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# **Financial asset prices, linear and nonlinear policy rules. An In-sample assessment of the reaction function of the South African Reserve Bank**

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## **Abstract**

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In this paper we provide an in-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. Given the controversial debate on whether central banks should target asset prices for economic stability, we investigate whether the SARB policy-makers pay close attention to asset and financial markets in its policy decisions. The main findings are 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. The SARB policy-makers pay close attention to the financial conditions index when setting interest rate. The SARB's response of monetary policy to inflation is greater during business cycle recessions with not much weight on output and seems to place high importance on inflationary pressures of output during boom periods. The 2007-2009 financial crisis witnesses an overall decreased reaction to inflation, output and financial conditions amidst increased economic uncertainty, with a shift from an asymmetric response to financial conditions over recessions to a more symmetric response irrespectively of the state of the economy.

Keywords: monetary policy, nonlinearity, financial conditions index

JEL: C51; C52; C53; E52; E58

## 1. Introduction

We investigate the objectives of the South African Reserve Bank (the SARB, hereafter) in the light of instrument rules. More precisely, we make use of 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 linear function for the preferences of the Central Banks (a number of other studies have made use of these types of preferences; Cukierman (2002), Bec et al., 2002, Ruge-Murcia (2003)), a nonlinear Phillips curve (Schaling 2004) or, if it follows the opportunistic approach to disinflation (OAD) (Aksoy *et al.* 2007).

These benchmark of monetary policy rules have been the subject of intense debate in the last few years as 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, Sarno, Valente 2004). The view that a central banks' 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, 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. On the other hand, 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), made similar remarks 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."

In the South African context, it is worth noting that the SARB's other primary goals, as defined in the Constitution, is to protect the value of the currency and achieve and maintain financial stability through the South African financial institutions experienced no direct exposure to the sub prime crisis in terms of interbank or liquidity problems of the type experienced in developed countries (see Mboweni, 2008a, 2008b and Mminele, 2009). Also South Africa's economy is highly capitalized. The market value of its financial assets was recently close to 100 percent of Gross Domestic Product, making it a more valid proxy for aggregate wealth (or a claim to aggregate consumption) than in some advanced economies (eg. Italy and Germany – see Campbell (2003), page 811).

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 an early work using such an index, Castro (2008) shows that, in contrast to the Federal Reserve and the Bank of England, ECB policymakers pay close attention to financial conditions when setting the Eurozone interest rate. This marks a significant point of departure for our paper: using inflation, output and a proxy for financial conditions as the main underlying variables, we examine whether monetary policy in the form of nonlinear Taylor rule models can provide additional information over a linear model. In particular, 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 us to test the ability of the state of the business cycles to best describe the nonlinear dynamics of the interest rate in South Africa also accounting for the information available in the financial conditions index. In this paper, the financial condition index is measured as an 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.<sup>1</sup> 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 provides 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).

We have 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. 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 non-linearities are accounted for. Thirdly, given that inflation has been relatively high during most of the sample period, the SARB's response of monetary policy to inflation is greater during business cycle recessions and does not seem to follow output during economic downturns. By contrast, there is high importance placed on inflationary pressures of output during boom periods. Fourthly, the 2007-2009 financial crisis witnesses an overall decreased reaction to inflation, output and financial conditions amidst uncertainty of the oncoming recession, having been in a boom recently. In addition, there has been a shift from an asymmetric policy response to financial conditions over business cycle recessions, to a more symmetric response irrespectively of the state of the economy. Fifthly, rolling estimation reveals that inflation, output gap and financial index coefficients are remarkably unstable since mid 2007 with the oncoming of the crisis.

The paper proceeds as follows. Section 2 summarises the linear and nonlinear models. Section 3 discusses the data. Section 4 reports the in-sample analysis. Section 5 provides some concluding remarks.

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<sup>1</sup> The literature has made a distinction between real-time versus ex post revised (final) data. In particular, Orphanides et al. (2001, 2002, 2005) have shown that empirical estimates of the output gap are subject to significant revisions.

## 2. Monetary policy rules

### 2.1. Linear and nonlinear Taylor rule models

Existing studies of the impact of inflation and output on monetary policy use a version of the Taylor (1993) rule

$$(1) \quad i_t^* = \hat{i} + \rho_\pi E_t(\pi_{t+p} - \pi^*) + \rho_y E_t y_{t+q} + \rho_f E_t \text{fin\_index}_{t+r}$$

where  $i_t^*$  is the desired nominal interest rate,  $\hat{i}$  is the equilibrium nominal interest rate,  $\pi$  is the inflation rate expected at time (t+p),  $\pi^*$  is the inflation target (or desired rate of inflation),  $y$  is the output gap expected at time (t+q),  $\text{fin\_index}$  is a measure of financial conditions gap expected at time (t+r) used to augment the original rule<sup>2</sup>,  $\rho_\pi$  is the weight on inflation,  $\rho_y$  is the weight on output gap and  $\rho_f$  is the weight on the financial index. Allowing for interest rate smoothing (see e.g. Woodford, 2003) by assuming that the actual nominal interest rate,  $i_t$ , adjusts towards the desired rate by

$$(2) \quad i_t = \rho_i(L)i_{t-1} + (1 - \rho_i)i_t^*$$

we write the empirical Taylor rule as

$$(3) \quad i_t = \rho_i(L)i_{t-1} + (1 - \rho_i)\{\rho_0 + \rho_\pi E_t \pi_{t+p} + \rho_y E_t y_{t+q} + \rho_f E_t \text{fin\_index}_{t+r}\} + \varepsilon_t$$

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),  $\rho_0 = \hat{i} - \rho_\pi \pi^*$ , and  $\varepsilon_t$  is an error term.

The theoretical basis of the linear Taylor rule (3) comes from the assumption that policymakers have a quadratic loss function and that the aggregate

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<sup>2</sup> The 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 Leroi (2010).

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. A nonlinear policy rule also results from assuming a nonlinear Phillips curve combined with a quadratic loss function.

We consider the following nonlinear policy rule type.

$$(4) \quad i_t = \rho_i(L)i_t + (1 - \rho_i) \left\{ \rho_0 + \theta_t^y(E_t y_{t+q}; \gamma^y; \tau) M_{1t} + (1 - \theta_t^y)(E_t y_{t+q}; \gamma^y; \tau) M_{2t} \right\} + \varepsilon_t$$

where  $M_{jt} = \rho_{j\pi} E_t \pi_{t+p} + \rho_{jy} E_t y_{t+q} + \rho_{jf} E_t \text{fin\_index}_{t+r}$  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)), at the beginning of period  $t$ , that output in period  $(t+q)$  will be less than  $\tau$  percent points from equilibrium. In model (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  $\tau$  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 (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):

$$(5) \quad \theta_t^y(E_t y_{t+q}; \gamma^y; \tau) = 1 - \frac{1}{1 + e^{-\gamma^y (E_t y_{t+q} - \tau) / \sigma(E_t y_{t+q})}}$$

In (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  $\gamma^y$  dimension-free by dividing it by the standard deviation of  $E_t y_{t+q}$ .

### 3. Data description

We use South African monthly seasonally adjusted data sourced from the SARB database. The sample ranges from 2000:01 to 2008:12, which covers the inflation targeting regime in South Africa. The repurchase rate (repo rate) measures the nominal interest rate. Inflation is measured by the annual change in the consumer price index. Output is measured using the coincident business cycle indicator computed by the SARB and we measure the output gap as the deviation of this from a Hodrick-Prescott (1997) trend.

The financial index variable pools together relevant information provided by a number of financial variables. The index is constructed as a weighted average of (i) the real effective exchange rate with the foreign exchange rate in the denominator, (ii) the real house price index 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 which is measured by the Johannesburg Stock Exchange All Share index, deflated by the consumer price index (iv) the credit spread which is the spread between the yield on the 10-year government bond and the yield on A rated corporate bonds, and (v) the future spread which is the change of spread between the 3-month interest rate futures contracts in the previous quarter and the current short-term interest rate.

The real effective exchange rate, stock price and house price variables are detrended by a HP filter. To tackle the end-point problem in calculating the HP trend (see Mise *et al*, 2005a,b), we applied an autoregressive (AR( $n$ )) model (with  $n$  set at 4 to eliminate serial correlation) to the output measure and the components of the financial index. The AR model was used to forecast twelve additional months that were then added to each of the series before applying the HP filter. The constructed financial index is expressed in standardised 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. Additionally, all data are seasonally adjusted. The index is also in the spirit of the UK financial conditions index provided by the Bank of England's Financial Stability Report (Bank of England, 2007).

The evolution of the main variables is shown in Figure 1. 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. Movements in the financial index have a similar pattern to the interest rate which indicates a close link between the two variables, particularly towards the end of the sample.

Using the above information set, we consider the models set out in section 2; these are reported in Table 1. Our preferred specifications allow  $p = q = 3$  for inflation ( $E_t \pi_{t+p}$ ) and output gap ( $E_t y_{t+q}$ ) and, a current rather than a forward-looking version for the financial index ( $E_t \text{fin\_index}_{t+r}$ ) 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 by the Generalised Method of Moments (GMM).

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 2008:M9 (this setup delivers 33 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.<sup>3</sup> The rolling scheme can also

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<sup>3</sup> 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.

be used to guard from moment or parameter drift which might be particularly relevant amidst the financial crisis.

## 4. In-sample analysis

### 4.1 Empirical results for the first window of estimation

To fix ideas, Table 2 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 ( $\rho_\pi$ ), output gap ( $\rho_y$ ) and financial index ( $\rho_f$ ) 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  $\rho_\pi$  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 above 1.61 percentage point. An estimate of the inflation target is derived as  $\pi^* = \frac{\hat{i} - \rho_0}{\rho_\pi}$ , where (see e.g. Clarida et al., 2000) we rely on the sample mean of the interest rate (which is equal to 10.03%) as a proxy for the equilibrium nominal interest rate  $\hat{i}$ . From Table 2, the linear model delivers an implied target of approximately  $\pi^* = 5.5\%$ , which is consistent with the SARB’s inflation target zone of 3-6%.

For the linear model (Model 1), the last three rows of Table 2 report Hamilton’s (2001)  $\lambda$ -test, and the  $\lambda_A$  and  $g$ -tests proposed by Dahl and González-Rivera (2003). Under the null hypothesis of linearity, these are Lagrange Multiplier test statistics following the  $\chi^2$  distribution<sup>4</sup>. These tests

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<sup>4</sup> 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.

are powerful in detecting non-linear regime-switching behaviour like the one considered by Model 2. All three tests reject linearity.

From Table 1, 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 0.5. The smoothness parameter  $\gamma^y$  has an estimated value of 5, indicating a rather quick switch from one regime to another. From the nonlinear model (column 2 of Table 2) we report that  $\rho_{1\pi} > \rho_{2\pi}$ ; hence, the response of monetary policy to inflation is greater during business cycle recessions and lower during business cycle expansions with the Taylor principle requirement not being met over business cycle upturns. Also,  $\rho_{1y} < \rho_{2y}$ , suggesting that the SARB reacts very aggressively to output gap in expansionary states of the economy. A plausible explanation is that given that inflation has been relatively high over the sample period, the monetary authority does not follow output in recession but is concerned over the inflation pressures that might arise as a consequence of a pronounced boom. The results also reveal that  $\rho_{1f} > \rho_{2f}$ , that is, a stronger response to the financial conditions index during business cycle downturns than during business cycle upturns.<sup>5</sup>

We have also attempted linear and nonlinear versions of Models 1 and 2 that exclude the financial index variable. Also nonlinear policy rules can be defined using inflation or the financial index as possible transition variables in the weight function (5). This implies that the response of interest rates to inflation, output gap and the financial index depends on inflation and financial

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<sup>5</sup> With the aim to determine the causal relationship between inflation and financial condition index we perform a Granger causality test. A VAR is modeled with a lag order of 2 as suggested by four of the Lag order selection tests among them the AIC. The Ganger causality test reveals that there is a unidirectional causality running from the financial condition index to inflation (the null of no Granger causality is rejected at 1% level of significance). In contrast, inflation does not Granger-cause the financial condition index as we fail to reject the null.

conditions regimes, respectively. Alternatively, one can use the quadratic logistic function as in Martin and Milas (2004). The advantage of this nonlinear form is that it allows for an inflation zone targeting regime. These nonlinear models were considered and in statistical terms, these models performed quite poorly compared to the models reported here in terms of AIC criterion. We therefore conclude 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., business cycles.

#### **4.2 Parameter evolution with recursive expanding windows of estimation**

To get an idea of how the response parameters  $\rho_\pi$ ,  $\rho_y$ , and  $\rho_f$  evolve over time, Figure 2 plots the recursive estimates (plus/minus 2\*standard errors) over expanding data windows, together with the implied inflation target rate,  $\pi^*$  for Model 1. Figure 3 plots recursive estimates (plus/minus 2\*standard errors) of the response parameters  $\rho_{j\pi}$ ,  $\rho_{jy}$ ,  $\rho_{jf}$  ( $j=1,2$ ) and the implied inflation target rate,  $\pi^*$  for Model 2.

For the linear model (Figure 2), 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 2006, then surprisingly falls and became insignificant in early 2008. However as stressed by 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. A possible explanation of our findings is that the magnitude of the response using final data of the output gap could suffer from downward bias owing to the errors-in-variables problem. The response to the financial index remains relatively stable until late 2007, 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 oncoming recession, having been in a boom recently. The evolution of the implied target inflation rate has been relatively

stable until late 2006, after which there has been an upward tendency to deviate from the target zone of 3-6%, conformed with the fall in the response to inflation over the recent business cycle downturn.

Figure 3 plots the recursively estimated response coefficients  $\rho_{1\pi}$ ,  $\rho_{1y}$ ,  $\rho_{1f}$ ,  $\rho_{2\pi}$ ,  $\rho_{2y}$ , and  $\rho_{2f}$  for the nonlinear Model 2. In this model, the policy response switches from  $\rho_{1\pi}$ ,  $\rho_{1y}$  and  $\rho_{1f}$  to  $\rho_{2\pi}$ ,  $\rho_{2y}$  and  $\rho_{2f}$ , 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 downturns has declined consistently while that over booming 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 has increased consistently over business cycle recessions while the response over business cycle booms has dropped dramatically and has become largely insignificant.

The financial index response is marginally higher over business cycle downturns versus upturns beginning of 2006. However as the financial crisis unfolds stabilisation of the financial conditions becomes equally important irrespectively of the state of the economy; indeed, the response to the financial index emerges the same by the end of our sample. The results also reveal that the monetary authorities pay close attention to the financial conditions index when setting interest rates by allowing a more symmetric response to financial conditions irrespectively of business cycle upturn or downturn. Our nonlinear estimates therefore indicate that the SARB policymakers use some discretion post 2007 as the financial crisis saw a shift from inflation targeting to output stabilisation and a shift, from an asymmetric policy response to financial conditions, to a more symmetric response irrespectively of the state of the economy. The implied inflation target rate has surprisingly fallen. However these results should be read with some caution as the confidence intervals of the recursive nonlinear responses get relatively wider with the financial crisis unfolding.

### 4.3 Parameter evolution with fixed-length rolling windows of estimation

Figure 4 plots the rolling fixed-length window estimated response coefficients (plus/minus 2\*standard errors)  $\rho_{\pi}$ ,  $\rho_y$ ,  $\rho_f$  for the linear Model 1 and figure 5 plots the rolling estimates (plus/minus 2\*standard errors)  $\rho_{j\pi}$ ,  $\rho_{jy}$ ,  $\rho_{jf}$  ( $j=1,2$ ) for Model 2.

Figure 4 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 to financial markets from 2007 onward. A stark finding come with an inspection of Figure 5 with a sharp hike and volatile responses toward the end of 2007. We conclude the findings that the rolling estimated inflation coefficients  $\rho_{1\pi} > \rho_{2\pi}$  support our earlier results with the recursive estimation, with a sharper fall in the 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 increased consistently over business cycle recessions while the response over business cycle booms has dropped dramatically and has become largely insignificant. The recursively estimated financial index coefficients  $\rho_{1f}$  and  $\rho_{2f}$  are fairly similar suggesting a sustained increased response to financial markets in the SARB monetary policy. There is also a fall in the implied inflation target rate which conforms with a subdued reaction to inflation post 2007.

An inspection of linear and nonlinear model from Table 2 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. Model 1 (the linear model) records the lowest Akaike Information Criterion (AIC). Figure 6 plots the recursive AIC values for both linear and nonlinear models with recursive and rolling estimations. The nonlinear model under fixed-length rolling estimation

records the best AIC criterion and consistently dominates the remaining estimates.

## 5. Conclusions

In this paper 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, we assess policy in-sample. In addition, we perform recursive and rolling estimations of the policy rules 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., 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 recessions with low response to output and a higher weight placed on output during boom periods to curtail inflationary pressures. On the other hand, the 2007-2009 financial crisis witnesses an overall decreased response to inflation, output and financial conditions with an asymmetric policy response to financial conditions during business cycle downturns, to a more symmetric response irrespectively of the state of the economy. 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 than in the US where financial conditions do not feature in the Federal Reserve Bank's reaction function. Similar results have

been found in the context of the European Central Bank that targets financial conditions, contrary to the UK and the US central banks. This lack of attention to the financial conditions might have made the UK and the US more vulnerable to the recent credit crunch than the Euro zone and economies such as South Africa.

Our work can be extended in several ways. It would be interesting to estimate our model using data for different Central Banks. Also out-of-sample predictions of the different models might provide further insights in the interest rate setting behaviour of Central Banks. We intend to address these issues in future work.



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Table 1: Model definitions

1	$i_t = \rho_1 i_{t-1} + (1 - \rho_1) \{ \rho_0 + \rho_\pi E_t \pi_{t+12} + \rho_y y_t + \rho_f \text{fin\_index}_{t-1} \} + \varepsilon_t$ <p>Linear model</p>
2	$i_t = \rho_1 i_{t-1} + (1 - \rho_1) \{ \rho_0 + \theta_t^y(y_t; \gamma^y, \phi) M_{1t} + (1 - \theta_t^y(y_t; \gamma^y, \phi)) M_{2t} \} + \varepsilon_t$ <p>where <math>M_{jt} = \rho_{j\pi} E_t \pi_{t+12} + \rho_{jy} y_t + \rho_{jf} \text{fin\_index}_{t-1}</math> for <math>j=1,2</math> and <math>y_t</math> is the transition variable.</p> <p>Nonlinear logistic model</p>

Table 2: Model estimates, 2000:M1-2005:M12

<b>Coefficients</b>	<b>Model 1</b>	<b>Model 2</b>
$\rho_0$	3.477(0.348)	2.086(0.216)
$\rho_1$	0.928(0.003)	0.924(0.002)
$\rho_\pi$	1.162(0.051)	
$\rho_y$	0.441(0.113)	
$\rho_f$	1.614(0.107)	
$\rho_{1\pi}$		1.640(0.051)
$\rho_{1y}$		0.189(0.096)
$\rho_{1f}$		2.033(0.108)
$\rho_{2\pi}$		0.772(0.041)
$\rho_{2y}$		3.672(0.166)
$\rho_{2f}$		1.593(0.474)
$\tau$		0.502(0.201)
$\gamma^y$		5.00 (2.02)
Implied $\pi^*$	5.50	6.05
AIC	0.79	0.98
Regression standard error	0.384	0.380
$\bar{R}^2$	0.974	0.974
J-stat	0.245	0.253
$\lambda$ -test	0.001	
$\lambda_A$ -test	0.000	
$g$ -test	0.001	

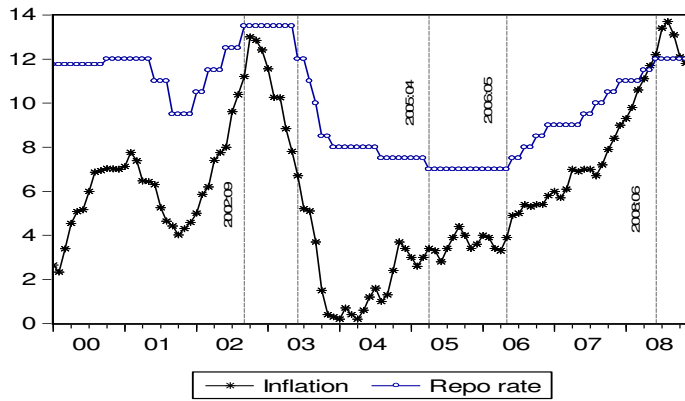
Notes: Numbers in parentheses are standard errors. (ii) The implied target  $\pi^*$  is derived as

$$\pi^* = \frac{\hat{i} - \rho_0}{\rho_\pi}, \text{ where } \hat{i} = 10.03\%. \text{ AIC is the Akaike Information Criterion.}$$

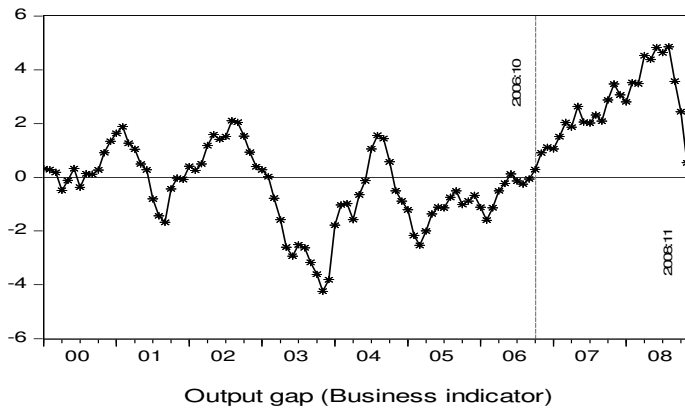
J stat is the  $p$ -value of a chi-square test of the model's over-identifying restrictions (Hansen, 1982). The set of instruments includes a constant, 1-6, 9, 12 lagged values of repo rate, the inflation, the output gap, the 10-year government bond, money (M3) growth, and the financial index. The table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

**Figure 1: Interest rate, inflation, output measures and the financial index**

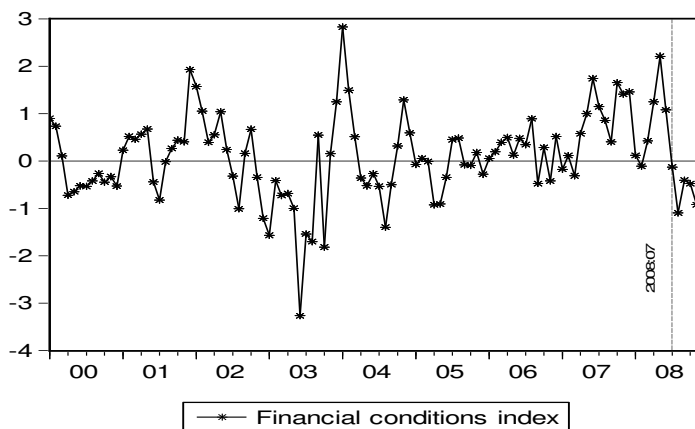
**a) Interest rate and inflation measures**



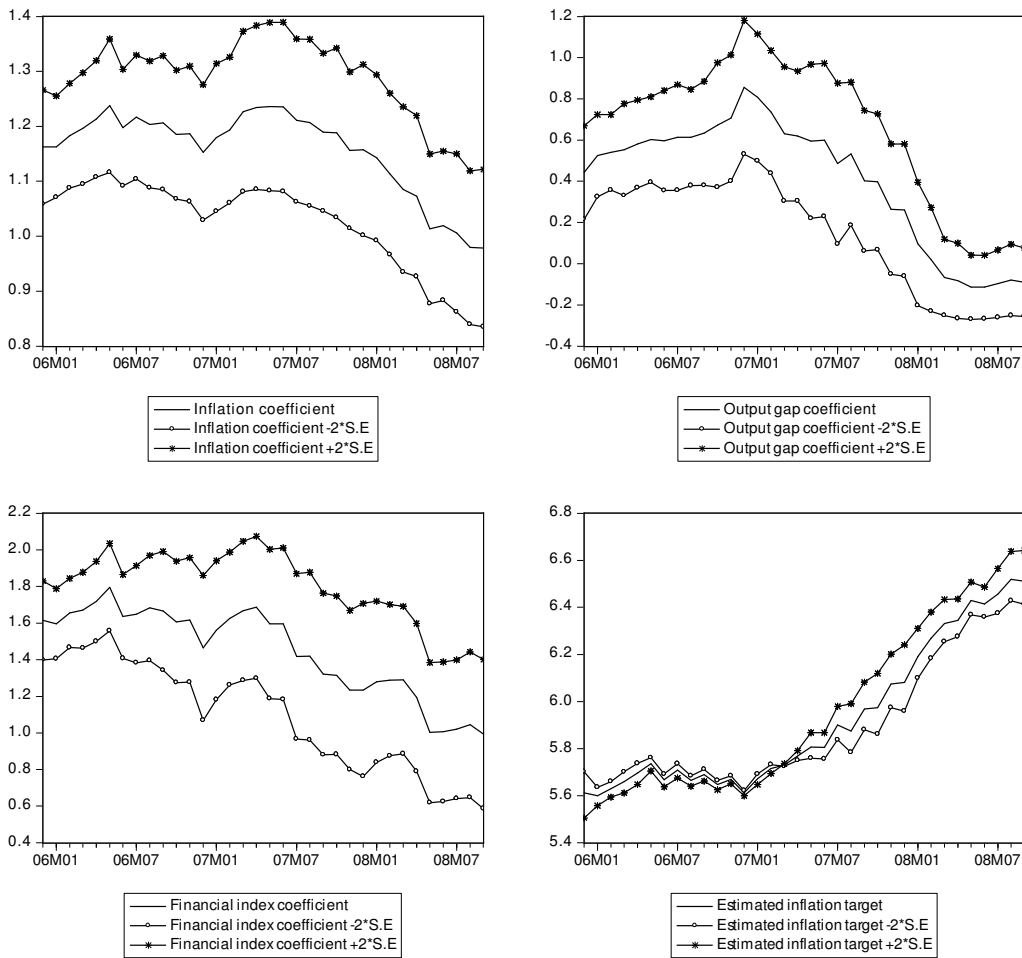
**b) Output measures**



**c) Financial index**

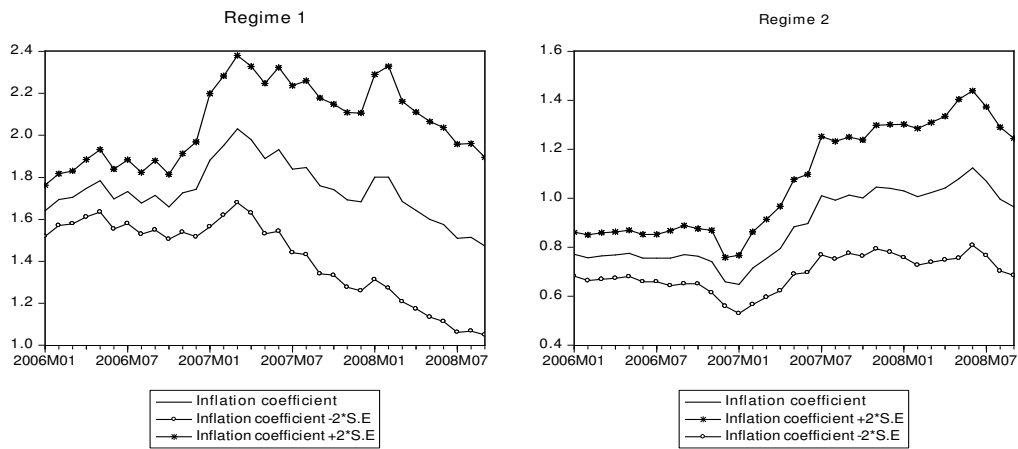


**Figure 2: Recursive inflation, output gap, and financial index coefficients together with implied inflation target (linear model)**

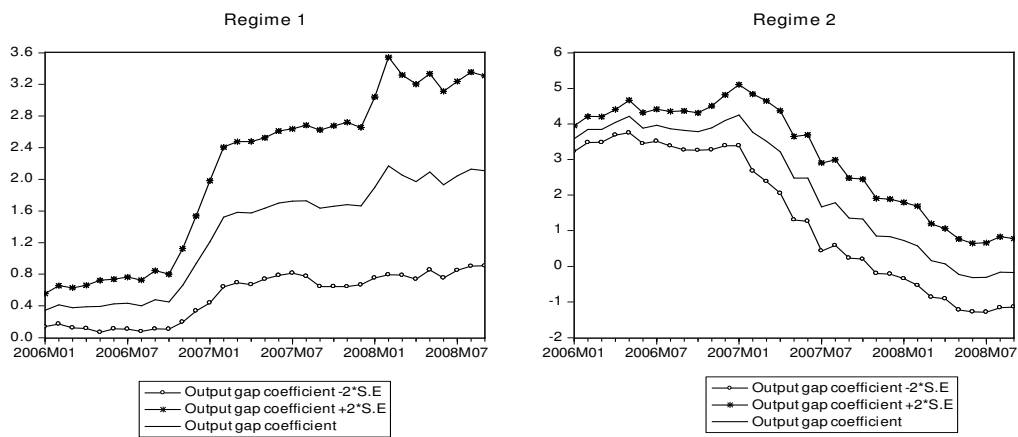


**Figure 3: Recursive inflation, output gap, and financial index coefficients together with implied inflation target (nonlinear model)**

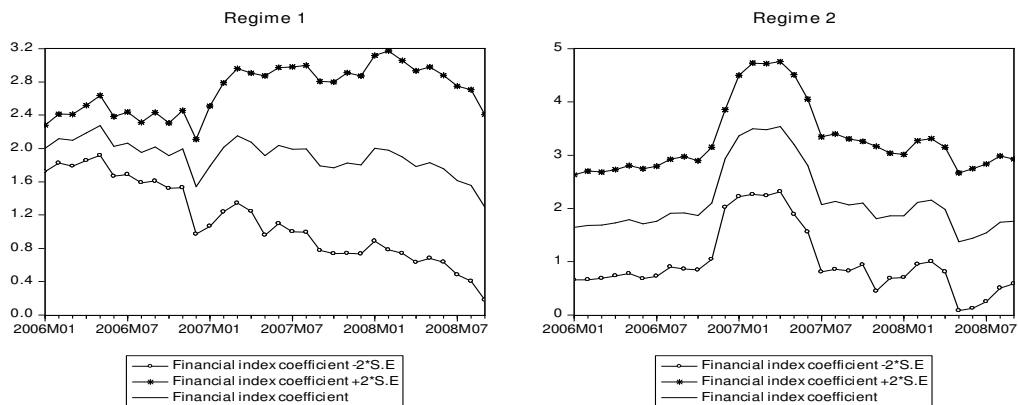
**a) Inflation coefficients  $\rho_{1\pi}$  and  $\rho_{2\pi}$**



**b) Output gap coefficients  $\rho_{1y}$  and  $\rho_{2y}$**

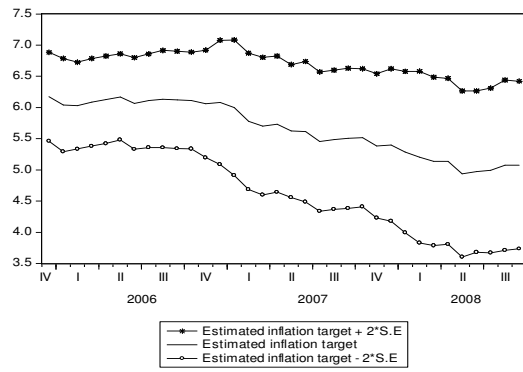


**c) Financial conditions index coefficients  $\rho_{1f}$  and  $\rho_{2f}$**

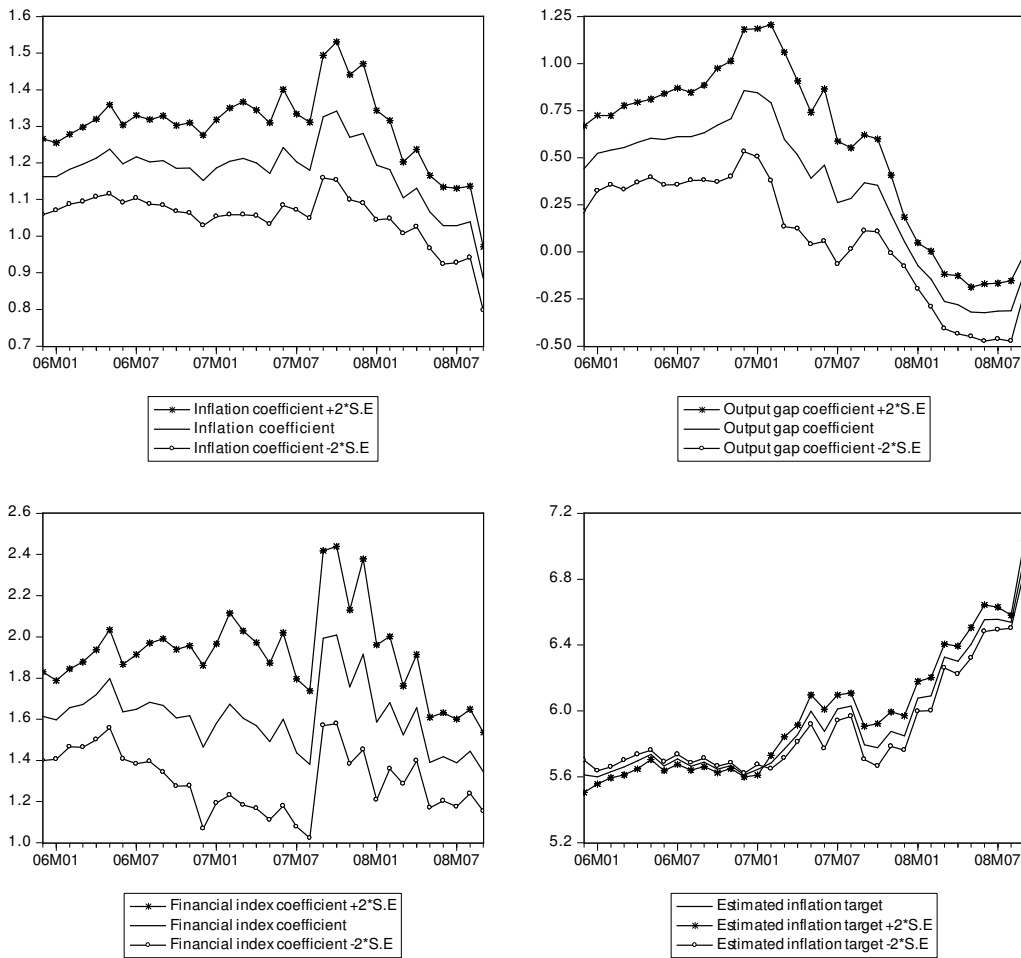




### d) Estimated inflation target

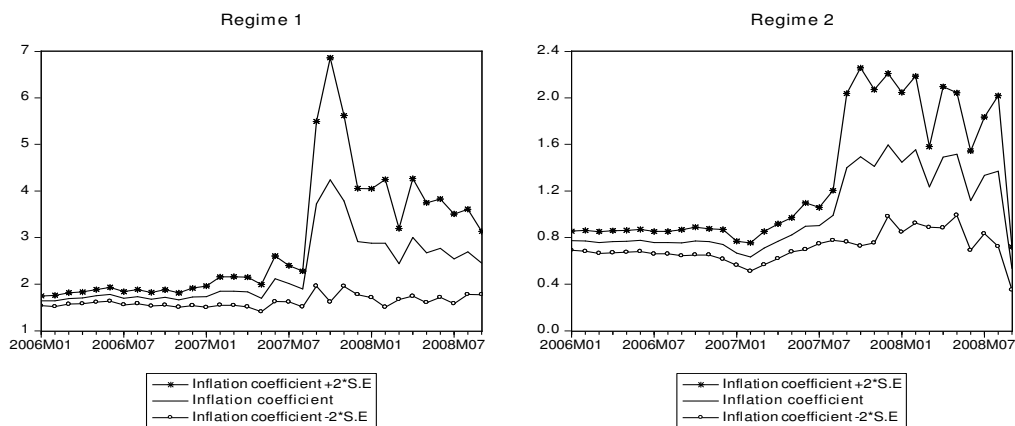


**Figure 4: Rolling inflation, output gap, and financial index coefficients together with implied inflation target (linear model)**

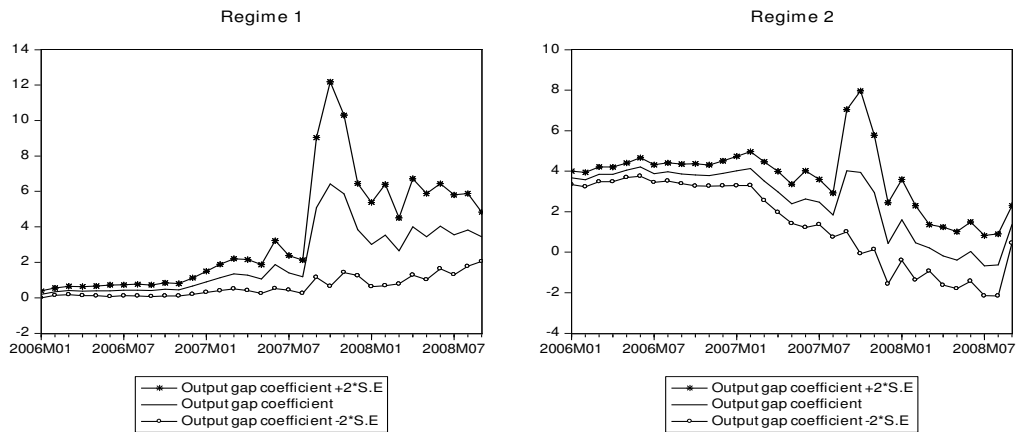


**Figure 5: Rolling inflation, output gap, and financial index coefficients together with implied inflation target (nonlinear model)**

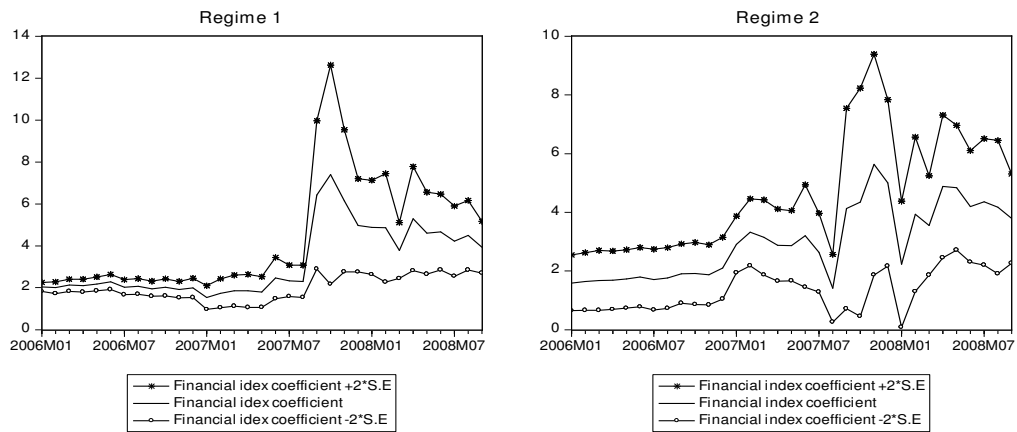
a) Inflation coefficients  $\rho_{1\pi}$  and  $\rho_{2\pi}$



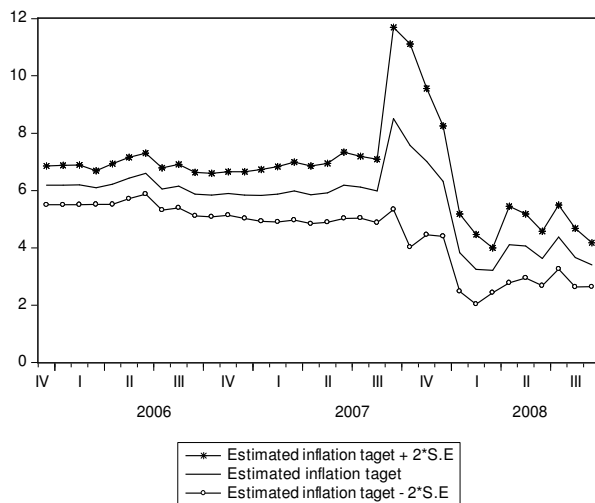
**b) Output gap coefficients  $\rho_{1y}$  and  $\rho_{2y}$**



**c) Financial conditions index coefficients  $\rho_{1f}$  and  $\rho_{2f}$**



**d) Estimated inflation target**



**Figure 6: Akaike Information Criterion (AIC)**

