the so-called overidentified system is the GMM. Indeed, GMM procedure is an extension of the traditional MOM approach able to deal with the case in which there are more estimating equations moment conditions L than unknown parameters β (Mittelhammer *et al.*, 2000). Though there is generally no exact solution for an overidentified system, GMM is deemed to reformulate the problem by choosing a β that makes the sample moment as close to zero vector as possible. In pursuit of this objective the following quadratic function is used:

$$\begin{aligned}
 J(\beta, \hat{W}_T) &= T m_T(\beta)' \hat{W}_T^{-1} m_T(\beta) \\
 &= \frac{1}{T} u(\beta)' Z \hat{W}_T^{-1} Z' u(\beta)
 \end{aligned}
 \tag{3.4}$$

where W_T is an ($m \times m$) weighting matrix which minimizes the weighted distance between the theoretical and actual values. At this stage, it worth mentioning two other benefits of using GMM: first, it produces consistent estimates with any positive definite weighting matrix. For instance, Mittelhammer *et al.* (2000) insist that the GMM approach defines an entire family of consistent and asymptotically normally distributed estimators as a function of the weighting matrix. Another benefit arise in the presence of heteroscedastic errors in that GMM is asymptotically more efficient than its special cases (for example 2SLS).

3.3.2. Testing the validity of a GMM in Eviews

3.3.2.1. Instrument orthogonality test

For the orthogonality condition $E(Z'u(\beta))=0$, Eviews uses the C-test also known as Eichenbaum, Hansen and Singleton (EHS) Test to test whether the orthogonality conditions are satisfied by a subset of the instruments Z_1 but not satisfied by the remaining instruments Z_2 (see Eichenbaum *et al.*, 1988 for further discussion on the test).

$$\begin{aligned}
 E(Z_1'u(\beta)) &= 0 \\
 E(Z_2'u(\beta)) &\neq 0
 \end{aligned}
 \tag{3.5}$$

The orthogonality test, C_T , is calculated as the difference between the *J-statistic* (see equation (3.4)) of the original model that uses the entire set of instruments Z and the *J-statistic* of the secondary model which considers Z_1 only.

$$C_T = J(\beta, \hat{W}_T)_Z - J(\beta, \hat{W}_T)_{Z_1}
 \tag{3.6}$$

where the subscripts Z and Z_1 respectively stand for the entire set of instruments and the subset of instruments for which the condition is assumed to hold. The test statistic should be less than χ^2 degrees of freedom equal to the number of instruments Z_2 for which the condition of orthogonality is assumed not to hold.

3.3.2.2. Regressor Endogeneity Test

In Eviews, the Durbin-Wu-Hausman test is used to perform the regressor endogeneity test. A regressor is exogenous if it is not explained by the listed instruments, while an endogenous regressor is the one explained by such instruments. Candidate variables for endogeneity test are those which are specified in the regressor list but not appearing in the instrument list. By this test, the researcher identifies endogenous regressors and then evaluate whether the endogeneity has any effect on the consistency of β .

The test is performed by comparing the *J-statistic* of the original estimation to the *J-statistic* of the secondary estimation. As such, the endogeneity test, H_T , is calculated as the difference between the two *J-statistics*. The instruments in the secondary estimation are those of the original estimation augmented by the variables which are being tested for endogeneity.

$$H_T = J(\beta, \hat{W}_T)_2 - J(\beta, \hat{W}_T)_1 \quad (3.7)$$

where subscripts 1 and 2 respectively stand for original and secondary equation. The test statistic should be less than χ^2 with degrees of freedom equal to the number of regressors being tested for endogeneity.

3.3.2.3. Weak Instrument Diagnostic

As proposed by Eviews, Moment Selection Criteria (MSC) that can provide a comparison of different sets of instruments is one way to have diagnostic information

on whether the instruments are weak or not. There are three different MSCs in Eviews: the *Schwarz criterion* based and the *Hannan-Quin criterion* based proposed by Andrews (1999), and the *Relevant Moment Selection criterion* proposed by Hall *et al.* (2007). These three tests are respectively calculated as follows:

$$SIC - \text{based} = J_T - (c - k)\ln(T)$$

$$HQIQ - \text{based} = J_T - 2.01(c - k)\ln(\ln(T))$$

$$\text{Relevant MSC} = \ln(1/T\Omega)(1/\tau)(c - k)\ln(\tau)$$

where c is the number of instruments, k is the number of explanatory variables, T is the number of observations, Ω is the estimation covariance matrix, $\tau = \left(\frac{T}{b}\right)^{1/2}$, and b is the bandwidth used (for Weighting Matrix: Times series (HAC)) to estimate GMM.

3.3.4. Application of GMM on the Taylor monetary policy rule

To estimate an equation by GMM, one need to consider a set of instrumental variables (IV) and their number must be at least as many as there are unknown parameters for identification purpose (Eviews 7 user's guide, 2009). Another proposal is that such instrumental variables have to be highly correlated with explanatory variables but uncorrelated with the residuals.

For illustration purpose we consider the reduced form of the original Taylor rule (equation (2.10)) augmented with the financial conditions index f_t .

$$\hat{i}_t = \rho_0 + \rho_\pi \pi_t + \rho_y y_t + \rho_f f_t \quad (3.5)$$

for which the following orthogonality conditions in the system of equations (3.6) has to be satisfied.

$$\begin{aligned} \sum (\hat{i}_t - \rho_0 - \rho_\pi \pi_t - \rho_y y_t - \rho_f f_t - \rho_i i_{t-1}) &= 0 \\ \sum (\hat{i}_t - \rho_0 - \rho_\pi \pi_t - \rho_y y_t - \rho_f f_t - \rho_i i_{t-1}) Z_{t-1} &= 0 \\ \sum (\hat{i}_t - \rho_0 - \rho_\pi \pi_t - \rho_y y_t - \rho_f f_t - \rho_i i_{t-1}) Z_{t-2} &= 0 \\ \sum (\hat{i}_t - \rho_0 - \rho_\pi \pi_t - \rho_y y_t - \rho_f f_t - \rho_i i_{t-1}) Z_{t-3} &= 0 \\ \sum (\hat{i}_t - \rho_0 - \rho_\pi \pi_t - \rho_y y_t - \rho_f f_t - \rho_i i_{t-1}) Z_{t-4} &= 0 \\ \sum (\hat{i}_t - \rho_0 - \rho_\pi \pi_t - \rho_y y_t - \rho_f f_t - \rho_i i_{t-1}) Z_{t-5} &= 0 \\ \sum (\hat{i}_t - \rho_0 - \rho_\pi \pi_t - \rho_y y_t - \rho_f f_t - \rho_i i_{t-1}) Z_{t-6} &= 0 \end{aligned} \quad (3.6)$$

In the system of equations (3.6), the instrumental variables are assumed to have the lags ranging from 1 to 6 ($t-1$, $t-2$, $t-3$, $t-4$, $t-5$, $t-6$).

3.4. Conclusion

Chapter 3 deals with research econometric methods to be used. As such, the chapter provides an overview on the Hodrick-Prescott Filter used to detrend some series. However, more focus is oriented on a class of estimators called Generalized Method of Moments (GMM) estimators. GMM is important in that it can be applied to several estimation contexts besides the linear model. In fact, GMM provides a useful framework for the comparison and evaluation of nested estimators. Furthermore, GMM can provide a simple alternative to other estimators, especially when it is difficult to write down the maximum likelihood estimator. For the specific case of monetary policy rules, GMM is also useful for the estimation of forward-looking reaction function which contains expected values not observable at the moment the central bank makes the decision with respect to interest rate. The method can also eliminate a potential simultaneity bias between the instrument and the explanatory variables.

Chapter 4

Data analysis and preliminary results

4.1. Introduction

In addition to this introduction and the conclusion, chapter 4 is composed of two sections. Section 4.2 is aimed to provide better understanding of the data used in the thesis. The section is composed of three subsections; namely data transformation, time series plot and descriptive statistics, and unit root test. Section 4.3 reports the results for monetary policy rules that take into account interest rate smoothing together with backward and forward looking versions. In the section, two measures of output gap and three measures of financial conditions index are explored with the aim to maintain the ones with better results for further investigations in subsequent chapters.

4.2. Data source and analysis

We use South African monthly seasonally adjusted data mainly sourced from the SARB database. The sample ranges from 2000:01 to 2010:12, which covers the inflation targeting regime in South Africa. The raw data and their sources are listed in Table 1 in alphabetical order.

Table 1: List of monthly raw data and source

No	Series name	Source	Code
1.	All share index	SARB	JFIA001E
2.	Coincident business cycle indicator	SARB	DIFN002A
3.	Consumer price index	SARB	VPI1000A + KBP7170N
4.	Corporate bonds* (most traded): 4(a) AB06 – Absa 4(b) ABS3 – Absa 4(c) CAL01 – Calyon 4(d) FRB03 – FirstRand 4(e) IV01 – Investec 4(f) NED5 – Nedbank 4(g) SBK5 - Standard Bank 4(h) Eskom bonds	SARB SARB SARB SARB SARB SARB SARB SARB	BEYJ296M BEYJ271M BEYJ251M BEYJ279M BEYJ051M BEYJ302M BEYJ217M KBP2004M
5.	Government bonds - 10 years and over	SARB	KBP2003M
6.	House price index	ABSA	ABSAHPI
7.	Industrial production	SARB	DIFN033B
8.	Johannesburg Inter Bank Agreed Rate (JIBAR/JIBA rate) : 3 months	SARB	KBP1450W
9.	Monetary aggregate/Money supply	SARB	KBP1374N
10.	Real effective exchange rate (15 trading partners)	SARB	KBP5378M
11.	Repo rate	SARB	MMSM009E

*Corporate bond = $\frac{1}{n} \sum_{i=1}^n cb_i$, where cb_i is an individual corporate bond defined as 4(a) to 4(h).

4.2.1. Data transformation

This sub section shows the process followed to convert data from their status of raw data to the final status for modelling use. In fact, some of the series are slightly transformed (e.g. percent change) but some others are combined to compose one index after substantial transformations.

4.2.1.1. The measure of price stability

The computations of new data include inflation which is measured as the annual change of the consumer price index. Until December 2008, the latter is defined as the consumer price index (CPI) for metropolitan and other urban areas, with the exclusion of the interest rate cost on mortgage bonds. This exclusion was to limit the effects of interest rates on inflation targets. However, since the beginning of 2009, the CPI for all urban areas became the new measure of inflation-target. The latter includes owners' equivalent rent considered to be positively related to interest rate changes (SARB, 2011e).

4.2.1.2. The measurement of economic activity

In this thesis, two alternative measures of economic activity have initially been considered: namely, the coincident business cycle indicator and industrial production. The advantage the two measurements have over GDP is the availability of monthly data and the fact that they are not subject to major alterations like the GDP does. But still, industrial production is used with some caution. For instance, Bernanke *et al.* (2004) argue that the concept of “economic activity” may not be perfectly represented by

industrial production or real GDP. The authors suggest an alternative to treat “economic activity” as an unobserved factor with multiple observable indicators. Therefore, coincident business cycle indicator which is the reference cycle for aggregate economic activity is expected to provide a more comprehensive image than industrial production. Coincident business cycle indicator is in fact the average of many specific cycles, among them the industrial production.

The choice of the method of measurement of economic activity is based on the information according to which the interest rate decision of the SARB considers among other factors, expected output gap between actual and potential output (SARB, 2011f). This study assumes that the level of output deviations from its potential captures the output objective of the SARB adequately. Walsh (2002) suggests using the growth in output relative to the growth in potential rather than the output gap itself (the level of output relative to potential). Accordingly, the thesis considers output gap measured as a percentage deviation of actual output from its Hodrick-Prescott (1997) trend.

4.2.1.3. The measurement of financial conditions index

Major transformation of the data concerns the measurement of the financial conditions index. In fact, although financial stability is one of the SARB objectives, the bank does not give an idea about variables that go into play in pursuing the objective of financial stability. In this study we are guided by views from different economic figures and institutions (see Castro, 2008 and 2010; Luüs, 2007; Montagnoli and Napolitano, 2005; Gerlach-Kristen, 2004; Castelnovo, 2003, Goodhart and Hoofmann, 2001; and

Dudley, 1999) to develop a financial condition index composed of the following five variables:

- (i) the real effective exchange rate ($REER_t$) where the rand appreciation increases the index;
- (ii) the real house price index (RH_t) where the house price index is an average price of all houses compiled by the ABSA bank, deflated by the consumer price index;
- (iii) the real stock price (RS_t) which is measured by the Johannesburg Stock Exchange All Share index, deflated by the consumer price index;
- (iv) the credit spread (CS_t) which is the spread between the yield on the 10-year government bond and the yield on A rated corporate bonds²; and
- (v) the future interest spread which is the change of spread between the 3-month interest rate futures contracts (F_t) in the previous quarter and the current short-term interest rate.

First, the inclusion of asset prices, explicitly property and share prices, within the model is motivated by the fact that some economists (e.g. Montagnoli and Napolitano, 2005) consider that change in interest rate modifies the set of discount factors economic agents apply to their profit expectations or the future stream of services or revenues from the asset they hold. Furthermore, central banks would like to respond to asset

² For instance Burger (2008) argued that the spread between the mortgage rate and the 10-year government bond rate is very much like an intermediate monetary target since its change leads to an opposite change in output or price level.

prices as they play an important role in the transmission of monetary policy. As noted by Montagnoli and Napolitano (2005), a rise in asset prices may have direct impact on aggregate demand and may, therefore, be associated with growing inflationary pressures. They emphasize that asset prices also influence the collateral values and bank's willingness to lend.

Second, the inclusion of real effective exchange rate is motivated by the fact that it is perceived as being the most important determinant (beside the interest rate) of aggregate demand and channel of monetary policy transmission in open economies. For example, external factors may cause the currency to depreciate and so stimulate higher exports that will in turn cause GDP growth to accelerate (see Luüs, 2007). Some banks, such as the Bank of Canada and the Reserve bank of New Zealand consider exchange rate as an operating target while others such as the Bank of Finland and the bank of Norway consider the former as an indicator for monetary policy (see Montagnoli and Napolitano, 2005).

Third, credit spread enters the model. Some economists such as Castelnuovo (2003) and Gerlach-Kristen (2004) advocated in favour of the credit spread within the interest rule and few years later, Driffill *et al* (2006) report empirical evidence of its overwhelming importance. To support the view, Castro (2010) states that credit spread is considered a leading indicator of the business cycle and of financial stress. The last variable is futures interest rate spread. As noted by Castro (2010) the futures interest rate spread provides

an indication of the degree of volatility in economic agents' expectations that the central bank aims to reduce.

The constructed financial index is expressed in standardized form, relative to the mean value of 2000 and where the vertical scale measures deviations in terms of standard deviations; therefore, a value of 1 represents a 1-standard deviation difference from the mean. The construction of the index is in the spirit of the UK financial conditions index provided by the Bank of England's *Financial Stability Report* (Bank of England, 2007). Having motivated the choice of variables to compose the FCI, the remaining issue is to determine the weight attached to each of them. In fact, it would be easier to model the Taylor rule augmented with all the 5 additional regressors but unfortunately, such inclusion can severely affect the degrees-of-freedom. To avoid such degrees-of-freedom problems, all these 5 variables are compressed in a single index called financial conditions index (FCI). However, the determination of their weights is not straightforward since there is not a widely accepted definition of financial stability indicator (see Akram and Eitrheim, 2008; and references herein). This study explores 3 alternative measurements of the FCI.

The first option of constructing the FCI is to assume that it is an equal weight average of the five variables composing the index. By using this easy option, we keep in mind that the approach can be subjected to criticism *per se* as the components of the FCI do not have equal impact on the economic activity. However, the aim of this exercise is not to provide tips of how the FCI is ought to be computed. We are rather motivated to

tackle the best measurement of the FCI in describing the behaviour of the SARB. Therefore, the financial conditions index resulting from equal weights average (FCI_{EW_t}) is also evaluated alongside other methods. FCI_{EW_t} can be described as follow:

$$FCI_{EW_t} = \frac{1}{n} \sum_{i=1}^n x_i, \text{ where } x_i \text{ is an individual component.} \quad (4.1)$$

The second option proposed in this paper amounts to choosing the optimal weights obtained from OLS estimation of the output gap on assets prices and financial variables composing the financial conditions index. By this approach, the weight of each variable depends on the importance it has in explaining the economic activity. The equation is given by

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 rir_{t-1} + \beta_1 reer_{t-1} + \beta_2 rh_{t-1} + \beta_3 rs_{t-1} + \beta_4 CS_{t-1} + \beta_5 F_{t-1} + \varepsilon_t \quad (4.2)$$

where rir , $reer$, rh and rs are respectively the deviations from the long run equilibrium path of real interest rate, real effective exchange rate ($REER_t$), real house price (RH_t) and real stock price (RS_t). The weight attached to each variable is measured as

$$w_i = \frac{|\beta_i|}{\sum_{k=1}^5 |\beta_k|}$$

Therefore, the FCI obtained from the OLS estimation is given by

$$FCI_{OLS} = w'_x \sum_{k=1}^5 x_k.$$

Where x is the matrix of financial variables $reer, rh, rs, CS$ and F . This logic of drawing the weights from the OLS estimation of the IS equation produces constant parameters and so constant weights. However, as discussed in Castro (2010) weights might depend on the relative economic importance of each variable at each particular moment in time. As such, the third option is to follow the methodology suggested by Montagnoli and Napolitano (2005) and Castro (2010) in determining the weights of the components of the financial conditions index. By this approach, financial conditions index is constructed as a weighted average of the series composing the index; where the weight of each variable depends on the importance it has in explaining the economic activity at particular moment. Therefore, time varying estimates of a state space are provided by applying Kalman filter approach on the assumed economy's backward-looking IS curve (see Castro, 2010).

$$y_t = b_0 + \sum_{k=1}^p b_k y_{t-k} + \sum_{l=1}^q b_l rir_{t-l} + \sum_{i=1}^5 \sum_{j=1}^{n_i} b_{ij} x_{i,t-j} + \mu_t^d \quad (4.3)$$

Where rir and (x) are as defined above. Equation (4.3) is estimated using the Kalman filter over the following state-space form:

$$y_t = X\beta_t + \mu_t \text{ (Measurement equation)}$$

$$\beta_t = F\beta_{t-1} + \omega_t \text{ (Transition equation)}$$

where X is the matrix of regressors plus the constant, β_t is the state vector composed of time varying coefficients and F is an identity matrix. The weight of each variable is measured as

$$w_{x_{i,t}} = \frac{|\beta_{x_{i,t}}|}{\sum_{k=1}^5 |\beta_{x_{k,t}}|},$$

where $\beta_{x_{i,t}}$ is the coefficient of variable x_i at time t . The FCI obtained from the Kalman-Filter algorithm is given by

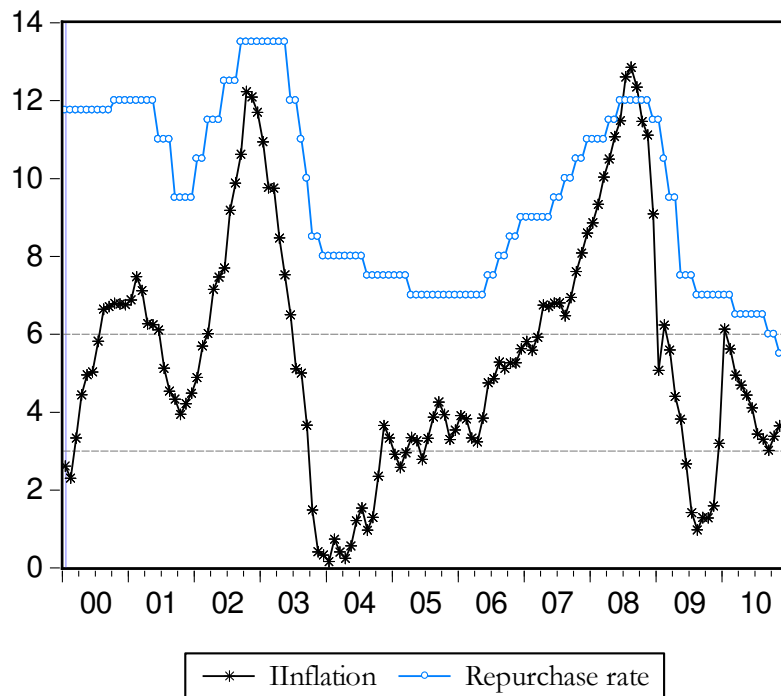
$$FCI_{KAL_t} = w'_{x_t} x_t$$

Having the above three alternatives of measurement, they are alternatively included in the modified Taylor rule with the aim to obtain the most accurate FCI in describing the behaviour of the SARB.

4.2.2. Time series plot and descriptive statistics

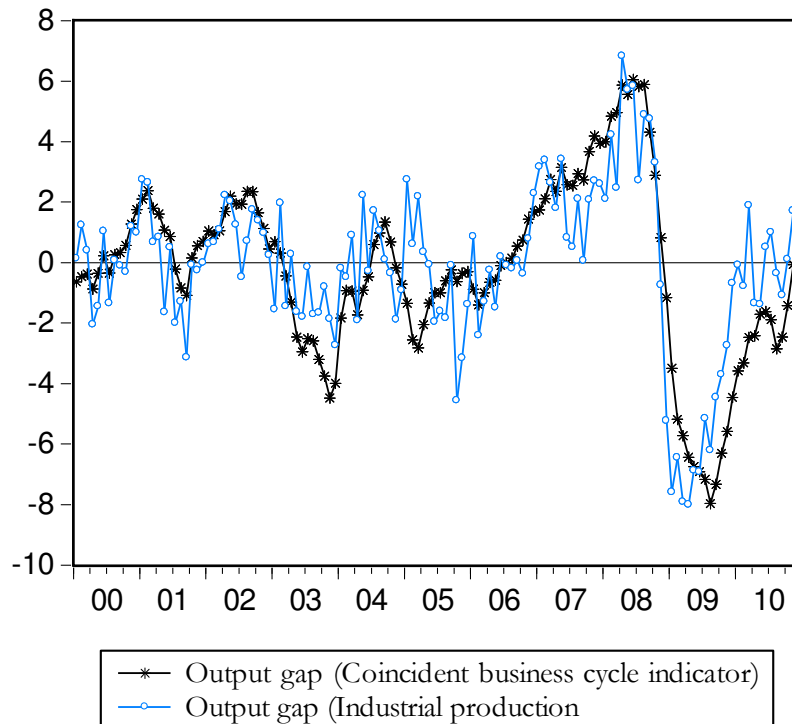
The evolution of the main variables is shown in Figures 1 to 3. The inflation rate (Figure 1) is showing significant fluctuations with an accompanying pattern of the interest rate; indicating the close link between the two variables.

Figure 1: Interest rate and inflation



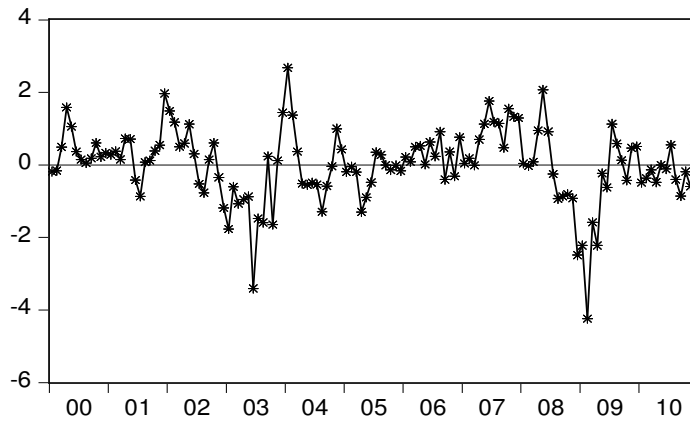
The output gap (Figure 2) is showing a severe downturn by the end of 2008 and a recovery is observed by the end of 2010. Movements in the two measures of output gap have a similar and close pattern showing the importance the industrial production has among other indexes composing the coincident business cycle indicator.

Figure 2: Output measures

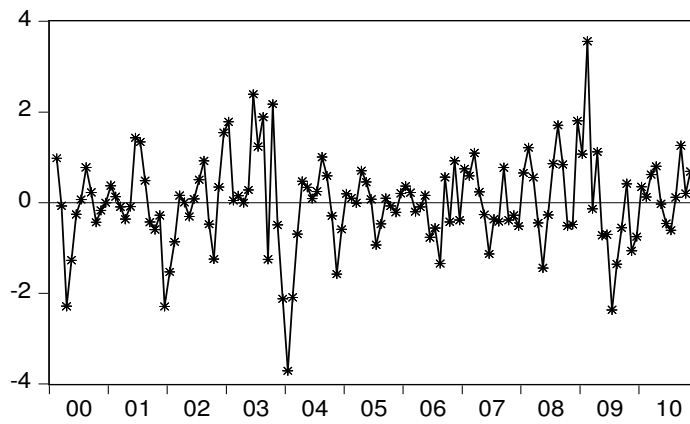


The financial conditions index (Figure 3) is showing a high level of volatility compared to Figures 1 and 2. The high level of volatility is indeed the concern of Bernanke and Gertler (1999) and Filardo (2001) about the potential costs of responding to asset price given its volatility relative to their information content while Mishkin and White (2002) suggest that monetary authorities should only be concerned by asset price misalignments when they affect financial stability. Descriptive statistics are reported in Table 2.

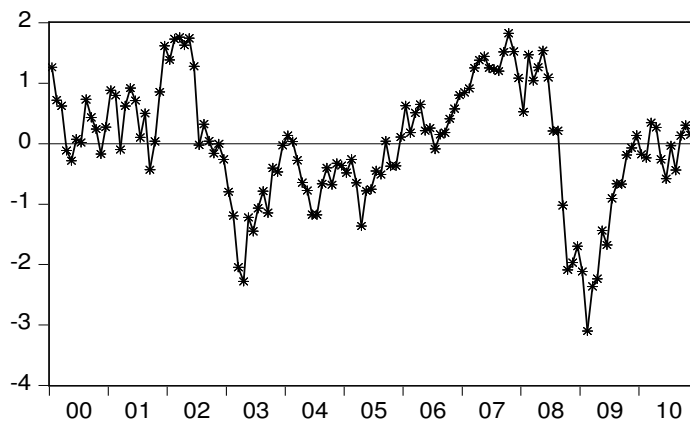
Figure 3: Financial conditions index



Financial conditions index (Equal weight)



Financial conditions index (Kalman filter)



Financial conditions index (OLS)

Table 2: Descriptive statistics of the main variables

	i_t	π_t	y_t _{(BC)*}	y_t _{(IP)*}	FCI_{EW}	FCI_{KAL}	FCI_{OLS}
Mean	9.52	5.43	-0.21	-0.12	10.70	0.00	-0.01
Median	9.50	5.03	-0.18	0.07	10.66	0.00	0.04
Maximum	13.50	12.85	6.05	6.82	53.12	3.56	1.83
Minimum	5.50	0.16	-7.96	-8.00	-29.48	-3.71	-3.10
Std. Dev.	2.30	3.07	2.90	2.67	11.44	1.00	1.00
Skewness	0.13	0.53	-0.34	-0.63	-0.05	-0.14	-0.44
Kurtosis	1.65	2.75	3.32	4.26	5.10	4.97	3.13
Jarque-Bera	10.36	6.40	3.06	17.45	24.15	21.69	4.24
Probability	0.01	0.04	0.22	0.00	0.00	0.00	0.12

*BC is coincident business cycle indicator and IP is industrial production.

4.2.3. Unit root test

This subsection carries out the unit root tests aimed to investigate whether the series to be used in the subsequent econometric modelling are stationary in their levels or in their first or second differences. The study uses the Augmented Dickey-Fuller (Dickey and Fuller, 1979; and MacKinnon 1991 and 1996), Phillips-Perron (1988), GLS-detrended Dickey-Fuller (Elliot *et al.*, 1996) and Kwiatkowski *et al.* (KPSS, 1992). In the next paragraphs, the tests are respectively abbreviated as ADF, PP, DFGLS and KPSS. The testing procedure has also tested the joint hypothesis of non existence of the trend (or

constant) and the presence of unit root, using the non-standard F -statistic ϕ_3 (or ϕ_1) reported in Dickey and Fuller (1981). Failing to reject the joint hypothesis implies that the trend (or constant) is significant under the null of a unit root. As such, the asymptotic normality of the t -statistic follows and so, the standard t -statistic is used instead of the ADF critical values. Given that the literature suggests using such standard t -statistic with caution, the series were subjected to further testing steps.

In performing the unit root test, we keep in mind that it is rare to find an inflation series which follows a stationary process but that it can be treated as stationary in line with common practice (see Fuhrer and Moore 1995, for discussion of similar issues). The unit root tests reported in Table 3 below suggest that all the series follow a stationary process.

Table 3: Unit root test

Series	Model	ADF			PP Test	DFGLS	KPSS	Conclusion
		$\tau_\tau, \tau_\mu, \tau$	ϕ_3, ϕ_1	$t - stat$				
Repo rate	Intercept & Trend	-4.84***	15.89***	-4.84***	-2.30	-4.67***	0.11 ⁺	I(0)
	Intercept	-4.57***	18.13***	-4.57***	-1.54	-1.91*	0.53	
	None	-3.28***	-	-	-1.27	-	-	
Inflation	Intercept & Trend	-3.31*	10.33***	-3.31***	-2.53	-2.98*	0.08 ⁺	I(0)
	Intercept	-3.34**	12.98***	-3.34***	-2.54	-0.77	0.08 ⁺	
	None	-0.78	-	-	-1.16	-	-	
Output gap (Coincident business cycle indicator)	Intercept & Trend	-2.68	21.73***	-2.68***	-2.47	-2.70*	0.08 ⁺	I(0)
	Intercept	-2.67*	32.75***	-2.67***	-2.45	-2.68***	0.12 ⁺	
	None	-2.68***	-	-	-2.45**	-	-	
Output gap (Industrial production)	Intercept & Trend	-2.84	8.54***	-2.84***	-4.15***	-2.87*	0.05 ⁺	I(0)
	Intercept	-2.84*	12.88***	-2.84***	-4.14***	-2.86***	0.07 ⁺	
	None	-2.86***	-	-	-4.15***	-	-	
FCI _{AV}	Intercept & Trend	-5.99***	17.13***	-5.99***	-6.95***	-4.10***	0.02 ⁺	I(0)
	Intercept	-6.02***	20.14***	-6.02***	-7.00***	-2.81***	0.02 ⁺	
	None	-2.43**	-	-	-5.12***	-	-	
FCI _{KAL}	Intercept & Trend	-5.73***	14.73***	-5.73***	-7.13***	-4.32***	0.02 ⁺	I(0)
	Intercept	-5.75***	17.30***	-5.75***	-7.23***	-3.36***	0.05 ⁺	
	None	-5.77***	-	-	-7.17***	-	-	
FCI _{OLS}	Intercept & Trend	-2.74	3.95	-	-2.99	-2.48	0.07 ⁺	I(0)
	Intercept	-2.81*	7.94***	-2.81***	-3.05**	-1.98**	0.11 ⁺	
	None	-2.82***	-	-	-3.06***	-	-	

*(**)[***] Unit root is rejected at a 10(5)[1] % level of significance. ⁺ Stationarity is not rejected at 10% level of significance.

4.3. Preliminary results

The Taylor (1993) rule and its extensions seem to be the most popular model in its field. Modified or not, the Taylor rule (1993) enjoys such popularity because it can describe not only the inflation targeting regime's component, but also certain other characteristics, such as monetary policy response to business cycles. As it has been noticed in chapter 2, the trial modifications of the Taylor rule include interest rate smoothing, backward and forward looking versions. Early versions of the Taylor rule that allowed inclusion of lagged interest rate include Clarida *et al.* (1998, 2000), Amato and Laubach (1999), Goodhart (1999), Levin *et al.* (1999) and Woodford (1999, 2003). Examples of estimation including both backward and forward looking versions include Rudebusch (2002); Orphanides (2002); Osborn *et al.* (2005), and Dolado *et al.* (2005). See Rudebusch & Svensson (1999), Batini and Nelson (1999); Clarida *et al.* (2000), Orphanides (2001, 2003) and Huang *et al.* (2001) for forward looking versions.

Table 4 reports the results for rules that take into account interest rate smoothing together with backward and forward looking versions. In this section, two measures of output gap are explored but the one with better results will be maintained for further investigations in subsequent chapters. A forward looking version as defined in the Table's notes performs quite well especially when coincident business cycle indicator is concerned.

Table 4: GMM estimates of a non extended linear Taylor rule (2000-2010)

Model	ρ_i	ρ_π	ρ_y	AIC	S.E	\bar{R}^2	J-statistic (<i>p</i> value)
Panel A: Using coincident business cycle indicator							
1. Backward-looking	0.93*** (0.01)	0.24* (0.14)	1.00*** (0.22)	1.01	0.39	0.97	0.16
2. Forward-looking	0.93*** (0.01)	0.94*** (0.09)	0.58*** (0.12)	0.87	0.37	0.97	0.15
3. Within-month	0.93*** (0.01)	0.38*** (0.09)	0.94*** (0.16)	0.97	0.39	0.97	0.15
Panel B: Using industrial production as output measure							
4. Backward-looking	0.93*** (0.01)	0.40*** (0.10)	0.98*** (0.24)	1.08	0.41	0.97	0.16
5. Forward-looking	0.91*** (0.01)	1.08*** (0.08)	0.06 (0.09)	0.88	0.37	0.97	0.18
6. Within-month	0.94*** (0.01)	0.50*** (0.10)	1.10*** (0.22)	1.03	0.40	0.97	0.17

Notes: Numbers in parentheses are standard errors. S.E is the regression standard error. AIC is Akaike Information criterion. J-statistic is the *p*-value of a chi-square test of the model's over-identifying restrictions (Hansen, 1982). The set of instruments includes a constant, 1-6, 9, 12 lagged values of repo rate, the inflation, the output gap, the financial conditions index, the 10-year government bond, and money (M3) growth.

Even the forward looking version using industrial production as output measure is having lower AIC compared to its counterparts but the later is not statistically different from zero. All in all, a forward looking version is going to be used in the following models that consider the inclusion of financial conditions index. The forward looking version is in line with what the SARB does. In fact, Mminele (2010) stipulates that the regular consultation between the SARB and the Cabinet Minister responsible for national financial matters helps to anchor inflation expectations. He says that it requires forward-looking policy-decision making based on expected inflation which allows for

flexibility to respond to shocks not offered by strict monetary policy rules and fixed exchange rates. Similarly, the SARB's governor Gill Marcus (2010) insists that the monetary policy always has to be implemented in a forward-looking manner, given the lags between a policy change and its full impact on the economy.

In concomitance with modifications regarding backward and forward looking versions, there has been increasing debate on whether central banks should respond to asset prices and financial variables. For example, Clarida *et al*, (2000) extend a forward looking Taylor rule by the inclusion of exchange rate within the model. Other examples include Knedlik (2006) who combines the estimation of the Monetary Conditions Index (MCI) with the theoretic modelling of monetary policy rules for South Africa with the assumption that monetary policy is not only interested in optimal monetary conditions but also in external stability. Table 5 proposes three options of computing the financial conditions index with the following objective: to investigate whether the inclusion of the financial conditions index can provide better understanding of the behaviour of the SARB or not. As reported in Table 5, empirical evidences show that the behaviour of the SARB is best described by a Taylor rule extended by the inclusion of the financial conditions index. In fact, the findings reveal that every option of FCI is better than the counterpart model which ignores such inclusion in Table 4. Surprisingly though, it is found that the SARB allocates equal weight to variables composing the index as opposed to any of the weighted averages. With regard to the output measurement, none of the three alternative models exhibits a significant industrial production. As expected, coincident business cycle indicator performs better than industrial production which is

indeed a component of the former. As such, the remainder of the thesis chooses to use the business cycle indicator as the measure of economic activity. Furthermore, the remainder of the thesis considers the financial conditions index measured as an equal weight average (FCI_{EW}) as it is the one that has described the SARB's behaviour better than any other tested measurement.

Table 5: GMM estimates of the linear forward-looking Taylor rule extended with FCI (2000-2010)

Model	ρ_i	ρ_π	ρ_y	ρ_f	AIC	S.E	\bar{R}^2	J-statistic (<i>p</i> value)
Panel A: Using coincident business cycle indicator								
1. FCI_{AV}	0.93*** (0.01)	1.06*** (0.08)	0.49*** (0.12)	0.07*** (0.01)	0.84	0.36	0.97	0.18
2. FCI_{KAL}	0.93*** (0.01)	1.03*** (0.08)	0.45*** (0.11)	-0.72*** (0.20)	0.86	0.36	0.97	0.18
3. FCI_{OLS}	0.93*** (0.01)	0.96*** (0.07)	0.46*** (0.12)	-0.07 (0.36)	0.92	0.38	0.97	0.18
Panel B: Using industrial production as output measure								
4. FCI_{AV}	0.93*** (0.01)	1.24*** (0.10)	0.13 (0.09)	0.08*** (0.02)	0.83	0.36	0.97	0.19
5. FCI_{KAL}	0.92*** (0.01)	1.19*** (0.08)	0.09 (0.08)	-0.78*** (0.23)	0.86	0.36	0.97	0.18
6. FCI_{OLS}	0.92*** (0.01)	1.07*** (0.07)	-0.14 (0.09)	0.86** (0.35)	0.93	0.38	0.97	0.18

Notes: Numbers in parentheses are standard errors. S.E is the regression standard error. AIC is Akaike Information criterion. J-statistic is the *p*-value of a chi-square test of the model's over-identifying restrictions (Hansen, 1982). The set of instruments includes a constant, 1-6, 9, 12 lagged values of repo rate, the inflation, the output gap, the financial conditions index, the 10-year government bond, and money (M3) growth.

4.4. Conclusion

The chapter was aimed to provide the source of data, to show the transformation made to some of them and to explore the data for preliminary results. To perform unit root tests, the study has used the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), GLS transformed Dickey-Fuller (DFGLS) and Kwiatkowski, *et. al.* (KPSS). Overall, the unit root tests have suggested that all the series follow a stationary process.

In this chapter, the backward, current and forward looking versions of the Taylor rule have been modelled. The later has outperformed the others. As such, the forward looking version has been considered to investigate whether the inclusion of the financial conditions index improves the fit of the monetary policy rule model. With the aim to find the most appropriate specification of the financial conditions index, three alternatives have been computed. The findings have revealed that the models that do not include financial conditions index display higher AICs. Therefore, no matter the methodology used to compute the financial conditions index, the models that accommodate the index describe the behaviour of the SARB better than the ones that ignore the financial variables. The financial conditions index measured as an equal weight average of its components yields a smallest AIC and so is considered for further modelling in subsequent chapters. In concomitance of the evaluation of the role of financial conditions index, the two measurements of output gap have been evaluated. The models that consider coincident business cycle indicator, rather than industrial production, perform better in terms of goodness of fit. Similarly, the coincident

business cycle indicator is maintained for subsequent chapters. In fact, as defined by the SARB, the industrial production is only one of many components of the coincident business cycle indicator.

Chapter 5

Financial assets, linear and nonlinear policy rules: an in-sample assessment of the reaction function of the South African Reserve Bank³

5.1. Introduction

This chapter investigates the objectives of the South African Reserve Bank (the SARB, hereafter) in the light of instrument rules. More precisely, we use the Taylor rule model and its extensions (e.g. Taylor, 1993; Clarida *et al.*, 2000), where interest rates relate linearly to the gap between actual and desired values of inflation and output. Recently however, researchers have questioned the linear specification and a nonlinear framework applies if, for instance, the central bank has asymmetric preferences as originally propounded by Nobay and Peel (2003) in the context of a linear function for the preferences of the central banks⁴, a nonlinear Phillips curve (Schaling, 2004) or, if it follows the opportunistic approach to disinflation (OAD) (Aksoy *et al.*, 2007).

³ Forthcoming in the Journal of Economic Studies. We thank an anonymous referee of the Journal of Economic Studies and a referee of the ERSA for their helpful comments, seminar participants at the University of Pretoria, participants at the African Econometric Society conference and the Economic Society of South Africa conference for valuable feedback on this chapter.

⁴A number of other studies have made use of these types of preferences; Bec *et al.*, 2002; Cukierman, 2002; Huang and Shen, 2002 and Ruge-Murcia, 2003.

These abovementioned nonlinear specifications have been the subject of intense debate in the last few years and recent economic events have turned the attention on the behaviour of certain asset prices (stock prices, house prices, the exchange rate) and the concern by central banks over the maintenance of financial stability (see Bernanke and Gertler, 2001; Chadha *et al.*, 2004). The view that a central bank's objective function (which addresses inflation and output stabilisation ignoring movements in assets prices and other financial variables) may be too restrictive is gaining momentum. For instance, De Grauwe (2007) argues that asset prices should be targeted as central banks cannot avoid taking more responsibilities beyond inflation targeting. In particular the vice president of the European Central Bank, Papademos (2009), in a similar remark said that "... close monitoring and deeper analysis of asset price movements, monetary and credit developments, ...can provide valuable information for the conduct of monetary policy." He further argues that "The ECB's monetary policy strategy provides a framework for such analysis." However, it should be kept in mind that Mishkin (2008) points out that asset price bubbles are hard to identify and even if they are identified, their response to interest rates is far from certain.

In the South African context, it is worth noting that one of the SARB's primary goals is to protect the value of the currency and achieve and maintain financial stability. This implicit goal might be the reason why the South African financial institutions experienced no direct exposure to the subprime crisis in terms of interbank or liquidity problems of the type experienced in developed countries (see Mboweni, 2008a, 2008b and Mminele, 2009). The current governor of the SARB, Gill Marcus (2010) has

emphasised that the central bank has an implicit financial stability mandate. But the question is how does the SARB fulfil this implicit financial stability mandate? Does the SARB respond to financial fluctuations?

Few works in the monetary policy literature have concentrated on nonlinear models and fewer have considered the financial index as a variable targeted by central bankers. For a recent work using such an index, Castro (2010) shows that, in contrast to the Federal Reserve and the Bank of England, ECB policymakers pay close attention to financial conditions when setting the Euro zone interest rate. This marks a significant point of departure of the chapter: using inflation, output and a proxy for financial conditions as the main underlying variables, the thesis examines whether monetary policy in the form of nonlinear Taylor type rule models can provide additional information over a linear model. This is motivated by a widespread dissatisfaction with the assumption that the interest rate's response to inflation and output is constant whatever the state of the economy. Asymmetric and zone models have econometrically dominated linear policy rules. For instance, Boinet and Martin (2008) and Martin and Milas (2010a), have recently reported the outperformance of nonlinear policy rules over the linear ones in explaining central banks' monetary policy setting of the interest rate in-sample at least. In this chapter, we employ an extension of the linear Taylor rule to a regime-switching framework, where the transition from one regime to the other occurs in a smooth way. The switching between regimes is controlled by output. This feature of the smooth transition model allows to test the ability of the state of the business cycles in describing the nonlinear dynamics of the interest rate in South Africa. Given the results reported in

chapter 4, this chapter chooses the financial conditions index constructed as an equal weight average of the real effective exchange rate, real house prices, real stock prices, credit spread and futures interest rate spread.

To assess the ability of the alternative policy rules to predict the SARB's interest rates in-sample, we use final data. All models are estimated over sequences of both recursive expanding windows of data and fixed-length rolling windows of data. Recursive and rolling estimations of the policy rules provide significant information on how the response coefficients to inflation, output and financial conditions have varied across times and across regimes (the state of business cycles).

The chapter reports five main findings. First, we find that the nonlinear Taylor rule improves its performance with the advent of the financial crisis, providing the best description of in-sample SARB interest rate setting behaviour with fixed-length rolling window estimation. The latter estimation technique is better able to capture parameter shifts as the crisis unfolds. However, one should also keep in mind that the number of crisis observations as a proportion of the total number of observations is greater in the case of fixed-length rolling estimation and thus the parameters can be more sensitive to changes over time and would therefore provide more accurate information as to how the SARB has reacted with the advent of the crisis. Secondly, the SARB policy-makers pay close attention to the financial conditions index when setting interest rates; the effect of the index remains significant even when nonlinearities are accounted for. Thirdly, given that inflation has been relatively high during most of the sample period

(see Tawadros, 2009, who evaluated inflation targeting effect on inflation for 27 countries that have adopted an inflation-targeting regime), the SARB's response of monetary policy to inflation is greater during business cycle expansions and lower during economic downturns. By contrast, high importance is placed on output during downturns. Fourthly, the 2007-2009 financial crisis witnesses an overall decreased reaction to inflation and financial conditions amidst uncertainty on the onset of recession. Fifthly, rolling estimation reveals that inflation, the output gap and financial index coefficients are remarkably unstable since mid 2007 with the onset of the crisis.

The chapter proceeds as follows. Section 5.2 summarises the linear and nonlinear models. Section 5.3 reports the in-sample analysis. Section 5.4 provides some concluding remarks.

5.2. Linear and nonlinear Taylor rule models

The model specification of this chapter departs from equation (2.10) which allows a forward looking version and the inclusion of the financial conditions index f as follows

$$\hat{i}_t = \rho_0 + \rho_\pi \pi_{t+p} + \rho_y y_{t+q} + \rho_f f_{t+r} \quad (5.1)$$

As in chapter 2, $\rho_0 = r^* - \alpha_\pi \pi^*$, $\rho_\pi = 1 + \alpha_\pi$, $\rho_y = \alpha_y$, $y_t = Y_t - Y_t^*$ and \hat{i}_t is the desired nominal interest rate. π_{t+p} is the inflation rate expected at time $(t + p)$, y_{t+q} is the

output gap expected at time $(t+q)$, f_{t+r} is a measure of financial conditions index expected at time $(t+r)$ used to augment the original rule,⁵ ρ_π is the weight on inflation, ρ_y is the weight on output gap and ρ_f is the weight on the financial conditions index. The inclusion of the financial index is based on the assumption that policymakers have preferences for this index being close to equilibrium, reflecting their desire to stabilise the financial system. Walsh (2009) points out that when financial factors cause distortions, these distortions will in general introduce corresponding terms in a loss function for monetary policy (see for example the theoretical model of Martin and Milas, 2010b; Papademos, 2009, re-iterates that the ECB aims at safeguarding financial stability in addition to achieving price stability). An alternative theoretical justification for the inclusion of the financial index in the policy rule is that the index determines movements in the differential between policy rates and 3-month interbank rates, the latter being the benchmark for private sector interest rates (see for example Martin and Milas, 2009).

Given the above, the financial conditions index is included in the Taylor rule that allows for interest rate smoothing (see e.g. Woodford, 2003). Interest rate smoothing is also in line with gradualism in the conduct of monetary policy as suggested by Helder and Manoel (2010). Hence, it is assumed that the actual nominal interest rate, i_t , adjusts towards the desired rate as follows

⁵The theoretical justification for including the financial conditions measure might either be that it enters the aggregate demand curve, similar to Castro (2008) or Goodhart and Hoffman (2002) or still the policymaker might have preferences for this index being close to equilibrium as in Naraidoo and Raputsoane (2010).

$$i_t = \rho_i(L)i_{t-1} + (1 - \rho_i)i_t^* \quad (5.2)$$

We write the empirical Taylor rule as

Model 1:

$$i_t = \rho_i(L)i_{t-1} + (1 - \rho_i)\{\rho_0 + \rho_\pi\pi_{t+p} + \rho_y y_{t+q} + \rho_f f_{t+r}\} + \varepsilon_t \quad (5.3)$$

where, $\rho_i(L) = \rho_{i1} + \rho_{i2}L + \dots + \rho_{in}L^{n-1}$ (we can use $\rho_i \equiv \rho_i(1)$ as a measure of interest rate persistence) and ε_t is an error term.

The theoretical basis of the linear Taylor rule (5.3) comes from the assumption that policymakers have a quadratic loss function and that the aggregate supply or Phillips curve is linear. Asymmetric preferences, instead, lead to a Taylor rule model in which the response of interest rates to inflation and/or output is different for positive and negative inflation and/or output deviations from their desired level. This chapter considers the case where monetary policy response differs over output regimes, viz., business cycle booms versus recessions. The theoretical reason for such variation follows the work of Cukierman (2002) whereby monetary policymakers are more sensitive to negative than to positive output gaps. Furthermore, as posited by Bec *et al.* (2002), there is the widespread belief that central bankers' interventions through changes in a short-term interest rate are influenced by the state of the current and/or expected state of the business cycle.

We consider the following nonlinear policy rule

Model 2:

$$i_t = \rho_i(L)i_t + (1 - \rho_i) \left\{ \rho_0 + \theta_t^y(E_t y_{t+q}; \gamma^y; \tau) M_{1t} + (1 - \theta_t^y)(E_t y_{t+q}; \gamma^y; \tau) M_{2t} \right\} + \varepsilon_t \quad (5.4)$$

where $M_{jt} = \rho_{j\pi} E_t \pi_{t+p} + \rho_{jy} E_t y_{t+q} + \rho_{jf} f_{t+r}$ for $j=1,2$ and the function $\theta_t^y(E_t y_{t+q}; \gamma^y; \tau)$ is the weight (defined below in (5.5)), at the beginning of period t , that output in period $(t+q)$ will be less than τ percent points from equilibrium. In model (5.4), the response to inflation, the output gap and the financial index is allowed to differ between output regimes. M_{1t} is a linear Taylor rule that represents the behaviour of policymakers during business cycle recessions (when output is expected to be less than τ percentage points from equilibrium), and M_{2t} is a linear Taylor rule that represents the behaviour of policymakers during business cycle expansions. If $\rho_{1\pi} = \rho_{2\pi}$, $\rho_{1y} = \rho_{2y}$ and $\rho_{1f} = \rho_{2f}$ the model simplifies to the linear Taylor rule in (5.3). It is worth noting that if $\rho_{1\pi} < \rho_{2\pi}$ the response of monetary policy to inflation is greater during business cycle expansions and lower during business cycle recessions. The weight $\theta_t^y(E_t y_{t+q}; \gamma^y; \tau)$ is modelled using the following logistic function (see e.g. van Dijk *et al.*, 2002):

$$\theta_t^y(E_t y_{t+q}; \gamma^y; \tau) = 1 - \frac{1}{1 + e^{-\gamma^y (E_t y_{t+q} - \tau) / \sigma(E_t y_{t+q})}} \quad (5.5)$$

In (5.5) the smoothness parameter $\gamma^y > 0$ determines the smoothness of the transition regimes. We follow Granger and Teräsvirta (1993) and Teräsvirta (1994) in making γ^y

dimension-free by dividing it by the standard deviation of $E_t y_{t+q}$. The switch between regimes is endogenously determined as both γ^y and the threshold τ are estimated jointly with the remaining parameters.

5.3. In-sample analysis

Findings for the models set out in section 2 are reported in Table 6. The specification which fits the data best allows for $p = q = 3$ for inflation ($E_t \pi_{t+q}$) and output gap ($E_t y_{t+q}$) and, a current rather than a forward-looking version for the financial index ($E_t f_{t+r}$) and one lag of the interest rate. Assuming perfect foresight for inflation and output gap, we replace forecasts of inflation and output gap by final realizations of inflation and output gap and then estimate models 1 and 2 by the Generalized Method of Moments (GMM). The set of instruments includes a constant, lagged values of inflation, the output gap, the 10-year government bond, M3 growth, and the financial index.

We estimate over recursive expanding windows of data, where the first data window runs from 2000:M1 to 2005:M12, and each successive data window is extended by one observation, hence, the last data window runs from 2000:M1 to 2010:M9 (this setup delivers 57 expanding windows). From a policy point of view, this allows us to identify the evolution of the estimated model parameters over time and across regimes. For robustness reasons, however, our exercise also reports results based on a sequence of fixed-length rolling windows where each successive window is constructed by shifting

the preceding window ahead by one observation. It should be noted that in the forecasting arena, Stock and Watson (2005) have argued that recursive forecasts are more accurate than the rolling forecasts for macroeconomic datasets whereas Giacomini and White (2006) have found that rolling window can lead to substantial forecast accuracy gains over the recursive schemes. The rolling scheme can also be used to guard against moment or parameter drift which might be particularly relevant amidst the financial crisis.

5.3.1 Empirical results for the first window of estimation

Table 6 reports estimates of the Taylor rule Models 1 and 2 (linear and nonlinear models respectively) over the first data window, which runs from 2000:M1 to 2005:M12. In all cases, the inflation (ρ_π), output gap (ρ_y) and financial index (ρ_f) effects are statistically significant. For the linear model, and in line with previous literature (see e.g. Castro, 2008; Gerdesmeier and Roffia, 2005; and references therein), the inflation effect ρ_π is higher than one, satisfying the “Taylor principle” that inflation increases trigger an increase in the real interest rate. The linear model records a statistically significant effect from the financial indicator variable; a one standard deviation increase in the index relative to its mean triggers an increase in the interest rate at 0.1 percentage point. An estimate of the inflation target is derived as

$\pi^* = \frac{i^* - \rho_0}{\rho_\pi}$, where (see e.g. Clarida *et al.*, 2000) we rely on the sample mean of the interest rate (which is equal to 9.53%) as a proxy for the equilibrium nominal interest rate i^* . From Table 6, the linear model delivers an implied target of approximately

$\pi^* = 6.03\%$, which is on the upper bound of the SARB's inflation target zone of 3-6%. One can also note that implied inflation target of the nonlinear model is 6.58. The two implied inflation targets indicate the so-called hardening of the upper bound of the inflation target since the values seem close to the 6% official upper bound.

For the linear model (Model 1), the last three rows of Table 6 report Hamilton's (2001) λ -test, and the λ_A and g -tests proposed by Dahl and González-Rivera (2003). Under the null hypothesis of linearity, these are Lagrange Multiplier test statistics following the χ^2 distribution.⁶ These tests are powerful in detecting non-linear regime-switching behaviour like the one considered by Model 2. All three tests reject linearity.

From Table 6, Model 2 reports the response of interest rates to inflation, output gap and financial index effects depending on whether output gap is positive or negative with an estimated output gap threshold of zero. The smoothness parameter γ^y has an estimated value of 5, indicating a rather quick switch from one regime to another. From the nonlinear model (column 2 of Table 6) we report that $\rho_{1\pi} < \rho_{2\pi}$; hence, the response of monetary policy to inflation is greater during business cycle upturns and lower during business cycle downswing with the Taylor principle requirement not being met over business cycle downturns.

⁶ We run the tests using Gauss codes obtained from Hamilton's web page at: <http://weber.ucsd.edu/~jhamilto/software.htm#other>. To account for the small sample, we report bootstrapped p -values of the three tests based on 1000 re-samples.

Table 6: Model estimates, 2000:M01 - 2005:M12

Coefficients	Model 1 (Linear)	Model 2 (Nonlinear)
ρ_0	2.228*** (0.48)	1.634*** (0.20)
ρ_1	0.918*** (0.01)	0.918*** (0.00)
ρ_π	1.211*** (0.06)	
ρ_y	0.240*** (0.08)	
ρ_f	0.098*** (0.01)	
$\rho_{1\pi}$		0.625*** (0.04)
ρ_{1y}		3.720*** (0.24)
ρ_{1f}		0.036* (0.02)
$\rho_{2\pi}$		1.778*** (0.04)
ρ_{2y}		0.555*** (0.09)
ρ_{2f}		0.140*** (0.01)
τ		0.00 0.00
γ^y		5.00
Implied π^*	6.034	6.580
AIC	0.983	0.975
S.E	0.380	0.370
\bar{R}^2	0.974	0.975
J-stat	0.253	0.243
λ -test	0.001	
λ_A -test	0.000	
g -test	0.001	

Notes:

- (i) Where Model 1 is $i_t = \rho_1 i_{t-1} + (1 - \rho_1) \{ \rho_0 + \rho_\pi E_t \pi_{t+3} + \rho_y E_t y_{t+3} + \rho_f E_t f_t \} + \varepsilon_t$ and Model 2 is $i_t = \rho_1 i_{t-1} + (1 - \rho_1) \{ \rho_0 + \theta_i^y (y_t; \gamma^y; \tau) M_{1t} + (1 - \theta_i^y) (y_t; \gamma^y; \tau) M_{2t} \} + \varepsilon_t$ with $M_{jt} = \rho_{j\pi} E_t \pi_{t+3} + \rho_{jy} E_t y_{t+3} + \rho_{jf} E_t f_t$ for $j=1, 2$ and y_t is the transition variable.

- (ii) Numbers in parentheses are standard errors. *(**)[***] indicate that the parameter is significant at a 10(5)[1] % level respectively. The implied target π^* is derived as $\pi^* = \frac{i^* - \rho_0}{\rho_\pi}$, where $i^* = 9.53\%$. AIC is the Akaike

Information Criterion. J stat is the p -value of a chi-square test of the model's over-identifying restrictions (Hansen, 1982). The set of instruments includes a constant, 1-6, 9, 12 lagged values of repo rate, the inflation, the output gap, the 10-year government bond, money (M3) growth, and the financial index. The table also reports bootstrapped p -values of the λ , λ_A , and g tests based on 1000 re-samples.

Also, $\rho_{1y} > \rho_{2y}$, suggesting that the SARB reacts very aggressively to output gap in recessionary states of the economy. The results also reveal that $\rho_{1f} < \rho_{2f}$, that is, a stronger response to the financial conditions index during business cycle upturns than during business cycle downturns. In fact, Rudebusch (2002) raises the issue of an omitted variables problem by pointing out that the significance of interest rate persistence in the policy rule could be due to omitting a financial spread variable from the estimated regression. Gerlach-Kristen (2003) and English *et al.* (2003) find that inclusion of a financial spread reduces the empirical importance of interest rate smoothing (amongst others, Estrella and Mishkin (1997) analyse the influence of a term structure variable in policy rules). Keeping this in mind, the empirical models that exclude the financial index variable performed very poorly compared to the models reported here in terms of the AIC criterion. Therefore, the conclusion is that the SARB pays close attention to financial conditions when setting interest rate; moreover, the response to the financial index depends on the state of the economy, viz., the business cycles.

5.3.2 Parameter evolution with recursive expanding windows of estimation

To get an idea of how the response parameters ρ_{π} , ρ_y , and ρ_f evolve over time, Figures 4 and 5 plot respectively the recursive estimates (plus/minus 2*standard errors) over expanding data windows and the implied inflation target rate, π^* for Model 1. Figures 6 and 7 plot respectively recursive estimates (plus/minus 2*standard errors) of

the response parameters $\rho_{j\pi}$, ρ_{jy} , ρ_{jf} ($j=1,2$) and the implied inflation target rate, π^* for Model 2.

For the linear model (Figure 4), the response to inflation is relatively stable up until late 2007 after which it drops. The response to the output gap increases initially till end of 2007, then surprisingly falls significantly in the second semester of 2008. A possible explanation of our findings is that during that period the SARB has tended to focus exclusively on the double digit inflation. Indeed, the level of inflation was on average 11.5% which is almost the double of the upper bound of inflation target zone. The response to the financial index remains relatively stable until early 2009 but after which it drops slightly. Overall, the reaction to the objectives of the central bank has dropped. A plausible explanation is that the authority was faced with high uncertainty over evolving economic conditions with the onset of recession, having been in a boom recently. The evolution of the implied target inflation rate depicted in Figure 5 has been relatively stable with a slight upward tendency to deviate from the target zone of 3-6%, conformed to the fall in the response to inflation over the recent business cycle downturn.

Figure 4: Recursive coefficients for the linear model

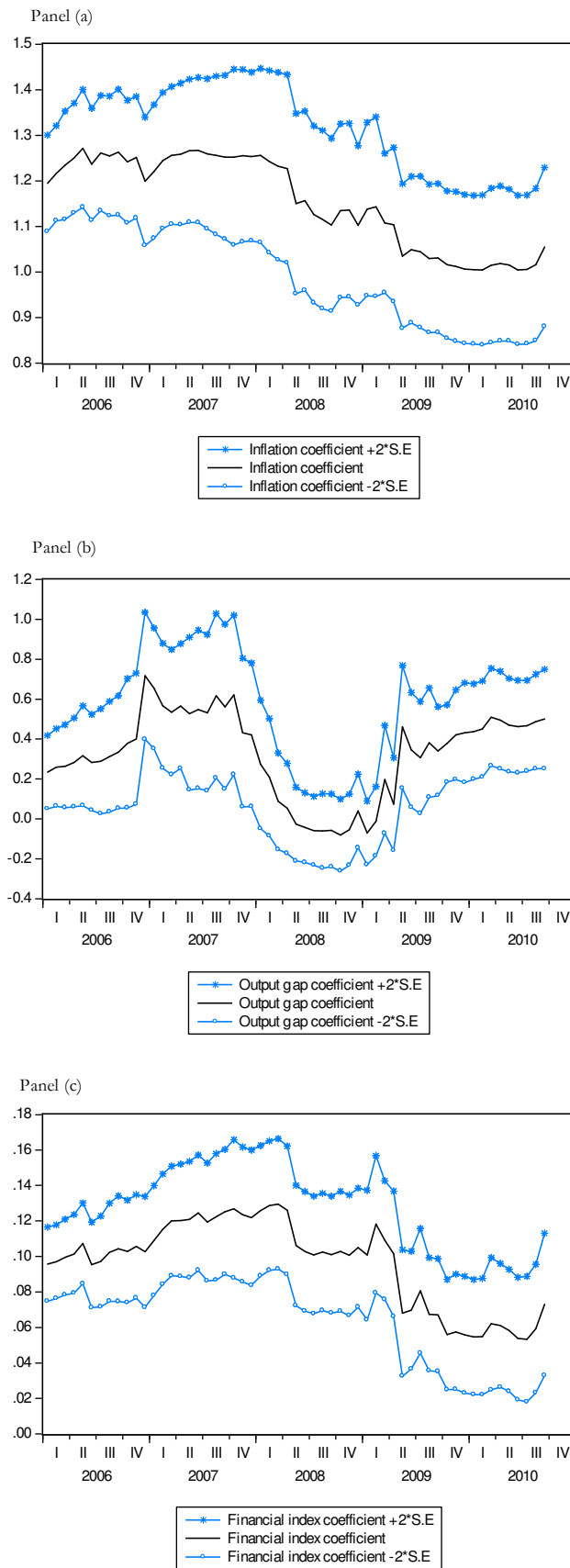


Figure 5: Implied inflation target for the linear recursive model

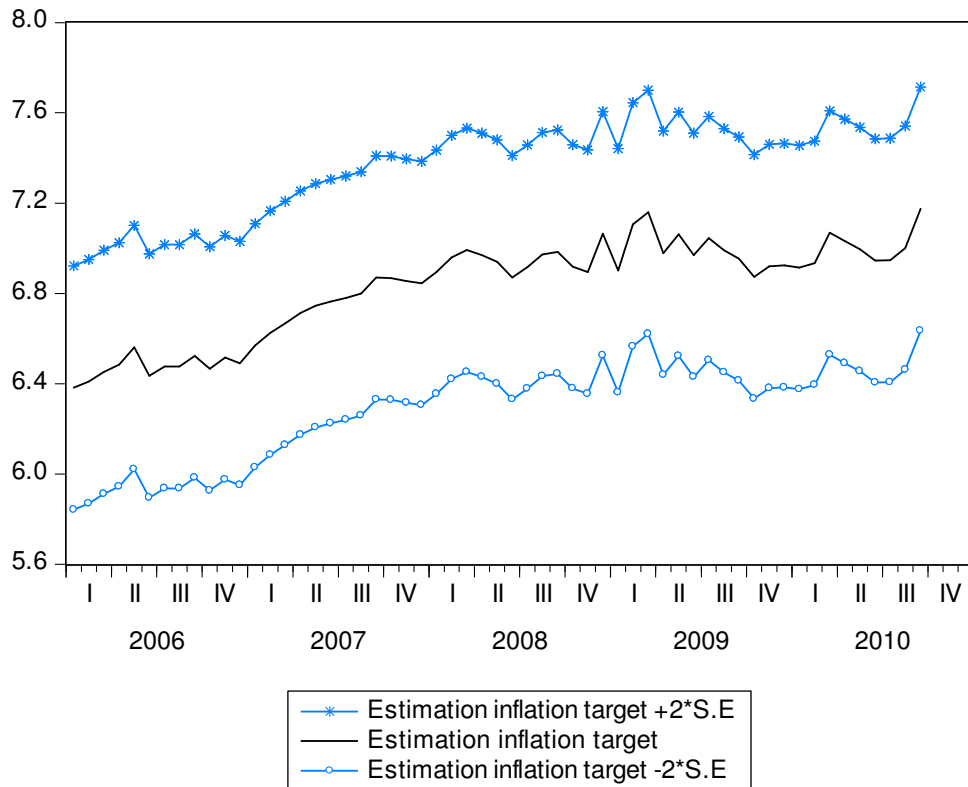


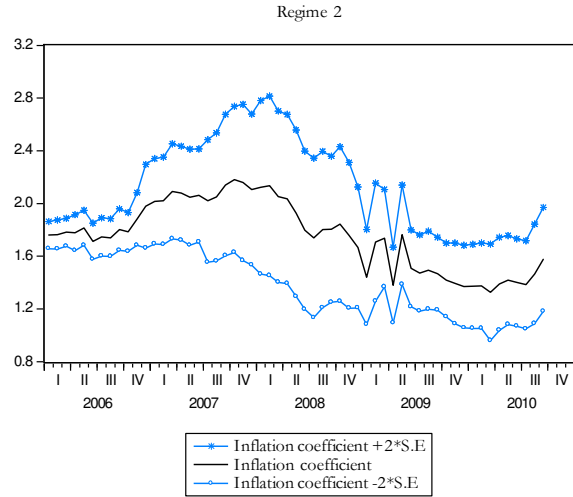
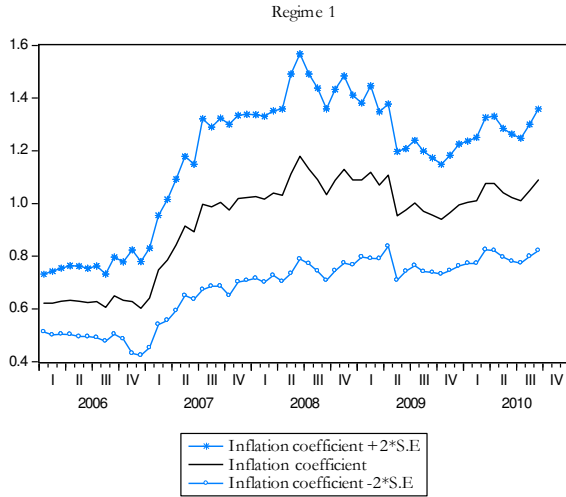
Figure 6 plots the recursively estimated response coefficients $\rho_{1\pi}$, ρ_{1y} , ρ_{1f} , $\rho_{2\pi}$, ρ_{2y} , and ρ_{2f} for the nonlinear Model 2. In this model, the policy response switches from $\rho_{1\pi}$, ρ_{1y} and ρ_{1f} to $\rho_{2\pi}$, ρ_{2y} and ρ_{2f} , respectively depending on whether expected output gap is below or above the threshold level. The recursively estimated inflation coefficients $\rho_{1\pi} < \rho_{2\pi}$ support our earlier findings over the first window of estimation. From 2007 onward, the response to inflation over business cycle upturns has declined slightly while that over recessionary states suggests an upward movement. From early 2007 onwards and as we move into the financial crisis period, the policy

response to the output gap over business cycle booms has increased while the response has dropped dramatically over business cycle recessions and has become largely insignificant. The financial index response is marginally higher over business cycle upturns versus downturns beginning of 2006. However as the financial crisis unfolds, the response to the financial conditions becomes more important in downturns than in upturns.

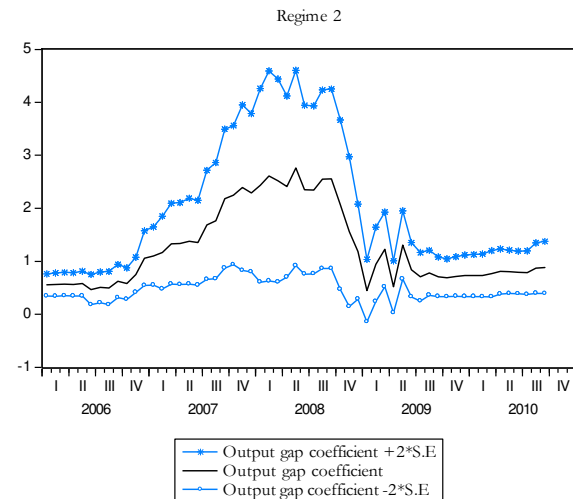
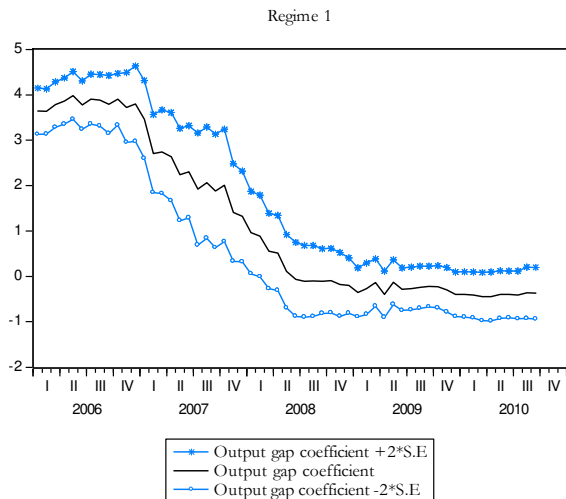
The results also reveal that the monetary authorities pay close attention to the financial conditions index when setting interest rates by allowing an asymmetric response to financial conditions depending on whether the business cycle is in upturn or in downturn. The nonlinear estimates indicate that the SARB has kept its firm instance on targeting inflation given South Africa's past history of high inflation and the concern for output stabilisation seems to drop as the crisis unfolds. This result should however be taken with caution as the uncertainties associated with measuring the output gap have largely been documented in the field and the lack of real time data leaves us with no strong conclusion to draw. The crisis also saw a shift from a symmetric policy response to financial conditions, to a more asymmetric response depending on the state of the economy. According to Mminele (2010), "inflation targeting in effect tries to strike a balance between the application of inflexible policy rules and potentially undisciplined monetary policy discretion, and has been aptly referred to by Bernanke (2003) as a framework of constrained discretion." He also reiterates that the SARB is undoubtedly a flexible inflation targeter rather than a strict inflation targeter. As such, the SARB has discretion as to the time horizon for bringing inflation back into the target range.

Figure 6: Recursive coefficients for the nonlinear model

(a) Inflation



(b) Output gap



(c) Financial conditions index (FCI_{EW})

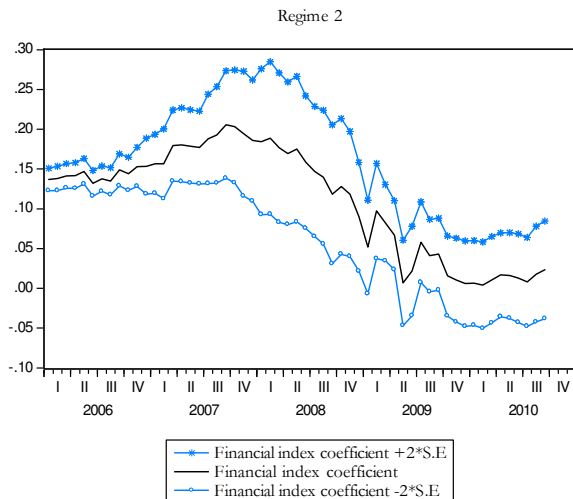
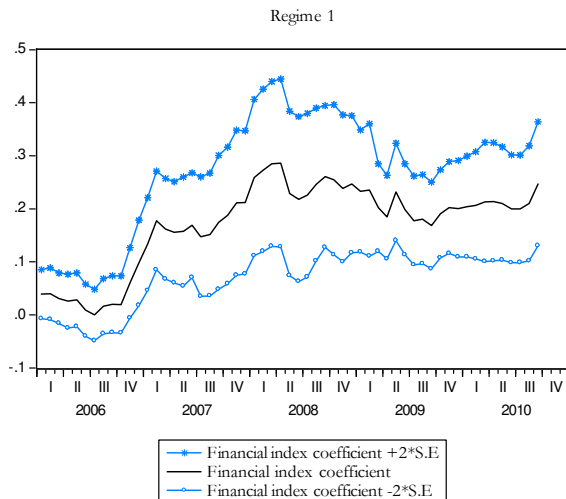


Figure 7: Implied inflation target for the nonlinear model

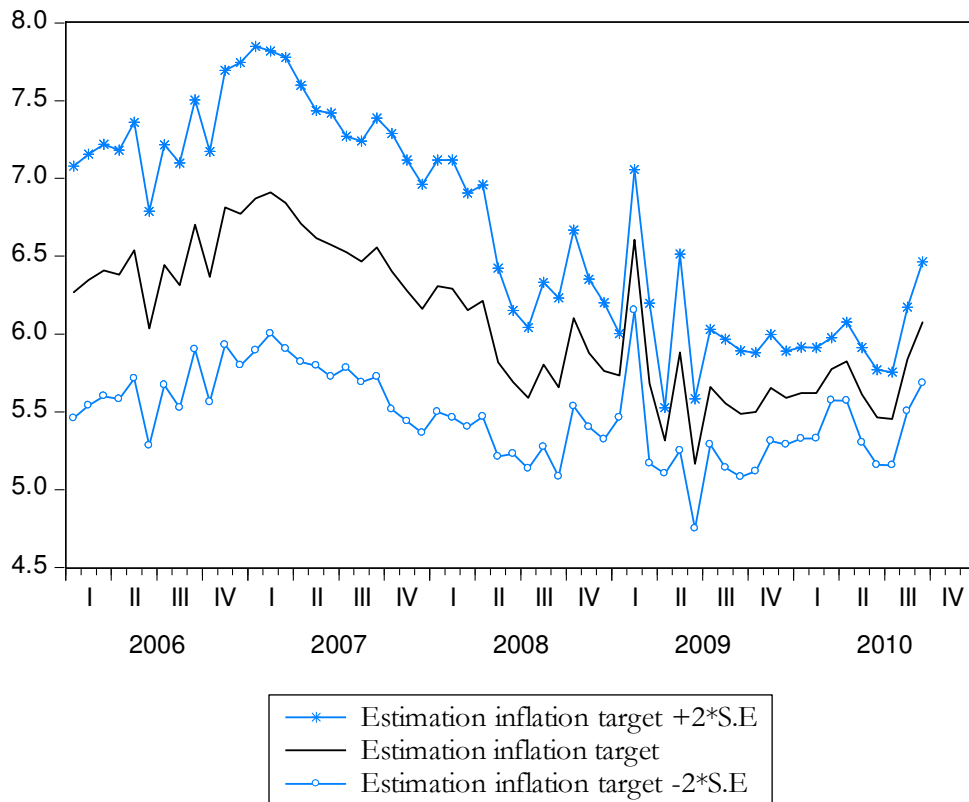
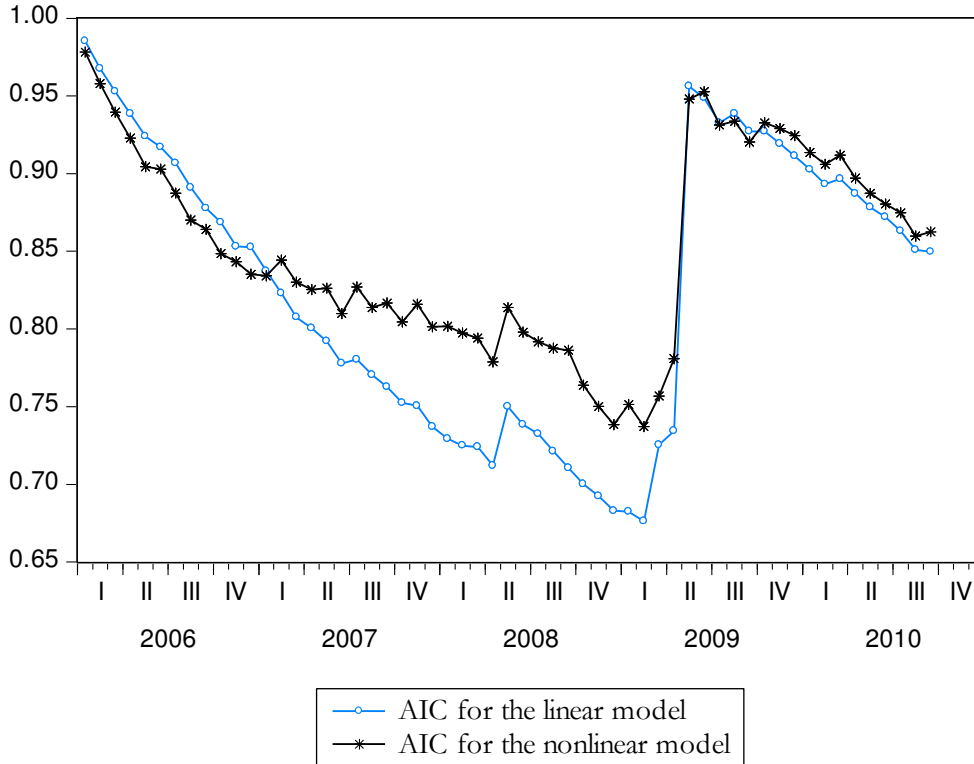


Figure 7 depicts the estimated implied inflation target rate for the recursive nonlinear model is relatively stable around the upper bound and the confidence intervals get relatively narrower with the change of the CPI's definition.

An inspection of recursive models shows that there is very little to discriminate amongst the estimated Taylor rule models in terms of the adjusted R^2 and the regression standard error. Figure 8 plots the recursive AIC values for both linear and nonlinear recursive

models. On average, Model 1 (the linear model) records lower Akaike Information Criterion (AIC).

Figure 8: AIC for linear and nonlinear recursive models



5.3.3. Parameter evolution with fixed-length rolling windows of estimation

Figure 9 plots the rolling fixed-length window estimated response coefficients (plus/minus 2*standard errors) ρ_π , ρ_y , ρ_f for the linear Model 1 and figure 11 plots the rolling estimates (plus/minus 2*standard errors) $\rho_{j\pi}$, ρ_{jy} , ρ_{jf} ($j=1,2$) for Model 2.

Figure 9: Rolling coefficients for the linear model

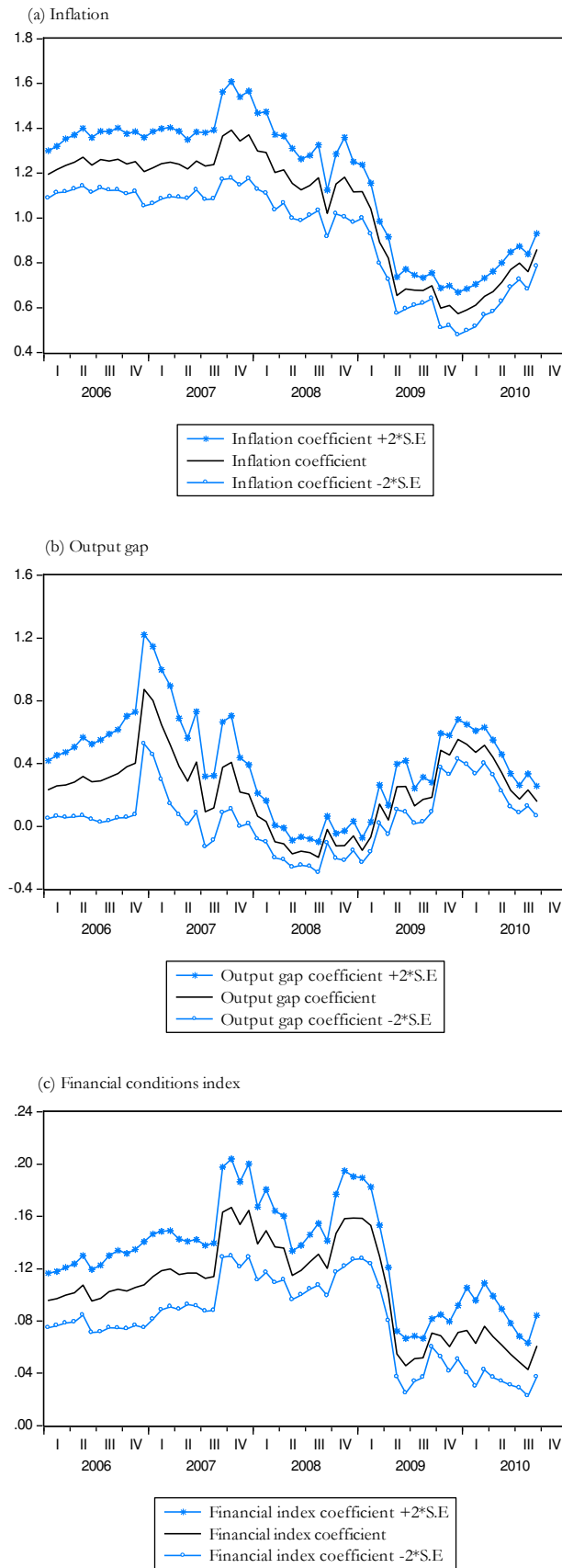


Figure 9 displays similar patterns for the responses to inflation, output gap and financial conditions as obtained under the recursive estimation, with a somewhat stronger and more volatile response since the onset of the financial crisis onward. The implied inflation target reported in Figure 10 has constantly increased above the upper bound of 6%.

Figure 10: Implied inflation target for the linear rolling model

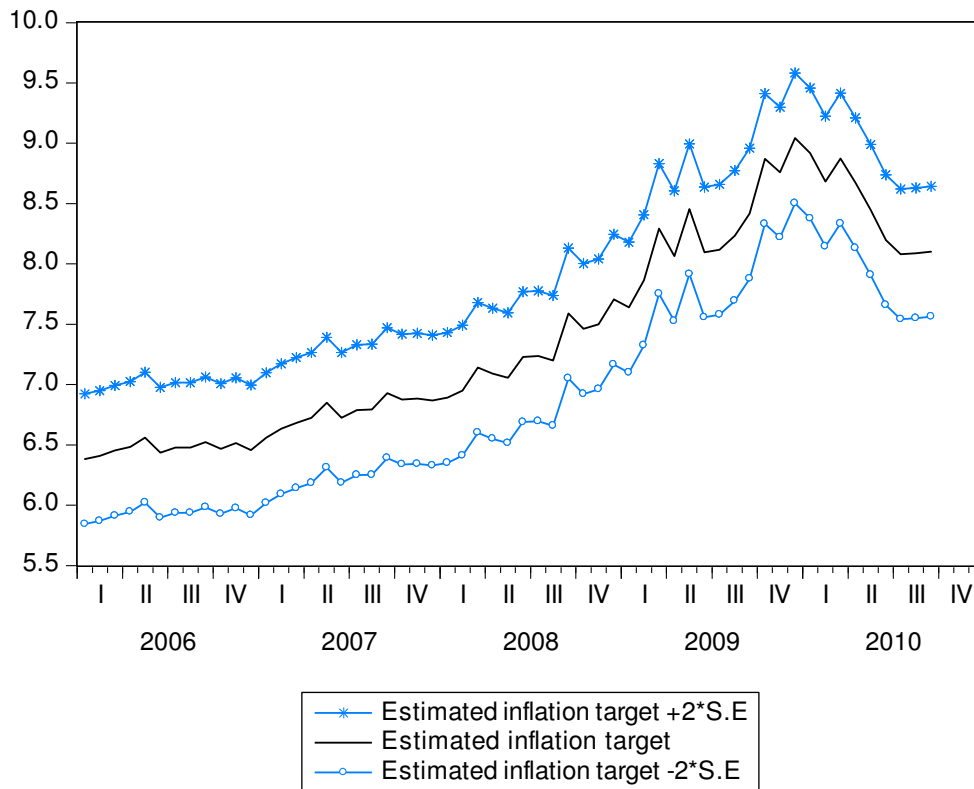
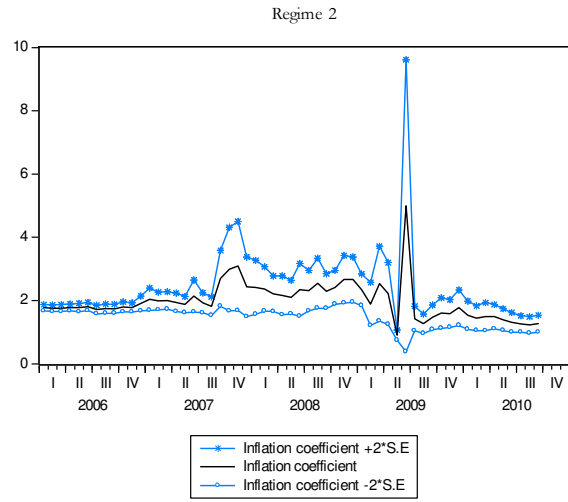
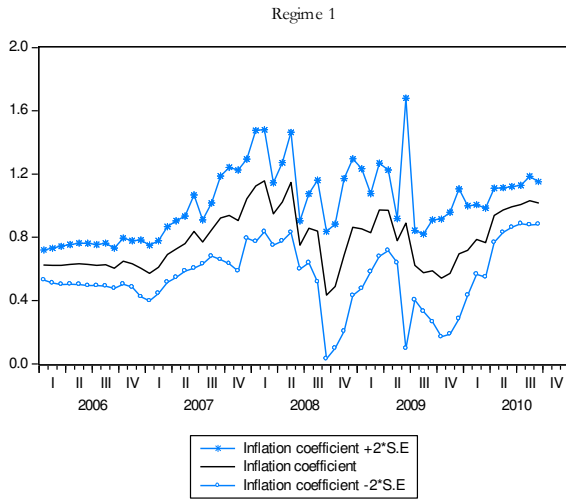
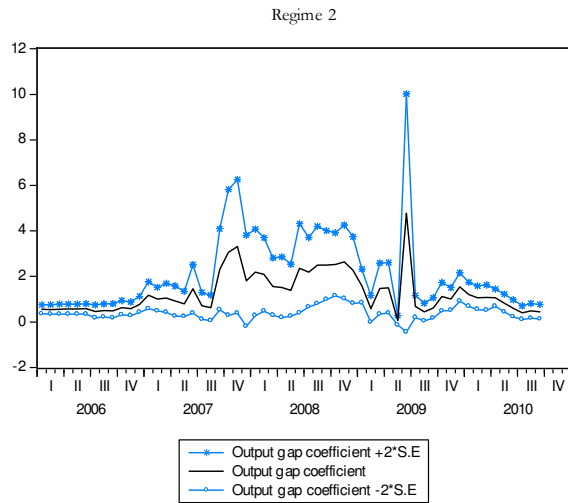
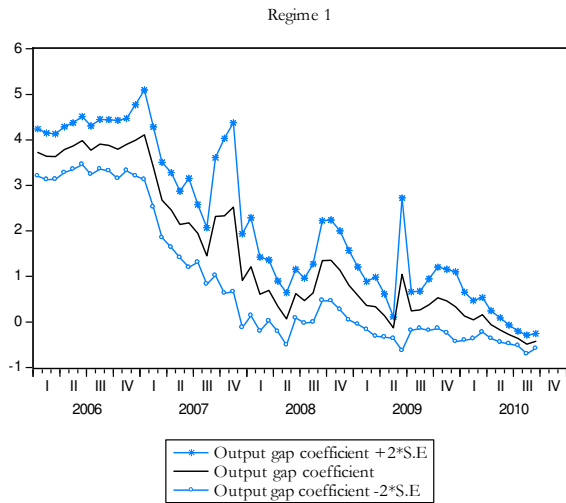


Figure 11: Rolling coefficients for the nonlinear model

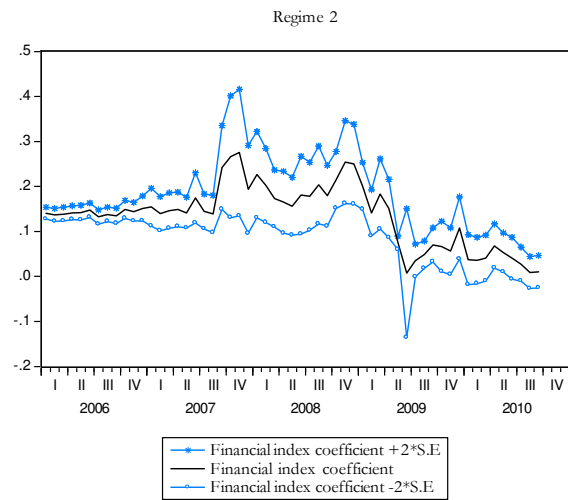
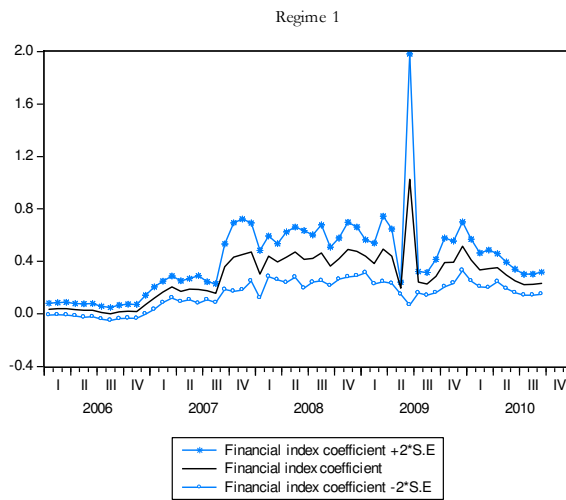
(a) Inflation



(b) Output gap



(c) Financial conditions index



A stark finding comes with an inspection of Figure 11 with volatile responses toward the end of 2007. Findings make clear that the rolling estimated inflation coefficients $\rho_{1\pi} < \rho_{2\pi}$ support our earlier results with the recursive estimation, with a more volatile response during business cycle downturns post 2007. From early 2007 onwards and as we move into the financial crisis period, the policy response to the output gap has dropped dramatically over business cycle recessions and has become largely insignificant while the response over business cycle booms has been relatively stable. The recursively estimated financial index coefficients ρ_{1f} and ρ_{2f} are fairly stable suggesting a sustained response to financial markets in the SARB monetary policy. There is also a volatile implied inflation target rate around the official upper bound of 6% which confirms the so-called hardening of the upper bound.

Figure 12: Implied inflation target for the nonlinear rolling model

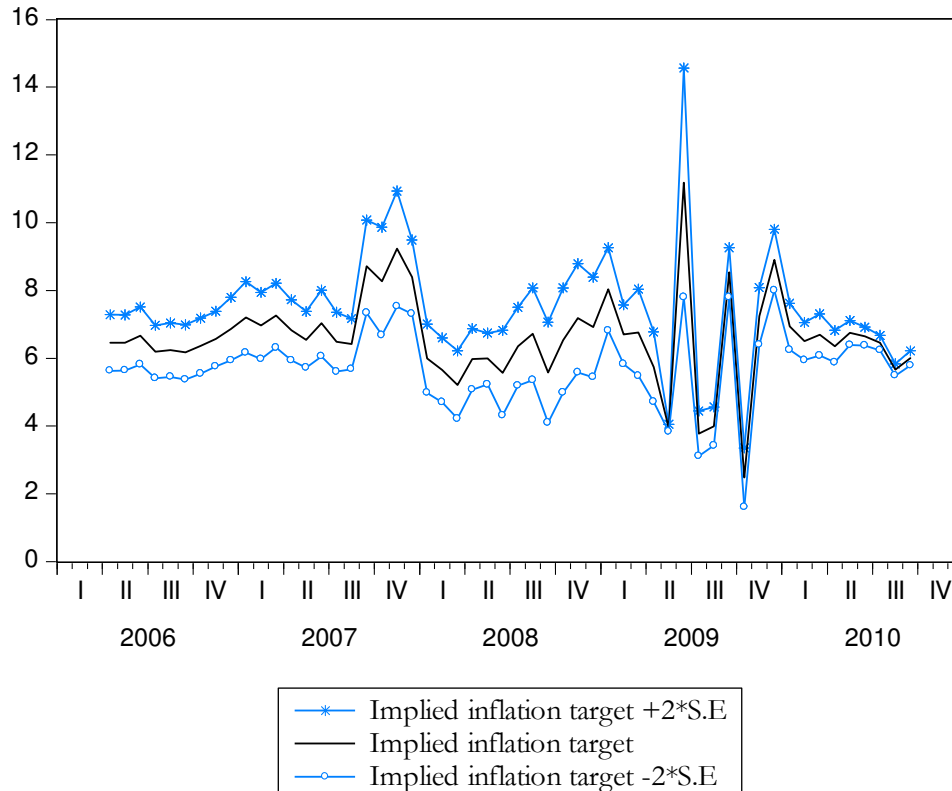


Figure 13: AIC for linear and nonlinear rolling models

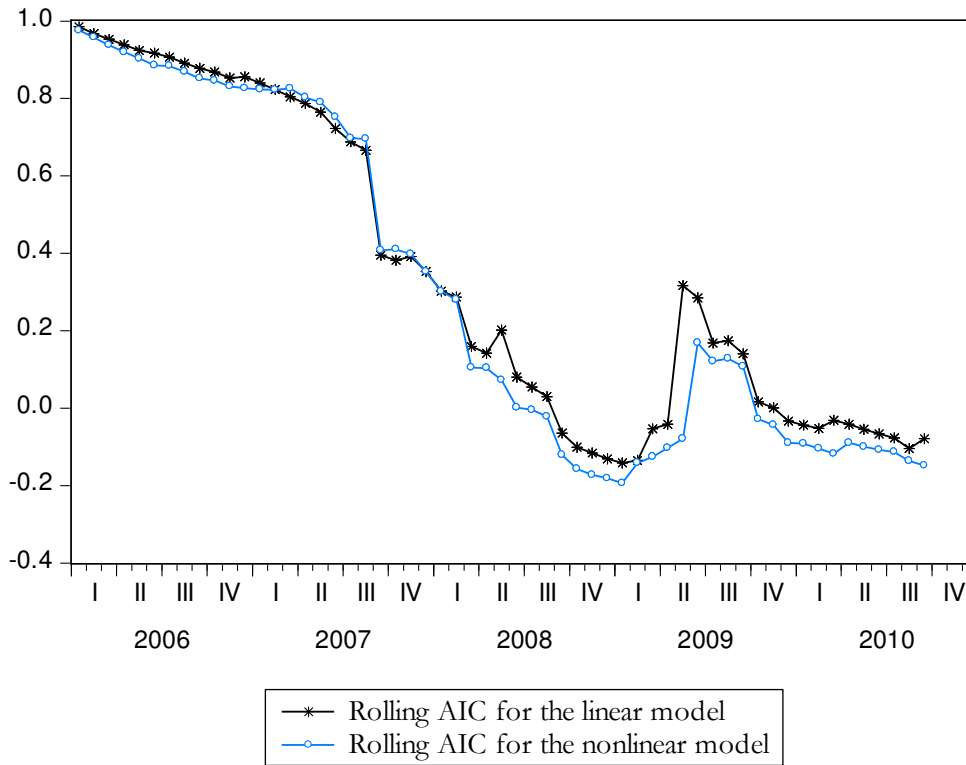


Figure 13 plots the rolling AIC values for both linear and nonlinear models. Unlike the recursive models, the nonlinear model under fixed-length rolling estimation records the lower AIC criterion and consistently dominates the linear estimates with the oncoming of the financial crisis.

5.4. Conclusions

In this Chapter we investigate both linear and nonlinear Taylor type monetary policy reaction functions for the SARB. Using inflation, output and a proxy for financial conditions as the main underlying variables, the study assesses policy in-sample. In addition, recursive and rolling estimations of the policy rules are performed with the aim to provide significant information on how the response coefficients to inflation, output and financial conditions have varied across times and across regimes (with respect to the state of the economy, viz., the business cycles).

We find that the nonlinear model under fixed-length rolling estimation records the best description of the interest rate setting behaviour of the SARB. The estimation unanimously shows that the SARB pays close attention to the financial conditions index when setting interest rates. Furthermore, we also found that owing to the relatively high inflation rate over the sample period, the SARB's response of monetary policy to inflation is greater during business cycle expansions with low response to output and a higher weight placed on output during recession periods. On the other hand, the 2007-2009 financial crisis witnesses a more asymmetric response to financial conditions depending on whether the business cycle is in upturn or in downturn. Rolling estimation reveals that inflation, output gap and financial index coefficients are highly unstable since mid 2007.

The response of the SARB policy-makers to financial conditions arguably has important policy implications as it might shed some light on why the current downturn in South Africa where the financial market occupies 25 percent of its total output is less severe.

Chapter 6

The opportunistic approach to monetary policy and financial market conditions⁷

6.1. Introduction

It is now almost two decades that economists approximate central banker's reaction function using mostly the Taylor rule (Taylor, 1993) and its modification by Clarida *et al.* (2000) and Woodford (2003). These models assume a constant proportional reaction of the interest rate to inflation and/or output deviations from desired levels. However, a number of academics (e.g. Nobay and Peel, 2003; Cukierman and Gerlach, 2004; Bec *et al.*, 2002; Orphanides and Wieland, 2000, and Favero *et al.*, 1999) have put into question the linear restriction. The view is that monetary policymakers behave rationally and so not rigid in their decision making. In fact, economic recession and economic expansion have different impact on future economic performance. Likewise, low inflation (below the target), desired inflation (hitting the target) and high inflation (above the target) have different impact on the monetary policy stance and the economy. As such, the inflation

⁷ Revised and resubmitted to Applied Economics. We thank an anonymous referee of the Applied Economics and seminar participants at the University of Pretoria for their helpful comments.

target band practice suggests that policymakers may exhibit ‘zone-like’ behaviour by responding more to inflation when inflation is some way from the target band and passively when inflation is inside the target.

In this chapter we test the opportunistic approach to monetary policy developed by Orphanides and Wilcox (2002) and Martin and Milas (2010a) have provided the first empirical evidence of this model using US data. The theoretical foundations provided by Orphanides and Wilcox (2002) assume that monetary policy is set depending on a ‘zone of inaction’. In fact, asymmetries resulting from a framework of target range of inflation can be described as a necessary condition for an opportunistic monetary policy but not as a sufficient one. The sufficient condition is met for central banks which do not respond to inflation when it lies within the target range and when the feature of an intermediate inflation rather than inflation target should be met. Accordingly, the literature suggests that when inflation is within the zone, the focus of the central bank is on output rather than inflation stabilisation (see Orphanides and Wilcox (2002) and a somewhat different theoretical model provided by Minford and Srinivasan (2006) for this same concept). In their contribution to the topic, Bomfim and Rudebusch (2000) judge that though opportunistic strategy may be able to achieve disinflation at a lower cost, it can probably take longer to achieve price stability than a deliberate approach. The latter is an approach which takes a deliberate path to an ultimate goal of low inflation. Although the deliberate and the opportunistic approaches have the same ultimate goal of low inflation, the latter assumes that the policy maker takes action only when inflation is too high. Bomfim and Rudebusch (2000) consider that “*the opportunistic*

policymaker takes no deliberate action to reduce inflation further, but waits to exploit recessions and favourable supply shocks to lower inflation. When inflation gets pushed down by a shock, the interim inflation target is reset to equal the new prevailing lower rate, and, in this fashion, price stability is eventually achieved'. From this statement, the two features of the opportunistic approach emerge clearly.

The first feature is related to the concept of the zone of discretion for which policymakers are supposed to behave opportunistically by accommodating shocks that tend to move inflation towards the desired level. By contrast, it is argued that policymakers should react when inflation tends to move away from the desired level. The interest rate will be raised when inflation is above the zone of discretion and decreased if inflation is below the zone. The second feature is that monetary policy should move inflation toward an intermediate inflation resulting from inflation target and previous actual inflation rates. This feature of intermediate inflation is based on the idea that the central bank should not pursue a target for inflation that is too ambitious in the short run but, it should instead pursue a practical target for inflation that is within the grasp of the short term. This is particularly relevant for developing countries which might be more concerned about the inflation-output trade-off in the short-run.

The recent financial crisis has provided an additional challenge to simple Taylor rule models adding to the debate on whether Central Banks can improve macroeconomic stability by targeting financial asset prices (such as exchange rates, house prices and stock prices). For instance, amongst others, De Grauwe (2007) argues that asset prices

should figure out as an objective for the central bank whereas Federal Reserve governor Mishkin (2008) and Bernanke and Gertler (2001) argue for the converse. We follow previous works by Naraidoo and Raputsoane (2010) and Naraidoo and Kasai (2010) who find that the SARB has been reacting to financial conditions and that the inclusion of a financial conditions index in the reaction function improves the fit of the model. This motivation follows from works by Rudebusch (2002) who raises the issue of an omitted variables problem by pointing out that the significance of interest rate persistence in the policy rule could be due to omitting a financial spread variable from the estimated regression. For instance, Gerlach-Kirsten (2004) and English *et al.* (2003) find that the inclusion of a financial spread reduces the empirical importance of interest rate smoothing (amongst others, Estrella and Mishkin (1997) analyse the influence of a term structure variable in policy rules).

The contribution in this chapter on top of investigating whether the monetary policy reaction function for the (SARB) could express the consistency of the opportunistic approach, is to augment such framework with a more comprehensive financial index variable that pools together relevant information provided by a number of financial variables. Furthermore, the main model is estimated over expanding windows of data. Recursive estimation provides significant information on how the response coefficients to inflation, output gap and financial conditions have varied across times and across regimes (within and outside the zone of discretion) with the oncoming of the sub-prime crisis.

There are a number of findings worth mentioning. The models that include intermediate rather than a simple inflation target improve the fit of the models. Among linear and nonlinear models, a quadratic logistic function outperforms all other models and provides support that monetary policymakers of the SARB have behaved opportunistically by accommodating shocks when inflation is within the zone of discretion but reacting aggressively otherwise. The outperforming model reveals that the zone of discretion is symmetrically extending from 2.05 percent below and above the intermediate inflation rate. Estimated inflation target range of 4.10 percent is reasonable for the SARB as the difference between the pre-announced lower and upper bound is 3 percent. Taking the official target range of 3 to 6 percent as a benchmark to our estimate, one can suggest that estimated target zone spans from 2.45 to 6.55 percent. We further use the preferred model to evaluate parameter evolution since January 2006. Recursive and rolling estimations reveal that in general, the 2007-2009 financial crisis witnesses an overall increased reaction to inflation and financial conditions. These results also indicate that until the end of 2008, the SARB increases the importance that it attaches to inflation and financial conditions relative to the output gap. A plausible explanation is that for that period inflation was on average approaching 12 percent, which is indeed the double of the upper bound of the announced target range. However, since early 2009, there has been a renewed attempt to stabilise output as a result of the new CPI inflation target which is lower than the previous measure.

The remainder of the chapter proceeds as follows. Section 2 outlines the model of Orphanides and Wilcox (2002) and Aksoy *et al.* (2006) and motivates the inclusion of

financial conditions in the framework and we suggest how it might be estimated. Section 3 explains the data. Section 4 discusses findings. Section 5 provides some concluding remarks.

6.2. Model specification

We use the model of Orphanides and Wilcox (2002) with the inclusion of financial conditions *a la* Martin and Milas (2010b). Martin and Milas (2010b) develop a flexible theoretical model to allow for changes in the preferences of policymakers when there is a financial crisis. Unlike the conventional loss function, the loss function in this chapter reflects a concern with financial stability by including a measure of domestic financial stability (f). For instance, Walsh (2009) points out that when financial factors cause distortions, these distortions will in general introduce corresponding terms in a loss function for monetary policy. As in Martin and Milas (2010b), equation (6.4) assumes that financial stability can be increased by reducing nominal interest rates; allowing financial institutions to re-capitalize at a lower cost.

$$L = (\pi - \pi^l)^2 + \gamma y^2 + \kappa f^2 + \psi \text{abs}(y) \quad (6.1)$$

$$\pi_t = \pi^e + \alpha y_t + \varepsilon_{st} \quad (6.2)$$

$$y_t = \alpha_0 - \alpha_r (r_t - r^*) + \varepsilon_{dt} \quad (6.3)$$

$$f_t = \bar{f} - \alpha_f (i_t - i^*) + \varepsilon_{ft} \quad (6.4)$$

where π is the inflation rate, π^l is the intermediate inflation target, y is the output gap, f is the financial conditions index, r is the real interest rate, r^* is the

equilibrium real interest rate, i is the nominal interest rate, i^* is the equilibrium nominal interest rate, α s are positive parameters, ε_s is a supply shock, ε_d is a demand shock and ε_f is a financial shock. Equation (6.1) specifies the policymaker's loss function in terms of expected discounted sums of quadratic deviations of inflation from the intermediate inflation target, the loss from output comprising a conventional quadratic term, a linear function of the absolute value of the output and the preferences of the policy maker for the financial conditions index to be close to equilibrium, reflecting their desire to stabilize the financial system.⁸ Equation (6.2) is a static expectations-augmented Phillips curve while Equation (6.3) is a simple, static aggregate demand relationship.

Assuming that policy-makers choose the optimal interest rate for period t at the end of period $t - 1$ using information available up to the end of period $t - 1$, Orphanides and Wilcox (2002) proposed the optimal monetary policy rule similar to Equation (6.5) below:

$$\begin{aligned} \hat{i}_t &= i^* + \rho_{ZD} E_{t-1}(\pi_t - \pi_t^l) + \rho_y E_{t-1} y_t + \rho_f E_{t-1} f_t & \text{if } -\delta \leq E_{t-1}(\pi_t - \pi_t^l) \leq \delta \\ \hat{i}_t &= i^* + \rho_{OZD} E_{t-1}(\pi_t - \pi_t^l + \delta) + \rho_y E_{t-1} y_t + \rho_f E_{t-1} f_t & \text{if } -\delta > E_{t-1}(\pi_t - \pi_t^l) \\ \hat{i}_t &= i^* + \rho_{OZD} E_{t-1}(\pi_t - \pi_t^l - \delta) + \rho_y E_{t-1} y_t + \rho_f E_{t-1} f_t & \text{if } \delta < E_{t-1}(\pi_t - \pi_t^l) \end{aligned} \quad (6.5)$$

⁸ A detailed explanation of how the financial conditions index is constructed is provided in the data section.

The above nonlinear monetary policy rule comprises of two Taylor-like policy rules describing the reaction function of the policy-makers and it depends on whether expected inflation is below, within or above the zone of discretion. The zone ranges from δ percentage points below the intermediate inflation target to δ percentage points above. ρ_y and ρ_f are respectively the coefficient of output gap and financial conditions index. ρ_{ZD} and ρ_{OZD} are respectively the coefficient of inflation within the zone of discretion and the coefficient of inflation outside the zone. If $\rho_{ZD} \neq \rho_{OZD}$, it is an indication that the response by monetary policy makers depends on whether inflation is within the zone of discretion or not. By contrast, if $\rho_{ZD} = \rho_{OZD}$, it is an indication that the monetary policy reaction function is linear and so equation (6.5) simplifies to the following equation:

$$\hat{i}_t = i^* + \rho_\pi E_{t-1}(\pi_t - \pi_t^l) + \rho_y E_{t-1} y_t + \rho_f E_{t-1} f_t \quad (6.6)$$

Replacing the intermediate inflation target in equation (6.1) with the conventional point inflation target π^* , equation (6.6) becomes

$$\hat{i}_t = i^* + \rho_\pi E_{t-1}(\pi_t - \pi_t^*) + \rho_y E_{t-1} y_t + \rho_f E_{t-1} f_t \quad (6.7)$$

Allowing for interest rate smoothing as in for e.g. Woodford (2003) it is assumed that:

$$i_t = \rho_i(L)i_{t-1} + (1 - \rho_i)\hat{i}_t \quad (6.8)$$

Where $\rho_i(L) = \rho_{i1} + \rho_{i2}L + \dots + \rho_{in}L^{n-1}$ is an indicator of the degree of smoothing of the instrument and \hat{i} is the desired interest rate given by equation (6.7) above:

$$\hat{i}_t = i^* + \rho_\pi E_{t-1}(\pi_t - \pi_t^*) + \rho_y E_{t-1} y_t + \rho_f E_{t-1} f_t \quad (6.9)$$

Combining equations (6.8) and (6.9), solving for the expectation operator, E , and allowing for a forward looking version we have

$$i_t = \rho_i(L)i_{t-1} + (1 - \rho_i) \left\{ i^* + \rho_\pi (\pi_{t+p} - \pi^T) + \rho_y y_{t+q} + \rho_f f_{t+r} \right\} + \varepsilon_t \quad (6.10)$$

where ε_t is an error term composed of expectational errors. As seen above, one of the opportunistic approach features is the use of intermediate inflation rather than simple inflation target. To allow for this feature, we rewrite Equation (6.10) by replacing the inflation target by the intermediate inflation target to have

$$i_t = \rho_i(L)i_{t-1} + (1 - \rho_i) \left\{ i^* + \rho_\pi (\pi_{t+p}^I - \pi^T) + \rho_y y_{t+q} + \rho_f f_{t+r} \right\} + \varepsilon_t \quad (6.11)$$

where the intermediate inflation target is defined as

$$\pi_t^I = \mu \left(\frac{1}{n} \sum_{j=1}^n \pi_{t-j} \right) + (1 - \mu) \pi^T \quad (6.12)$$

It is worth noting that King (1996) has identified Equation (6.12) as a simple inflation learning rule. After experiencing high inflation for a long period of time, there may be good reasons for the private sector not to believe the disinflation policy fully (see also Bomfim and Rudebusch, 2000). In his discussion of endogenous learning, King (1996) says that it might be rational for the private sector to suppose that in trying to learn about the future inflation rate many of the relevant factors are exogenous to the path of inflation itself. In light of this, King assumes that private sector inflation expectations follow a simple rule; that is a linear function of the inflation target and the lagged inflation rate. Therefore, the intermediate inflation target is particularly applicable for countries which have experienced a relatively high inflation rate. Equation (6.11) allows us to approximate the intermediate inflation target included in the standard Taylor rule. Note that the inflation target will not be identified as it is part of the term i^* .⁹

To test for the presence of opportunistic behaviour, and so the presence of asymmetries, one can define different regimes and allow for the possibility that the dynamic behaviour of the monetary authority depends on whether inflation is lying within the target zone or not. As far as opportunistic approach is concerned, the model assumes two different regimes; namely the zone of discretion and the outside zone. Therefore, at this stage we consider the use of two-regime switching models. That is, the lower and upper boundaries of the target zone are regarded as the regime-determining processes. It is important to notice that the change from one regime to

⁹ Martin and Milas (2010a) have noted this feature previously.

another can be abrupt or smooth. If the change is abrupt, then the non linear model will be of the following form

$$\begin{aligned}
 i_t &= \rho_i(L)i_{t-1} + (1 - \rho_i) \left\{ \tilde{i}^* + \rho_{ZD} E_{t-1} (\pi_{t+p} - \pi_{t+p}^l) + \rho_y E_{t-1} y_{t+q} + \rho_f E_{t-1} f_{t+r} \right\} \\
 &\quad \text{if } -\delta \leq E_{t-1} (\pi_{t+p} - \pi_{t+p}^l) \leq \delta \\
 \\
 i_t &= \rho_i(L)i_{t-1} + (1 - \rho_i) \left\{ \tilde{i}^* + \rho_{OZD} E_{t-1} (\pi_{t+p} - \pi_{t+p}^l + \delta) + \rho_y E_{t-1} y_{t+q} + \rho_f E_{t-1} f_{t+r} \right\} \\
 &\quad \text{if } -\delta > E_{t-1} (\pi_{t+p} - \pi_{t+p}^l) \\
 \\
 i_t &= \rho_i(L)i_{t-1} + (1 - \rho_i) \left\{ \tilde{i}^* + \rho_{OZD} E_{t-1} (\pi_{t+p} - \pi_{t+p}^l - \delta) + \rho_y E_{t-1} y_{t+q} + \rho_f E_{t-1} f_{t+r} \right\} \\
 &\quad \text{if } \delta < E_{t-1} (\pi_{t+p} - \pi_{t+p}^l)
 \end{aligned} \tag{6.13}$$

However, it is more likely to experience a smooth change from one regime to another. In that case, a so called Smooth Transition Autoregressive (STAR) model is appropriate:

$$\begin{aligned}
 i_t &= \rho_i(L)i_{t-1} + (1 - \rho_i) \left\{ \tilde{i}^* + \rho_{ZD} E_{t-1} (\pi_{t+p} - \pi_{t+p}^l) + \rho_y E_{t-1} y_{t+q} + \rho_f E_{t-1} f_{t+r} \right\} \\
 &\quad pr \left\{ -\delta \leq E_{t-1} (\pi_{t+p} - \pi_{t+p}^l) \leq \delta \right\} \\
 \\
 i_t &= \rho_i(L)i_{t-1} + (1 - \rho_i) \left\{ \tilde{i}^* + \rho_{OZD} E_{t-1} (\pi_{t+p} - \pi_{t+p}^l + \delta) + \rho_y E_{t-1} y_{t+q} + \rho_f E_{t-1} f_{t+r} \right\} \\
 &\quad pr \left\{ -\delta > E_{t-1} (\pi_{t+p} - \pi_{t+p}^l) \right\} \\
 \\
 i_t &= \rho_i(L)i_{t-1} + (1 - \rho_i) \left\{ \tilde{i}^* + \rho_{OZD} E_{t-1} (\pi_{t+p} - \pi_{t+p}^l - \delta) + \rho_y E_{t-1} y_{t+q} + \rho_f E_{t-1} f_{t+r} \right\} \\
 &\quad pr \left\{ \delta < E_{t-1} (\pi_{t+p} - \pi_{t+p}^l) \right\}
 \end{aligned} \tag{6.14}$$

We model the probabilities in (6.14) using the logistic functions (see e.g. van Dijk *et al.*, 2002)

$$pr\{\delta > E_{t-1}(\pi_{t+p} - \pi_{t+p}^I)\} = 1 - \frac{1}{1 + e^{-\gamma E_{t-1}(\pi_{t+p} - \pi_{t+p}^I + \delta) / \sigma_{E_{t-1}(\pi_{t+p} - \pi_{t+p}^I)}}} \quad (6.15a)$$

and

$$pr\{\delta < E_{t-1}(\pi_{t+p} - \pi_{t+p}^I)\} = \frac{1}{1 + e^{-\gamma E_{t-1}(\pi_{t+p} - \pi_{t+p}^I - \delta) / \sigma_{E_{t-1}(\pi_{t+p} - \pi_{t+p}^I)}}} \quad (6.15b)$$

In (6.15 a, b) we follow Granger and Teräsvirta (1993) and Teräsvirta (1994) in making the smoothness parameter $\gamma > 0$ dimension-free by dividing it by the standard deviation of $E_{t-1}(\pi_{t+p} - \pi_{t+p}^I)$. In equation (6.14) it is assumed that the policy maker responds to $E_{t-1}(\pi_{t+p} - \pi_{t+p}^I + \delta)$ when inflation is below the zone of discretion and to $E_{t-1}(\pi_{t+p} - \pi_{t+p}^I - \delta)$ when the inflation is above the zone of discretion. As an alternative to (6.14), equation (6.16) assumes that the policymaker responds to $E_{t-1}(\pi_{t+p} - \pi_{t+p}^I)$.

$$i_t = \rho_i(L)i_{t-1} + (1 - \rho_i) \left\{ \begin{array}{l} i^* + \theta_i \rho_{ZD} E_{t-1}(\pi_{t+p} - \pi_{t+p}^I) + (1 - \theta_i) \rho_{OZD} E_{t-1}(\pi_{t+p} - \pi_{t+p}^I) \\ + \rho_y E_{t-1} y_{t+q} + \rho_f E_{t-1} f_{t+r} \end{array} \right\} + \varepsilon_t \quad (6.16)$$

where $\theta = pr\{-\delta \leq E_{t-1}(\pi_{t+p} - \pi_{t+p}^I) \leq \delta\}$ is the probability that the economy is within the zone of discretion. In equation (6.16) the response to inflation is contingent on whether

inflation is within the zone of discretion. We model the probability of being within the zone using the quadratic logistic function (see, for example, van Dijk *et al.*, 2002)

$$\theta = pr\{-\delta \leq E_{t-1}(\pi_{t+p} - \pi_{t+p}^I) \leq \delta\} = 1 - \frac{1}{1 + e^{\frac{-\gamma [E_{t-1}(\pi_{t+p} - \pi_{t+p}^I + \delta)] [E_{t-1}(\pi_{t+p} - \pi_{t+p}^I - \delta)]}{\sigma_{E_{t-1}(\pi_{t+p} - \pi_{t+p}^I)}^2}}} \quad (6.17)$$

Note that in equation (6.16), we have entered output and financial conditions linearly in the model. However, the study has investigated whether there is a different response of interest rates to output and financial conditions inside and outside the zone of discretion. There was no evidence of these effects.¹⁰

6.3. Empirical results

6.3.1. Tests and parameter estimates

The specification which fits the data best allows for one lag of the interest rate, $p = 1$ for inflation, $q = 0$ for the output gap, and $r = 0$ for the financial index. The set of instruments includes a constant, lagged values of inflation, the output gap, the financial conditions index, the 10-year government bond and M3 growth. The empirical models that exclude the financial index variable performed very poorly compared to the models reported here in terms of the AIC criterion and the lagged interest rate effect turned out to be slightly higher than the one reported here, therefore providing some support for an omitted variables problem as outlined in the introduction. Each case reveals evidence

¹⁰ Similar conclusions have been found in chapter 2 and by Naraidoo and Raputsoane (2010) in the context of financial market conditions whereby the monetary authorities place an equal weight on financial market booms and recessions.

that the SARB has been reacting to the financial conditions index since the null hypothesis $H_0: \rho_f = 0$ is rejected at 1% level of significance. Column (i) of Table 7 represents estimates of equation (6.10), the linear Taylor rule model. We find that $\rho_i = 0.91, \rho_\pi = 1.21, \rho_y = 0.24$ and that $\rho_f = 0.10$. This model is in line with the Taylor principle which stipulates that the response to inflation is expected to be in greater proportion than the variation of inflation.¹¹

The second step is the estimation of the equation (6.11) that uses intermediate inflation rather than a simple inflation target. The intermediate inflation target at period t , is computed as a weighted average of the inflation target and historical inflation measured as an average of inflation of three previous months. The study has also tried historical inflation measured as averages of 1-6, 9 and 12 months but none of these alternatives could outperform the average of three months.

¹¹ In contrast to previous results by Woglom (2003) and Naraidoo and Gupta (2010) who have reported inflation effect lower than one.

Table 7: GMM estimates of the opportunistic approach on SA data, (2000:M1-2005:M12)

Coefficient	(i)	(ii)	(iii)	(iv)	(v)
ρ_i	0.91*** (0.01)	0.908*** (0.01)	0.875*** 0.01	0.915** (0.01)	0.890*** (0.01)
ρ_π	1.211*** (0.06)	1.752*** (0.16)			
ρ_{ZD}			0.840*** 0.28	4.344 (4.17)	0.396 (0.30)
ρ_{OZD}			1.217*** 0.22	2.478*** (0.44)	1.509*** (0.09)
ρ_y	0.240*** (0.08)	0.431*** (0.05)	0.564*** 0.08	0.753*** (0.07)	0.330*** (0.05)
ρ_f	0.098*** (0.01)	0.073*** (0.01)	0.038*** 0.01	0.071*** (0.01)	0.041*** (0.01)
μ		0.465*** (0.03)	0.212* 0.12	0.465*** (0.03)	0.465*** (0.03)
δ			1.869*** 0.37	2.05	2.05
S.E	0.380	0.360	0.373	0.367	0.359
AIC	0.983	0.890	0.936	0.931	0.884
\bar{R}^2	0.974	0.977	0.975	0.976	0.977
$H_0: \rho_{ZD} = \rho_{OZD}$ (p value)	-	-	0.09	0.026	0.000
J-statistic (p value)	0.253	0.245	0.241	0.255	0.254
λ test (p value)	0.001	0.01			
λ_A test (p value)	0.000	0.00			
g test (p value)	0.001	0.01			

Notes: Numbers in parentheses are standard errors. S.E is the regression standard error. AIC is Akaike Information criterion. J-statistic is the p -value of a chi-square test of the model's over-identifying restrictions (Hansen, 1982). The set of instruments includes a constant, 1-6, 9, 12 lagged values of repo rate, the inflation, the output gap, the 10-year government bond, money (M3) growth, and the financial index. The table also reports bootstrapped p -values of the λ , λ_A , and g tests based on 1000 re-samples.

Findings in column (ii) of Table 7 show that the substitution of inflation target by intermediate inflation target is supported by the data. In terms of AIC, the model in column (ii) does better than the model in column (i). Furthermore, it is worth noting that μ , the weight on past inflation is estimated at $\mu=0.46$ and is statistically significant. This is evidence that intermediate inflation reveals the behaviour of the policy makers of the SARB better than a simple inflation target. Therefore, one of the features of opportunistic approach to monetary policy is met.

The third step is to test the consistency of the feature regarding the zone of discretion. In doing so, both linear models, equation (6.10) in column (i) and equation (6.11) in column (ii), are subject to powerful tests of linearity. The λ test by Hamilton (2001) and λ_A and g tests by Dahl and González-Riviera (2003) reject the null hypothesis of linearity.¹² We then provide estimates of equation (6.13) in column (iii) of Table 7. We find that $\delta=2.05$ and that in terms of the AIC, equation (6.13) performs better than the linear model presented in column (i) but does not outperform the model in column (ii).

The fourth step is aimed at comparing the nonlinear models, namely equations (6.13), (6.14) and (6.16). With the aim to reduce the number of parameters to be estimated in equations (6.14) and (6.16) we set $\mu=0.46$ as suggested by model (6.11) above and $\delta=2.05$ as estimated in column (iii). In terms of AIC, equation (6.14) is not different from the results of equation (6.13). However, results of equation (6.16) in column (v)

¹² We run the tests using Gauss codes obtained from Hamilton's web page at: <http://weber.ucsd.edu/~jhamilto/software.htm#other>. To account for the small sample, we report bootstrapped p -values of the three tests based on 1000 re-samples.

exhibits lower standard error and better AIC than any other model we have estimated. Therefore, we prefer this model for further investigations regarding parameter evolution in the next section. Estimation reveals that the null hypothesis of $\rho_{ZD} = 0$ is not rejected while the null of $\rho_{OZD} = 0$ is rejected. Therefore, the preferred model (Model 3, hereafter) supports the view that monetary policymakers of the SARB have behaved opportunistically by accommodating shocks when inflation is within the zone of discretion but reacting aggressively otherwise. From the outperforming equation (6.16) in column (v) we report that ρ_{ZD} is not statistically different from zero. The same column reveals that $\rho_y > \rho_{ZD}$, $\rho_f > \rho_{ZD}$ and that $\rho_{OZD} > \rho_{ZD}$. These results indicate that the SARB increases the importance that it attaches to inflation relative to the output gap and financial conditions once inflation moves outside the zone. This outperforming model reveals that the zone of discretion is symmetrically extending from 2.05 percent below and above the intermediate inflation target rate. The estimated zone of discretion of 4.10 percent is reasonable for the SARB as the difference between the announced lower bound and upper bound is 3 percent. Taking the official target range of 3 to 6 percent as a benchmark to our estimate, we can suggest that estimated target zone spans from 2.45 to 6.55 percent.

Figure 14: Transition function and inflation

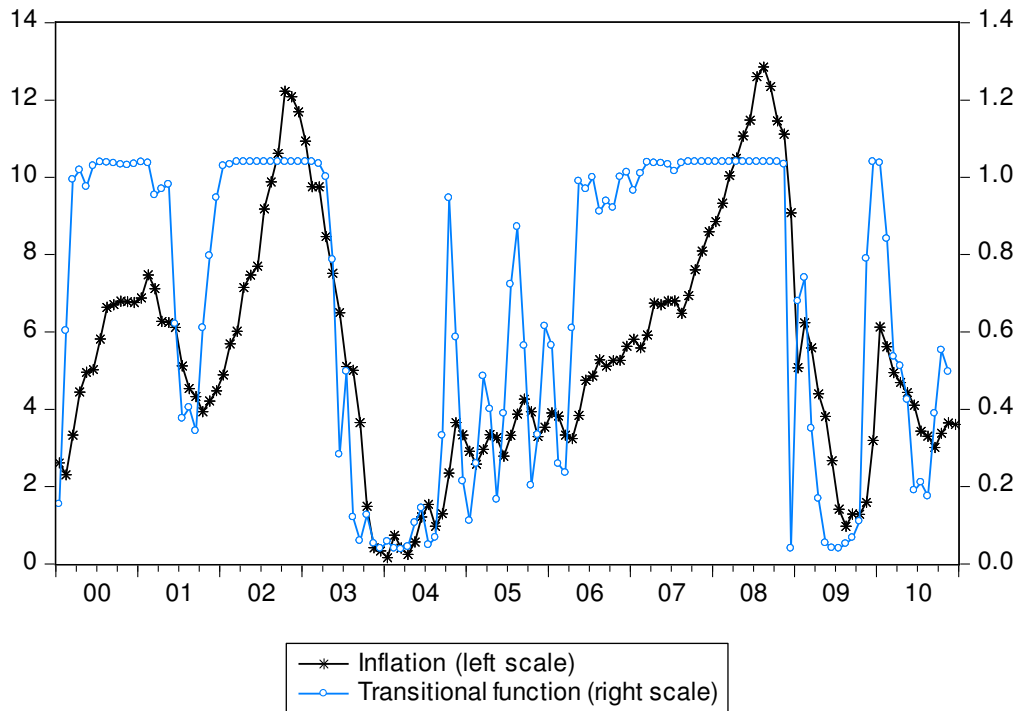


Figure 14 plots the transition function θ_t in equation (6.17) compared to the level of inflation. It can be seen that θ_t fluctuates between 0 and 1 depending on the level of inflation. Precisely, the transition function θ_t tends to 1 when inflation is high and as inflation tends to be low, θ_t tends to zero.

6.3.2. Recursive estimates

To obtain an idea of how the response parameters ρ_{OZD} , ρ_y , and ρ_f evolve over time, Figure 15 plots the recursive estimates (plus/minus 2*standard errors) over expanding data windows for the preferred model equation (6.16). The response to inflation is relatively stable up until late 2008. From early 2009 onward, the response has decreased but the Taylor principle still holds as the coefficient was higher than unity. The response to the output gap was decreasing until late 2008 but started increasing consistently only toward 2009. A plausible explanation is that in the second semester of 2008 inflation was on average approaching 12 percent, which is indeed the double of the upper bound of the announced target range. However, since early 2009, the relative importance turns to the output gap as a result of the new CPI inflation which is lower than the previous measure. Panel (c) in Figure 15 reveals an increasing response to the financial index until late in 2008. Since then, the response to financial conditions decreased and reached its level of 2006. Overall, the 2007-2009 financial crisis witnesses an overall increased reaction to inflation and financial conditions. The observed decrease of the reaction to output gap prior to 2009 might show the SARB's preference of price stability over economic stabilisation.

Figure 15: Recursive estimates for the OAD model

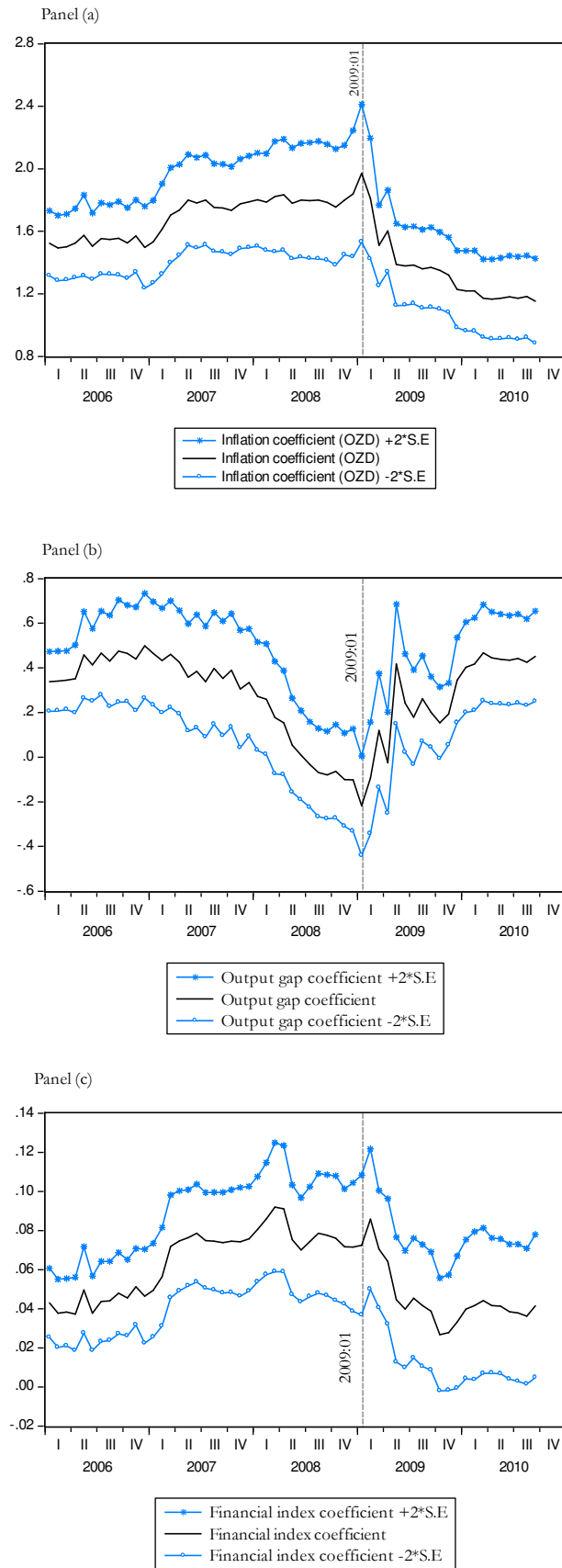
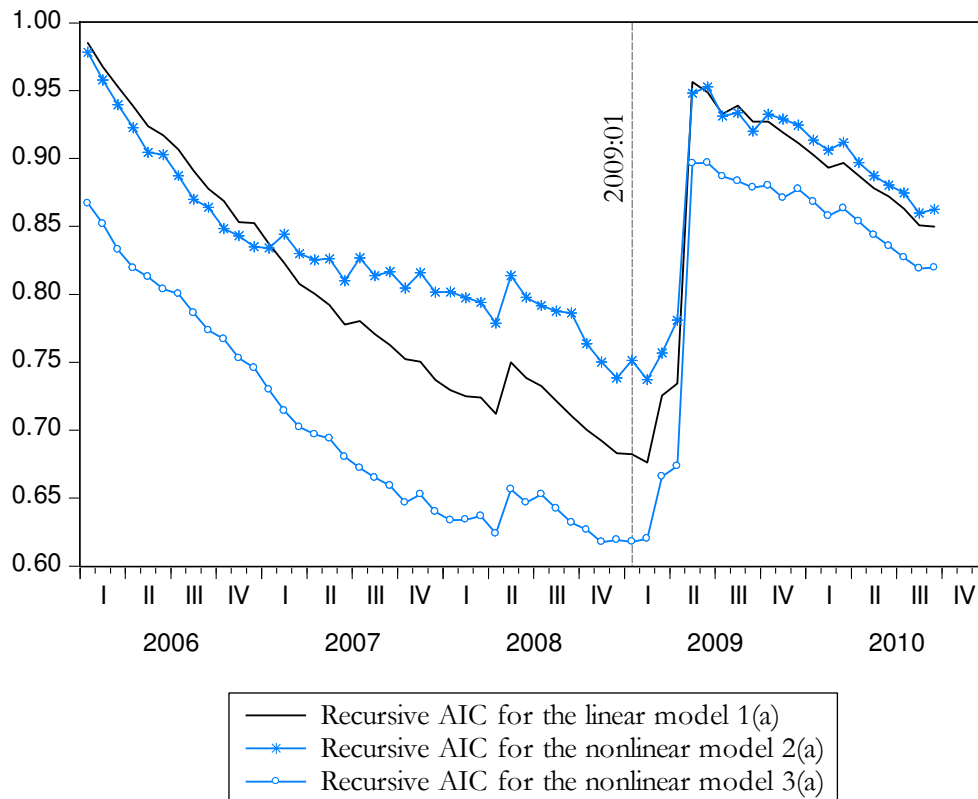


Figure 16: AIC for recursive Models 1, 2 and 3



In this section, we also compare the results for model 3 to the ones for models 1 and 2 reported in chapter 5. As reported by Figures 16, the quadratic logistic function (Model 3) exhibits the lowest AIC in terms of recursive estimates.

6.3.3. Rolling estimates

Figure 17 plots the rolling fixed-length window estimated response coefficients (plus/minus 2*standard errors) ρ_{OZD} , ρ_y , ρ_f for the model reported in column (v).

Figure 17 displays similar patterns for the responses to inflation, the output gap and

financial conditions as obtained under the recursive estimation in Figure 15, but with a somewhat stronger and more volatile response since the onset of the financial crisis. As for chapter 5, a plausible explanation is that the number of crisis observations as proportion of all observations is greater in the case of fixed-length rolling estimation and thus the parameter can be more sensitive to changes over time.

Figure 17: Rolling estimates for the OAD model

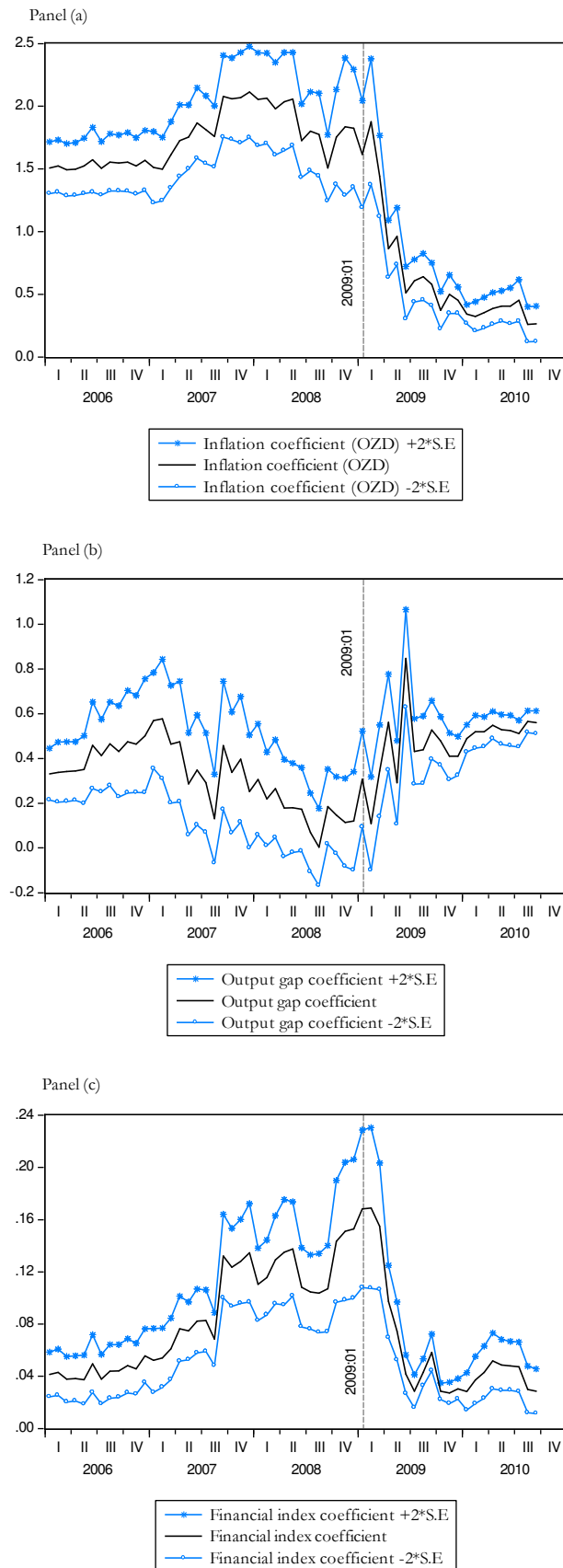
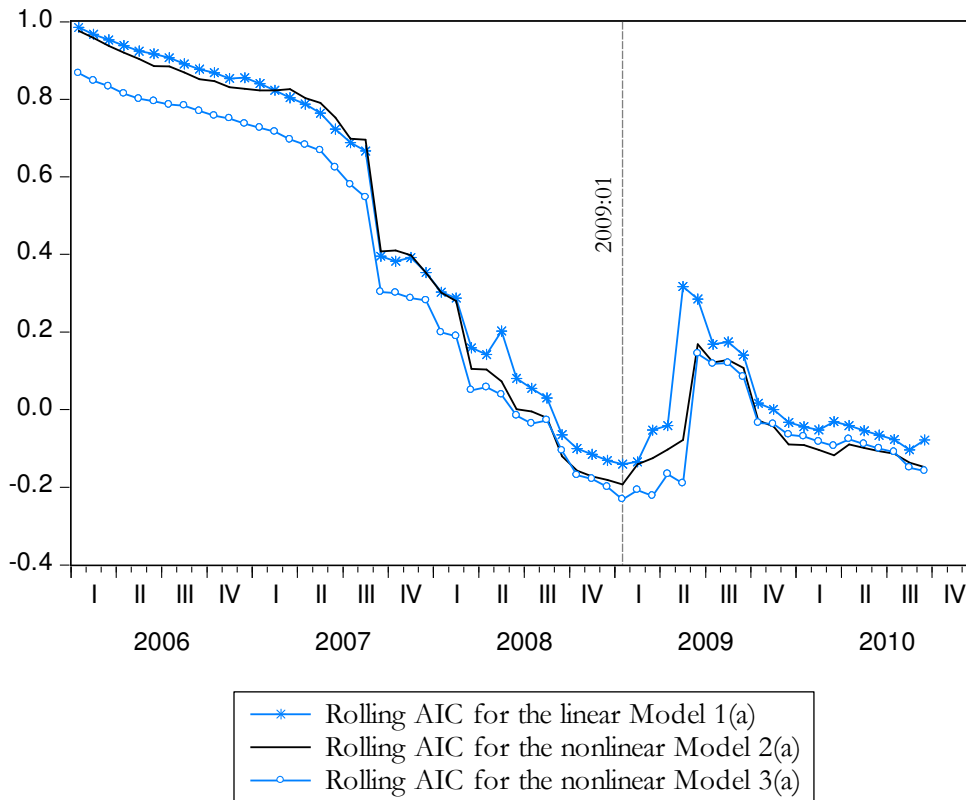


Figure 18: AIC for rolling Models 1, 2 and 3



Results for rolling estimations of chapter 6 are also compared to the ones for models 1 and 2 reported in chapter 5. As for the recursive estimates, Figures 18 shows that the quadratic logistic function (Model 3) exhibits the lowest AIC in terms of rolling estimates. All in all, it can be concluded that a quadratic logistic function which accommodates a band of inaction provides a better in-sample representation of the SARB's policy rule.

6.4. Conclusion

With the aim to test whether the SARB's monetary policy makers have behaved opportunistically, we have estimated a monetary policy reaction function for the period spanning from 2000M1 to 2010M12. We first test whether monetary policy-makers of the SARB have been using an intermediate inflation target rather than a simple inflation target. The equations that include intermediate rather than a simple inflation target improve the fit of the models. For linear models we use powerful tests for linearity and find that the null of linear model is rejected by the data. In addition, it has been tested whether policy makers have been responding aggressively to inflation when it is outside the zone of discretion but accommodating the shock when inflation is within the target zone. We compare different linear and nonlinear models and find that a smooth transition model, supporting the view of opportunistic approach, fits the data better. In the preferred model, we find that the zone of discretion is symmetric, extending from 2.05 percent below and above the intermediate inflation rate. The estimated inflation target range of 4.10 percent is reasonable for the SARB as the difference between the announced lower bound and upper bound is 3 percent. Taking the official target range of 3 to 6 percent as a benchmark to our estimate, one can suggest that the estimated target zone spans from 2.45 to 6.55 percent.

With the aim to appraise how monetary policy makers have behaved during the sub-prime crisis, the study has also assessed parameter evolution of the preferred model by

recursive estimation of the data window adding one data point at each time. It is reported that in general the 2007-2009 financial crisis witnesses an overall increased reaction to inflation and financial conditions. However, the relative importance turns to the output gap since early 2009. This is quite comprehensible as the South African economy took the toll of the financial crisis only lately. It is also worth noting that there has been lower concern to inflation beginning 2009 as a result of the new CPI inflation target which is lower than the previous measure.

Chapter 7

Evaluating the forecasting performance of monetary policy rules in South Africa

7.1. Introduction

Empirical evidence in the field of monetary policy continues to prove that the behaviour of central bankers is not symmetric either around a certain level of policy instrument, the inflation target or potential output. More recent examples include Hayat and Mishra (2010) and Martin and Milas (2010) among others. In these cases, besides the failure to reject the null hypothesis of linearity, nonlinear models are found to outperform their rival linear models in terms of goodness-of-fit. It is well known that one of the prime benefits of robust economic models is the predictive accuracy they have. In the field of monetary policy, for instance, a robust monetary policy reaction function can help monetary authorities to predict more accurately the future values of the policy instrument. Reid and Du Plessis (2010) advocate for greater transparency that could be achieved if the SARB were to publish a forecast of the expected path of its policy instrument. Furthermore, as propounded by the same authors, forecasts of the policy instrument would shed some lights on the forward-looking nature of monetary policy and thereby enhance the predictability of the SARB's policy stance.

Given the recent in-sample outperformance of nonlinear monetary policy reaction functions, one can expect the latter to predict the behaviour of central banks better than a simple linear policy rule. However, early in the 1990s, De Gooijer and Kumar (1992) concluded that there was no clear evidence in favour of non-linear over linear models in terms of forecast performance. More than a decade later, Clements *et al.* (2004) suspect that the situation has not changed very much, as we had not gone very far in the area of non-linear forecast models. The literature review by Clements *et al.* (2004) suggests that the forecasting performance of nonlinear models is on average not particularly good relative to rival linear models. As far as monetary policy rules are concerned, Qin and Enders (2008) find more challenging results as they report that the univariate models forecast better than the Taylor rules, linear and nonlinear. More recently, Naraidoo and Paya (2010) compare linear and nonlinear parametric models and, non-parametric and semi-parametric models in forecasting the South African Reserve Bank's repurchase rate. They find that a semi-parametric model that relaxes the functional form of the monetary policy rule outperforms other models especially in long horizon forecasting.

This chapter contributes to the scarce literature that uses Taylor rules to forecast the nominal interest rate out-of-sample. Some notable exceptions are Qin and Enders (2008), Moura and Carvalho (2010) and Naraidoo and Paya (2010). In this study about South Africa, we construct the forecasts from linear and nonlinear Taylor type rule models under a backward looking expectations formation for the target variables and examine their forecasting gains over the period 2006:M01 to 2010:M12. The aim of the chapter is to evaluate predictive accuracy of three competing models based on a number

of forecasting tests; namely the mean squared prediction error (MSPE), median squared prediction error (MedSPE), the modified Diebold Mariano, and the Clark and West.

The rest of the chapter is organized as follows. In the next section, we discuss the linear and nonlinear Taylor rule versions to be evaluated for predictive ability. Section 3 discusses the data and forecasting methodology. Section 4 passes into review in-sample properties of the four alternative models by comparing their goodness of fit in terms of the Akaike information criterion (AIC). Section 5 reports an in-depth forecasting evaluation of different models with the aim to determine the best model in predictive ability. Section 6 concludes.

7.2. Alternative models

In this Chapter we make comparative forecasting evaluation among the models discussed in chapters 5 and 6. However, for forecasting purposes we consider backward looking versions rather than the forward looking ones. Although chapter 4 suggests that forward looking version of the Taylor rule describes better the behaviour of the SARB than the backward-looking, an out-of-sample forecasting exercise cannot use future values of variables in the pure forecasting sense. Therefore, models 1 to 3 are rewritten in their backward looking versions.

Model 1 (b):

$$i_t = \rho_i(L)i_{t-1} + (1 - \rho_i) \{ \rho_0 + \rho_\pi (\pi_{t-1} - \pi^*) + \rho_y y_{t-1} + \rho_f f_{t-1} \} \quad (7.1)$$

Equation (7.1) is characterized by three modifications made on the original simple Taylor rule, namely interest rate smoothing, the forward-looking version and the inclusion of financial condition index.

The next step is to allow for nonlinearities in interest rate setting behaviour of the monetary authorities (see chapter 5 for more discussion). The first nonlinear version is based on the widespread belief that central bankers' interventions through changes in a short-term interest rate are influenced by the state of the business cycle (see for instance, Bec *et al.*, 2002). This being the case, the following nonlinear policy rule is considered.¹³

Model 2 (b):

$$i_t = \rho_i i_{t-1} + (1 - \rho_i) \left\{ \rho_0 + \theta_t^y(y_{t-1}; \gamma^y; \tau) M_{1t} + (1 - \theta_t^y)(y_{t-1}; \gamma^y; \tau) M_{2t} \right\} + \varepsilon_t \quad (7.2)$$

where $M_{jt} = \rho_{j\pi} \pi_{t-1} + \rho_{jy} y_{t-1} + \rho_{jf} f_{t-1}$ for $j=1,2$ and the function $\theta_t^y(y_{t-1}; \gamma^y; \tau)$ is the weight similar to equation (5.5). M_{1t} is a linear Taylor rule that represents the behaviour of policymakers during business cycle recessions and M_{2t} is a linear Taylor rule that represents the behaviour of policymakers during business cycle expansions. The weight $\theta_t^y(y_{t-1}; \gamma^y; \tau)$ is modelled using the following logistic function (see e.g. van Dijk *et al.*, 2002):

¹³ In chapter 2 it is reported that the nonlinear Taylor rule improves its performance with the advent of the financial crisis, providing the best description of in-sample SARB interest rate setting behavior.

$$\theta_t^y(y_{t-1}; \gamma^y; \tau) = 1 - \frac{1}{1 + e^{-\gamma^y(y_{t-1} - \tau)/\sigma(y_{t-1})}} \quad (7.3)$$

In (7.3) the smoothness parameter $\gamma^y > 0$ determines the smoothness of the transition regimes. We follow Granger and Teräsvirta (1993) and Teräsvirta (1994) in making γ^y dimension-free by dividing it by the standard deviation of y_{t-1} .

In chapter 6 it has been reported that opportunistic approach to monetary policy also deserves its particular attention in the context of the South African economy. On this regard, we choose a quadratic logistic function that was reported in chapter 6 to outperform all other models. As such, equation (7.2) is revised to accommodate the two features of opportunistic approach to monetary policy. The model is specified as follows:

Model 3 (b):

$$i_t = \rho_i(L)i_{t-1} + (1 - \rho_i) \left\{ \begin{array}{l} i^* + \theta_t \rho_{ZD} (\pi_{t-1} - \pi_{t-1}^I) + (1 - \theta_t) \rho_{OZD} (\pi_{t-1} - \pi_{t-1}^I) \\ + \rho_y y_{t-1} + \rho_f f_{t-1} \end{array} \right\} + \varepsilon_t \quad (7.4)$$

where π_t^I is the intermediate inflation target defined as $\pi_t^I = \mu \left(\frac{1}{n} \sum_{j=1}^n \pi_{t-j} \right) + (1 - \mu) \pi^*$ and

$\theta = pr \{ -\delta \leq E_t(\pi_{t-1} - \pi_{t-1}^I) \leq \delta \}$ is the probability that inflation is within the zone of discretion.

$$\theta = pr \left\{ -\delta \leq (\pi_{t-1} - \pi_{t-1}^I) \leq \delta \right\} = 1 - \frac{1}{1 + e^{-\gamma \left[(\pi_{t-1} - \pi_{t-1}^I + \delta) \right] \left[(\pi_{t-1} - \pi_{t-1}^I - \delta) \right] \frac{\sigma^2}{(\pi_{t-1} - \pi_{t-1}^I)}}} \quad (7.5)$$

Similarly, we follow Granger and Teräsvirta (1993) and Teräsvirta (1994) in making the smoothness parameter $\gamma > 0$ dimension-free by dividing it by the standard deviation of $(\pi_{t-1} - \pi_{t-1}^I)$. In equation (7.5) it is assumed that the policy maker responds to $(\pi_{t-1} - \pi_{t-1}^I)$. The response is assumed to depend on whether the inflation is within the target zone or not.

Within sample we would expect the fit of such alternative models to be barely distinguishable, given the high correlations between the interest rate and its lags. However, the key distinguishing feature amongst linear and nonlinear models lies in their forecast implications, namely that the equilibrium to which the reaction function returns depends on the size of the shocks/inflation and business cycle states. A linear Taylor type rule model will forecast the interest rate to stay roughly where it is if non-stationary; or, if stationary, to revert to some deterministic equilibrium. Thus the forecast implications of linear as opposed to nonlinear models are quite different. This is kept in mind when forecasting out-of-sample in section 5 below.

7.3. Forecasting methodology

In this chapter, in-sample observations spans from 2000:01 to 2005:12 and out-of-sample observations covers the period spanning from 2006:01 to 2010:12. The number

of in-sample and out-of-sample observations is denoted by R and P , respectively, so that the total number of observations is $T = R + P$. As we perform recursive out-of-sample forecasts, the in-sample observations increase from R to $T - h$. In the recursive exercise, the parameters of the model are re-estimated by employing data up to time $t - 1$ so as to generate forecast for the following h horizons. The number of forecasts corresponding to horizon h is equal to $P - h + 1$. The forecasting nonlinear monetary policy rule can be described by the following model

$$i_t = F(X_{t-1}; \theta) + \varepsilon_t \quad (7.6)$$

Where $\varepsilon_t \sim iid(0, \sigma^2)$ and X_t is a $(k \times 1)$ vector of the exogenous variables and lagged repo rate as defined in Section 2. The optimal one-step-ahead forecast equals

$$\hat{i}_{t+1/t} = E[i_{t+1} / X_t] = F(X_t; \theta) \quad (7.7)$$

which is equivalent to the optimal one-step-ahead for the alternative linear model. An easy way of obtaining a 2-step-ahead forecast is to draw it from the 1-step-ahead forecast and have

$$\hat{i}_{t+2/t}^{(n)} = F(X_{t+1}; \theta). \quad (7.8)$$

However, this approach has been a subject of strong criticisms to the extent of being named 'naïve' by Brown and Mariano (1989) or 'skeleton' forecast by Tong (1990). These fair criticisms are based on the fact that equation (7.7) considers $E(\varepsilon_{t+1} / X_t) = 0$ and

are supported by simulation evidence by Lin and Granger (1994) reporting substantial losses of efficiency.

As opposed to the so called ‘naïve’ or ‘skeleton’ approach numerical techniques are required in forecasting nonlinear models like the ones in section 2. Detailed discussions on the techniques are provided by Granger and Teräsvirta (1993), Franses and van Dijk (2000) and Fan and Yao (2003). In this chapter, the residuals ($\hat{\epsilon}_t$) of the estimated model is obtained through bootstrapping. With this method, the density of $\hat{\epsilon}_t$ is composed of N independent error vectors $\{\epsilon_{t+1}^{(1)}, \dots, \epsilon_{t+1}^{(N)}\}$ giving a better approximation of the 2-step-ahead forecast as follows:

$$i_{t+2/t}^B = \left(\frac{1}{N} \right) \sum_{i=1}^N F(X_{t+1/t} + \epsilon_{t+1}^i; \theta) \quad (7.9)$$

To obtain h-step-ahead, one generates $\epsilon_{t+1}^{(i)}, \dots, \epsilon_{t+h}^{(i)}$, $i=1, \dots, N$ and sequentially computes N forecasts for $i_{t+1/t}, \dots, i_{t+h/t}$ with $h \geq 2$ and where a single point forecast for a particular point in time is obtained by simple averaging its corresponding N forecasts (see Teräsvirta, 2006).

Forecasting performance is evaluated using the Mean Squared Prediction Error (MSPE) and Median Squared Prediction Error (MedSPE) criteria. For robustness purpose, we also test the null hypothesis of equal forecasting accuracy using modified Diebold-Mariano statistics ($DM-t$, see Harvey *et al.*, 1997). The $DM-t$ for any two models

denoted by 1 and 2 is computed as follows

$$DM - t = (P - h + 1)^{1/2} \frac{\bar{d}}{\hat{S}_{dd}^{1/2}},$$

where $\hat{d}_{t+h} = \hat{e}_{1,t+h}^2 - \hat{e}_{2,t+h}^2$; $\hat{e}_{i,t+h}$ being h-step ahead prediction error for model i ;

$$\bar{d} = (P - h + 1)^{-1} \sum_{t=R}^{T-h} \hat{d}_{t+h} = MSPE_1 - MSPE_2;$$

$$\hat{\Gamma}_{dd}(j) = (P - h + 1)^{-1} \sum_{t=R}^{T-h} \hat{d}_{t+h} \hat{d}_{t+h-j} \text{ for: } j \geq 0 \text{ and } \hat{\Gamma}_{dd}(j) = \hat{\Gamma}_{dd}(-j);$$

$$\hat{S}_{dd} = \sum_{j=-\bar{j}}^{\bar{j}} K(j/M) \hat{\Gamma}_{dd}(j) \text{ denotes the long-run variance of } d_{t+h} \text{ estimated using}$$

a kernel-based estimator with function $K(\cdot)$, bandwidth parameter M and maximum number of lags \bar{j} . We follow Harvey *et al.* (1997) in correcting for small-sample bias and so the corrected test statistic is obtained by multiplying the above $DM - t$ by

$$\zeta = \sqrt{\frac{P - 2h + h(h-1)/(P-h+1)}{(P-h+1)}}$$

The hypotheses to be tested are

$$H_0 : \hat{e}_{1,t+h} - \hat{e}_{2,t+h} = 0$$

and

$$H_1 : \hat{e}_{1,t+h} - \hat{e}_{2,t+h} \neq 0$$

The rejection of the null is based on Student's t distribution with $(n - 1)$ degrees of freedom rather than the standard normal distribution (see Harvey *et al.*, 1997). It is worth to mention that nonlinear Taylor rule equations nest the linear equations and

therefore their population errors are identical under the null hypothesis making the variance d_{t+h} equal to zero (see McCracken, 2007). Indeed, it has been argued that asymptotic distribution theory for the Diebold and Mariano (1995) test does not hold for nested models (see McCracken, 2000; Clark and McCracken, 2001 and Teräsvirta, 2005). However, Giacomini and White (2006) showed that when in-sample size remains finite, the asymptotic distribution of the Diebold and Mariano statistic (DM statistic) is still standard normal when forecasts are compared from nested models. Bhardwaj and Swanson (2006) also argue that the $DM-t$ statistic can still be used as an important diagnostic in predictive accuracy as the non-standard limit distribution is reasonably approximated by a standard normal in many contexts.

As far as the issue of nestedness is concerned, we apply the Clark and McCracken (2001) encompassing test ($ENC-t$) and Clark and West (2007). Both tests are designed to test the null hypothesis of equal forecasting accuracy for nested models. The $ENC-t$ statistic is given by

$$ENC-t = (P-1)^{1/2} \frac{\bar{c}}{\left(P^{-1} \sum_{t=R}^{T-1} (c_{t+h} - \bar{c}) \right)^{1/2}},$$

where $c_{t+h} = \hat{e}_{1,t+h}(\hat{e}_{1,t+h} - \hat{e}_{2,t+h}) = \hat{e}_{1,t+h}^2 - \hat{e}_{1,t+h}\hat{e}_{2,t+h}$ and $\bar{c} = P^{-1} \sum_{t=R}^{T-h} c_{t+h}$. The $ENC-t$ has the same null hypothesis as the $DM-t$ test, but the alternative is $H_1: \hat{e}_{1,t+h} - \hat{e}_{2,t+h} > 0$ which is more restrictive than the $DM-t$ that

considers $H_1 = \hat{e}_{1,t+h} - \hat{e}_{2,t+h} \neq 0$. For $h=1$, the limiting distribution is $N(0,1)$. By contrast, Clark and McCracken (2001) show that for multistep-ahead ($h>1$) forecasts, the limiting distribution is non-standard. However, as noted by Bhardwaj and Swanson (2006), tabulated critical values are quite close to the $N(0,1)$ values when Newey and West (1987)-type estimator is used for $h>1$. As such, standard normal distribution can be used as a rough guide for multistep-ahead forecasts comparison (see Clark and McCracken, 2001 for further details).

An alternative test for equal forecast errors is the Clark and West test (CW-test) statistics is given by

$$\hat{f}_{t+h} = (i_{t+h} - \hat{i}_{1t,t+h})^2 - [(i_{t+h} - \hat{i}_{2t,t+h})^2 - (\hat{i}_{1t,t+h} - \hat{i}_{2t,t+h})^2].$$

Where the period t forecast of the repo rate i_{t+h} from the two models are denoted $\hat{i}_{1t,t+h}$ and $\hat{i}_{2t,t+h}$ with corresponding period $t+h$ forecast errors $i_{t+h} - \hat{i}_{1t,t+h}$ and $i_{t+h} - \hat{i}_{2t,t+h}$.

The test for equal MSPE is performed by regressing \hat{f}_{t+h} on a constant and using the resulting t -statistic for a zero coefficient (see Clark and West, 2007). As above, the null hypothesis is equal MSPE while the alternative is model 2 has a smaller MSPE than model 1. In line with Clark and West (2007), the null is rejected if the t -statistic is greater than +1.282 (for a one sided 0.10 test) or +1.645 (for a one sided 0.05 test).

7.4. In-sample evaluation

Using the same set of data as above, this section reviews the in-sample properties of backward looking models that are going to be tested for out-of-sample properties in the next section. Tables 8 and 9 report estimates of the Taylor rule Models 1(b), 2(b) and 3(b) for the in-sample period which runs from 2000:M1 to 2005:M12. Model 3 (b) in Table 9 exhibits the lowers AIC and shows that the inflation outside the zone of discretion, output gap and financial index effects are statistically significant but not the inflation within the zone of discretion. The results are in line with the opportunistic approach theory.

Table 8: In-sample estimates for the backward looking versions of Models 1&2

Coefficients	Model 1 (Linear)	Model 2 (Nonlinear)
ρ_0	0.882*** (0.01)	6.876*** (0.19)
ρ_1	0.478*** (0.04)	0.859*** (0.01)
ρ_π	1.077*** (0.08)	
ρ_y	0.023** (0.01)	
ρ_f	0.882*** (0.01)	
$\rho_{1\pi}$		0.697*** (0.03)
ρ_{1y}		0.286 (0.23)
ρ_{1f}		0.059*** (0.01)
$\rho_{2\pi}$		0.062 (0.09)
ρ_{2y}		0.116 (0.08)
ρ_{2f}		-0.024** (0.01)
τ		0.00 (0.00)
γ^y		5.00
AIC	1.173	1.205
S.E	0.418	0.416
\bar{R}^2	0.969	0.969
J-stat	0.248	0.230
λ -test	0.001	
λ_A -test	0.000	
g-test	0.001	

Notes:

(i) Where Model 1 is $i_t = \rho_i i_{t-1} + (1 - \rho_i) \{\rho_0 + \rho_\pi \pi_{t-1} + \rho_y y_{t-1} + \rho_f f_{t-1}\} + \varepsilon_t$ and Model 2 is $i_t = \rho_i i_{t-1} + (1 - \rho_i) \{\rho_0 + \theta_i^y (y_{t-1}; \gamma^y; \tau) M_{1t} + (1 - \theta_i^y) (y_{t-1}; \gamma^y; \tau) M_{2t}\} + \varepsilon_t$ with $M_{jt} = \rho_{j\pi} \pi_{t-1} + \rho_{jy} y_{t-1} + \rho_{jf} f_{t-1}$ for $j=1, 2$ and y_t is the transition variable.

(ii) Numbers in parentheses are standard errors. (**)[***] indicate that the parameter is significant at a 10(5)[1] % level respectively. AIC is the Akaike Information Criterion. J-stat is the p -value of a chi-square test of the model's over-identifying restrictions (Hansen, 1982). The set of instruments includes a constant, 1-6, 9, 12 lagged values of repo rate, the inflation, the output gap, the 10-year government bond, money (M3) growth, and the financial index.

Table 9: Backward looking version of the Opportunistic Approach Model 3

Coefficients	Model 3
ρ_i	0.832*** (0.01)
ρ_π	
ρ_{ZD}	0.396 (0.30)
ρ_{OZD}	1.147*** (0.04)
ρ_y	0.523*** (0.03)
ρ_f	0.008*** (0.00)
μ	0.530*** (0.03)
δ	2.05
S.E	0.394
AIC	1.052
\bar{R}^2	0.972
$H_0: \rho_{ZD} = \rho_{OZD}$ (p value)	0.000
J-statistic (p value)	0.249

Notes: Numbers in parentheses are standard errors. S.E is the regression standard error. AIC is Akaike Information criterion. J-statistic is the p -value of a chi-square test of the model's over-identifying restrictions (Hansen, 1982). The set of instruments includes a constant, 1-6, 9, 12 lagged values of repo rate, the inflation, the output gap, the 10-year government bond, money (M3) growth, and the financial index.

7.5. Out-of-sample evaluation

This chapter is aimed at evaluating the predictive accuracy of a variety of models for South Africa for the period spanning from 2000:M01 to 2010:M12. We split the sample into in-sample and out-of-sample periods for model estimation and recursive out-of-sample experiments. In-sample observations span from 2000:01 to 2005:12 and out-of-sample observations covers the period spanning from 2006:01 to 2010:12.

7.5.1. Testing predictive ability

One of the prime usages of robust economic models is to predict the future pattern of economic series. Therefore, most economic models, linear or non-linear can be judged in terms of their forecasting performance. As such, this chapter uses a variety of functional forms discussed in section 7.2 and section 7.4 with the aim of obtaining the best model in predictive ability. The forecast evaluation based on the mean squared prediction error (MSPE) and the median squared prediction error (MedSPE) have been reported. These two forecast error statistics are scale dependent. According to the criteria, smaller errors show better predictive ability and therefore the closer to zero the better the predictive ability of the model. The ranks of the 3 competing models' forecasts are shown in Tables 10 and 11. The comparison of forecast performance is made vertically for each horizon in terms of forecasting test. As shown in Tables 10 and 11, nonlinear Model 2 (b) yields the smallest MSPE and MedSPE for the short and long horizons and so ranked the first in terms of these criteria. Comparing the remaining two

models, one can observe that linear Model 1 (b) is ranked the second best for the very short horizon. However, multi-step ahead ($h > 3$) forecast evaluation reveals empirical evidence in favour of the nonlinear model 3(b) in terms of MSPE. It is known that significant in-sample evidence of predictability does not guarantee significant out-of-sample predictability. This might be due to a number of factors such as the power of tests (see Inoue and Kilian, 2004). In terms of MedSPE, the linear Model 1 (b) is ranked second. Average ranking respectively based on MSPE and MedSPE is reported in the last columns of Table 10 and 11 showing the superiority of nonlinear model 2 (b).

Table 10: Mean squared prediction error rank (recursive estimates)

Model	h=1	h=2	h=3	h=4	h=5	h=6	h=7	h=8	h=9	h=10	h=11	h=12	Average rank
1 (b)	2	2	2	3	3	3	3	3	3	3	3	3	2.75
2 (b)	1	1	1	1	1	1	1	1	1	1	1	1	1
3 (b)	3	3	3	2	2	2	2	2	2	2	2	2	2.25

Notes: The Table reports the out-of-sample forecasting ranks of Models 1(b), 2(b) and 3(b) across the recursive windows for forecasting horizons $h=1, \dots, 12$, using the Mean Squared Prediction Error (MSPE). The last column reports the average forecasting rank. Model 1(b) is the linear estimation, Model 2(b) is nonlinear with output as transition variable and Model 3(b) is a nonlinear estimation that accommodates the opportunistic approach to disinflation.

Table 11: Median squared prediction error rank (recursive estimates)

Model	h=1	h=2	h=3	h=4	h=5	h=6	h=7	h=8	h=9	h=10	h=11	h=12	Average rank
1 (b)	2	2	2	2	2	3	3	2	2	2	2	2	2.16
2 (b)	1	1	1	1	1	1	1	1	1	1	1	1	1
3 (b)	3	3	3	3	3	2	2	3	3	3	3	3	2.83

Note: The Table reports the out-of-sample forecasting ranks of Models 1(b), 2(b) and 3(b) across the recursive windows for forecasting horizons $h=1, \dots, 12$, using the Median Squared Prediction Error (MedSPE). The last column reports the average forecasting rank. See Table 10 for the forecasting model definitions.

The modified Diebold-Mariano ($DM-t$) test results are reported in Table 12. These examine the statistical significance of MSPE reductions with uniform weight placed on forecast losses. The Table provides pair wise out-of-sample forecast comparisons based on recursive estimates. Table 12 shows that the modified Diebold and Mariano (1995) test points to the superiority of the Model 2(b) over the linear model for the short and medium term horizons ($2 \leq h \leq 8$), but such dominance disappears as the forecast horizon lengthens ($h \geq 9$). On the other hand, the nonlinear Model 3 (b) is never significantly better than the linear one.

Turning to the tests designed to test the null hypothesis of equal forecasting accuracy for nested models, the judgment based on ENC_t and CW_t , respectively reported in Tables 13 and 14, is not much different from the one based on MSPE above. In fact, the results in Tables 13 and 14 reveal strong empirical evidence in favour of nonlinear models. Relative to the linear Model 1 (b), nonlinear Model 2 (b) is reported to yield the best predictive accuracy for all horizons in terms of both the encompassing (ENC_t) and Clark and West (CW_t) tests. Comparing predictive accuracy for linear model 1 (b) and nonlinear Model 3 (b) it is also clear that for multi-step ahead ($h > 3$), the nonlinear Model 3 (b) can be judged best ranked for these longer horizons. However, the linear Model 1 (b) can predict the near future ($h \leq 3$) better than the nonlinear Model 3 (b).

All in all, Model 2 (b) is best in closely matching the historical record for all the horizons. Overall ranking also shows that the nonlinear Model 3 (b) is second best in medium and long horizons. As such, the findings would alleviate the concern by Clements *et al.* (2004) who reported lack of predictive ability for most of nonlinear models relative to their benchmark linear ones.

Table 12: Forecast Accuracy Evaluation ($DM - t$)

	Step1	Step2	Step3	Step4	Step5	Step6	Step7	Step8	Step9	Step10	Step11	Step12
Model 1 (b) vs												
Model 2 (b)	0.02	1.46*	1.96**	2.06**	2.07**	1.78**	1.50*	1.31*	1.20	1.14	1.09	1.13
Model 3 (b)	-1.28	-1.08	-0.71	-0.34	-0.23	-0.18	-0.11	-0.08	-0.02	0.01	0.03	0.06
Model 2 (b) vs												
Model 3 (b)	-0.75	-2.08	-2.19	-1.82	-1.75	-1.60	-1.42	-1.26	-1.13	-1.07	-1.01	-1.05

Note: Table 12 shows forecast comparisons based on modified Diebold-Mariano statistics ($DM - t$) for horizons extending from 1 to 12. The entries in the table show the test statistics for the null hypothesis that Model i 's forecast performance as measured by MSPE is not superior to that of Model j at the 5% and 10% significance level respectively denoted by two and one asterisks. For definitions of Models, see footnote for Table 10.

Table 13: Forecast Accuracy Evaluation ($ENC - t$)

	Step1	Step2	Step3	Step4	Step5	Step6	Step7	Step8	Step9	Step10	Step11	Step12
Model 1 (b) vs												
Model 2 (b)	1.38*	2.07**	2.43**	2.61**	2.91**	3.22**	3.54**	3.84**	4.20**	4.77**	5.14**	5.70**
Model 3 (b)	0.73	0.47	0.66	1.31*	1.67**	1.92**	2.25**	2.42**	2.57**	2.88**	3.08**	3.45**
Model 2 (b) vs												
Model 3 (b)	1.78**	1.23	0.98	1.20	1.16	1.09	1.02	0.93	0.77	0.70	0.65	0.55

Note: Table 13 shows forecast comparisons based on Clark and McCracken (2001) encompassing test statistics ($ENC - t$) for horizons extending from 1 to 12. The entries in the table show the test statistics for the null hypothesis that Model i 's forecast performance as measured by MSPE is not superior to that of Model j at the 5% and 10% significance level respectively denoted by two and one asterisks. For definitions of Models, see footnote for Table 10.

Table 14: Forecast Accuracy Evaluation ($CW - t$)

	Step1	Step2	Step3	Step4	Step5	Step6	Step7	Step8	Step9	Step10	Step11	Step12
Model 1 (b) vs												
Model 2 (b)	1.732*	3.922**	4.693**	4.568**	4.796**	4.999**	5.017**	4.916**	4.705**	4.536**	4.309**	4.204**
Model 3 (b)	0.721	0.470	0.657	1.303*	1.635*	1.868**	2.173**	2.312**	2.432*	2.697**	2.855**	3.163**
Model 2 (b) vs												
Model 3 (b)	1.761**	1.221	0.969	1.192	1.140	1.064	0.980	0.889	0.731	0.652	0.598	0.503

Note: Table 14 shows forecast comparisons based on modified Clark and West statistics ($CW - t$) for horizons extending from 1 to 12. The entries in the table show the test statistics for the null hypothesis that Model i 's forecast performance as measured by MSPE is not superior to that of Model j at the 5% and 10% significance level respectively denoted by two and one asterisks. For definitions of Models, see footnote for Table 10.

7.6. Conclusion

In this chapter, three functional forms of a Taylor type policy rule have been used for forecasting exercise with the aim of obtaining the best model in predictive ability. For forecasting purposes, models in chapters 5 and 6 have been rewritten in backward looking versions. Out-of-sample properties are assessed using point forecast for the linear model while forecast obtained by means of bootstrapping method is used for nonlinear models.

Comparison of the forecasts from nonlinear functional forms with those from their benchmark linear model, show the advantage of considering nonlinearities in monetary policy reaction functions for most of the cases. Indeed, based on several forecasting accuracy tests, overall ranking reveals the superiority of the nonlinear model that distinguishes between downward and upward movements in the business cycles in closely matching the historical record. As such, forecasting performance tests reveal that the SARB pays particular attention to business cycles movements when setting its policy rate.

Chapter 8

Conclusions and implications

8.1. Introduction

In this thesis we provide an in-sample and out-of-sample assessment of how the South African Reserve Bank (SARB) sets policy rate in the context of both linear and nonlinear Taylor-type rule models of monetary policy. The usual Taylor rule relates the interest rate to deviations of inflation and output from their targets. However, given the controversial debate on whether central banks should target asset prices for economic stability, we investigate whether the SARB pays close attention to asset and financial markets in their policy decisions. For instance, one of the SARB's primary goals is to protect the value of the currency and achieve and maintain financial stability. But the question is “how is financial stability maintained?” To answer to this question, the Taylor rule is augmented with a financial conditions index that reflects the state of the housing market, the stock market, the real exchange rate and credit risk measures.

In this thesis the repurchase rate (repo rate) measures the nominal interest rate, inflation is measured by the annual change in the consumer price index and output is alternatively measured using the coincident business cycle indicator or industrial production and we measure the output gap as the deviation from their Hodrick-Prescott

(1997) trend. We use monthly seasonally adjusted data sourced from the SARB database. The sample ranges from 2000:01 to 2010:12, which covers the inflation targeting regime in South Africa. The start of the sample (2000) is conditioned by the date the Ministry of Finance announced its decision of setting an inflation target range of 3-6%.

The thesis had the following objectives:

1. To investigate whether the SARB pays close attention to asset and financial markets in their policy decisions;
2. To test nonlinearities controlled by the output gap;
3. To do recursive and rolling estimation;
4. To test the opportunistic approach to disinflation;
5. To evaluate the out-of-sample forecast performance;
6. To propose measures that can enhance monetary policy rules for South Africa.

The first three objectives are tested in chapter 5. The opportunistic approach (4th objective) is tested in chapter 6 and out-of-sample forecasts (5th objective) are evaluated in chapter 7. Proposition of measures (6th objective) emerges from overall findings.

8.2. Findings

8.2.1. Findings on the first three objectives (chapter 5)

Being augmented with the financial conditions index, both linear and nonlinear monetary policy rules are tested in the second chapter. The nonlinear one is a logistic smooth transition autoregressive (LSTAR) model which aims to test for the presence of asymmetric pattern over business cycle. We have five main findings:

1. The SARB policy-makers pay close attention to the financial conditions index when setting interest rates; the effect of the index remains significant even when nonlinearities are accounted for.
2. The nonlinear Taylor rule improves its performance with the advent of the financial crisis, providing the best description of in-sample SARB interest rate setting behaviour with fixed-length rolling window estimation. The latter estimation technique is better able to capture parameter shifts as the crisis unfolds.
3. The 2007-2009 financial crisis witnesses an overall increased reaction to inflation and financial conditions. In addition, the financial crisis saw a shift from output stabilisation to inflation targeting and a shift, from a symmetric policy response to financial conditions, to a more asymmetric response depending on the state of the economy.

4. Given that inflation has been relatively high during the second semester of 2008, the SARB's response of monetary policy to output during that period has dropped significantly although it was expected to be set according to the financial crisis.
5. Rolling estimation reveals that inflation, output gap and financial index coefficients are remarkably unstable since mid 2007 with the oncoming of the crisis.

8.2.2. Findings on opportunistic approach (chapter 6)

The Opportunistic Approach to monetary policy is tested in chapter 6. It is worth reminding the two features of the opportunistic approach. The first feature is that monetary policy should move inflation toward an intermediate inflation target which is a function of past inflation rates and the inflation target rather than inflation target itself. The second feature is related to the concept of the zone of discretion for which policymakers are supposed to behave opportunistically by accommodating shocks that tend to move inflation towards the desired level. The interest rate will be raised when inflation is above the zone of discretion and decreased if inflation is below the zone.

Empirical findings are reported below:

1. The models that include intermediate rather than simple inflation target improve the fit of the models.

2. Among linear and nonlinear models, a quadratic logistic function outperforms all other models and provides support that the monetary policymakers of the SARB behaved opportunistically by accommodating shocks when inflation is within the zone of discretion but reacting aggressively otherwise.
3. The outperforming model reveals that the zone of discretion is symmetrically extending from 2.05 percent below and above the intermediate inflation rate. Estimated inflation target range of 4.10 percent is reasonable for the SARB as the difference between the pre-announced lower bound and upper bound is 3 percent.
4. Taking the official target range of 3 to 6 percent as a benchmark to our estimates, we can suggest that estimated target zone spans from 2.45 to 6.55 percent.
5. Recursive estimation of the preferred model reveals that in general the 2007-2009 financial crisis witnesses an overall increased reaction to inflation and financial conditions. However, the relative importance turns to the output gap since early 2009 as a result of the relatively low inflation.

8.2.3. Findings on forecast evaluation (chapter 7)

The main aim of chapter 7 is to evaluate predictive accuracy of six competing models based on several forecasting accuracy tests; namely the mean squared prediction error (MSPE), the median squared prediction error (MedSPE) the modified Diebold and Mariano, the encompassing and Clark and West tests.

1. Forecast evaluation reveals empirical evidence in favour of nonlinear models.
2. Overall ranking reveals the superiority of the nonlinear model that distinguishes between downward and upward movements in the business cycles in closely matching the historical record. As such, forecasting performance tests reveal that the SARB pays particular attention to business cycles movements when setting its policy rate.

8.3. Policy implications

The aforementioned findings have clear policy implications:

1. The Taylor (1993) rule assumes that the response of policymakers is only limited to inflation and output. However, empirical evidences show that financial stability matters in setting the South African monetary policy instrument. Indeed, these findings are in light with the implicit financial stability mandate of the SARB. The response of the SARB policy-makers to financial conditions arguably has important policy implications as it might

shed some light on why the current downturn in South Africa where the financial market occupies 25 percent of its total output is less severe.

2. On the other hand the Taylor (1993) rule assumes a constant response of policymakers to changes in inflation and output deviations from their desired levels. However, findings reveal that:
 - a. The response of the SARB is not constant as it is found to depend on the sign of deviation of actual output from the steady-state level.
 - b. The response of the policymakers is not constant as it also depends on whether inflation is within the zone of discretion (target zone) or not. Also, unlike the Taylor (1993) rule which accommodates simple inflation target, this modified policy rule accommodates intermediate inflation target, which is a function of past inflation rates and the inflation target itself.

All in all, the consideration of nonlinearities, the accommodation of intermediate inflation and the inclusion of a proxy to account for financial stability can provide better understanding of the behaviour of the SARB. As such, the South African Reserve Bank is encouraged to design a policy rule that explicitly accommodate financial variables. It is also positive that the SARB does not turn a blind eye on periods of distress (inflationary, macroeconomic and probably financial). Indeed, the SARB is encouraged to keep reacting aggressively in periods of distress and respond passively in periods of calm. It would not make sense to be aggressive on stability which is, indeed, the ultimate goal of any economy.

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