![The University of Sydney]

School of Economics and Political Science

Working Papers

Asymmetric Monetary Policy in Australia

Shawn Chen-Yu Leu and Jeffrey Sheen

ECON2005-2

Discipline of Economics
Faculty of Economics and Business

Faculty of Economics and Business

e+b

Asymmetric Monetary Policy in Australia

Shawn Chen-Yu Leu and Jeffrey Sheen

School of Economics and Political Science
University of Sydney, Australia

Email: jeffs@econ.usyd.edu.au

ABSTRACT

We find evidence for asymmetric behaviour in Australian monetary policy. During 1984-1990, the Reserve Bank of Australia acted with considerable discretion yielding poor performance of an interest rate rule. However it behaved asymmetrically to inflation and the output gap in downturns and upturns. On embracing inflation targeting from 1991, it enhanced its credibility by anchoring inflation expectations. Not only did its actions become more predictable in 1991-2002, it responded asymmetrically only to output, switching to act more acutely in downturns. While its asymmetric behaviour could result from asymmetric preferences or non-linear aggregate supply, our results support the former explanation.

CONTENTS

1. Introduction

For countries that have floating exchange rates and free capital mobility, monetary policy has come to play an increasingly vital role in the stabilization of the economy. Though monetary policy instruments can affect a wide range of macroeconomic variables, attention is usually focused on a measure of aggregate output and the rate of inflation. Taylor (1993) proposed a simple symmetric monetary policy rule whereby the monetary authority adjusts the short-term interest rate—the ubiquitous monetary policy instrument—to respond to observed inflation and output fluctuations in the economy. This feedback rule was shown to fit the Federal Reserve's interest rate setting behaviour remarkably well for the period between 1987 and 1997 (see Taylor (1999a)). The ability of this simple monetary policy rule to capture an inherently complex decision-making process is appealing, and has prompted much research.

Monetary policymaking, however, is forward-looking by nature due to long and variable policy lags. Monetary authorities utilize forecasts of future economic conditions to formulate policy actions in the present. Clarida, Gali and Gertler (1998, 1999, 2000) extended the baseline Taylor specification with the monetary authority assumed to adjust the short-term interest rate in response to expected future inflation deviations from its target value and current output deviations from its trend value. In both the backward-looking and forward-looking specifications, the implication is that the monetary authority responds with symmetrical intensity to positive and negative deviations in inflation and/or output in relation to their respective target values.

Several papers have provided explicit micro-foundations to derive the symmetric monetary policy rule—for example, Svensson (1997, 1999), Rotemberg and Woodford (1998), and Clarida, Gali and Gertler (1999). Given the optimizing behaviour of the monetary authority, the preferences of policy-makers are usually approximated by a quadratic loss function of deviations of inflation from its target value and output from its trend value (for example, see equation (2.7) in Clarida, Gali and Gertler (1999), p.1668). When the quadratic function is combined with a linear aggregate supply relation (or a Phillips curve), the first-order result of minimizing the loss function yields a linear symmetric monetary policy rule. The ultimate policy goal is to maximize the welfare of the society, but this does not necessarily imply that the monetary authority should deem positive inflation and output gaps as unpalatable as the negative ones.

Extending the influential inflation bias framework propounded by Kydland and Prescott (1977) and Barro and Gordon (1983), Cukierman (2000) developed an environment where the monetary authority is uncertain about the state of the economy and displays greater aversion to under- than over-employment. He showed that the monetary authority may respond relatively more aggressively to negative output gaps generated by an adverse supply shock than positive output gaps generated by a favourable supply shock of the same magnitude. In addition, the monetary authority is assumed to attract more criticism when pre-emptively contracting the economy to reduce inflation compared with stimulating the economy to reduce unemployment. These possibilities imply that the monetary authority possesses an asymmetric preference function. Gerlach (2000), Bec, Salem and Collard (2002) and Ruge-Murcia (2002, 2004) provided evidence that central banks in different countries exhibit asymmetric behaviour. While this observed asymmetric behaviour may be explained by asymmetric preferences, Dolado, Maria-Dolores and Naveira (2005) have shown that it may also arise from a non-linear aggregate supply relation. There is other recent evidence that suggests a convex relationship between inflation and output (see Debelle and Laxton (1997), Debelle and Vickery (1998)).

This paper tests for the presence of asymmetric policymaking behaviour by the Reserve Bank of Australia (RBA) in the post-float era after 1983. We examine whether the RBA reacted differently to future expected inflation and output gaps during the expansionary and contractionary phases of the business cycle. Following de Brouwer and Gilbert (2005) who identified 1991 as a point of policy break due to the implementation of inflation targeting, we split our sample then to see if there is a difference in the asymmetry of monetary policy before and after the inception inflation targeting.[1] For each of the two periods, we estimate and test for evidence that the RBA behaved asymmetrically across the two states of the business cycle. If the evidence favours asymmetry, we ask the following questions: Did the RBA view the future expected deviations in inflation and/or output gaps from the target values to be more costly during expansions than contractions, or vice versa? Did the introduction of an explicit inflation target range restore symmetry in the response of the RBA to inflation? Did it change the intensity of its response to output gaps in downturns relative to upturns? What was the implied neutral (or natural, or medium-run

equilibrium) interest rate for each period? Finally, what was responsible for any observed asymmetric behaviour— asymmetric preferences or a non-linear supply relation?

We extend the forward-looking interest rate setting rule in a non-linear fashion by applying a threshold model representation. In devising a dummy variable to classify the two states of the business cycle, Bec, Salem and Collard (2002) used the sign of lagged output gap, where the current period is classified as an expansion (contraction) if the lagged output gap is positive (negative). Working with monthly data, these authors assumed that a monthly lag of the *level* of the output gap is a good indicator of the contemporaneous state of the business cycle. According to Debelle (1999), the RBA formulates current policy actions by considering the future business cycle in terms of expected output growth. Therefore we use *changes* in the output gap as a classification scheme to better capture this aspect of policymaking.

The forward-looking non-linear monetary policy rule is estimated by the generalized method of moments (GMM), which exploits a set of orthogonality conditions based on the assumption that the monetary authority forms expectations rationally. Assuming the monetary authority is forward-looking, it must generate forecasts with the aid of information available at the time of setting the interest rate. The GMM estimation in this context is therefore built on a weak rational expectations hypothesis that the forecast errors are not systematically related to the information set used by the monetary authority.

We find significant evidence of asymmetric policymaking by the RBA in the post-float era. The form of the asymmetry, however, differed as the monetary policy framework moved from monetary aggregate targeting and the checklist approach in the 1980s into the current inflation targeting regime that began in the early 1990s. In the first period from 1984 to 1990, when inflation was relatively high, the estimation results suggest that the RBA adjusted the cash rate more aggressively during expansions than contractions to counter future expected inflation and output gaps. This result reflects the intensity with which the RBA fought to bring down inflation, which culminated in the high interest rate in the late 1980s that set the economy on its subsequent disinflation path. In the early 1990s, the RBA took the opportunity to lock in the low inflation environment by introducing first an implicit inflation target, and then an explicit one. We find that the pattern of asymmetric behaviour differed in the inflation targeting period, with the RBA responding asymmetrically to future expected output gaps only. Although the RBA's explicit policy objective was an inflation target band of 2 to 3 percent, it was a medium-run consideration, and their

---

[1] Grenville (1997) pointed out that the RBA started to focus internally on an inflation target by 1991, however, the new regime and the target were not announced publicly until 1993.

responses to deviations from that appeared to be symmetric. The estimated coefficients indicate that the RBA placed a greater weight on stabilizing output during contractions than expansions.[2] Our asymmetry output-gap result demonstrates the degree of flexibility that can be and was exercised to attend to the real economy in the short run. This was consistent with the commentaries provided by some RBA officials (see Debelle (1999) and Stevens (2003, 2004)). From our asymmetric results, we deduce that the explanation was likely to be asymmetric preferences rather than a non-linear aggregate supply relation.

This paper is organized as follows. Section 2 reviews the theoretical and empirical literature on monetary policy rules. Section 3 provides an estimable form of the non-linear monetary policy rule. In section 4 we briefly discuss the applicability of GMM to estimating forward-looking monetary policy rules. Section 5 describes the data used in the estimation, provides the GMM estimation results, and checks for possible problems with weak instruments. Section 6 concludes.

2. Literature Review

2.1   A Linear Monetary Policy Rule
In the context of the debate on rules versus discretion, Taylor (1993) advocated the embedding of a policy rule in the research on the conduct and design of monetary policy. Using the assumption that the operating instrument of monetary policy is the short-term interest rate, a simple feedback rule was proposed which calls for the interest rate to adjust in response to changes in the inflation rate and fluctuations in real output. The rule was of the form:

$$i_t^* = \bar{i} + \beta(\pi_{t-1} - \pi^T) + \gamma x_{t-1} \tag{1}$$

where $\bar{i} = \bar{r} + \pi_{t-1}$, $\beta > 0$ and $\gamma > 0$. In this formulation, the target interest rate that the monetary authority controls is i_t^*, $\bar{i}$ becomes the *neutral* nominal interest rate in medium-run equilibrium when inflation is on target and the

output gap is zero, and $\bar{r}$ is the neutral real interest rate[3], π_{t-1} and π^T are the current and (implicit or explicit) target inflation rates respectively, x_{t-1} denotes the output gap which is defined as $x_{t-1} \equiv y_{t-1} - y^*$, where y_{t-1} is current output and y^* is potential output that would arise if wages and prices were perfectly flexible.[4]

According to (1) any positive deviation of the inflation rate from its target value prompts the monetary authority to raise the level of target interest rate more than one-for-one, that is by $1+\beta$. This is necessary so that the real interest rate rises to curb economic activity when inflation increases. The feedback rule also stabilizes economic activity since the monetary authority increases the target interest rate when a positive output gap is observed.

In Bryant, Hooper and Mann (1993), nine different multi-country econometric models using variants of the interest rate rule were compared on their performance in terms of output and price variability. There are three types of interest rate rules utilized in these models: interest rates responding to deviations of the money supply from some target; interest rates responding to deviations of the exchange rate from some target; and interest rates responding to weighted deviations of the inflation rate and real output from some target. In particular, the authors found that the interest rate rule focusing on inflation and real output movements delivers the smallest output and price variability. Further supporting the use of interest rate rule to describe the behaviour of the monetary authority, Taylor (1999a) informally chose $1+\beta = 1.5$, $\bar{r} = 2$, $\pi^T = 2$, and two sub-cases of $\gamma = 0.5$ and $\gamma = 1$ for the policy rule to fit the actual interest rate time series.[5] It was shown that the federal funds rate implied by (1) with the fixed weights from both sub-cases tracks its realized counterpart remarkably well over the period 1987-1997.

This simple and intuitive configuration of the interest rate rule is appealing to those studying the systematic behaviour of the monetary authority.

---

[2] Employing a hyperbolic tangent smooth transition regression model and linex function to examine Australia during the inflation targeting period, Karagedikli and Lees (2004) drew a similar conclusion—a larger movement in the cash rate is associated with a negative output gap than with a positive output gap.

[3] The 'neutral' interest rate is a concept that has been used increasingly by central bank officials. For example, see www.rba.gov.au/Education/UnderstandingStatistics/box_d_bu_0801_1.pdf. The idea is that at this interest rate inflation is stable and output is growing at a normal rate.

[4] We use $t-1$ values for observed inflation and output because almost all interest rate decisions will be made (and recorded at the end of period t) using $t-1$ information.

[5] The original assignment of the coefficient for the output gap in Taylor (1993) was $\gamma = 0.5$. Subsequent studies, such as Ball (1998), proposed that γ should be closer to 1 in order to achieve an efficient monetary policy rule, which is defined as having minimum output and inflation variances.

Indeed, since Taylor (1993) popularized the concept there has been much interest on the research of monetary policy rules for policy evaluation. However, the backward-looking Taylor rule does not capture the essential features of contemporary monetary policymaking. Most notably since the adoption of an inflation targeting regime by a number of central banks around the world starting in the early 1990s, the process of monetary policy decision-making is best characterized as forward-looking in nature.[6] At the heart of the regime is the specification of a numerical inflation target, and in most cases, an explicit tolerance band around the inflation target. Meyer (2001) described the Australian regime as having an explicit inflation target with a dual mandate of maintaining price stability and full employment. More specifically, the mandate calls for the inflation to be managed between 2 and 3 percent 'on average, over the cycle' (Stevens (2003), p.20) which makes inflation targeting a medium-run objective. This recognizes that inflation is harder to control precisely in the short run, and attempts to do so may create unnecessary macroeconomic volatility. Therefore the short-run focus of the RBA is to stabilize the real side of the economy while allowing for temporary blips on the inflation radar (Stevens (2003)). Because of both uncertainty and the policy lag inherent in monetary policy design, monetary authorities invariably rely on forecasts of future economic condition for guidance in aligning the expected future inflation path with the target (see Svensson (1997) and Stevens (2004)).

Clarida, Gali and Gertler (1998, 1999, 2000) generalized the baseline Taylor (1993) specification by incorporating forward-looking behaviour exhibited by the monetary authority. In their papers, the interest rate is set in response to future expected inflation deviation from the target value, as well as the contemporaneous output gap. In this paper we assume that the target interest rate in each period is a function of the expected future gaps in inflation from the target value and output from the trend value:

$$i_t^* = \bar{i} + \beta(E[\pi_{t+m} | \Lambda_t] - \pi^T) + \gamma E[x_{t+n} | \Lambda_t] \qquad (2)$$

where E is the expectation operator and Λ_t represents the collection of information available to the monetary authority at the time of setting the interest rate. Hence $E[\pi_{t+m}|\Lambda_t]$ and $E[x_{t+n}|\Lambda_t]$ are forecasted values of inflation and output gap in periods $t+m$ and $t+n$ respectively which are based on the information set Λ in period t. This forward-looking specification nests the baseline Taylor specification as a special case. If either current inflation or a linear combination of lagged inflation and the current output gap are a sufficient predictor for future inflation, the forward-looking specification collapses to the baseline Taylor rule. It also extends in a realistic fashion the ability of the monetary authority to consider a broader array of information, beyond lagged inflation and output, to form beliefs about the future condition of the economy.

Neither the backward-looking nor the forward-looking version of the interest rate rule is able to capture the observed tendency of central banks to smooth changes in interest rates (for a survey of the issue, see Lowe and Ellis (1997)). English, Nelson and Sack (2003) offered two possible reasons for such behaviour. First, an inertial policy represents an optimal response to shocks. The slow adjustment of interest rates, through its influence on the expectations of future policy movements, prevents the policy-makers from suffering credibility losses from sudden and large policy reversals, thus delivering a more effective control over inflation and output. Battellino, Broadbent and Lowe (1997) extended this line of reasoning to the fear of disrupting capital markets associated with aggressive movements in the short-term interest rate. Second, interest rate smoothing is seen as a precautionary stance against uncertainty about the structure and parameters of the true macroeconomic model, or about the quality of contemporaneous data releases. Given the observed sluggish movements in the short-term interest rate controlled by the monetary authority, we allow for a first-order partial adjustment specification to capture possible inertia in monetary policy implementation:

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

where $\rho \in [0,1]$ is a parameter that measures the degree of interest rate smoothing and v_t is an exogenous random shock to the interest rate assumed to be identically and independently distributed.[7] Under this partial adjustment

---

[7] More generally the inertial movement of interest rate can be described by:

$$i_t = (1-\rho)i_t^* + \rho(L)i_{t-1} + v_t$$

scheme, the actual short-term interest rate i_t moves gradually towards the target interest rate i_t^* by eliminating a fraction $(1-\rho)$ of the gap between the two variables in each period.

Substitute the nominal target interest rate rule (2) into the partial adjustment mechanism (3) to yield the policy rule:

$$i_t = (1-\rho)\{\bar{i} + \beta(E[\pi_{t+m} \mid \Lambda_t] - \pi^T) + \gamma E[x_{t+n} \mid \Lambda_t]\} + \rho i_{t-1} + v_t \qquad (4)$$

where m, $n > 0$.

Assuming weak rational expectations (so that the central bank's forecast errors are random), we replace the unobserved forecast variables in (4) with their realized values to obtain an estimable function:

$$i_t = (1-\rho)\{\bar{i} + \beta(\pi_{t+m} - \pi^T) + \gamma x_{t+n}\} + \rho i_{t-1} + \varepsilon_t \qquad (5)$$

where $\varepsilon_t = -(1-\rho)\{\beta(\pi_{t+m} - \beta(E[\pi_{t+m} \mid \Lambda_t]) + \gamma(x_{t+n} - E[x_{t+n} \mid \Lambda_t])\} + v_t$.

The residual term ε_t is a linear combination of the forecast errors of inflation and output gap and the exogenous disturbance v_t. Let λ_t denote a vector of variables that is a subset of the monetary authority's information set. Given the assumed rational expectations of the monetary authority, the implication is that the elements inside λ_t are uncorrelated with the forecast errors contained in ε_t.

2.2 A Non-Linear Monetary Policy Rule

The linear interest rate rule described in the previous section can be derived from an explicit theoretical foundation. For example, Svensson (1997, 1999), Rotemberg and Woodford (1998), and Clarida, Gali and Gertler (1999) showed that the monetary policy rule can be derived from the optimizing behaviour of a monetary authority that minimizes a quadratic loss function over the expected deviations of inflation and output in relation to their target and trend values

respectively.[8] Depending on the backward and forward nature of wage and price setting, and on the assumptions regarding the information available to the monetary authority, both the inflation and output gaps appear in the interest rate rule either as current terms or as expectations of future values.

There have been two recent strands in the literature on monetary policy rules that seek to extend the traditional linear-quadratic model. In the first, the monetary authority has asymmetric preferences with respect to inflation and/or output, while in the second, the aggregate supply relation (Phillips curve) is non-linear.

2.2.1 Asymmetric Preferences

The first extension relaxes the assumption of a quadratic loss function and instead adopts an asymmetric preference specification. This approach is related to the inflation bias issue raised by Kydland and Prescott (1977) and Barro and Gordon (1983). There, the inflation bias arises because the monetary authority is assumed to have a twofold objective of price stability and employment, with the preferred level of employment above the natural level. With room to exercise discretionary power, policy-makers will try to create inflation surprises in order to push employment above its natural level towards the higher desired level. But rational economic agents understand the temptations faced by the monetary authority and correctly forecast inflation, which eventually neutralizes any effect of inflation on employment. As a consequence employment remains at its natural level in the medium run but monetary policy is subject to a suboptimal inflation bias.

Two decades later, some have questioned the relevance of the features in the Kydland-Prescott and Barro-Gordon papers that generate the inflation bias. Since the monetary authorities must realize the futility of expanding output by means of inflation surprises, according to McCallum (1995), they will normally refrain from such practices, even under discretion. Blinder (1998) argued that policy-makers at the Federal Reserve actually try to maintain employment at the natural level rather than above it. Using a simple theoretical framework, Cukierman (2000) demonstrated that even when policy-makers are assumed to target the natural level of employment, an inflation bias is still possible when the monetary authority is more concerned about under- than over-employment and there is uncertainty surrounding the future state of the

---

economy. For example, if there is some probability that an adverse supply shock will substantially reduce employment below its natural rate, economic agents will attach a greater likelihood to the monetary authority engaging in expansionary measures to reverse employment back to the target level. This leads to upward pressure on prices. Conversely, the monetary authority is assumed to take no action when a favourable supply shock pushes employment above the natural level. Similar conclusions were reached in Gerlach (2000) where the monetary authority has a greater aversion towards contraction than expansion if the policy-maker possesses an asymmetric preference. As well as looking at asymmetric preferences over output that delivers the same inflation bias as in Cukierman (2000), Nobay and Peel (2003) also examined the case of asymmetric preferences over inflation for comparison. They showed that an asymmetric preference towards the inflation target is likely to generate a 'deflationary bias', where the monetary authority is relatively more comfortable with a policy outcome that undershoots rather than overshoots its inflation target. This is consistent with the description in Mishkin and Posen (1997) about the behaviour of the Bank of Canada and the Bank of England who display an asymmetric reaction to positive and negative deviations of inflation from its target rate.

There are a number of empirical studies that support the existence of asymmetry in the reaction function of monetary authorities. Dolado, Maria-Dolores and Naveira (2000) examined an asymmetric policy rule that depends on the sign of the inflation gap for France, Germany, Spain, and the US after 1980. The estimation results confirm that the Bundesbank, Bank of France, and the Federal Reserve respond more strongly to positive inflation deviations than negative inflation deviations, however, the same conclusion could not be extended to the Spanish experience.[9] Gerlach (2000) concentrated on the asymmetry of output gap responses and finds that the Federal Reserve may have been more concerned about the negative rather than the positive output gaps in the pre-1980 period. Following the same asymmetric scheme, Bec, Salem and Collard (2002) focused on the post-1982 period for the US, Germany, and France. Generally, they found more aggressive behaviour towards inflation during expansions than contractions for the US and Germany. In addition, the Bundesbank placed a higher weight on output stabilization during expansions

than contractions which confirms its reputation for being inflation-averse.[10] Instead of relying on the sign of the output gap to determine asymmetry, Ruge-Murcia (2002, 2004) used unemployment and found evidence in favour of non-linear behaviour for central banks in the OECD and the G7 countries.

2.2.2 Non-Linear Phillips Curves

The second extension examines the convexity of the Phillips curve (for example, see Schaling (2004) and Dolado, Maria-Dolores and Naveira (2005)). In particular, the difference between the actual and expected inflation is a convex function of the output gap which implies a non-linear aggregate supply relation. The theoretical underpinning of this specification relates to the traditional Keynesian assumption that nominal wages are flexible upwards but rigid downwards. This implies that an increase in unemployment will drive inflation down by much less when unemployment is high than when it is low. When the non-linear aggregate supply curve is combined with a standard quadratic loss function, the resultant optimal interest rate rule is also non-linear and suggests that the monetary authority will increase interest rate more forcefully when inflation is above the target than when inflation is below. Dolado, Maria-Dolores and Naveira (2005) confirmed that there are non-linearities in the operating procedures of the five central banks under examination when setting the short-term interest rate as the instrument of monetary policy.[11]

Dolado, Maria-Dolores and Ruge-Murcia (2004) constructed a general model that incorporates asymmetric preferences of the monetary authority (using a linex function) and a particular non-linear aggregate supply curve. Applying the model to the US data, the source of the asymmetry was found to originate from the monetary authority responding differently to either positive or negative inflation gaps. Their results imply that the US monetary policy can be characterized by a non-linear policy rule due to asymmetric inflation preferences of the Federal Reserve after 1983, but that the rule was found to be linear prior to 1979.

---

[9] The authors noted that the inflation figures from Spain during the sample period were below the target value. Therefore they estimated an alternative asymmetric reaction function that depends on the accelerations and decelerations of the price level rather than the inflation gap. However, the test for asymmetry in the policy rule was still rejected.

[10] The estimation result for France suggested that more attention was paid to fighting inflation during recessions than expansions. The authors concluded that this may be related to the "competitive disinflation" policy conducted by the successive French governments from 1983 to the mid-1990s. The policy was aimed at, despite its negative impact on employment, restoring the competitiveness of French exports and satisfying the Maastricht criteria imposed on France as a member of the European Monetary Union.

[11] The central banks are: Banque de France (France), Bundesbank (Germany), Banco de Espana (Spain), the Federal Reserve (US), and the European Central Bank.

3. The Non-Linear Monetary Policy Rule for Estimation

We depart from the standard linear-quadratic framework and pursue the two possible extensions that the loss function of the monetary authority may be state-contingent on the business cycle, and that the Phillips curve may have a non-linear kink. In Appendix 1 and 2, we show how to derive the optimal interest rate rules for these two extensions.[12] In the former case, the state contingency affects the response to both inflation and the output gap in the rule, whereas in the latter it only affects the inflation response. From these two extensions, we obtain the following general model to estimate and to test whether the monetary authority responds more (less) aggressively to inflation and/or output gaps depending on the state of the business cycle:

$$i_t^* = \bar{i}$$
$$+ \left\{ \beta_e \left(E\left[\pi_{t+m} | \Lambda_t \right] - \pi^T \right) + \gamma_e E\left[x_{t+n} | \Lambda_t \right] \right\} I_{[\Delta x_t > 0]} \quad (6)$$
$$+ \left\{ \beta_r \left(E\left[\pi_{t+m} | \Lambda_t \right] - \pi^T \right) + \gamma_r E\left[x_{t+n} | \Lambda_t \right] \right\} I_{[\Delta x_t < 0]}$$

where the subscripts e and r denote the expansionary and contractionary phases of the business cycle, and $I_{[\bullet]}$ is the Heaviside function which is equal to unity when the condition in the associated brackets holds, and zero otherwise. The non-linear monetary policy rule (6) allows for changes in the behaviour of policy-makers when the economy moves from one state to another, where the specification hinges on the determination of a threshold value to separate the states. In Bec, Salem and Collard (2002), the business cycle phases were classified according to the sign of the output gap from period t–1. If the lagged output gap has a positive sign, the economy is deemed to be in expansion in the current period; and the economy is classified as in contraction in the current period if the sign of the lagged output gap is negative. This classification scheme may be unsuitable for the Australian monetary policy framework. As Debelle (1999) explained in his paper, the design of Australian monetary policy centres on the inflation target in the medium run, and so this approach allows for more

attention on the issue of output stabilization in the short run. With the purpose of illustrating the flexibility of the Australian framework, he cited three economic episodes that took place during the current inflation target regime.[13] In each instance, the RBA based their pre-emptive policy move on the expected future output growth and inflation movement. So the change in the output gap, i.e. $\Delta x_t = x_t - x_{t-1}$, equivalent to the gap between actual and 'normal' output growth, is used to classify the two states of the business cycle. We feel this indicator variable captures better the realistic manner in which the RBA views future business cycles.

Combining the state-contingent monetary policy reaction function (6) with the first-order partial adjustment scheme (3), and replacing the unobservable forecasts with actual future values yields:

$$i_t = (1-\rho)\bar{i} + \rho i_{t-1}$$
$$+ (1-\rho)\left[\beta_e \left(\pi_{t+m} - \pi^T \right) + \gamma_e x_{t+n} \right] I_{[\Delta x_t > 0]}$$
$$+ (1-\rho)\left[\beta_r \left(\pi_{t+m} - \pi^T \right) + \gamma_r x_{t+n} \right] I_{[\Delta x_t < 0]} \quad (7)$$
$$+ \varepsilon_t$$

where

$$\varepsilon_t = -(1-\rho)\left\{ \left[\beta_e \left(\pi_{t+m} - E\left[\pi_{t+m} | \Lambda_t \right] \right) + \gamma_e \left(x_{t+n} - E\left[x_{t+n} | \Lambda_t \right] \right) \right] I_{[\Delta x_t > 0]} \right.$$
$$+ \left. \left[\beta_r \left(\pi_{t+m} - E\left[\pi_{t+m} | \Lambda_t \right] \right) + \gamma_r \left(x_{t+n} - E\left[x_{t+n} | \Lambda_t \right] \right) \right] I_{[\Delta x_t < 0]} \right\} + \nu_t$$

(7) has an effective threshold value at $\Delta x_t = 0$. Empirically, such an event occurs with a probability of measure 0, and so ignoring it has no statistical consequences. Time periods that satisfy $\Delta x_t > 0$ are classified as expansionary phases of the business cycle. The sensitivity of the monetary authority towards future expected inflation and output gaps are measured by β_e and γ_e respectively. Conversely, time periods that satisfy $\Delta x_t < 0$ are classified as contractionary phases. The monetary authority responds to future expected inflation and output gaps in this alternative regime with intensity β_r and γ_r respectively. Note

---

[12] Our two extensions are designed to derive similar forms for the policy rule. We have also considered a non-linear Phillips curve as in Dolado, Maria-Dolores and Naveira (2005), where the function is smooth and convex. This yields an optimal policy rule with an additional cross-product term in inflation and the output gap. Preliminary tests indicated that this cross-product was insignificant.

[13] The three economic episodes are: the interest rate tightening in 1994 due to the fear of the economy overheating; the interest rate easing in 1996 given the forecast of future inflation returning to the tolerance band of between 2 and 3 percent; and the neutral position taken by the RBA during the Asian financial crisis.

that if $\beta_e = \beta_r$ and $\gamma_e = \gamma_r$ the threshold specification (7) collapses back to the linear interest rate equation (5).

4. Instrumental Variable Estimation

Irrespective of whether the monetary authority is modelled to react symmetrically (2) or asymmetrically (6) towards future expected inflation and output gaps, the residual term ε_t is assumed to be orthogonal to the variables contained in the information set of the monetary authority at the time of setting the interest rate. This implies that the forecast errors of the monetary authority regarding future values of the inflation and output gaps are uncorrelated with the information that assist in the decision-making. Therefore this suggests a testable hypothesis of weak rational expectations on the part of the monetary authority: as long as a subset of the information actually used by the monetary authority is available to the econometrician, a set of orthogonality conditions can be constructed to form the centrepiece of the GMM estimation procedure. The seminal contribution to the GMM literature by Hansen (1982) offered an alternative principle for parameter estimation that requires the specification of moment conditions in contrast to specifying the full density as required under the principle of maximum likelihood—see Appendix 3 for further details.

To apply the GMM methodology to forward-looking monetary policy rules, we first cast the estimation of the linear interest rate equation (5) in terms of Hansen's (1982) formulation. Let $\theta \equiv [\bar{i}, \beta, \gamma, \rho]'$ denote the unknown slope parameters and $w_t \equiv (i_t, i_{t-1}, \pi_{t+m}, x_{t+n}, \lambda_t')'$ denote the vector of variables for period t that are observed by the econometrician. Inside w_t is the vector of instruments known at the time of setting the interest rate, i.e. $\lambda_t \in \Lambda_t$. The rational expectations hypothesis postulates that the forecast error ε_t is orthogonal to any variable in λ_t. This naturally translates into a set of p orthogonality conditions:

$$E\left\{i_t - (1-\rho)\left[\bar{i} + \beta\left(\pi_{t+m} - \pi^T\right) + \gamma x_{t+n}\right] - \rho i_{t-1} \Big| \lambda_t\right\} = 0 \tag{8}$$

where the monetary authority's inflation target is exogenously imposed. The slope coefficients $\hat{\theta}$ are obtained from the first-order condition (shown as

(A3.4) in Appendix 3) and any over-identifying restrictions can be tested by the J-test (shown as (A3.5)).

Turning attention to the non-linear interest rate equation (7), the vector of coefficients to be estimated is denoted by $\theta \equiv [\bar{i}, \beta_e, \beta_r, \gamma_e, \gamma_r, \rho]$, and the observable random variables on date t denoted by w_t is the same as in the linear case. Hence the set of p orthogonality conditions are represented by:

$$E\Big\{i_t - (1-\rho)\bar{i} - (1-\rho)\left[\beta_e\left(\pi_{t+m} - \pi^T\right) + \gamma_e x_{t+n}\right]I_{[\Delta x_t > 0]}$$
$$-(1-\rho)\left[\beta_r\left(\pi_{t+m} - \pi^T\right) + \gamma_r x_{t+n}\right]I_{[\Delta x_t < 0]} - \rho i_{t-1} \Big| \lambda_t\Big\} = 0 \tag{9}$$

The instrument set will contain variables that are helpful in forecasting future inflation and output gaps. When the model is over-identified, the GMM estimator is a two-step non-linear two-stage least squares estimator (Hansen (1982)). The set of instruments used in the estimation contains the following: 1 to 4 lagged values of the four-quarter change in the logarithm of the trade-weighted index exchange rate and the first-difference in the output gap; 2 to 5 lagged values of the cash rate and the inflation rate; and 1 to 5 lagged values of the federal funds rate.

5. Data and Empirical Results

5.1 Data

The estimation is conducted on quarterly data for the Australian economy that spans the period from 1984:1 to 2002:3, which coincides with the advent of the flexible exchange rate regime in December 1983. Basic statistics and graphs of the principal macroeconomic time series are presented in the Data Appendix. Given the assumption that the monetary policy instrument is a nominal short-term interest rate, we use the 11am call rate of the inter-bank market or the cash rate, which is representative of the policy stance of the RBA. This was obtained from www.rba.gov.au/Statistics/OP10_update.xls. Inflation is based on the Australian Commonwealth Treasury underlying consumer price index (CPI) inflation rate spliced in September 1999 to the headline CPI. This was obtained from www.rba.gov.au/ Statistics/Bulletin/G01hist.xls. The temporary spike in the general price level that is linked to the introduction of the new general sales tax, or GST, in September 2000 is removed by taking 3 percent off the annual

inflation rate for the four affected quarters—September 2000 to June 2001. Potential output is obtained from the Hodrick-Prescott (HP) trend of the Australian real GDP (obtained from www.rba.gov.au/Statistics/Bulletin/G10 hist.xls). The output gap is then computed as the difference between the logarithm of real GDP and its HP trend. The exchange rate is the nominal trade-weighted index (obtained from www.rba.gov.au/Statistics/Bulletin/F11 hist.xls.) The federal funds rate was obtained from www.rba.gov.au/Statistics/Bulletin/F13hist.xls.

We divide the sample into two main periods. The merit in breaking up the post-float sample period into two periods can be found in de Brouwer and Gilbert (2005), who evaluated the linear interest rate rule for Australia in both the backward-looking (1) and forward-looking (2) specifications before and after the inception of the inflation targeting regime. They consistently find a clear policy break represented by the disinflation at the start of the 1990s. During the first period between 1984:1 and 1990:4, the RBA operated with considerable discretionary power, while from 1991 it moved into the present relatively more rule-based inflation targeting regime. From 1977 to 1985, the RBA had a monetary targeting regime which set 'conditional projections' for the growth rate of M3, and the regime enjoyed limited success in reducing inflation.[14] The practice of monetary targeting, however, was suspended in February 1985 as the medium-run relationship between money growth and inflation broke down due to the deregulation measures introduced from 1983. Instead, a checklist approach to monetary policymaking was installed while the RBA searched for a new prototype. The checklist included a wide-ranging and *ad hoc* mixture of factors that were conceivably relevant for framing monetary policy.[15] The problem with this approach was that the RBA commanded a high degree of discretion, making it difficult for the private sector to form expectations about monetary policy, and possibly locking in an inflationary bias arising from time inconsistency. The comparatively high inflation rate in Australia in relation to the average inflation rate of the OECD countries during the second half of this period led the RBA to be increasingly concerned about the distortionary effects

of the high inflation rate on resource allocation and economic decision-making. Between 1987 and 1990, monetary policy was given a more active role in reducing the inflation rate with the cash rate reaching a peak above 18 percent in December 1989, which implied a high real interest rate of nearly 11 percent. By early 1990, inflation was on a downward path as a result of the recession induced by tight monetary policy (and fiscal policy) in the late 1980s. The RBA then sought to capitalize on this opportunity to achieve a permanent downward shift in inflation by developing a monetary policy regime that directly targeted medium-run inflation to lock in expectations and thus maintain low inflation. Following Grenville's (1997) account, a natural point to commence the second period is 1991:1 when the regime shifted to focus on an inflation target. Initially the target was implicit, but by 1993, the policy was explicit. One of the highlights in this period was the low and stable inflation associated with one of the longest post-war expansions in Australia. In the next section we will present the empirical results from estimating a non-linear monetary policy rule for each period.

5.2   Evidence of Asymmetric Monetary Policymaking in Australia

Table 1 presents the estimated parameters of the non-linear monetary policy rule incorporating the smoothing mechanism from (7) with $m = n = 1$:[16]

$$
\begin{aligned}
i_t = {} & (1-\rho)(\bar{r} + \pi_{t-1}) + \rho i_{t-1} \\
& + (1-\rho)\Big[\beta_e(\pi_{t+m} - \pi^T) + \gamma_e x_{t+n}\Big]I_{[\Delta x_t > 0]} \\
& + (1-\rho)\Big[\beta_r(\pi_{t+m} - \pi^T) + \gamma_r x_{t+n}\Big]I_{[\Delta x_t < 0]} \\
& + \varepsilon_t
\end{aligned}
\tag{10}
$$

where we impose an additional restriction of a numerical value for the inflation target for each period to uncover an estimate for the neutral real interest rate $\bar{r}$ jointly with the parameter vector $(\beta_e, \beta_r, \gamma_e, \gamma_r, \rho)$. Clarida, Gali and Gertler (1998) instead imposed exogenously the sample average real interest rate for $\bar{r}$ to obtain an estimate for π^T.[17] They additionally noted that if the monetary

---

[14] In reality, however, monetary targeting was subordinated to the wages policy which was seen by the government to be the principal tool for achieving price stability (see Grenville (1997), pp. 129-130).

[15] According to Johnston (1985, p. 812): 'The relevant indicators include all the monetary aggregates; interest rates; the exchange rate; the external accounts; the current performance and outlook for the economy, including movements in asset prices, inflation, the outlook for inflation and market expectations about inflation'.

[16] A range of values for m and n was tested, and $m = n = 1$ was the only specification that generated sensible results on a consistent basis.

[17] They write the estimable linear forward-looking interest rate equation as:

authority is following the linear forward-looking monetary policy rule with the sample average real interest rate proxying for $\overline{r}$, then the estimated value of π^T is not expected to differ to a great extent from the sample average of π. By inserting an inflation target in (10), we can test whether the parameter estimate of the neutral real interest rate is statistically equal to the sample average real interest rate. If the test cannot reject equality between the two values, and assuming that the non-linear interest rate equation (10) gives an adequate description of the behaviour of the monetary authority, then the Clarida, Gali and Gertler observation suggests that the exogenously imposed π^T should represent the implied target value that the RBA followed in that time period.

A number of results in Table 1 can be highlighted before examining each period in more detail. First, the J-statistics from both periods indicate that the over-identifying restrictions are not rejected at the 5% significance level. Therefore the model specification is not rejected by the data. To further verify the model specification we test for serial correlation, ARCH, and non-normality. The diagnostic results reject non-normality, serial correlation and ARCH in the residuals. Second, the estimated coefficients of β_e, β_r, γ_e, γ_r, ρ and $\overline{r}$ from both periods all possess their expected signs and are statistically significant with most p-values below 1% and only two at the 7% significance level. Finally, the estimate of the smoothing parameter ρ indicates an increasing degree of interest rate inertia over time: 53% (pre-inflation targeting) and 19% (with inflation targeting) of a change in the target interest rate is reflected in the cash rate within the quarter of the change. The dramatic increase in the degree of smoothing over time is a sign of the RBA's increasingly cautious attitude to interest rate changes once it got inflation under control. Given the presence of long and uncertain policy lags, the observed inertia in cash rate movements may have helped to avoid costly policy reversals in the future which could have resulted in a potential loss of credibility.

The primary question of this paper is whether the RBA considered inflation deviations from the target value and output gaps in upturns and downturns equally costly to the economy. We test for asymmetric responses using the Wald test on the inflation and output gap elasticities of the interest rate. The null hypothesis assumes respectively a symmetric response to the inflation gap ($\beta_e = \beta_r$) and the output gap ($\gamma_e = \gamma_r$) across the two states of the business cycle.

For the period between 1984:1 and 1990:4, the test results in the bottom panel of Table 1 reject both null hypotheses at the 1% significance level. The magnitudes of the parameter estimates suggest that the RBA reacted more aggressively towards both inflation and output gaps during upswings. In this first period, the policy framework shifted from a regime of monetary targeting to the checklist approach. At the start of this period Australia had witnessed a strong recovery coming out of the contraction of 1982, but because of the tight wages policy in place at the time, inflation fell sharply to a relatively low level at 5% (down from 12% in 1982).[18] With changes in inflation moderated by tight wages policy, the response of interest rates to the output gap needed to be much larger than the response to inflation. From 1985 Australia suffered from a gradual rise in inflation. Between February 1985 and October 1986, the exchange rate depreciated as a result of growing concerns about the current account deficit, thus driving up inflation, and then the interest rate. Between 1987 and 1989 (after a cut in interest rates to compensate for the possible slowdown effects of the October 1987 stock market crash), the economy grew strongly, fuelled by an asset price boom. The fear of rising inflation led the RBA to raise the interest rate with a newfound determination, hoping to finally break the inflation psychology. This set in motion a painful disinflation episode that culminated in the recession of 1991.

Our GMM results for this period confirm the RBA's efforts to contain output and inflation deviations throughout the 1980s. To recover an estimate for the 'neutral' real interest rate[19], we impose an arbitrary inflation target of

---

$$ i_t = (1-\rho)\left[\alpha + \beta\pi_{t+m} + \gamma x_{t+n}\right] + \rho i_{t-1} + \varepsilon_t $$

where $\alpha \equiv \overline{i} - \beta\pi^T$. By using $\overline{i} = \overline{r} + \pi^T$ and therefore $\alpha \equiv \overline{r} + (1-\beta)\pi^T$, this implies that an estimate of the monetary authority's inflation target can be recovered through $\pi^T = (\overline{r} - \alpha)/(\beta - 1)$ by using the parameter estimates α and β, and $\overline{r}$ proxied by the sample average real interest rate.

[18] The wages policy refers to the 'Wages Pause' introduced by the Fraser Government in 1982 and the subsequent centralized wage award system known as the Accords under the Hawke-Keating governments that was operational until the mid-1990s.

[19] Our estimate of the 'neutral' interest rate cannot be interpreted as an estimate of the medium-run equilibrium value of that interest rate. Our data span in each period is too short, with too few business cycle phases, to be able to identify a medium-run equilibrium measure.

5.4%. We test the estimated coefficient $\bar{r} = 7.61\%$ and find that it is not statistically different (at 1%) from the sample average real interest rate (7.69%) for the first period. Provided the RBA was implicitly following the non-linear monetary policy rule in (10), we can infer that our assumed implicit inflation target of 5.4% for the period was a reasonable representation.[20]

Looking at the second period with the inflation targeting regime, the Wald test result shows that we can reject the null hypothesis of $\gamma_e = \gamma_r$ (at 2%) but not $\beta_e = \beta_r$. This indicates asymmetric behaviour in the RBA's policy response to output gaps only. In particular, the estimated coefficients $\gamma_e < \gamma_r$ suggest that the RBA switched to attach a greater weight on output stabilization in contractions than in expansions. A similar conclusion was drawn in Karagedikli and Lees (2004), where a negative output gap elicits a larger movement in the cash rate than a positive output gap of the same magnitude from the RBA. As discussed before, the Australian monetary policy framework stipulates targeting inflation as a medium-run consideration. This allows for sufficient flexibility in the short run to focus more on output or employment fluctuations. It is consistent with our larger estimated values for γ than for β. The fact that we cannot reject symmetry in the policy response to inflation gaps confirms that an inflation target became the primary overall policy objective of the RBA, with deviations equally important in both upturns and downturns. However when the economy is in a downturn, our results suggest that the RBA almost doubled its short-run priority on output stabilization.

The Asian financial crisis is an episode that can be used to illustrate this point. Before the onset of the crisis in the middle of 1997, Australia was growing relatively strongly with a widening current account deficit. The Australian dollar depreciated by around 20% reflecting the growing concerns about the deficit. Instead of responding to the usual fears of rising inflation expectations and future inflation brought about by the weakening Australian dollar, the RBA decided to leave the cash rate unchanged since the medium-run inflation target was not in jeopardy but the outlook on output growth was likely to be below trend. Indeed the RBA subsequently lowered the cash rate by 25 basis points in late 1998.

Given the RBA's explicit inflation target band of 2 to 3 percent, we impose the midpoint 2.5% in **Error! Reference source not found.**. The estimate of the neutral real interest rate is 4.42%, and highly significant. We conduct a Wald test to see if the estimated neutral real interest rate is statistically equal to the average real interest rate for the period at 3.58% and the test reveals no significant difference.

To gain some feel for how well our asymmetric specification of the monetary policy rule is explaining the behaviour of the RBA, the two panels in Figure 1 show the actual, fitted, and residual series for the cash rate based on the GMM estimation reported in Table 1. In the first period, due to the instrument set using up to 5 lagged values, the in-sample forecasts only cover the period between 1985:2 and 1990:4. The predictions from the non-linear threshold model do not closely track the actual cash rate before 1988. This variance in performance of the model relates to the evolving state of the monetary policy regime, which exhibited considerable discretion with the "checklist" prior to 1988. As the RBA progressively sharpened its focus on inflation, we observe that the increase in cash rate after 1989 is better predicted by the non-linear monetary policy rule. In the inflation targeting period from 1991, the fitted cash rate tracks the actual cash rate very closely.[21] However, there are two notable unexplained outcomes that required dummy variables to obtain a statistically reasonable model over this period: 1. The rapid increase in cash rate at the end of 1994 (apparently due to a belief at the RBA that the early 1990s recession was truly over, and a global expansion was likely). 2. The reduction of the cash rate in response to the negative sentiments after the September 11 2001 bombings in the U.S.

What do our results suggest for the two postulated sources of asymmetry—asymmetric preferences or a non-linear Phillips curve? For the first period, we could not reject asymmetry in the central bank's response to both inflation and output. Given the implications (discussed at the beginning of section 3) of the two sources, asymmetric preferences is necessary to explain our first period results, while the non-linear Phillips curve might only have played a supporting role. For the second period, we detected asymmetry only with regard to the output gap. This is not possible with our non-linear Phillips curve, and so we conclude that asymmetric preferences provide a more likely explanation.

5.3 Instrument Relevance
The GMM estimation uses instruments to proxy for the two endogenous expectational variables, i.e. $E_t\pi_{t+1}$ and $E_t x_{t+1}$. If the instruments used in this

---

[20] de Brouwer and Gilbert (2005) chose to impose an inflation target of 4.7% for the 1980s.

[21] The adjusted measure of R[2] increased from 0.25 in the first period to 0.97 in the second.

chapter are weak then inferences based on the GMM results are seriously undermined.[22] The most common way to examine if the instruments are relevant is to check the R^2 from the first stage regressions, and so we regress the two realized variables that replace the expectational variables, π_{t+1} and x_{t+1}, on the list of instruments for each period:

$$\pi_{t+1} = \Gamma_\pi \lambda_t + \upsilon_t^\pi$$
$$x_{t+1} = \Gamma_x \lambda_t + \upsilon_t^x$$
(11)

The first-stage F-test is a test that the coefficients on all the instruments are jointly zero in the regressions (11). In Table 2, we report the F-statistics and the associated p-values for each period. As can be seen, the null hypothesis that the instruments are jointly irrelevant is rejected in all four cases. The R^2 from first stage regressions are above 0.57.

6   Conclusions

The Australian monetary policy framework since financial market deregulation in the early 1980s can be characterized as an evolution, beginning with monetary aggregate targeting which was abandoned in 1985 because of the increasingly unstable relationship between money growth and inflation. A checklist approach was then installed while the RBA searched for an alternative framework. The RBA became increasingly focused on inflation as the principal medium-term policy objective. Its growing determination to beat inflation was evident in the high interest rates of the late 1980s. By 1991, the low inflation environment, engineered by that sharp disinflation, gave the RBA an opportunity to introduce the current inflation targeting regime.

To motivate the policy rule used in this regime, the preferences of the monetary authority are usually approximated by a quadratic loss function in deviations of inflation and output from target values. In this manner, de Brouwer and Gilbert (2005) examined a forward-looking reaction function for the RBA and found that a linear policy rule appears to give a reasonable description of the conduct of monetary policy in Australia in the inflation targeting period. The implication of this linear rule, however, is that the RBA is assumed to have treated positive inflation and output deviations as distasteful as

the negative ones of the same magnitude. We have extended their analysis by testing whether the RBA responded in an asymmetric fashion to future expected inflation and output gaps depending on the state of the business cycle. An affirmative result for a non-linear policy rule would be consistent with the hypothesis that the RBA possessed an asymmetric preference function, and would mean that inferences drawn from linear symmetric preferences may not accurately reflect the reality of monetary policymaking. It could also be consistent with the existence of a non-linear Phillips curve.

We obtained GMM estimates of a non-linear forward-looking monetary policy rule for Australia during the post-float period. The results favour the hypothesis of asymmetric preferences of the RBA. The first period from 1984 to 1990 featured high inflation rates, and the estimates suggest that the RBA reacted more aggressively towards *both* future expected inflation and output gaps during expansions than in contractions. In this first period, the RBA had not yet established credibility for its monetary policy design in the newly deregulated environment. Consequently, it needed particularly large interest rate responses to inflation and output gaps to have the desired effects. Thus the goodness-of-fit of the estimated interest rate rule was unsurprisingly modest.

With the successful disinflation at the end of the first period, the RBA gained credibility for its policy stance, and it chose to lock this in by developing an (eventually explicit) inflation targeting regime. Thus in the second period from 1991 to 2002, the estimated interest rate responses to the output gap was much smaller and the goodness-of-fit of the rule was much tighter, reflecting a payoff to enhanced credibility. Interestingly, the nature of the asymmetry changed in this second period.

In this inflation targeting period, the RBA responded in an asymmetric manner with respect to *only* future expected output gaps, with the estimated coefficients indicating that the RBA switched to place a greater weight on stabilizing output during contractions than in expansions. This partial restoration of symmetry is consistent with the move to an explicit inflation targeting regime, for which deviations in either direction will be equally costly. The inflation symmetry result also supports the notion that the non-linear policy rule arose from asymmetric preferences rather than a non-linear Phillips curve.

Our result that the RBA switched to respond more acutely to output in downturns is another positive pay-off from the credibility acquired with its inflation targeting regime. With inflation low and in check, the RBA has been more able to use monetary policy to stabilize the business cycle of output, particularly in downturns. Its enhanced credibility through anchored inflation

---

expectations meant that it needed to worry much less about the inflationary consequences of boom conditions. With the policy objective successfully revolving around an explicit inflation target band of 2 to 3 percent, as a medium-run consideration, our results demonstrate the degree of flexibility that the RBA has apparently given itself to attend to the real economy, which is consistent with the descriptions provided by some RBA officials (see Debelle (1999) and Stevens (2003, 2004)).

7. References

Ball, L. (1998) "Policy Rules for Open Economies" *NBER Working Paper 6760*.

Barro, R.J. and D.B. Gordon (1983) "A Positive Theory of Monetary Policy in a Natural Rate Model" *Journal of Political Economy*, 91(4), pp. 589-610.

Battellino, R., J. Broadbent, and P. Lowe (1997) "The Implementation of Monetary Policy in Australia" *Reserve Bank of Australia Discussion Paper 9703*.

Bec, F., M.B. Salem, and F. Collard (2002) "Asymmetries in Monetary Policy Reaction Function: Evidence for U.S., French, and German Central Banks" *Studies in Non-linear Dynamics and Econometrics*, 6(2), pp. 1-21.

Blinder, A.S. (1998) *Central Banking in Theory and Practice*, Cambridge and London: MIT Press.

Bryant, R.C., P. Hooper, and C.L. Mann (1993) *Evaluating Policy Regimes: New Research in Empirical Macroconomics*, Washington, D.C.: Brookings Institution.

Clarida, R., J. Gali, and M. Gertler (1998) "Monetary Policy Rules in Practice: Some International Evidence" *European Economic Review*, 42(6), pp. 1033-67.

Clarida, R., J. Gali, and M. Gertler (1999) "The Science of Monetary Policy: A New Keynesian Perspective" *Journal of Economic Literature*, 37(4), pp. 1661-707.

Clarida, R., J. Gali, and M. Gertler (2000) "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory" *Quarterly Journal of Economics*, 115(1), pp. 147-80.

Cukierman, A. (2000) "The Inflation Bias Result Revisited" *mimeo, Tel-Aviv University*.

Cukierman, A. and S. Gerlach (2003) "The Inflation Bias Revisited: Theory and Some International Evidence" *Manchester School*, 71(5), pp. 541-65.

de Brouwer, G. and J. Gilbert (2005) "Monetary Policy Reaction Functions In Australia" *Economic Record, June*

Debelle, G. (1999) "Inflation Targeting and Output Stabilization" *RBA Research Discussion Paper 1999-08*.

Dolado, J.J., R. Maria-Dolores, and M. Naveira (2000) "Asymmetries in Monetary Policy Rules: Evidence for Four Central Banks" *CEPR Discussion Paper 2441*.

Dolado, J.J., R. Maria-Dolores, and M. Naveira (2005) "Are Monetary Policy Reaction Functions Asymmetric?: The Role of Non-linearity in the Phillips Curve" *European Economic Review*, 49(2), pp. 485-503.

Dolado, J.J., R. Maria-Dolores, and F.J. Ruge-Murcia (2004) "Non-linear Monetary Policy Rules: Some New Evidence for the US" *Studies in Non-linear Dynamics & Econometrics,* 8(3), pp. 1-32.

English, W.B., W.R. Nelson, and B.R. Sack (2003) "Interpreting the Significance of the Lagged Interest Rate in Estimated Monetary Policy Rules" *Contributions to Macroeconomics*, 3(1), pp. 1073-89.

Gerlach, S. (2000) "Asymmetric Policy Reactions and Inflation" *mimeo, Bank for International Settlements.*

Grenville, S.A. (1997) "The Evolution of Monetary Policy: From Money Targets to Inflation Targets," in *Monetary Policy and Inflation Targeting.* P.W. Lowe ed: Reserve Bank of Australia, pp. 125-58.

Hansen, L.P. (1982) "Large Sample Properties of Generalized Method of Moments Estimators" *Econometrica*, 50(4), pp. 1029-54.

Johnston, R.A. (1985) "Monetary Policy - The Changing Environment" *Reserve Bank of Australia Bulletin, June*, pp. 807-13.

Karagedikli, O. and K. Lees (2004) "Do Inflation Targeting Central Banks Behave Asymmetrically? Evidence from Australia and New Zealand" *Reserve Bank of New Zealand Discussion Paper DP2004/02.*

Kydland, F.E. and E.C. Prescott (1977) "Rules Rather Than Discretion: The Inconsistency of Optimal Plans" *Journal of Political Economy*, 85(3), pp. 473-91.

Lowe, P.W. and L. Ellis (1997) "The Smoothing of Official Interest Rates" in *Monetary Policy and Inflation Targeting.* P.W. Lowe ed: Reserve Bank of Australia, pp. 286-312.

McCallum, B.T. (1995) "Two Fallacies Concerning Central-Bank Independence" *American Economic Review, Papers and Proceedings*, 85(2), pp. 207-11.

Meyer, L.H. (2001) "Inflation Targets and Inflation Targeting" *Federal Reserve Board, speech at the UCSD Economics Roundtable, July 17, 2001, www.federalreserve.gov/boarddocs/speeches/2001/20010717/default.htm.*

Mishkin, F.S. and A.S. Posen (1997) "Inflation Targeting: Lessons from Four Countries" *Federal Reserve Bank of New York Economic Policy Review*, 3(3), pp. 9-110.

Newey, W.K. and K.D. West (1987a) "A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix" *Econometrica*, 55(3), pp. 703-8.

Newey, W.K. and K.D. West (1987b) "Hypothesis Testing with Efficient Method of Moments Estimation" *International Economic Review*, 28(3), pp. 777-87.

Newey, W.K. and K.D. West (1994) "Automatic Lag Selection in Covariance Matrix Estimation" *Review of Economic Studies*, 61(4), pp. 631-53.

Nobay, A.R. and D.A. Peel (2003) "Optimal Discretionary Monetary Policy in a Model of Asymmetric Central Bank Preferences" *Economic Journal*, 113(489), pp. 657-65.

Rotemberg, J.J. and M. Woodford (1998) "Interest-Rate Rules in an Estimated Sticky Price Model" *NBER Working Paper 6618.*

Ruge-Murcia, F.J. (2002) "A Prudent Central Banker" *IMF Staff Papers*, 49(3), pp. 456-69.

Ruge-Murcia, F.J. (2004) "The Inflation Bias When the Central Bank Targets the Natural Rate of Unemployment" *European Economic Review*, 48(1), pp. 91-107.

Schaling, E. (2004) "The Non-linear Phillips Curve and Inflation Forecast Targeting: Symmetric versus Asymmetric Monetary Policy Rules" *Journal of Money, Credit, and Banking*, 36(3), pp. 361-86.

Stevens, G.R. (2003) "Inflation Targeting: A Decade of Australian Experience" *Reserve Bank of Australia Bulletin, April*, pp. 17-29.

Stevens, G.R. (2004) "Recent Issues for the Conduct of Monetary Policy" *Reserve Bank of Australia Bulletin, March*, pp. 1-8.

Stock, J.H., J.H. Wright, and M. Yogo (2002) "A Survey of Weak Instruments and Weak Identification in Generalized Method of Moments" *Journal of Business and Economic Statistics*, 20(4), pp. 518-29.

Svensson, L.E.O. (1997) "Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets" *European Economic Review*, 41(6), pp. 1111-46.

Svensson, L.E.O. (1999) "Inflation Targeting as a Monetary Policy Rule" *Journal of Monetary Economics*, 43(3), pp. 607-54.

Taylor, J.B. (1993) "Discretion versus Policy Rules in Practice" *Carnegie-Rochester Conference Series on Public Policy*, 39(0), pp. 195-214.

Taylor, J.B. (1999a) "A Historical Analysis of Monetary Policy Rules" in *Monetary Policy Rules.* J.B. Taylor ed. Chicago and London: University of Chicago Press, pp. 319-48.

Taylor, J.B. (1999b) "The Robustness and Efficiency of Monetary Policy Rules as Guidelines for Interest Rate Setting by the European Central Bank" *Journal of Monetary Economics*, 43(3), pp. 655-79.

Table 1: GMM Estimates of the Non-Linear Monetary Policy Rule
Error! Reference source not found.

	$\bar{r}$	ρ	β_e	γ_e	β_r	γ_r
1984:1~1990:4	7.61	0.47	0.57	2.44	0.26	1.79
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
1991:1~2002:3	4.42	0.81	0.47	0.93	0.30	1.77
	(0.00)	(0.00)	(0.07)	(0.00)	(0.07)	(0.00)

	$\bar{r}=sample$ mean	$\beta_e=\beta_r$	$\gamma_e=\gamma_r$	*J*-statistic	*Q*-statistic (4 lags)	LM-statistic (4 lags)	Normality-statistic
1984:1~1990:4	F(1,17)	F(1,17)	F(1,17)	$\chi^2(15)$	$\chi^2(4)$	$\chi^2(4)$	$\chi^2(2)$
Sample $\bar{r}$ = 7.69	0.14	97	18	8.26	6.94	6.79	1.58
	(0.79)	(0.00)	(0.00)	(0.91)	(0.14)	(0.14)	(0.45)
1991:1~2002:3	F(1,38)	F(1,38)	F(1,38)	$\chi^2(12)$	$\chi^2(4)$	$\chi^2(4)$	$\chi^2(2)$
Sample $\bar{r}$ = 3.58	2.64	1.51	5.73	7.20	0.27	4.18	0.80
	(0.11)	(0.23)	(0.02)	(0.84)	(0.99)	(0.38)	(0.67)

Notes: *P*-values are reported in parentheses. The set of instruments includes: cash rate (-2 to -5), federal funds rate (-1 to -5), rate of change in the trade-weighted index (-1 to -4), change in the output gap (-1 to -4), and inflation (-2 to -5). The GMM estimation is carried out using EViews 5.0 with the Bartlett kernel and the Newey and West (1987b) fixed bandwidth of q = 2 for the first sample and the Newey and West (1994) variable bandwidth of q = 5 for the second. In the first sample, prewhitening of the moments was required. In the second, dummies had to be introduced for the sudden rise in the cash rate at the end of 1994, and for the sudden fall after the September 2001 quarter. The *Q*-statistic is the Ljung-Box test for serial correlation, the LM statistic is the test for ARCH, and the Normality statistic is the Jarque-Bera test.

Table 2: Results from the F-Tests

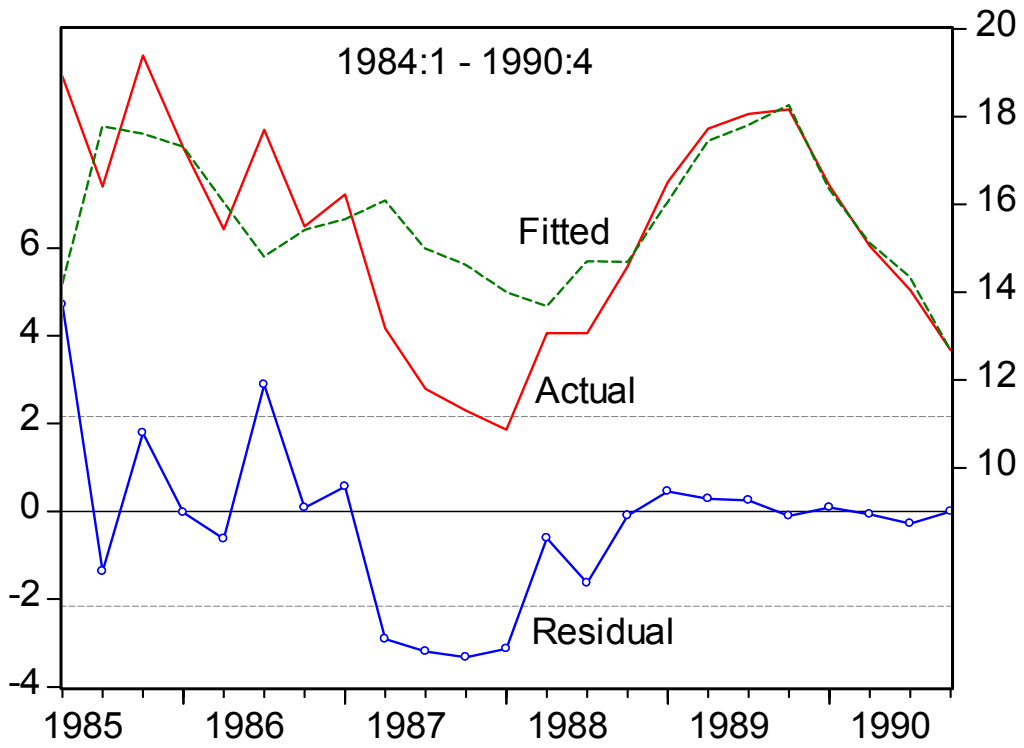|	π_{t+1}		x_{t+1}	
	F(21,2) (p-value)	Adjusted R²	F(21,25) (p-vlaue)	Adjusted R²
1984:1~1990:4	1593 (0.00)	0.98	74 (0.00)	0.57
1991:1~2002:3	260 (0.00)	0.99	14 (0.00)	0.85

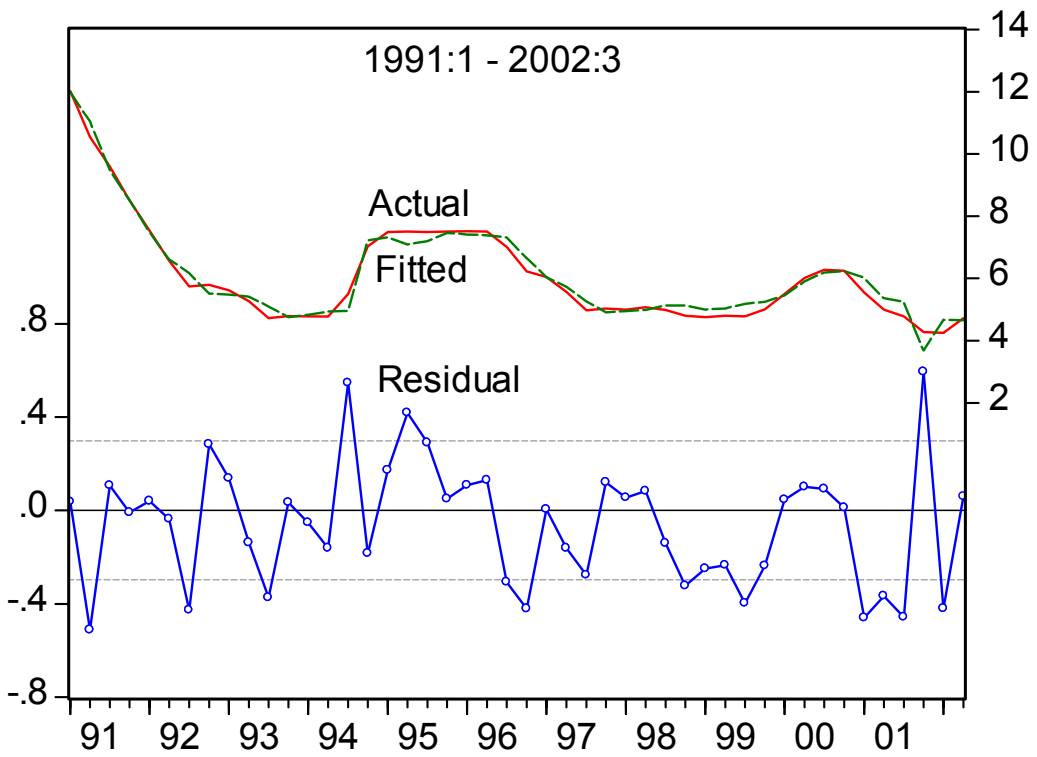Figure 1a: Actual, Fitted, and Residual of the Cash Rate 1985:2~1990:4

Figure 1b: Actual, Fitted, and Residual of the Cash Rate 1991:1~2002:3

Appendix 1
Deriving the Optimal Interest Rate Rule with Asymmetric Preferences

The monetary authority is assumed to manage monetary policy through the use of an interest rate setting rule. In period t, the monetary authority commits to a state contingent sequence of short-term interest rates that minimize an asymmetric intertemporal loss function:

$$E_t \sum_{\tau=0}^{\infty} \delta^{\tau} \left\{ \frac{1}{2} \left[\left(\pi_{t+\tau} - \pi^T \right)^2 + \omega_e x_{t+\tau}^2 \right] I_{[\Delta x>0]} + \frac{1}{2} \left[\left(\pi_{t+\tau} - \pi^T \right)^2 + \omega_r x_{t+\tau}^2 \right] I_{[\Delta x<0]} \right\} \tag{A1.1}$$

subject to

$$\pi_{t+1} = \pi_t + \alpha x_t + \mu_{t+1} \tag{A1.2}$$

$$x_{t+1} = \varphi_0 + \varphi_1 x_t - \varphi_2 \left(i_t - \pi_{t-1} \right) + \eta_{t+1} \tag{A1.3}$$

where E_t is the conditional expectations operator and $\delta \in (0,1)$ is the discount factor. The coefficients are expected to satisfy α, φ_0, $\varphi_2 > 0$, and $\varphi_1 \in (0,1)$. μ_{t+1} and η_{t+1} are zero mean normally distributed disturbances to inflation and output gap, respectively. (A1.2) specifies an aggregate supply relation where the first-difference in inflation depends positively on lagged output gap. The aggregate demand is described by (A1.3) where output gap exhibits sluggish adjustment and depends negatively on the real interest rate. We assume that private sector expectations are (believed to be) well-explained by lagged inflation. Since the real interest rate affects output with a one-period lag, it therefore affects inflation with a two-period lag.

To derive the first-order condition, Svensson (1997, Appendix B) showed that it is useful to study a related two-stage problem. First, choose x_t and π_t to minimize:

$$V\left(\pi_t \right) = \left\{ \frac{1}{2} \left[\left(\pi_t - \pi^T \right)^2 + \omega_e x_t^2 \right] I_{[\Delta x>0]} + \frac{1}{2} \left[\left(\pi_t - \pi^T \right)^2 + \omega_r x_t^2 \right] I_{[\Delta x<0]} \right. $$
$$\left. + \delta E_t V\left(\pi_{t+1} \right) \right\} \tag{A1.4}$$

subject to (A1.2). Next, substitute in the optimal values of x_t and π_t into the aggregate demand relation (A1.3) to determine the implied value of i_t.

Given the asymmetric preferences of the monetary authority, the first-stage minimization is performed with respect to the two output gap variables for the expansionary and contractionary phases of the business cycle, i.e. $x_t I_{[\Delta x>0]}$ and $x_t I_{[\Delta x<0]}$.

Before deriving the first-order conditions, we predict the indirect loss function $V(\pi_t)$ to be quadratic and dependent on the phases of the business cycle:

$$V\left(\pi_t \right) = k_0 + \frac{1}{2} k_e \left(\pi_t - \pi^T \right)^2 I_{[\Delta x>0]} + \frac{1}{2} k_r \left(\pi_t - \pi^T \right)^2 I_{[\Delta x\leq 0]} \tag{A1.5}$$

where the coefficients k_0, k_e, and k_r are to be determined later.

Hence, the first-order conditions are:

$$\left[\omega_e x_t + \delta E_t \alpha V_{\pi}\left(\pi_{t+1} \right) \right] I_{(\Delta x>0)} = \left[\omega_e x_t + \delta \alpha k_e \left(E_t \pi_{t+1} - \pi^T \right) \right] I_{(\Delta x>0)} = 0$$
$$\left[\omega_r x_t + \delta E_t \alpha V_{\pi}\left(\pi_{t+1} \right) \right] I_{(\Delta x<0)} = \left[\omega_r x_t + \delta \alpha k_r \left(E_t \pi_{t+1} - \pi^T \right) \right] I_{(\Delta x<0)} = 0 \tag{A1.6}$$

where $V_{\pi}(.) = \partial V(.) / \partial \pi$.

To identify k_0, k_e, and k_r we exploit the envelope theorem for (A1.4) and (A1.5):

$$V_{\pi}\left(\pi_t \right) = \left[\left(\pi_t - \pi^T \right) + \delta k_e \left(E_t \pi_{t+1} - \pi^T \right) \right] I_{[\Delta x>0]}$$
$$+ \left[\left(\pi_t - \pi^T \right) + \delta k_r \left(E_t \pi_{t+1} - \pi^T \right) \right] I_{[\Delta x<0]} \tag{A1.7}$$

Rearranging the first order conditions (A1.6) and using $E_t \pi_{t+1} = \pi_t + \alpha x_t$ we get:

$$x_t I_{[\Delta x>0]} = -\frac{\delta\alpha k_e}{\omega_e + \delta\alpha^2 k_e}\left(\pi_t - \pi^T\right)I_{[\Delta x>0]}$$

$$x_t I_{[\Delta x<0]} = -\frac{\delta\alpha k_r}{\omega_r + \delta\alpha^2 k_r}\left(\pi_t - \pi^T\right)I_{[\Delta x<0]}$$

(A1.8)

Next we substitute out $E_t\pi_{t+1}$ in (A1.7) and use (A1.8) to obtain:

$$V_\pi\left(\pi_t\right) = \left[\left(1 + \frac{\delta\omega_e k_e}{\omega_e + \delta\alpha^2 k_e}\right)\left(\pi_t - \pi^T\right)\right]I_{[\Delta x>0]}$$
$$+ \left[\left(1 + \frac{\delta\omega_r k_r}{\omega_r + \delta\alpha^2 k_r}\right)\left(\pi_t - \pi^T\right)\right]I_{[\Delta x<0]}$$

(A1.9)

Given that $V_\pi\left(\pi_t\right) = k_e\left(\pi_t - \pi^T\right)I_{[\Delta x>0]} + k_r\left(\pi_t - \pi^T\right)I_{[\Delta x<0]}$, the identification of k_0, k_e, and k_r is achieved by matching up the coefficients:

$$k_0 = 0$$

$$k_j = 1 + \frac{\delta\omega_j k_j}{\omega_j + \delta\alpha^2 k_j}, \quad j = e, r$$

(A1.10)

There is a unique positive solution each for k_e and k_r that can be solved analytically from the resulting quadratic:

$$k_j = \frac{1}{2}\left[1 - \frac{\omega_j(1-\delta)}{\delta\alpha^2} + \sqrt{\left(1 + \frac{\omega_j(1-\delta)}{\delta\alpha^2}\right)^2 + \frac{4\omega_j}{\alpha^2}}\right] \geq 1, \quad j = e, r$$

(A1.11)

Given these results, we reformulate the constrained minimization of (A1.4) subject to (A1.2) to derive an optimal asymmetric monetary policy rule:

$$V\left(E_t\pi_{t+1}\right) = \left\{\frac{1}{2}\left[\left(E_t\pi_{t+1} - \pi^T\right)^2 + \omega_e E_t x_{t+1}^2\right]I_{[\Delta x>0]}\right.$$
$$\left. + \frac{1}{2}\left[\left(E_t\pi_{t+1} - \pi^T\right)^2 + \omega_r E_t x_{t+1}^2\right]I_{[\Delta x<0]} + \delta E_t V\left(E_{t+1}\pi_{t+2}\right)\right\}$$

(A1.12)

subject to

$$E_{t+1}\pi_{t+2} = \pi_{t+1} + \alpha x_{t+1}$$

where $E_t x_{t+1} I_{[\Delta x>0]}$ and $E_t x_{t+1} I_{[\Delta x<0]}$ are regarded as the control variables.

Analogous to (A1.6), the first order conditions we obtain can be written as:

$$E_t x_{t+1} I_{[\Delta x>0]} = -\frac{\delta\alpha k_e}{\omega_e}\left(E_t\pi_{t+2} - \pi^T\right)I_{[\Delta x>0]}$$

$$E_t x_{t+1} I_{[\Delta x<0]} = -\frac{\delta\alpha k_r}{\omega_r}\left(E_t\pi_{t+2} - \pi^T\right)I_{[\Delta x<0]}$$

(A1.13)

From the aggregate demand relation (A1.3), the implied optimal interest rate i_t^* is

$$i_t^* - \pi_{t-1} = \frac{\varphi_0}{\varphi_2} - \frac{1}{\varphi_2}E_t x_{t+1} + \frac{\varphi_1}{\varphi_2}x_t$$
$$= \frac{\varphi_0}{\varphi_2} - \frac{1}{\varphi_2}\left(E_t x_{t+1} I_{[\Delta x>0]} + E_t x_{t+1} I_{[\Delta x<0]}\right) + \frac{\varphi_1}{\varphi_2}\left(x_t I_{[\Delta x>0]} + x_t I_{[\Delta x<0]}\right)$$

Substituting (A1.13) into this and grouping like terms, yields the optimal asymmetric monetary policy rule:

$$i_t^* = \frac{\varphi_0}{\varphi_2} + \pi_{t-1} + \left[(1-\varphi_1)\frac{\delta\alpha k_e}{\omega_e\varphi_2}\left(E_t\pi_{t+1} - \pi^T\right) + \frac{\delta\alpha^2 k_e}{\omega_e\varphi_2}E_t x_{t+1}\right]I_{[\Delta x>0]}$$

$$+ \left[(1-\varphi_1)\frac{\delta\alpha k_r}{\omega_r\varphi_2}\left(E_t\pi_{t+1} - \pi^T\right) + \frac{\delta\alpha^2 k_r}{\omega_r\varphi_2}E_t x_{t+1}\right]I_{[\Delta x<0]}$$

which can be rewritten as:

$$i_t^* = \bar{r} + \pi_{t-1} + \left[\beta_e\left(E_t\pi_{t+1} - \pi^T\right) + \gamma_e E_t x_{t+1}\right]I_{[\Delta x>0]}$$
$$+ \left[\beta_r\left(E_t\pi_{t+1} - \pi^T\right) + \gamma_r E_t x_{t+1}\right]I_{[\Delta x<0]}$$

(A1.14)

Appendix 2
Deriving the Optimal Monetary Policy Rule with a Non-Linear Phillips Curve

In period t, the monetary authority is assumed to choose the path of the interest rate that minimizes the expected present discounted value of the following symmetric intertemporal loss function:

$$E_t\sum_{\tau=0}^{\infty}\delta^\tau\frac{1}{2}\left[\left(\pi_{t+\tau} - \pi^T\right)^2 + \omega x_{t+\tau}^2\right]$$

(A2.1)

subject to the following two equations describing the evolution of the economy:

$$\pi_{t+1} = \pi_t + f\left(x_t\right) + \mu_{t+1}$$

(A2.2)

with

$$f\left(x_t\right) = \begin{cases}\alpha_e x_t & \text{if } \Delta x_t > 0 \\ \alpha_r x_t & \text{if } \Delta x_t < 0\end{cases}$$

(A2.3)

where

$$f' = \begin{cases}\alpha_e & \text{if } \Delta x_t > 0 \\ \alpha_r & \text{if } \Delta x_t < 0\end{cases}$$

and

$$x_{t+1} = \varphi_0 + \varphi_1 x_t - \varphi_2\left(i_t - \pi_{t-1}\right) + \eta_{t+1}$$

(A2.4)

where the coefficients are expected to satisfy $\alpha_e > \alpha_r > 0$, $\varphi_0, \varphi_2 > 0$, and $\varphi_1 \in (0,1)$. The source of asymmetry in the optimal monetary policy rule comes from (A2.2), which can be interpreted as a kinked Phillips curve (or aggregate supply relation). Inflation changes depend on the output gap in a non-linear way, as defined in (A2.3), where linearity is recovered when $\alpha_e = \alpha_r$. When output is growing, unemployment will be falling and so wage and price inflation will be rising. However when output growth is negative, the downward pressure on wages and prices will be muted by downward inflexibility or hysteresis effects.

Consider two adjacent periods, $\tau+1$ and $\tau+2$ in the dynamic optimization problem:

$$...\frac{\delta^{\tau+1-t}}{2}[(E_t\pi_{\tau+1} - \pi^T)^2 + \omega E_t x_{\tau+1}^2] + \frac{\delta^{\tau+2-t}}{2}[(E_t\pi_{\tau+2} - \pi^T)^2 + \omega E_t x_{\tau+2}^2)]..$$

Substitute out for $E_t x_{\tau+1}$, $E_t x_{\tau+2}$, and $E_t\pi_{\tau+2}$ by using (A2.2)-(A2.4), and then minimize with respect to i_τ to give:

$$\omega E_t x_{\tau+1} + \omega\delta\varphi_1 E_t x_{\tau+2} + f'\delta\left(E_t\pi_{\tau+2} - \pi^T\right) = 0$$

Replacing $E_t x_{\tau+2}$ in terms of $E_t x_{\tau+1}$, $E_t i_{\tau+1}$, and $E_t\pi_{\tau+1}$ using (A2.4) gives:

$$E_t i_{\tau+1} = \frac{\varphi_0}{\varphi_2} + \pi_\tau + \frac{f'}{\delta\omega\varphi_1\varphi_2}\left(E_t\pi_{\tau+2} - \pi^T\right) + \frac{1+\delta\varphi_1^2}{\delta\varphi_1\varphi_2}E_t x_{\tau+1}$$

Iterating this back to t gives the implied optimal short-term interest rate, i_t^*:

$$i_t^* = \frac{\varphi_0}{\varphi_2} + \pi_{t-1} + \frac{f'}{\omega\varphi_1\varphi_2}\left(E_t\pi_{t+1} - \pi^T\right) + \frac{1+\delta\varphi_1^2}{\delta\varphi_1\varphi_2}x_t$$

Recalling (A2.3), this can be rewritten as:

$$\begin{aligned}
i_t^* = \bar{r} + \pi_{t-1} + &\left\{\beta_e\left(E\left[\pi_{t+1}|\Lambda_t\right] - \pi^T\right)\right\}I_{[\Delta x_t > 0]} \\
+ &\left\{\beta_r\left(E\left[\pi_{t+1}|\Lambda_t\right] - \pi^T\right)\right\}I_{[\Delta x_t < 0]} + \gamma x_t
\end{aligned}$$

(A2.5)

We obtain a modified Taylor rule (A2.5) which differs from the conventional linear specification (for example, Clarida, Gali and Gertler (1998, 2000)) because it includes a kink due to f' from (A2.3) which operates *only* on the gap between expected inflation and the target. Given $\alpha_e > \alpha_r > 0$ and thus $\beta_e > \beta_r > 0$, if inflation is expected to be higher than the target, the central bank will raise the cash rate more when output growth is greater than normal ($\Delta x_t > 0$) than when less ($\Delta x_t < 0$). This interaction effect does not operate on the central bank's response to the output gap.

Appendix 3

Generalized Method of Moments Estimation Procedure

Let w_t denote the ($k\times1$) vector of variables observed at date t, and let θ be the ($a\times1$) parameter vector of interest. Define $h(\theta, w_t)$ as a ($p\times1$) vector of moments which is a stationary process, with $p \geq a$. The vector of moments is assumed to satisfy a set of p orthogonality conditions when θ is equal to its true value of θ_0:

$$E\left[h\left(\theta_0, w_t\right)\right] = 0$$

(A3.1)

Given a sample of size T, we stack up all of the observations into a ($Tk\times1$) vector, $u_t \equiv (w_T', w_{T-1}', \ldots, w_1')'$, and thus define the sample average of $h(\theta, w_t)$ as:

$$g\left(\theta, u_t\right) \equiv \left(\frac{1}{T}\right)\sum_{t=1}^{T}h\left(\theta, w_t\right)$$

The GMM estimator $\hat{\theta}$ is chosen to make the sample moment $g(\theta, u_t)$ as close as possible to the population moment of zero in (A3.1). This translates into a minimization problem of the following objective function with respect to θ:

$$\min_{\theta}\quad Q\left(\theta, u_t\right) = \left[g\left(\theta, u_t\right)\right]'W_T\left[g\left(\theta, u_t\right)\right]$$

(A3.2)

where $\{W_T\}_{T=1}^{\infty}$ is a sequence of ($p\times p$) positive definite weighting matrices which may be dependent on the data u_t.

Let Ω be the covariance matrix of $h(\theta_0, w_t)$ which is given by:

$$\Omega = \sum_{j=-\infty}^{\infty}E\left\{\left[h\left(\theta_0, w_t\right)\right]\left[h\left(\theta_0, w_{t-j}\right)\right]'\right\}$$

If the vector process $\{h(\theta_0, w_t)\}_{t=-\infty}^{\infty}$ was serially uncorrelated, the efficient GMM estimator $\hat{\theta}$ chooses $\hat{\Omega}$ so that it converges in probability to the asymptotic covariance matrix:

$$\hat{\Omega} = \left(\frac{1}{T}\right)\sum_{t=1}^{T}\left[h\left(\hat{\theta}, w_t\right)\right]\left[h\left(\hat{\theta}, w_t\right)\right]' \xrightarrow{p} \Omega$$

(A3.3)

In another words, the GMM estimator $\hat{\theta}$ achieves minimum variance when the optimal value for the weighting matrix W_T in (A3.2) is given by the inverse of the covariance matrix $\hat{\Omega}^{-1}$.

Therefore the first-order condition of the minimization problem described by (A3.2) is a system of non-linear equations:

$$\left\{ \left. \frac{\partial g\left(\theta,u_t\right)}{\partial \theta'} \right|_{\theta=\hat\theta} \right\}' \times \hat\Omega^{-1} \times \left[g\left(\hat\theta,u_t\right) \right] = 0 \qquad\qquad (A3.4)$$

where $[\partial g(\theta,u_t)/\partial\theta']|_{\theta=\hat\theta}$ denotes the ($p \times a$) matrix of derivatives of the function $g(\theta,u_t)$ with the derivatives evaluated at the GMM estimate $\hat\theta$.

Hansen (1982) showed that, under general conditions, the GMM estimator $\hat\theta$ is $\sqrt{T}$ consistent and asymptotically normal. Therefore the asymptotic variance of $\hat\theta$ is

$$\hat V = \left[\left\{ \left. \frac{\partial g\left(\theta,u_t\right)}{\partial \theta'} \right|_{\theta=\hat\theta} \right\} \hat\Omega^{-1} \left\{ \left. \frac{\partial g\left(\theta,u_t\right)}{\partial \theta'} \right|_{\theta=\hat\theta} \right\}' \right]^{-1}$$

The objective function (A3.2), when evaluated at the estimated parameter vector and suitably normalized by the sample size, is asymptotically chi-squared:

$$J \equiv \left[\sqrt{T} \cdot g\left(\hat\theta,u_t\right) \right]' \hat\Omega^{-1} \left[\sqrt{T} \cdot g\left(\hat\theta,u_t\right) \right] \xrightarrow{L} \chi^2\left(p-a\right) \qquad\qquad (A3.5)$$

This is a specification test suggested by Hansen (1982) when the model is over-identified—i.e. the number of orthogonality conditions exceeds the number of parameters to be estimated ($p > a$). Also known as the "*J*-test" in the literature, it tests for the validity of the over-identifying restrictions, with the null hypothesis that all restrictions imposed on the model are satisfied.

A two-stage estimation is carried out given its superior performance in small samples. In the first stage, an initial estimate $\hat\theta^{(0)}$ is obtained by minimizing (A3.2) with an identity matrix $W_T = I_p$. The initial estimated coefficient vector is then inserted in (A3.3) to form an initial estimate $\hat\Omega^{(0)}$. In the second stage, (A3.2) is minimized with $W_T = [\hat\Omega^{(0)}]^{-1}$ to arrive at a new coefficient estimate $\hat\theta^{(1)}$, and which is then put back into (A3.3) to obtain a new estimate $\hat\Omega^{(1)}$. Simultaneously updating of the coefficients and weighting matrix at each iteration continues until both converge, i.e. $\hat\theta^{(j)} \cong \hat\theta^{(j+1)}$ and $\hat\Omega^{(j)} \cong \hat\Omega^{(j+1)}$. To make sure the weighting matrix is robust to heteroskedasticity and serial correlation, the Bartlett kernel (Newey and West (1987a)) is used to weight the covariance matrix Ω in the second stage. The optimal weighting matrix is thus constructed to be heteroskedasticity and autocorrelation consistent (HAC):

$$\hat\Omega_{HAC} = \hat\Gamma_0 + \sum_{j=1}^q k\left(j,q\right)\left(\hat\Gamma_j - \hat\Gamma'_j\right) \qquad\qquad (A3.6)$$

where $\hat\Gamma_j = \left(\frac{1}{T}\right) \sum_{t=j+1}^T \left[h\left(\hat\theta,w_t\right) \right]\left[h\left(\hat\theta,w_{t-j}\right) \right]'$.

Both the Newey and West (1987b) parametric (applied to the first sample) and the Newey and West (1994) nonparametric (applied to the second sample) methods are employed to select the bandwidth of the kernel, $k(j,q)$, which is used to weight the covariances so that $\hat\Omega_{HAC}$ is ensured to be positive semi-definite. Inside the kernel, the bandwidth q needs to be chosen which determines how the weights given by the kernel change with lags in the estimation of $\hat\Omega_{HAC}$.

Data Appendix

Descriptive Statistics		1984Q1 – 1990Q4	1991Q1 – 2002Q3
Cash Rate	Mean	14.83	6.07
	SD	2.57	1.65
Inflation	Mean	7.14	2.49
	SD	1.53	0.72
Output Gap	Mean	0.50	-0.26
	SD	1.17	0.86

Australian Cash Rate

Australian Inflation (GST adjusted)

Australian Output Gap

US Fed Funds Rate