Chapter 1

Introduction

The inflation targeting framework is an important development that has recently been adopted by a growing number of central banks in developed and developing countries (Mishkin and Schmidt-Hebbel, 2001). This monetary policy framework is characterised by point targeting as well as zone targeting. A point targeting monetary policy framework permits inflation to fluctuate by some margin around the specified target. A zone targeting monetary policy framework allows some toleration to the fluctuation of inflation within a specified target range. A number of central banks including the South African Reserve Bank have adopted the latter. Orphanides and Wilcox (2002) argue that when monetary authorities endowed with inflation and output stabilisation, they may exhibit asymmetric behaviour by having an inflation bias when inflation overshoots the target and an output bias during output declines. The monetary authorities may also exhibit zone-like behaviour by being passive when they are within the target range and penalising more when inflation or output move out of the target range.

The aim of the thesis is to address issues concerning modelling and evaluation of monetary policy by obtaining targeting rules from optimisation techniques using welfare loss functions that capture asymmetries and zone targeting monetary policy preferences following Nobay and Peel (2003), Boinet and Martin (2008), and Aksoy et al. (2006). Orphanides and Wieland (2000) argue that 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. Thus, an empirical framework that allows for target zones and asymmetries in monetary policy preferences is more relevant to evaluate the actual practice of monetary policy by central banks.

First, the response of monetary policy to the deviations of inflation and output from their target values based on a framework that allows asymmetric and zone targeting

monetary authorities' preferences is estimated. The motivation is that the monetary authorities may have an inflation bias when inflation overshoots the target and an output bias during output declines following Ruge-Murcia (2003), Surico (2007a,b) and Boinet and Martin (2008). The results show that the monetary authorities' response towards inflation is zone symmetric so that they react in a passive manner when inflation is within the target band and become increasingly aggressive when it deviates from the target band. The monetary authorities also react with the same level of aggressiveness regardless of whether inflation overshoots or undershoots the inflation target band. The second major finding is that the monetary authorities' response to output fluctuations is asymmetric. That is, they react more aggressively to negative deviations of output from the potential so that they weigh business cycle recessions more than expansions.

Second, the monetary policy reaction function that is augmented with the index of financial conditions for South Africa is estimated based on a framework that allows asymmetric and zone targeting monetary authorities' preferences. The index of financial conditions is a comprehensive index that collects and synthesises information from the financial asset markets to address the current debate on the importance of financial assets prices in monetary policy decision making following Goodhart and Hoffman (2001), Montagnoli and Napolitano (2005) and Castro (2008). The motivation is that the recent economic crisis has highlighted the importance of the behaviour of certain financial asset variables such as stock prices, house prices and the exchange rate. It has also heightened the concern by central banks over the maintenance of financial stability. The results reveal that that the conditions in the financial asset markets form an important information set for the monetary authorities in South Africa. The monetary authorities pay close attention to the conditions in the financial markets by placing an equal weight on financial asset markets booms and recessions.

Third, the impact of uncertainty about the state of the economy on monetary policy in South Africa is analysed using a framework that allows asymmetric and zone targeting monetary authorities' preferences. The analytical framework that is augmented with the index of financial conditions following Castro (2008). The motivation is to objectively reveal how the monetary authorities design and conduct

monetary policy when faced with uncertainty following Svensson (1999), Rudebusch (2001), Sonderstrom (2002), Swanson (2004) and Martin and Milas (2009). The economic environment in which central banks implement monetary policy is ambiguous in that the monetary authorities have to contend with challenges pertaining to uncertainty that pose challenges and have implications for the design and conduct of monetary policy. The empirical results reveal a significant impact of uncertainty about the state of the economy on domestic interest rates during the inflation targeting period and that the monetary authorities exhibit discretionary behaviour when implementing monetary policy under uncertainty.

The thesis contributes to the body of knowledge in the field of economics and enhances the understanding of monetary policy design and conduct in South Africa in ways that have not been done before. The thesis addresses important aspects of monetary policy design and implementation in South Africa using a framework that captures the stylised features of monetary policy practice at central banks. It addresses the recent macroeconomic fluctuations that have brought about a renewed focus on the formulation and practice of monetary policy using a comprehensive index that collects and synthesises information from the financial asset markets. It also addresses uncertainty, which is a fundamental and integral part of monetary policy decision making that the monetary authorities have to contend with in the design and conduct of monetary policy on an ongoing basis. All these issues are important and are currently debated in the context of South Africa and most central banks around the world.

Chapter 2

Optimal monetary policy reaction function with target zones and asymmetric preferences for South Africa[3]

2.1 Introduction

Policy makers around the world have sought to improve transparency and accountability of their policy objectives by specifying explicit targets for variables such as inflation and output. An important development in the recent past has been the adoption of the inflation targeting framework by a growing number of developed and developing countries (Mishkin and Schmidt-Hebbel, 2001). Under this framework, the monetary authorities make public announcements of the target inflation rate and use of interest rates to steer actual inflation towards the target with the objective of achieving price stability. This monetary policy framework is characterised by point targeting, which permits inflation to fluctuate by some margin around the specified inflation target. The South African Reserve Bank, together with other central banks have adopted a zone targeting monetary policy framework. Inflation is targeted between 3 to 6 percent in South Africa. This allows for some toleration to the fluctuation of inflation within this specified target range.

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 when the output undershoots its long term trend (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

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preferences is more relevant to evaluate the monetary authorities' actual practice of monetary policy setting.

Orphanides and Wieland (2000) argue that 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. The empirical work on the analysis of monetary policy is dominated by studies that use the linear Taylor rule with relatively few studies that have estimated asymmetric monetary policy reaction functions. Cukierman and Gerlach (2003), Ruge-Murcia (2003), Dolado et al. (2004, 2005), Surico (2007a,b) have shown evidence supporting asymmetries by adopting a monetary policy reaction function that feature asymmetries in either inflation or the output gap for the United States, United Kingdom, European Union and OECD countries. Boinet and Martin (2008) also implemented a monetary policy reaction function that feature asymmetries and zone-like behaviours for the United Kingdom and found the evidence of zone-like responses to inflation.

This chapter estimates the monetary authorities' response to deviations of inflation and output from their target values using an empirical framework which allows central bank's policy preferences to be zone like and asymmetric. Of particular interest is whether the monetary authorities' preferences are such that they react differently to deviations in inflation and output when they overshoot or are below their target values and/or when inflation is within or outside the target range. The modelling strategy is an adaptation of the New Keynesian framework, which is the intertemporal optimisation problem where the central bank minimises a loss function subject to the constraints given by the structure of the economy. The study is important in that it allows the evaluation of the South African Reserve Bank's monetary policy outcomes using an analytical framework that captures the authentic inflation target band monetary policy practice under which the South African Reserve Bank operate.

The attempt to model South Africa's monetary policy using an optimal monetary policy reaction function with zone-like and asymmetric preferences is the first to our knowledge. The only piece of work that have attempted estimating nonlinear

monetary policy rule in the context of South Africa is Naraidoo and Gupta (2010) who make use of a smooth transition model with a quadratic logistic function to capture inflation zone targeting practice. The monetary policy reaction function with zone-like and asymmetric preferences is consistent with the actual practice of inflation zone targeting by the South African Reserve Bank. This is because South Africa has undergone important changes in its monetary policy settings over the last two decades moving from a constant money supply growth targeting rule adopted in 1986 to inflation targeting regime starting from 2000. Before then, there was an emphasis on an eclectic set of economic indicators including the exchange rate, asset prices and total credit extension. An extensive survey on the monetary regimes and institutions in place in South Africa since the 1960s can be found in Aron and Muellbauer (2000), and Jonsson (2001).

The chapter is organised as follows. The next section details the theoretical model where the optimal monetary policy rule is derived from the monetary authorities' optimisation problem. Section 3 discusses the data. In section 4, the optimal monetary policy rule is estimated and the results are reported and discussed. Section 5 concludes.

2.2 Theoretical model

The central bank's monetary policy design problem is a targeting rule following Svensson (1999) and draws from Boinet and Martin (2008). The monetary policy reaction function is an adaptation of the New Keynesian setup that is modelled as an intertemporal optimisation problem where the central bank is assumed to use all available information available at any point in time to bring the target variables in line with their desired values.

2.2.1 Central bank's preferences

The central bank sets the interest rate at the beginning of period t based on the information, which is available at the end of period $t-1$. The following timing mechanism captures this intertemporal criterion as in Clarida et al. (1999):

$$\underset{\{i_t\}}{Min}\, E_{t-1}\sum_{\tau=0}^{\infty}\delta^{\tau}L_{t+\tau} \qquad [1]$$

where δ and L is the discount factor and the period loss function, respectively.

The period loss function is a linex specification and was first introduced in the monetary policy literature by Nobay and Peel (2003). It departs from the conventional quadratic specification in that the central bank is allowed to treat differently the positive and negative deviations of inflation and output from their targets. The central bank is also indifferent between inflation rates and output within these target zones as in Boinet and Martin (2008). It extends on Surico (2007a,b) in that the linex specification is general because it approximates a number of different functions. The range of values for the rate of inflation for which the loss function is constant forms the target zone for inflation.

The period loss function is specified as follows:

$$L_t = \frac{e^{\alpha_\pi(\pi-\pi^*)^{\beta_\pi}} - \alpha_\pi(\pi_t-\pi^*)^{\beta_\pi} - 1}{\beta_\pi\alpha_\pi^2} + \lambda_y\left(\frac{e^{\alpha_y(y_t)^{\beta_y}} - \alpha_y(y_t)^{\beta_y} - 1}{\beta_y{\alpha_y}^2}\right) + \frac{\lambda_i}{2}(i_t-i^*)^2 \qquad [2]$$

where α_π and α_y capture the asymmetries, while β_π and β_y capture the zone-like properties in the central bank's preferences. i^* is the desired level of interest rate, while π^* is the inflation target. $\lambda_y > 0$ is a coefficient that measures the central bank's aversion to output level fluctuation relative to the potential level, while $\lambda_i > 0$ is a coefficient that measures the central bank's aversion to interest rate fluctuations around the desired level. The policy preference towards inflation stability is normalised to one so that λ_y and λ_y are expressed in relative terms.

The loss function embodies numerous characteristics of linearities, asymmetries and zone-like central bank's preferences depending on the values of α_π, α_y, β_π and β_y. As special cases, whenever β_π and β_y approach one, the period loss function

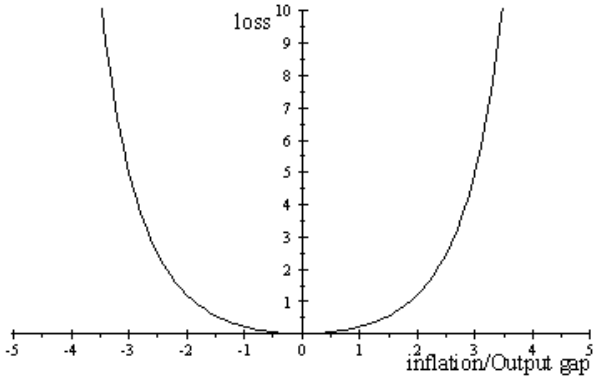
generalises to a linex function. Applying L'Hopital's rule on the loss function allowing α_π and α_y approach zero and β_π and β_y approach one simultaneously achieves a quadratic loss function. Figure 2.1 illustrates the monetary authorities' preferences assuming that the central bank is more concerned about inflation overshooting its target and output undershooting its potential. Under these assumptions, high inflation relative to the target is more costly to the monetary authorities than low inflation. On the other hand, low output relative to the potential is weighted more severely than higher output.

As illustrated in Figure 2.1 (a) and (b), when α_π and α_y approach zero, the loss function is symmetric so that the deviations of inflation from its target and output from its potential are weighted equally by the monetary authorities. The loss function exhibits zone-like properties when β_π and β_y are greater than one. Given a positive value of α_π, whenever π_t is greater than zero, the linear component of the loss function is dominated by the exponential component as illustrated in Figure 2.1 (c) and (d). Thus, the central bank penalises higher inflation relative to the target more severely than lower inflation. In similar manner, given the negative value of α_y, the exponential component dominates the linear component of the loss function whenever y_t is less than zero, while the opposite is true for output values greater than zero as illustrated in Figure 2.1 (e) and (f). Thus, the central bank weighs output contraction relative to the potential level more heavily than output expansions of the same level.

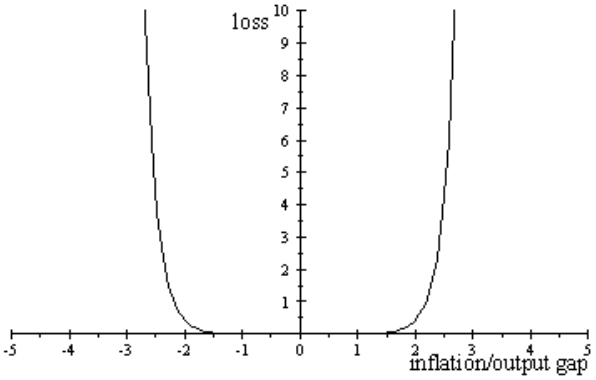
Whenever β_π and β_y are greater than one, the central bank's preferences are zone-like. This feature was introduced by Orphanides and Wieland (2000). Within the target zones, the central bank's marginal loss is zero. Whenever β_π and β_y are even, the inflation and output targets are symmetric so that the loss from inflation and output outside the targets are symmetric. Both the inflation and output target zone and the loss from inflation and output outside the target zone are asymmetric whenever β_π and β_y are odd. Higher values of β_π and β_y widen the target zone. The responses to inflation and output gaps may be different so that β_π and β_y may not be equal.

Figure 2.1 The loss functions

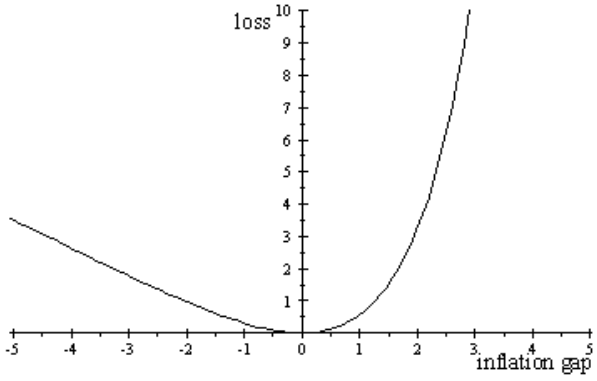
(a) $\alpha_{\pi;y} \to 0; \beta_{\pi;y} = 1$



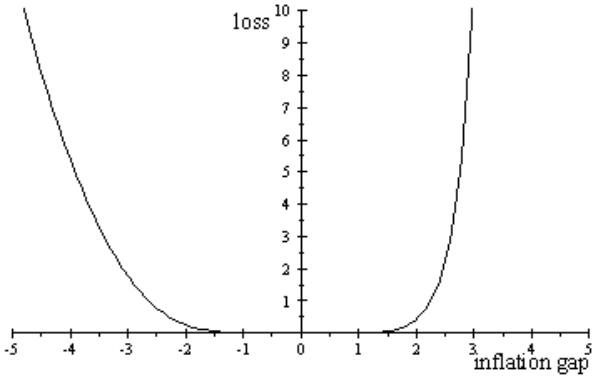
(b) $\alpha_{\pi;y} \to 0; \beta_{\pi;y} = 2,4,6,...$



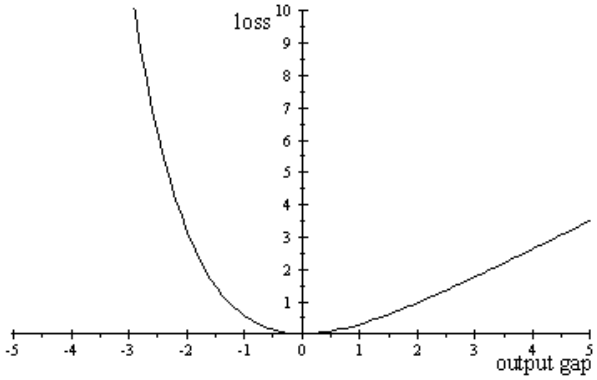
(c) $\alpha_{\pi} > 0; \beta_{\pi} = 1$



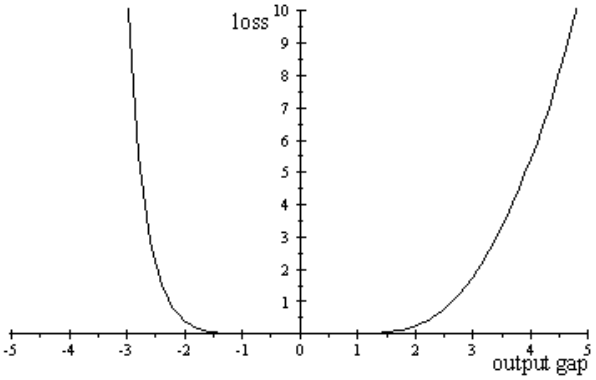
(d) $\alpha_{\pi} > 0; \beta_{\pi} = 3,5,7,...$



(e) $\alpha_{y} < 0; \beta_{y} = 1$



(f) $\alpha_{y} < 0; \beta_{y} = 3,5,7,...$



Note:The Figure illustrates the preferences over inflation and output embodied by the loss function assuming that monetary authorities have deflationary bias and dislike output contractions

The shape of the linex specification depends on the signs of α_π and α_y such that if the central bank weighs deflation more severely than inflation, then α_π would be negative. α_y can also be positive in which case the central bank is averse to output contractions than expansions. Thus under asymmetric setting, the central bank is concerned about the magnitudes as well as the signs whereas under the symmetric setting, the only concern is the magnitude of deviations of target variables from their reference values. See Martin and Boinet (2008) for a detailed discussion on all the possible configurations of the loss function.

2.2.2 **Structure of the economy**

The framework for the evolution of monetary policy is the New-Keynesian sticky price forward looking model of the business cycle. The model is derived in Yun (1996) and Woodford (2003). The economy is represented by a two equation system comprising the aggregate demand and aggregate supply (Phillip's curve) functions. The aggregate demand is a log linearised version of the standard Euler equation for consumption combined with the relevant market clearing condition:

$$y_t = \eta_y E_t y_{t+1} - \psi_y \left(i_{t-1} - E_{t-1}\pi_t \right) + \varepsilon_t^y \qquad [3]$$

where y_t is the output gap, i_t is the nominal interest rate, π_t is the inflation rate, while $\eta_y > 0$ and $\psi_y > 0$ are the coefficients and ε_t^y is a demand shock. The aggregate supply curve incorporates consumption smoothing into the aggregate demand formulation where the output gap increases with its future value, while it decreases with the real interest rate $i_{t-1} - E_{t-1}\pi_t$ (Clarida et al., 1999). The aggregate supply (Phillips curve) captures, in a log-linearised manner, the staggered feature of the Calvo type contract:

$$\pi_t = \eta_\pi E_t \pi_{t+1} + k y_t + \varepsilon_t^\pi \qquad [4]$$

where $\eta_\pi > 0$ and $k > 0$ are the coefficients, while ε_t^π is the Independent and identically distributed supply shock.

2.2.3 **Optimal monetary policy**

The central bank chooses monetary policy rates under discretion and the per period instrument i_t is chosen to minimise the following objective function:

$$E_{t-1}\left(\frac{e^{\alpha_\pi(\pi_t-\pi^*)^{\beta_\pi}}-\alpha_\pi(\pi_t-\pi^*)^{\beta_\pi}-1}{\beta_\pi\alpha_\pi^2}\right)+\lambda_y E_{t-1}\left(\frac{e^{\alpha_y(y_t)^{\beta_y}}-\alpha_y(y_t)^{\beta_y}-1}{\beta_y\alpha_y^2}\right)+\frac{\lambda_i}{2}(i_t-i^*)^2+F_t \quad [5]$$

Subject to $y_t=-\psi_y i_{t-1}+g_t$ and $\pi_t=ky_t+f_t$ where $F_t\equiv E_{t-1}\sum_{\tau=1}^{\infty}\delta^\tau L_{t+\tau}$, $g_t\equiv\eta_y E_t y_{t+1}-\psi_y E_t\pi_{t+1}+\varepsilon_t^d$ and $f_t\equiv\eta_\pi E_{t-1}\pi_t+\varepsilon_t^s$. The central bank cannot directly manipulate expectation. As a result, F_t, g_t and f_t are taken as given.

2.2.4 **Central bank's reaction function**

The reaction function according to which the central bank chooses monetary policy rates in response to developments in the economy is achieved by solving the central bank's optimisation problem above. This translates into the following first order condition that describes the central bank's optimal monetary policy rule.

$$\delta E_{t-1}f'\left(\pi_{t+1}-\pi^*\right)\frac{\partial\pi_{t+1}\partial y_{t+1}}{\partial y_{t+1}\partial i_t}+\lambda_y\delta E_{t-1}f'\left(y_{t+1}\right)\frac{\partial y_{t+1}}{\partial i_t}+\lambda_i(i_t-i^*)=0 \quad [6]$$

where $f\left(a_t;\alpha,\beta\right)=\left(\frac{e^{\alpha a_t^\beta}-\alpha a_t^\beta-1}{\beta\alpha^2}\right)$ and $f'(\cdot)$ is the first derivative of this function.

The parameter α and the exponential function determine the asymmetric response of monetary policy rates to the deviation of target variables from their reference values, while β captures the zone-like properties.

Solving equation [6] achieves the reduced form central bank's reaction function

$$\hat{i}_t = i^* + \omega_\pi E_{t-1} f'\left(\pi_{t+1} - \pi_t^*\right)\left(\pi_{t+1} - \pi_t^*\right) + \omega_y E_{t-1} f'\left(y_{t+1}\right)\left(y_{t+1}\right) \qquad [7]$$

where $\hat{i}$ is the optimal interest rate, $\omega_\pi = \left(\frac{k\psi_y\delta}{\lambda_i}\right)$ and $\omega_y = \left(\frac{\lambda_y\psi_y\delta}{\lambda_i}\right)$ are convolutions of parameters representing the central bank's preferences and the structure of the economy and $f'\left(a_t;\alpha,\beta\right) = a_t^{\beta-1}\left(\frac{e^{\alpha a_t^\beta} - 1}{\alpha}\right)$. The weight on inflation is given by $\omega_\pi E_{t-1} f'\left(\pi_{t+1} - \pi_t^*\right)$ while the weight on output stabilisation is $\omega_y E_{t-1} f'\left(y_{t+1}\right)$.

As a special case, the central bank's reaction function above embodies the linear form whenever α_π and α_y approach zero. Using L'Hopital's rule on equation [7] as α_π and α_y approach zero and β_π and β_y approach one, $f'(\cdot)$ tends to unity and the central bank's monetary policy rule generalises to a linear Taylor rule (Taylor, 1993)

$$\hat{i}_t = i^* + \omega_\pi E_{t-1}\left(\pi_{t+1} - \pi_t\right) + \omega_y E_{t-1}\left(y_{t+1}\right) \qquad [8]$$

The monetary authorities have linex preferences whenever β_π and β_y are equal to one. This monetary reaction function is similar to those in Nobay and Peel (2003), Ruge-Murcia (2003) and Surico (2007a,b).

The monetary policy reaction function generalise to a linear Taylor rule whenever α_π and α_y approach zero, while it is symmetric whenever β_π and β_y are greater than one as illustrated in Figure 2.2 (a) and (b), respectively. The monetary policy reaction function reveals asymmetries to inflation and output whenever α_π and α_y are greater than zero. Assuming that the monetary authority dislikes high inflation, whenever α_π is greater than zero, monetary authorities are more aggressive when inflation

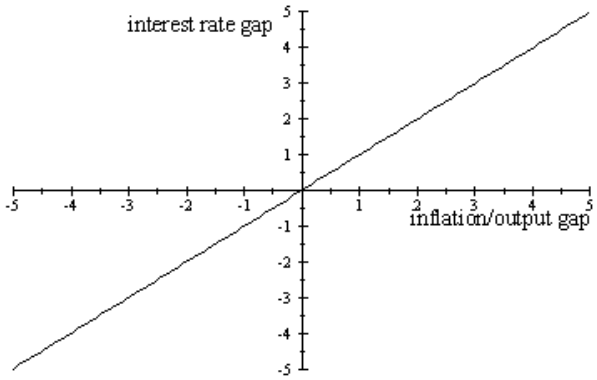
overshoots the target but less responsive when inflation undershoots the target as shown in Figure 2.2 (c) and (d). Further, assuming that monetary authorities are averse to output contractions, as shown in Figure 2.2 (e) and (f), the asymmetry is reversed whenever α_y is less than zero so that monetary authorities are more aggressive when output undershoots the target and relatively passive when it overshoots the target.

Whenever β_π and β_y are even, the monetary policy reaction function exhibits zone-like preferences similar to that proposed by Orphanides and Wieland (2000). In this case, monetary authorities are passive or do not respond to fluctuations in inflation and output inside the zone. However, the monetary authorities' reaction becomes increasingly aggressive whenever inflation and output moves outside this zone. Their reaction outside the zone is symmetric and increasingly aggressive for the larger values of α_π and α_y. Whenever β_π and β_y are odd, the monetary policy reaction function is asymmetric and exhibits zone-like preferences' similar to that proposed by Boinet and Martin (2008). Similar to the previous case, monetary authorities are passive or do not respond to fluctuations in inflation and output inside the zone. Assuming that monetary authorities' dislike high inflation and output contractions, their response to inflation is somewhat passive when inflation moves below the target zone but becomes increasingly aggressive when inflation moves above the target zone and the response is also aggressive when output undershoots the target zone but less so when it overshoots it.

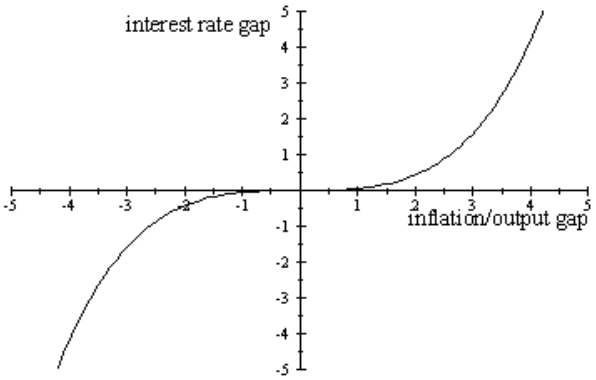
Thus, it is apparent from the preceding discussion that the monetary policy reaction function is flexible in that it can embody linearities and nonlinearities, symmetries and asymmetries as well as zone-like responses to inflation and output depending on the assumptions concerning the monetary authorities' preferences. As a result, determining which specification best fits the data allows the evaluation of the monetary authorities' preferences', which adequately capture the key features in monetary policy conduct.

Figure 2.2 Optimal monetary policy rules

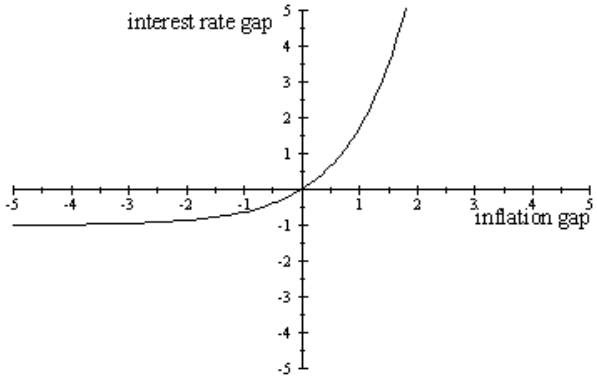
(a) $\alpha_{\pi;y} \to 0; \beta_{\pi;y} = 1$



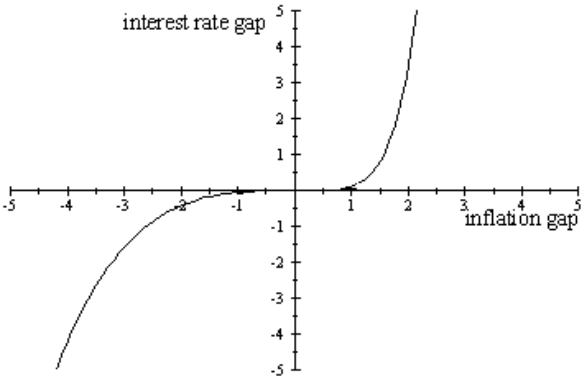
(b) $\alpha_{\pi;y} \neq 0; \beta_{\pi;y} = 2,4,6,...$



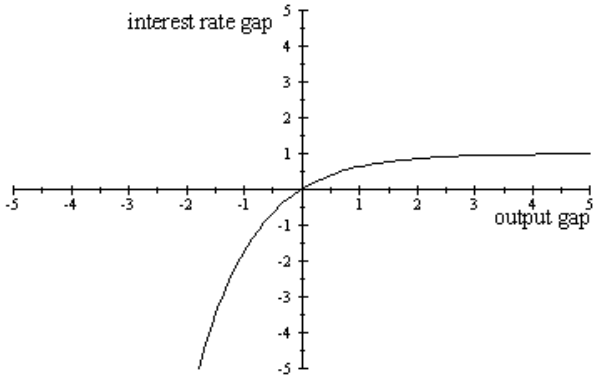
(c) $\alpha_{\pi} > 0; \beta_{\pi} = 1$



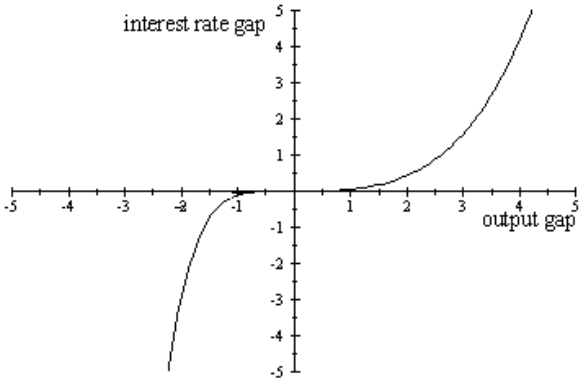
(d) $\alpha_{\pi} > 0; \beta_{\pi} = 3,5,7,...$



(e) $\alpha_{y} < 0; \beta_{y} = 1$



(f) $\alpha_{y} < 0; \beta_{y} = 3,5,7,...$



Note:The Figure illustrates the gap between the steady state and equilibrium interest rates calculated using equation [7] assuming that monetary authorities dislike inflation and output contractions.

Whenever β_π and β_y are even, the monetary policy reaction function exhibits zone-like preferences similar to that proposed by Orphanides and Wieland (2000). In this case, monetary authorities are passive or do not respond to fluctuations in inflation and output inside the zone. However, the monetary authorities' reaction becomes increasingly aggressive whenever inflation and output moves outside this zone. Their reaction outside the zone is symmetric and increasingly aggressive for the larger values of α_π and α_y. Whenever β_π and β_y are odd, the monetary policy reaction function is asymmetric and exhibits zone-like preferences' similar to that proposed by Boinet and Martin (2008). Similar to the previous case, monetary authorities are passive or do not respond to fluctuations in inflation and output inside the zone. Assuming that monetary authorities dislike high inflation and output contractions, their response to inflation is somewhat passive when inflation moves below the target zone but becomes increasingly aggressive when inflation moves above the target zone and the response is also aggressive when output undershoots the target zone but less so when it overshoots it.

Thus, it is apparent from the preceding discussion that the monetary policy reaction function is flexible in that it can embody linearities and nonlinearities, symmetries and asymmetries as well as zone-like responses to inflation and output depending on the assumptions concerning the monetary authorities' preferences. As a result, determining which specification best fits the data allows the evaluation of the monetary authorities' preferences, which adequately capture the key features in monetary policy conduct. See Martin and Boinet (2008) for a detailed discussion on all the possible configurations of the loss function.

2.2.5 **Empirical model**

Estimating the central bank's reaction function in equation [7] to test the statistical significance of the parameters amounts to testing linearity against a non-linear model. To overcome this problem, the central bank's reaction function is linearised to eliminate the exponential terms by approximating equation [7] using a first order Taylor series expansion when α_π and α_y tend to zero. Replacing the expectations

with realised values, the reduced form central bank's reaction function now becomes:

$$\hat{i}_t = i^* + \omega_\pi \left(\pi_{t+1} - \pi^*\right)^{2\beta_\pi - 1}\left(1 + \frac{\alpha_\pi}{2}\left(\pi_{t+1} - \pi^*\right)^{\beta_\pi}\right) + \omega_y \left(y_{t+1}\right)^{2\beta_y - 1}\left(1 + \frac{\alpha_y}{2}\left(y_{t+1}\right)^{\beta_y}\right) \qquad [9]$$

When β_π and β_y approach one, the monetary authorities have linex preferences. The monetary policy reaction function generalises to a linear Taylor rule when α_π and α_y approach zero. Adding a partial adjustment mechanism $i_t = \rho(L) i_{t-1} + (1 - \rho(L))\hat{i}_t$ to allow for interest rate persistence as in Clarida et al. (1999) achieves the following reduced form central bank's reaction function:

$$i_t = \rho(L) i_{t-1} + \left(1 - \rho(L)\right)\begin{pmatrix} \omega_0 + \omega_\pi \left(\pi_{t+1} - \pi^*\right)^{2\beta_\pi - 1}\left(1 + \frac{\alpha_\pi}{2}\left(\pi_{t+1} - \pi^*\right)^{\beta_\pi}\right) \\ + \omega_y \left(y_{t+1}\right)^{2\beta_y - 1}\left(1 + \frac{\alpha_y}{2}\left(y_{t+1}\right)^{\beta_y}\right) \end{pmatrix} + \varepsilon_t \qquad 10]$$

Where ε_t is the residual of the Taylor's series expansion.

The specification of the reduced form central bank's reaction function in equation [10] is consistent with the actual practice of inflation zone targeting by the South African reserve Bank. Therefore the specified central bank's reaction function that allows some toleration to the fluctuation of inflation within a specified target range and aggressiveness when inflation moves away from the target band is more appropriate framework for analysing monetary policy in South Africa.

2.3 Data description

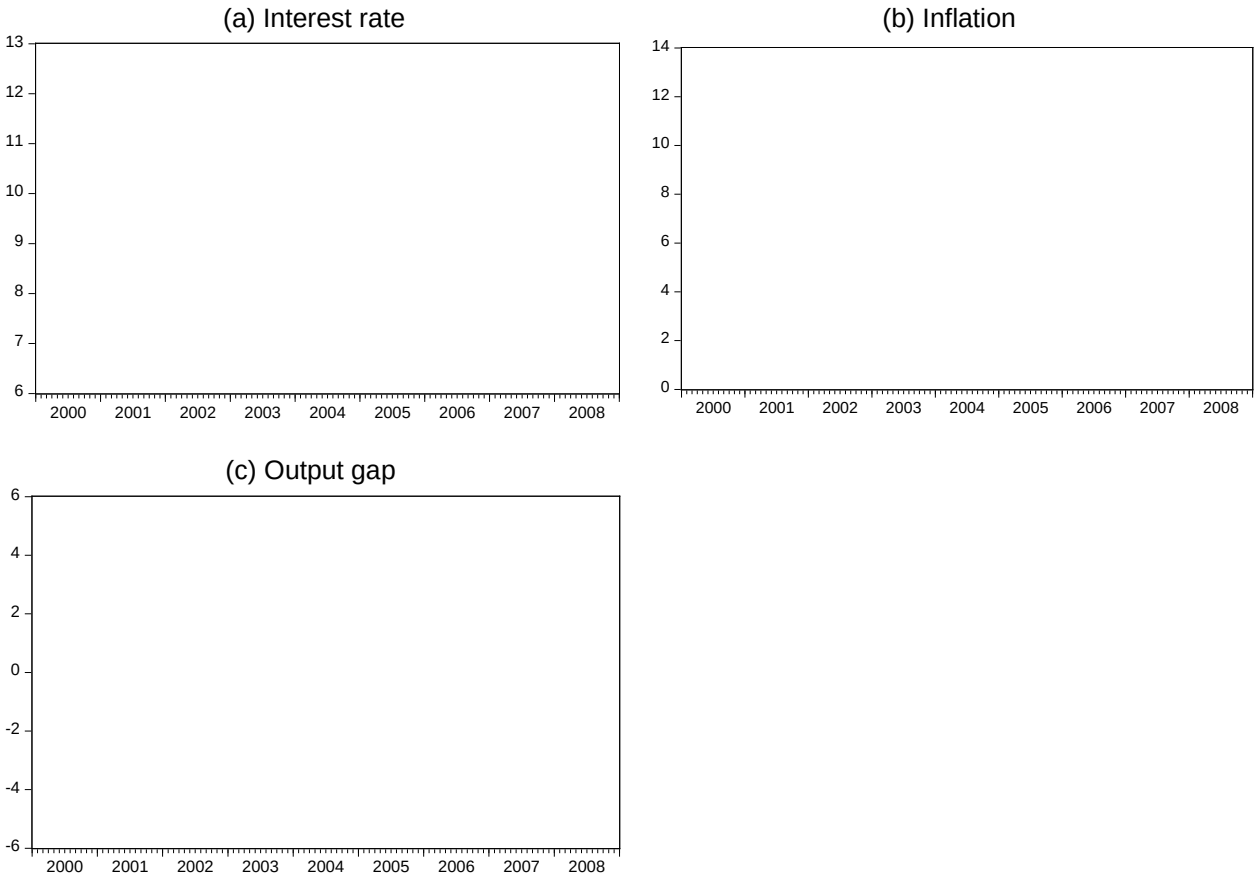
Monthly data for South Africa spanning the period January 2000 to December 2008 is used in the analysis. The three month treasury bill rate is used to measure the rate of interest. The short term Treasury bill rate has commonly been used to proxy the official policy rate, particularly in similar studies such as Martin and Boinet (2008),

Nelson (2003) for the United Kingdom. We prefer using this interest rate rather than the key policy rate, the repurchase rate, given that it contains more variation. The correlation between the repurchase rate and treasury bill rate during the sample period is sufficiently high at about 98 percent and drops to about 96 percent after 2007. This drop in correlation can be explained by the disruption of the close relationship between policy rates and money market interest rates during the recent financial crisis. Inflation gap is measured by the difference between the annual change in consumer price index and 4.5, which is the midpoint of the inflation target in South Africa.

Output gap is measured by the difference (in logarithms) between coincident business cycle indicator and its Hodrick and Prescott (1997) trend. Industrial production is often used as the measure of the output gap at the monthly frequency. However, this runs into operational problems because industrial production is not official data in South Africa. We also found that the coincident business cycle indicator is a better proxy for output because it is a much broader index and has a higher correlation with gross domestic product than industrial production at levels and in deviations from trend. The coincident business cycle indicator is the composite index comprising the following equally weighted components; Gross value added, Value of wholesale, retail and new vehicle sales, Utilisation of production capacity in manufacturing, Total formal non-agricultural employment and Industrial production index. The autoregressive (*n*) model with *n* set at 4 is applied to the output measure eliminate serial correlation and to tackle the end-point problem in calculating the Hodrick Prescott trend as in Mise et al. (2005a,b). This model was used to forecast twelve additional months that were then added to the series before applying the Hodrick Prescott filter.

The instrument set includes the lags of the independent variables, the long term government bond yield, annual change in M3 and the index of financial conditions gap. All the data is sourced from the South African Reserve Bank database. The main variables are depicted in Figure 2.3. The inflation rate is showing a persistent increase towards the end of the sample together with an accompanying increase in interest rate. The output gap is showing a severe downturn by the end of 2008.

Figure 2.3 Evolution of the main variables



Note: Own calculations with data sourced from the South African Reserve bank

2.4 Empirical results

The orthogonality conditions in the central bank's reaction function allow the use of Generalised Method of Moments in estimation. Equation [10] is estimated using a mixture of integer values of β_π and β_y when α_π and α_y approach zero and when α_π and α_y are not equal to zero. The optimal monetary policy reaction functions are estimated in a forward looking manner with a preferred specification that allows a lead structure of six on inflation gap and one on the output gap. The lead structure was chosen according to the AIC criteria and based on plausible economic results in terms of economic interpretability. The optimal monetary policy rule is achieved by

selecting the model with the lowest standard error among all the alternatives under the different assumptions for inflation and output. As discussed above, the inflation and output gaps can be assumed to be linear, asymmetric, zone symmetric and zone asymmetric.

Table 2.1 shows the standard errors for all the estimated models under different assumptions for inflation and output. Among the alternatives, the model with a symmetric zone inflation gap and an asymmetric output gap is the preferred model with the lowest standard error. This implies that the monetary authorities react in a passive manner when inflation is within the target band and become increasingly aggressive when it deviates from the target band where they react with the same level of aggressiveness regardless whether inflation overshoots or undershoots the inflation target band. In addition, the monetary authorities react differently to negative and positive deviations of output from the potential.

Table 2.1 Standard errors for the values of β_π and β_y

	Linear $\alpha_\pi \to 0; \beta_\pi = 1$	Asymmetric $\alpha_\pi \neq 0; \beta_\pi = 1$	Symmetric Zone $\alpha_\pi \neq 0; \beta_\pi = 2$	Asymmetric Zone $\alpha_\pi \neq 0; \beta_\pi = 3$
Linear $\alpha_y \to 0; \beta_y = 1$	0.320672	0.3117229	0.321301	0.325426
Asymmetric $\alpha_y \neq 0; \beta_y = 1$	0.310730	0.312119	0.304125	0.318219
Symmetric Zone $\alpha_y \neq 0; \beta_y = 2$	0.326905	0.322175	0.322711	0.322974
Asymmetric Zone $\alpha_y \neq 0; \beta_y = 3$	0.321068	0.317063	0.318193	0.319374

The estimated results for the preferred model with a symmetric zone inflation gap and an asymmetric output gap are presented in Table 2.2 together with the estimated results for the linear Taylor rule, which is a benchmark for the estimated monetary policy reaction functions. To determine the validity of the set of instruments, the Hansen's J- test is carried out under the null hypothesis that the over identifying restrictions are satisfied. The null hypothesis is accepted for both the preferred model and the benchmark model. However, the preferred model provides

slightly better fit to the data compared with the benchmark model and relatively better model diagnostics.

Table 2.2 Estimates for the non-linear monetary policy rule

	Linear inflation and linear output gap $\alpha_\pi \to 0; \alpha_y \to 0;$ $\beta_\pi = 1; \beta_y = 1$		Zone symmetric inflation and asymmetric output gap $\alpha_\pi \neq 0; \alpha_y \neq 0;$ $\beta_\pi = 2; \beta_y = 1$	
	Coefficient	Std error	Coefficient	Std error
ρ	0.938862*	0.007366	0.952855*	0.005851
ω_0	7.827308*	0.194708	8.392031*	0.289229
ω_π	0.804001*	0.118355	0.108174*	0.015844
α_π			-0.025877*	0.000660
ω_y	0.398205*	0.164511	0.779056*	0.181125
α_y			-0.805241*	0.158182
$\bar{R}^2$	0.970032		0.973045	
$Std.Error$	0.320672		0.304125	
$J-statistic$	0.984520		0.989988	
F_{ar}	1.37 [0.24]		0.71 [0.62]	
F_{arch}	3.02 [0.01]		1.10 [0.37]	
$Jaque\ Bera$	1.81 [0.40]		1.93 [0.38]	
$Chow\ F\text{-}stat$	2.87 [0.03]		1.16 [0.34]	
$RESET\ test$	26.38 [0.00]			

Note: * denotes statistical significance at 5 percent level. $J-statistic$ reports the p-value of Hansen's test for over identifying restrictions. F_{ar} is the Lagrange multiplier *F*-test for residual serial correlation of up to twelfth order. F_{arch} is the *F*-test for the twelfth order autoregressive conditional heteroscedasticity. $Jaque\ Bera$ is a chi-square test for normality. $Chow\ F\text{-}stat$ is a Chow test for parameter stability; the break is in 2003:m6. $RESET\ test$ is the Ramsey RESET test, which is a chi-square test for general specification of linear regression model and includes up to the cubic terms of the regressors.

The diagnostic tests show no serious misspecification except for a heteroscedasticity issue in the linear model. We implement two statistical tests to support the nonlinear results. The estimates of the linear model fail a Chow test of parameter stability. This conclusion is robust even when other dates for the break point of the stability test are used. This implies that the Taylor rule is inadequate as a model of monetary policy and provides further support for the model with target zones and asymmetries. The estimates of the preferred model with a symmetric zone response to inflation and a nonlinear response to output do not suffer from parameter instability. The Ramsey RESET test further concludes that the general specification of the linear regression model is not appropriate.

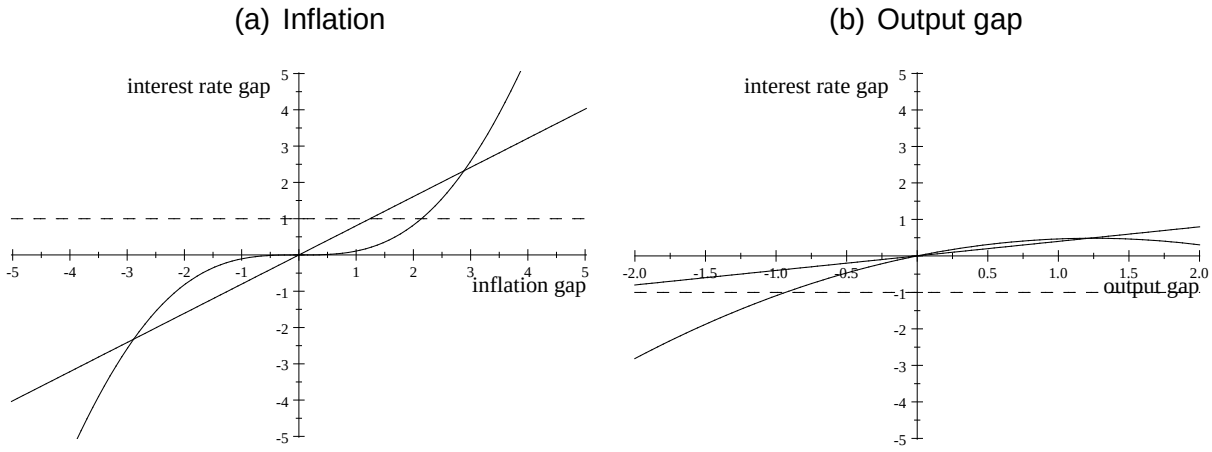
The results for both models show statistically significant coefficients for inflation gap and the output gap. The optimal monetary policy preferences implied by these estimates are illustrated in Figure 2.4. The preferred model shows a negligible response to inflation when it deviates by about 0.5 percent from the inflation target mid-point of 4.5 percent. The results show that the monetary authorities increase the nominal interest rates by 0.4 percent when inflation hits the upper threshold of the inflation target band so that the desired nominal interest rate is at 8.7 percent compared with the equilibrium interest rate of 8.4 percent. When inflation deviates by one percent outside the upper bound of the inflation target, the monetary authorities increase the nominal interest rates by 2.9 percent so that the desired nominal interest rate is 11.4 percent.

The benchmark model implies a constant response of interest rates to changes in inflation regardless of its deviation from the target. The results show that the monetary authorities move interest rates by 0.8 percent when inflation deviates from the inflation target range midpoint of 4.5 percent by 1 percent. The response of nominal interest rates to changes in inflation implied by the benchmark model is stronger than that which is implied by the preferred model when inflation is between 1.6 and 7.4 percent.

With regard to output, the estimated optimal monetary policy rule for the preferred model shows that the monetary authorities cut nominal interest rates by 1 percent when output undershoots the potential by 0.8 percent. The negative coefficient on

the parameter that governs asymmetry implies that monetary authorities' are more aggressive when output falls below that when it overshoots the potential. This implies that monetary authorities' preferences' are biased towards output expansions in that they weigh negative deviations of output more heavily than output expansions. The results for the benchmark model show a constant response to output contractions and expansions as discussed above. The estimated results show that the monetary authorities move the nominal interest rates by 0.4 percent when output deviates from the desired level by 1 percent. The preferred model implies a stronger reaction to output fluctuations compared with the benchmark model whenever output is below its potential.

Figure 2.4 Estimated optimal monetary policy responses to inflation and output



Note: The Figures are obtained by substituting the estimates of inflation and output in equation [7] for the both the linear and the non-linear monetary policy rules

The results for the benchmark monetary policy rule show lower coefficients compared to the recommended size of the coefficients for the Taylor rule. Thus, the estimated benchmark model does not adhere to the Taylor principle that the monetary authorities should move interest rates by more than one to one. This is particularly the case with regard to inflation whereas it is not much the case concerning the output gap. The type of model that is implied by the preferred model has not been estimated for South Africa. However, this chapter draws from Boinet and Martin (2008) who estimate the optimal monetary policy reaction function for the United Kingdom. They find similar results in terms of symmetric zone inflation but

linearity in terms of the output gap. The estimated coefficients in Boinet and Martin (2008) for the monetary authorities' response to inflation in the United Kingdom are larger than the estimated coefficients for the case of South Africa. One of the possible reasons for this is because the inflation target for the United Kingdom is 2.5 percent, which is much lower than that of South Africa. This calls for a more aggressive policy response on the part of the monetary authorities in the United Kingdom.

2.5 Conclusion

This chapter estimates the monetary authorities' response to deviations of inflation and output from their target values using an empirical framework that allows central bank's policy preferences to be zone like and asymmetric. Of particular interest is whether the monetary authorities' preferences are such that they behave differently to deviations in inflation and output when they overshoot or are below their target values and/or when inflation is within or outside the target range. Monthly data for South Africa spanning the period since inflation targeting framework was adopted is used in the analysis. The optimal monetary policy response functions are estimated in a forward looking manner for linearities and nonlinearities, symmetries and asymmetries as well as zone-like responses to inflation and output gaps.

The results show that the monetary authorities react in a passive manner when inflation is about 0.5 percent from the inflation target mid-point of 4.5 percent and become increasingly aggressive when it deviates from the target band. The monetary authorities increase the nominal interest rates by 0.4 percent when inflation hits the upper threshold of the inflation target band and they increase the nominal interest rates by 2.9 percent when inflation deviates by one percent outside the upper bound of the inflation target. The results also show that the monetary authorities react with the same level of aggressiveness regardless whether inflation overshoots or undershoots the inflation target band. With regard to output, the monetary authorities cut nominal interest rates by 1.0 percent when output undershoots the potential by 0.8 percent and they react differently to negative and positive deviations of output from the potential showing that they are more aggressive when output falls below that when it overshoots the potential.

Future research can extend this analysis by evaluating the monetary authorities' reaction to other macroeconomic and financial variables such as asset prices and exchange rates. This is addressed in the next chapter.