Asymmetric Monetary Policy in Australia

by

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Abstract

This thesis investigates possible asymmetric responses in the conduct of the Australian monetary policy in the face of economic expansions and contractions. We use both a Linex function and a threshold quadratic function to characterize these asymmetries, and the parameters are estimated by the generalized method of moments (GMM). Our empirical results confirm that the Reserve Bank of Australia (RBA) has asymmetric preferences. In particular, the RBA appears to place a greater weight on stabilizing output during contractions than in expansions.

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Chapter One: Introduction

The objective of this thesis is to investigate whether the Australian monetary policy has asymmetric responses to inflation and output during expansions and contractions. In addition, we ask the question whether this asymmetry in response is due to an asymmetric preference function or a non-linear aggregate supply curve.

The optimal control approach to the monetary policy often assumes the central bank minimizes a quadratic loss function subject to a linear constraint that represents the monetary policy trade-off. This yields linear first-order conditions that represent the optimal response of the central bank to the fluctuations in the economy. The majority papers in the literature consider a symmetric loss function that implicitly assumes the central bank responds to inflation and output gap in the same fashion regardless of the states of business cycle.

However, as argued by the former vice-Chairman of Federal Reserve Alan Blinder, the use of the symmetric loss function is more due to mathematical convenience rather than economic merit:

'*both practical central bankers and academics would benefit from more serious thinking about the functional form of the loss function*' (Blinder 1997).

Subsequent literature explores possible ways to incorporate the possible asymmetries into the loss function. Preferences are asymmetric in the sense that the central bank are allowed, but not required, to consider potentially different responses to inflation and output deviation from their target value during expansions and recessions. For example, Nobay and Peel (2003) use a linear-exponential (Linex) function to take possible asymmetric preference into account. Bec, Salem and Collard (2002) introduce asymmetries by applying a threshold concept to the classic quadratic loss function.

In this thesis, we relax the assumption of the symmetric quadratic central bank loss function, and allowing for both Linex and threshold representations to test the existence of asymmetric preferences of the Reserve Bank of Australia (RBA). Using quarterly Australian data from 1993Q1 to 2008Q1, we test whether the RBA behaves asymmetrically across the business cycle. If the evidence favors asymmetry, we ask the following questions: Does the RBA consider the deviations of inflation and output from their target values more costly during economic expansions than in contractions? Does this asymmetric response due to the asymmetric preference?

Using the generalized method of moment (GMM), our results indicate that the RBA responds symmetrically to deviations of inflation, whereas asymmetrically to output gap with the response to contractions being larger than the response to expansions of the same magnitude. This outcome is consistent with the objective of inflation targeting regime. The RBA keeps an inflation target band of 2 to 3 percent in a medium run, regardless of the two states of the business cycle. Furthermore, we find that this asymmetry is driven by the preferences of the RBA.

The rest of this thesis is outlined as follows: Section II reviews the literature on central banks' asymmetric preferences. Section III presents variants of our theoretical models and derives the reduced-form equations for estimation. In section IV we describe the data and discuss the econometric strategy. Section V illustrates the empirical and Section VI shows the sensitivity tests. Section VII concludes.

Chapter Two: Literature review

In this chapter, we review both theoretical and empirical evidence on central banks' asymmetric preferences with respect to inflation and output gap over the business cycles. We base our discussions on two alternative loss functions – Linex and threshold loss functions. We also discuss the asymmetry that is arisen from a nonlinear Phillips curve.

In the past two decades, monetary policy is the primary tool for monetary policymakers to achieve twin goals of price stability and economic growth. Under the assumption that the main operating instrument of monetary policy is the short term interest rate, a simple feedback rule is proposed by Taylor (1993), which indicates the federal funds rate respond to only of inflation and GDP deviations from their respective steady state values.

Taylor's contribution is twofold: First, this rule was shown to fit remarkably well to the Federal Reserve's policy interest rate from 1987 to 1997. Second, a key provision of the Taylor rule is that the monetary policy rule is shown to have desirable stabilization properties. To be specific, the nominal interest rate should increase by more than one percentage point for each one-percent rise in inflation.

Indeed, this Taylor rule has such an influential effect that the majority of the literature of the last decade has implemented this perspective by estimating and extending it.

For example, Ball (1998) augments exchange rate to the classic Taylor rule to examine the Taylor rule in an open economy. Taylor (1999) proposes a backward-looking model with lagged information to evaluate interest rate setting at the European Central Bank. In the contrary, Clarida, Gali and Gertler (1998, 2000) incorporate forward-looking behaviour to the baseline Taylor rule, and allows the central bank to consider future condition of the economy by considering a much broader range of information; Judd and Rudebusch (1998) estimate a dynamic Taylor-type reaction function which includes an additional lagged output gap term along with the contemporaneous output gap.

Of all these Taylor-type specifications, the common ground and the implication are the monetary policymakers respond with symmetrical intensity to positive and negative deviations in inflation and/or output in relation to their respective target value. This is because most of empirical analysis of monetary policy preferences has modelled the preferences of the policymaker as a symmetric quadratic loss function and some linear constraints describing the economy. Under these two assumptions, the first-order result from minimizing the loss function yields a linear symmetric monetary policy reaction function.

Nevertheless, the ultimate goal of monetary policy, or the optimal monetary policy, is to maximize the welfare of the society, it is not necessary to treat positive deviations of inflation with respect to its target and deviations of output with respect to its potential value as equally costly as negative ones. Since the optimal monetary policy rules can be derived by minimizing the central banks loss function subject to some constraints describing the economy, the micro-foundations give theoretical sources of possible asymmetries in monetary policymaking. This indicates that possible asymmetries arise as a result of either the central bank has an asymmetric preferences loss function, or the constraint is non-linear which implies the Phillips curve is non-linear. Thus, recent literature has considered the possibility that the loss function of central bank may not be quadratic and consequently the Taylor rule derived from such functions are not necessarily to be linear. Blinder states that:

'*in most situations the central bank will take far more political heat when it tightens pre-emptively to avoid higher inflation than when it eases pre-emptively to avoid higher unemployment*' (Blinder 1998).

This indicates that pressure from political reasons may induce Federal Reserve to be more averse to negative than to positive output gaps during normal times. This is just one kind of asymmetric preference that central banks could have. According to Cukierman and Muscatelli (2008), asymmetric preferences can be distinguished among three types: recession-avoidance preferences (RAP), which is consistent with what Blinder said about the Federal Reserve; inflation-avoidance preferences (IAP), which represent central bank dislike positive inflation deviations more than negative ones; and interest rate smoothing asymmetry.

2.1 *Asymmetric Preferences*

Preferences are asymmetric in the sense that the central bank is allowed, but not required, to respond differently to deviations of inflation and output gap depending on the states of the business cycle.

The preferences that central bank responds to output gaps is related to inflation bias issue proposed by Kydland and Prescott (1977) and Barro and Gordon (1983) (KP-BG). The inflation bias arises because central banks are assumed to have twofold objectives of price stability and certain level of employment that above the natural level[1]. Cukierman (2000) and Cukierman and Gerlach (2003) extend the KP-BG inflation bias framework, and demonstrate that even if policymakers target the natural level of employment, a bias arises if they are uncertain about economic conditions.

However, a central bank should concern negative deviations of employment from its normal level more than positive deviations. This is because even in democratic societies central banks are more or less influenced by social and political pressure, which make them are sensitive to the social costs of recessions. For instance, Global Financial Crisis of 2007 - 2008 significantly reduced employment below its natural rate in many countries; central banks in these countries were expected to engage in expansionary monetary policy to increase employment back to the natural level. Therefore, in the presence of economic uncertainties, monetary policy makers should

[1]For the purpose of achieving a level of employment above the natural level, discretion policymakers try to create inflation surprises to attain their goals. However, rational individuals understand the meaning of central banks' action, and correctly forecast inflation, neutralizing any effect of inflation on employment. Consequently, employment remains at its natural level but monetary policy is subject to a suboptimal inflation bias.

respond more and act faster to output gap deviations in a recession than in expansion. In other word, a central bank should consider positive output gaps as less costly than negative output gaps of the same magnitude.

Meanwhile, Goodhart (1998) disputes that if a policymaker tries to establish its credibility on inflation fighting, he would have a policy outcome that undershoots rather than overshoots its inflation target. European area is the place where we can find some evidence to support this is standpoint due to Germans hate inflation. The former President of the European Central Bank (ECB) Willem Duisenberg states this as the introductory statement of Press conferences of 8th Nov, 2001:

'The maintenance of price stability remains our first priority. […] today's action could be taken "without prejudice to price stability", and it thereby supported the other goals of Economic and Monetary Union, such as economic growth' (Duisenberg 2001)

This implies that policymakers of the ECB averse to more positive than to negative inflation gaps of equal size.

These two hypotheses are indeed the major explanations of the nature of the possible asymmetry preferences in central banks' loss function. And there are a number of empirical literature tests for asymmetries with respect to inflation and output gap in the preferences of central banks, such as Gerlach (2000), Cukierman and Muscatelli (2002), Florio (2005), Naraidoo and Raputsoane (2011), Cassou et al. (2012), Vasicek

(2012) and Sznajderska (2014). Of all these papers, authors confirm either asymmetry with respect to inflation, or asymmetry with respect to output gap, or both.

In addition, central banks could also have asymmetric preferences for interest rate smoothing. It is commonly observed that the central bank gradual responds of the interest rate, adjusting the interest rate in small discrete steps over an extended period of time. Clarida et al. (1999), Woodford (1999) and Wieland and Sack (2000) well account for the reasons that why monetary policy inertia. First, if policymakers are uncertain about the state of the economy and the effects of the monetary actions, it is usually for central bank to respond cautiously to a shock. The presence of uncertainty could be even responsible of asymmetric smoothing. For instance, when monetary policymaker dislike recessions more than inflation, a monetary policy tightening which can lead to a recession could be associated to a greater loss than a monetary easing. In this case, asymmetric central bank preferences with respect to rising or falling interest rates, that is asymmetric preferences over interest variability, might lead monetary policymakers to smooth interest rates adjustments asymmetrically. Briefly, asymmetric stabilization preferences could lead to asymmetric smoothing. The second type of explanation refers to fearing of disrupting financial markets. Large and sudden shift in interest rates can destabilize financial and exchange markets, because a central bank can cause large swings in cash flow among individual corporations, financial intermediaries, and governments with large debts.

Empirically, Florio (2006) examines monetary reaction function of the Federal

Reserve in terms of asymmetric preferences with respect to interest rate variability as a potential explanation for the non-linearity in interest rate smoothing. The results give strong evidence of asymmetric interest rate smoothing to the Federal Reserve's behaviour from 1973 to 2004. Florio (2009) proposes a theoretical model and show that an asymmetric preference by the central bank for stabilization implies asymmetric interest rate smoothing.

To evaluate and distinguish these three types of asymmetries in the central bank's loss function, empirical literature has employed two diverse models to identify the expansionary and contractionary phases of business cycle for estimation. One is threshold quadratic specification, where classic quadratic loss function is extended by a Heaviside function to identify appropriate states of the business cycle. The asymmetries can be examined by the tests that parameters of inflation and output gaps are statistically significant difference from each result of expansion and recession, respectively. If the parameter of inflation during economy downturns is statistically significant different from the parameter of inflation during economy upturns, an inference of asymmetry in the preferences of the central bank with respect to inflation can be concluded. A similar argument holds for output gap.

However, there is an issue that researchers cannot get a consensus on how to classify the business cycle phases. In Bec, Salem and Collard (2002), they use the sign of lagged output gap to identify the states of the business cycle. If the sign of lagged output gap is positive, the economy is considered to be in expansions in the current period; and the economy is in contraction in the current period if the lagged output gap has a negative sign. In the contrary, Leu and Sheen (2006) use the changes in the output gap to classify the two states of the business cycle.

One could also apply a Linex function to provide information on central bank's preferences.[2] Nobay and Peel (2003) are the pioneers to introduce this form of specification into central bank's loss function in the monetary policy literature. According to Ruge-Murcia (2003), this Linex function has several properties. First, it allows different weights for positive and negative output and inflation deviations from their respective targets. Second, it can estimate both the sign and magnitudes of these weights. Under the symmetric scenario, policymakers are assumed to care only about the magnitude of deviations, whereas under asymmetric preferences they care also about the sign. Third, it nests the quadratic function as a special case when the preference coefficient tends to be zero.[3]

There is a growing literature to test the asymmetric monetary policy response using both methods. For example, Bec, Salem and Collard (2002) are the first to apply threshold-quadratic specification to test the presence of asymmetry in the behaviour of the central banks of US, French, and German in the conduct of the monetary policy.

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[2] The Linex loss function is given by: $f(y) = \frac{\exp(\alpha y) - \alpha y - 1}{\alpha^2}$, where y is the loss associated with the predictive error and α is a given parameter. In particular, a positive α will reflect positive output deviations are weighted more severely than negative ones in the central banker's loss function.

[3] Formally, $\lim_{\alpha\to 0} \frac{\exp(\alpha y) - \alpha y - 1}{\alpha^2} = \lim_{\alpha\to 0} \frac{y\exp(y\alpha) - y}{2\alpha} = \lim_{\alpha\to 0} \frac{y^2 \exp(\alpha y)}{2} = \frac{y^2}{2}$.

Aguiar and Martins (2008) and Komlan (2013) employ this threshold-quadratic specification as well for examining the monetary policy reaction functions of the European Central Bank and Bank of Canada respectively.

For others who support the Linex function see Ruge-Murcia (2003, 2004), Surico (2003, 2007), Dolado *et al.* (2004). Surico (2003) describes the loss function as a Linex function form for both inflation and output gap aspects, and combines with a convex aggregate supply curve. Using monthly euro area data, he finds evidence of an asymmetric function could describe the behaviour of the European Central Bank from 1997 to 2002. Surico (2007) applies the same model to investigate the monetary reaction function of the U.S.

Obviously, we cannot identify the central bank's preferences by estimating the loss function. But we can identify them by estimating optimal monetary policy reaction function which is the first-order condition that minimizing the loss function subject to some constrains describing the economy. Both the Linex form and the threshold-quadratic specifications allow for nonlinearity in the monetary policy reaction function. Based on the estimation results, we conduct hypothesis testing to investigate whether there are asymmetric preferences in the central bank's loss function and the degree of this nonlinearity. However, it is worth noting that the source of this nonlinearity is not unique. A non-linear Phillips curve that serves as the constraint to the optimization problem may also induce non-linearity, which we discuss below.

2.2 *Non-Linear Phillips Curves*

Recall that the optimal monetary reaction function is the first-order condition of minimizing the loss function of central bank subject to some aggregate supply equation and aggregate demand equation describing the economy. Assuming that the aggregate supply curve is convex, and combine with a standard symmetric quadratic loss function, the resultant optimal monetary policy rule may also be nonlinear. The theoretical foundation is the traditional Keynesian assumption that nominal wages are flexible upwards but rigid downwards, therefore, convexity may arise. This implies that when the output is low, a raise in interest rate will cause a strong effect on output and a weaker impact on inflation. Laxton, Meredith, and Rose (1995) find evidence of nonlinearity of the Phillips curve by pooling data from the major seven OECD countries. Although a lower degree of convexity than found in Laxton, Meredith, and Rose (1995)'s estimate, Fisher et al. (1997) find the Phillips curve is asymmetric with UK data.

Some empirical evidence confirms the nonlinear monetary policy reaction function can be derived from a nonlinear aggregate supply curve. Schaling (2004) extends the Svensson (1997) inflation forecast targeting framework, particularly examines a nonlinear monetary policy reaction function. His model features a convex Phillips curve, in that positive deviations of aggregate demand from potential are more inflationary than negative deviations are disinflationary. He finds the reaction function is asymmetric. Assuming the monetary policymaker's loss function is quadratic, Dolado, Maria-Dolores and Naveira (2005) investigate the nonlinearity of monetary reaction function caused by the asymmetric aggregate supply curve for four European central banks and the Federal Reserve. They find significant evidence of nonlinearity in the policy rules of four European central banks after 1980, but not for the Federal Reserve. This conflicting result is due to the fact that higher downwards than upwards wage rigidity in Europe, whereas such is not the case in the more flexible US labour market.

2.3 *Empirical studies of monetary policy reaction functions*

Over the past decade, a number of countries have announced and adopted an explicit inflation targeting framework for monetary policy. New Zealand is the first one and Australia follows on his heels. The RBA has been looking for an appropriate monetary policy for Australia since financial market deregulation in the early 1980. It has experienced the evolution from monetary aggregate targeting to a checklist approach. It is not until 1993 that the RBA has the opportunity to apply the current inflation targeting regime due to the sharp disinflation. An expanding literature has discussed the practical experience with inflation targeting and provided formal evaluations, but most of the literature has focused on analysing the Federal Reserve and European Central Bank. Little research has conducted on the Reserve Bank of Australia. de Brouwer and Gilbert (2005), Leu and Sheen (2006), and Karagedikli and

Lees (2007) are the three papers which have profound influence on monetary policy analysing for future study.

de Brouwer and Gilbert (2005) estimate both backward-looking and forward-looking monetary policy reaction functions to assess the stability of Australian monetary policy in the post–float period. By comparing these two kinds of Taylor typed rules, they find the forward-looking equation explain the cash rate better than the backward-looking equation. In the meantime, the empirical outcomes suggest the weight on inflation in the reaction function has increased, and that on output has decreased.

On the one hand, Karagedikli and Lees (2007) employ Linex form function for analysing non-linearity in the monetary policy reaction functions of the RBA and the Central Bank of New Zealand. They extend the framework of Surico (2003) to evaluate the asymmetric response originates either from a convex aggregate supply equation or from a fairly accurate depiction of the RBA's preferences over macroeconomic outcomes. The GMM estimation outcomes indicate that little evidence of asymmetric behavior for the Reserve Bank of New Zealand, whereas the RBA monetary policy is efficiently represent as a nonlinear policy rule due to the fact that output contractions have required a larger policy response than output expansions.

On the other hand, Leu and Sheen (2006) follow Bec, Salem and Collard's (2002) framework to extend the forward-looking Taylor-typed rule by applying a threshold model representation. Moreover, they consider the nonlinearity of policy rule is generated from convexity of Phillips curve as well. Reduced-form nonlinear policy rule is estimated, and the GMM test results suggest that asymmetric behaviour exist in the monetary policy of the Reserve Bank of Australia (RBA) for different periods. From 1984 to 1990, RBA reacts more aggressively towards both future expected inflation and output gaps during expansion than in contractions. This result reflects the passion with which the RBA fight to bring down inflation, for in the late 1980s the interest rate is high. From 1991 to 2002, RBA places a greater weight on stabilizing output during contractions than in expansions. This outcome reveals the RBA has achieved its policy objective that an inflation target band of 2 to 3 percent; the RBA responses to deviations of inflation appear to be symmetric.

Chapter Three: Theoretical model

In this chapter, we discuss the Linex and threshold loss functions in detail. These two loss functions serve as the key to understand asymmetric preferences. Based on optimal control approach to monetary policy, we then derive the reduced-form equations for estimation.

The conventional optimal control approach to monetary policy assumes the central bank cares both inflation and output gaps. These two factors can be summarized into the central bank's period loss function L, and the objective of a central bank is to minimize the sum of all future expected period loss function:

$$\min_{i_t} E_t \sum_{s=0}^{\infty} \delta^{\sigma} L_{t+s} \qquad (1)$$

where $\delta \in (0,1)$ is the central bank's discount factor, and E_t is the conditional expectations operator. We assume the following functional form for the period loss function:

$$L_t = h(\pi_t - \pi^*) + \lambda_1 f(\hat{y}_t) + \lambda_2 g(i_t - i_{t-1}) \qquad (2)$$

where $\pi_t - \pi^*$ is the current inflation rate deviation from its target value, $\hat{y}_t$ measures the output gap and $i_t - i_{t-1}$ is the change of the policy rate. $h(\pi_t - \pi^*)$, $f(\hat{y}_t)$ and $g(i_t - i_{t-1})$ are functions that describe the central bank's preferences on these respective variables. The coefficients λ_1 and λ_2 measure the weights in the loss function for the output gap and changes in the interest rate relative to the level of inflation deviation, respectively.

One can introduce asymmetries into this monetary policy loss function by either replacing (2) with a Linex functional form or applying a threshold function on (2), based on measures of economic activities. We discuss these methods in more details below.

Both methods have been applied to the Australian data. For example, Leu and Sheen (2006) analyze the monetary policy rule of the Reserve Bank of Australia with a threshold linear-quadratic loss function, whereas Karagedikli and Lees (2007) use a Linex function to provides information on asymmetric preferences.

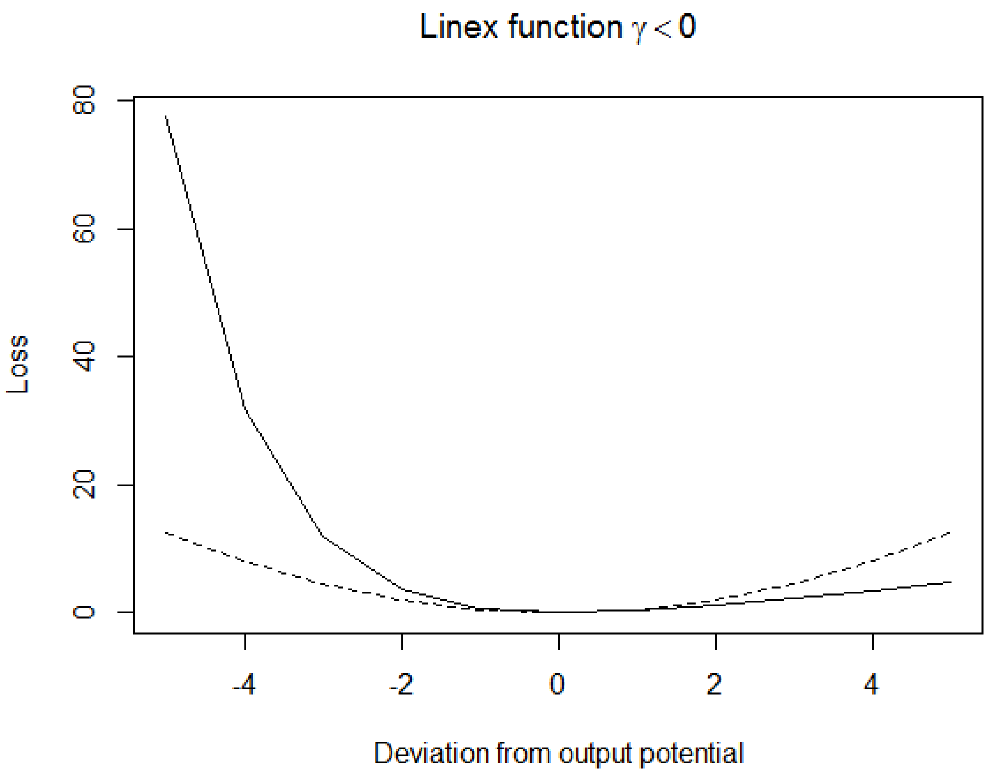
3.1 Linex preference

The Linex loss function was first introduced to analyze monetary policy rule by Nobay and Peel (2003). With respect to inflation and output gap, the Linex loss function takes the form

$$L_t^{linex} = \left[\frac{e^{\alpha(\pi_t-\pi^*)}-\alpha(\pi_t-\pi^*)-1}{\alpha^2}\right] + \lambda\left[\frac{e^{\gamma\hat{y}_t}-\gamma\hat{y}_t-1}{\gamma^2}\right] + \frac{\mu}{2}(i_t-i^*)^2 \quad (3)$$

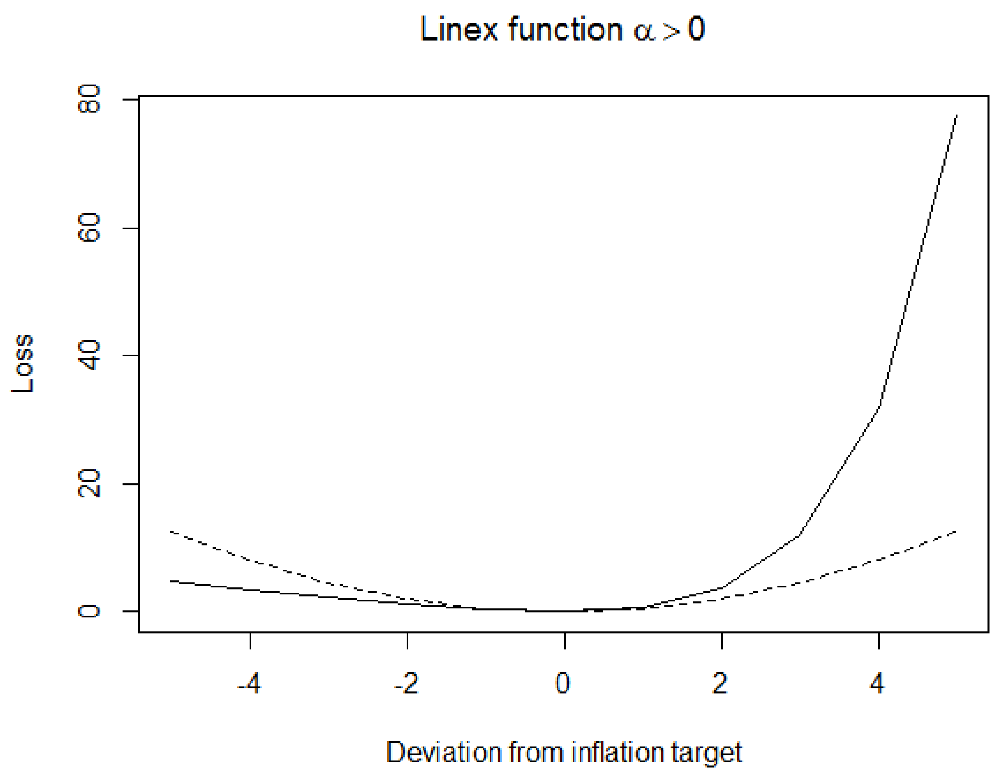
where the coefficients α and γ measure the degree of asymmetry with respect to inflation deviations and the output gap respectively. A negative value of γ indicates output gap during economic contractions are weighted more than during economic expansions of the same magnitude. To understand this, whenever $\hat{y}_t < 0$ the linear component of the loss function is dominated by the exponential component and the converse is true for $\hat{y}_t > 0$. Figure 1 shows the Linex (solid line) and the quadratic (dashed) loss function with the Y axis represent central bank’s loss and the X axis represent deviations from potential output. Both forms of loss functions exhibit increase in loss when output gap deviates from zero. However, the Linex loss function incurs a much larger cost under a negative output gap compares to a positive one.

Figure 1: Preference over output stabilization



The same argument applies to α. If the central bank is more concern about overshooting inflation target than undershooting it, the sign of α should be positive. Figure 2 shows the Linex function with $\alpha > 0$ against the quadratic loss function. A positive value of α makes the loss function more sensitive to a positive inflation deviation compares to a negative one.

Figure 2: Preference over inflation stabilization



In addition, this Linex function nests the quadratic specification as a special case. When both α and γ are close to zero, the loss function L_t^{linex} collapses to the symmetric quadratic specification, namely $L_t^{linex} = \frac{1}{2}(\pi_t - \pi^*)^2 + \lambda \times \frac{1}{2}\hat{y}_t^{\,2} + \frac{\mu}{2}(i_t - i^*)^2 = \frac{1}{2}\left[(\pi_t - \pi^*)^2 + \lambda\hat{y}_t^{\,2} + \mu(i_t - i^*)^2\right]$. See footnotes 3 on page 11 for more details of the derivation.

Following Surico (2003) and Karagedikli and Lees's (2007), we assume the economy can be described by a version of the New-Keynesian model similar to Clarida, Gali and Gertler (1999):

$$\hat{y}_t = E_t\hat{y}_{t+1} - \phi(i_t - uj_t\pi_{t+1}) + \varepsilon_t^d \qquad (4)$$

$$\pi_t = \frac{\kappa\hat{y}_t}{1-\kappa\tau\hat{y}_t} + \theta E_t\pi_{t+1} + \varepsilon_t^s \tag{5}$$

where ε_t^d and ε_t^s are zero mean normally distributed disturbances to output gap and inflation respectively. Equation (4) describes the aggregate demand curve where the output gap is a positive function of its future expected value and a negative function of the real interest rate. Equation (5) is the aggregate supply equation where marginal cost is approximated with the output gap. This starts from Calvo pricing in which only a fraction of firms adjust their price with a constant probability in each period. Moreover, the coefficient τ in the aggregate supply function (5) allows for non-linearity of Phillips curve as a possible explanation of non-linear monetary policy reaction function. When τ is zero, (5) has a linear form.

Minimizing the loss function of (3) subject to constrains (4) and (5) yields equation (6). The detailed derivation is described in the Appendix I.

$$-E_{t-1}\left(\frac{e^{[\alpha(\pi_t-\pi^*)]-1}}{\alpha}\right)\frac{\kappa\phi}{(1-\kappa\tau\hat{y}_t)^2} - E_{t-1}\left(\frac{e^{(\gamma\hat{y}_t)}-1}{\gamma}\right)\lambda\phi + \mu(i_t - i^*) = 0 \tag{6}$$

Using a second-order Taylor series expansion around $\pi_t - \pi^* = 0$ and $\hat{y}_t = 0$, adding a partial adjustment to account for interest rate smoothing, we can transform (6) to a form can be readily taken to the data:

$$i_t = (1-\rho)\{C_0 + C_1(\pi_t - \pi^*) + C_2\hat{y}_t + C_3{\hat{y}_t}^2 + C_4(\pi_t-\pi^*)^2 + C_5[(\pi_t-\pi^*)\hat{y}_t]\}$$
$$+ \rho i_{t-1} + \nu_t \tag{7}$$

where $\rho \in [0,1]$ is a parameter that measures the degree of interest rate smoothing, $C_0 \equiv i^*, C_1 \equiv \frac{\kappa\phi}{\mu}, C_2 \equiv \frac{\lambda\phi}{\mu}, C_3 \equiv \frac{\lambda\phi\gamma}{2\mu}, C_4 \equiv \frac{\alpha\kappa\phi}{2\mu}$, and $C_5 \equiv \frac{2\tau\phi\kappa^2}{\mu}$ .Equation (7) is linear in the coefficients, and the error term v_t is orthogonal to all variables available at time *t*. The asymmetric preferences parameters α and γ controls the degree of non-linearity in inflation and output gap respectively, whereas the nonlinear aggregate supply curve parameter τ introduces a cross-product term of inflation and output gap.[4] Our focus is on two parameters determining the degree of asymmetric responses of inflation and output gap: $\alpha = 2C_4/C_1$and $\gamma = 2C_3/C_2$. With delta method, we can test whether $\alpha = 0$, and/or $\gamma = 0$, respectively.

3.2 Threshold quadratic loss function

Leu and Sheen (2006) introduce non-linearity to Clarida, Gali and Gertler (1999)'s forward-looking linear-quadratic framework by applying a threshold on the model. They assume that the asymmetric intertemporal loss function $L_{\mathrm{t}}^{\mathrm{threshold}}$ takes the form:

$$E_{\mathrm{t}} \sum_{\mathrm{s}=0}^{\infty} \delta^{\mathrm{s}} \left\{\frac{1}{2}[(\pi_{\mathrm{t+s}} - \pi^*)^2 + \omega_{\mathrm{e}}\hat{y}_{\mathrm{t+s}}^2] I_{[\Delta\hat{y}>0]} + \frac{1}{2}[(\pi_{\mathrm{t+s}} - \pi^*)^2 + \omega_{\mathrm{r}}\hat{y}_{\mathrm{t+s}}^2] I_{[\Delta\hat{y}<0]}\right\} \quad (8)$$

where E_{t} is the conditional expectations operator, $\hat{y}_{\mathrm{t}}$ denotes the output gap and $\Delta y = \hat{y}_{\mathrm{t}} - \hat{y}_{\mathrm{t-1}}$. ω_{e} and ω_{r} are positive relative weights to output stabilization in expansions and contractions respectively. $\mathrm{I}[.]$ is the Heaviside function, which is equal to unity when the condition in the associated brackets holds and zero otherwise. Depending on the states of the business cycle, this loss function allows for asymmetric responses to inflation and output gap.

Note that this model nests the classic quadratic loss function as a special case where

[4] We cannot uncover the structural parameter τ. However, by construction, the reduced-form parameter C_1 contains all structural parameters (except τ) that are in C_5. We can conclude that τ is statistically significant if both C_1 and C_5 are significant. Or τ is statistically insignificant if C_1 is significant and C_5 is not significant.

$\omega_e = \omega_r$ in (8). In Bec, Salem and Collard (2002), similar threshold-quadratic loss function was used to capture asymmetries in the monetary policy, and they classify the business cycle by the sign of output gap at period *t-1*. If the lagged output gap has a negative value, the economy is considered to be in contraction in the current period; and the economy is regarded as in expansion in the current period if the sign of the lagged output gap is positive. Leu and Sheen (2006) argue this classification scheme may not be appropriate for Australian data due to the reasons explained in Debelle (1999). Debelle (1999) argues that the design of Australian monetary policy concentrate on the inflation target in the medium run, thus this approach allow the RBA to take into more attention on the issue of output stabilization in the short run. To demonstrate the flexibility of the Australian framework, he mentions three economic incidents that occur during the inflation target regime.[5] Of all these three incidents, the RBA bases their pre-emptive policy move on the expected future output growth and inflation movement. Therefore, Leu and Sheen (2006) use changes in the output gap, i.e. $\Delta\hat{y}_t = \hat{y}_t - \hat{y}_{t-1}$, to categorize the states of business cycle. We follow the same approach as in Leu and Sheen (2006).

To make our result comparable to Leu and Sheen (2006), we use the same constraint as in their paper:

$$\pi_{t+1} = \pi_t + \xi\hat{y}_t + \mu_{t+1} \qquad (9)$$

[5]The three economic incidents are: the interest rate tightening in 1994 because the RBA fears about the overheating of the economy; the interest rate easing in 1996 due to the forecasting that future inflation will back to the tolerance band of between 2 and 3 percent; and the neutral position taken by the RBA on the interest rate during the Asian financial crisis.

$$\hat{y}_{t+1} = \varphi_0 + \varphi_1 \hat{y}_t - \varphi_2 (i_t - \pi_{t-1}) + \eta_{t+1} \tag{10}$$

where π_t is the inflation, $\hat{y}_t$ denotes the output gap, and μ_{t+1} and η_{t+1} are zero mean normally distributed disturbances to inflation and output gap, respectively, and not known at time *t*. The parameters of ξ, φ_0 and φ_2 are expected to be positive, and $\varphi_1 \in (0,1)$. Function (9) specifies an aggregate supply relation where the first-difference in inflation depends positively on lagged output gap. Function (10) is the aggregate demand curve where output gap exhibits sluggish adjustment and depends negatively on the real interest rate. Hence, given the lag structure of this economy, any change in the nominal interest rate will affect demand and therefore equilibrium output with one-period lag, and therefore affects inflation with a two-period lag.

Leu and Sheen (2006) consider the possibly that the aggregate supply function may be non-linear as well, which is the aggregate supply function illustrated as follow:

$$\pi_{t+1} = \pi_t + f(\hat{y}_t) + \mu_{t+1} \tag{11}$$

$$\text{with } f(\hat{y}_t) = \begin{cases} \xi_e \hat{y}_t & \text{if } \Delta\hat{y}_t > 0 \\ \xi_r \hat{y}_t & \text{if } \Delta\hat{y}_t < 0 \end{cases} \tag{12}$$

Solving the problem of choosing the nominal interest rate minimizing (8) subject to (9), (10), (11) and (12) the central bank's optimal reaction function can be represent as follow:

$$\begin{aligned} i_t^* = \bar{\imath} + & \{\beta_e(E[\pi_{t+m}|\Lambda_t] - \pi^*) + \gamma_e E[\hat{y}_{t+n}|\Lambda_t]\} I_{[\Delta\hat{y}_t > 0]} \\ & + \{\beta_r(E[\pi_{t+m}|\Lambda_t] - \pi^*) + \gamma_r E[\hat{y}_{t+n}|\Lambda_t]\} I_{[\Delta\hat{y}_t < 0]} \end{aligned} \tag{13}$$

Details on how to derive the optimal interest rate rules for these two extensions see

Appendix 1 and 2 of Leu and Sheen (2006). In the former case, the asymmetric preference affects the response to both inflation and the output gap, whereas in the latter the nonlinear aggregate supply function only affects the inflation response.

Combining the state-contingent monetary policy reaction function (13) with a first-order partial adjustment specification to capture possible inertia in monetary policy, and replacing the unobservable forecasts with actual future values yields:

$$i_t = (1-\rho)\bar{\imath} + \rho i_{t-1} + (1-\rho)\left[\beta_e(\pi_{t+m} - \pi^*) + \gamma_e \hat{y}_{t+n}\right] I_{\Delta\hat{y}>0}$$

$$+ (1-\rho)\left[\beta_e(\pi_{t+m} - \pi^*) + \gamma_e \hat{y}_{t+n}\right] I_{\Delta\hat{y}_t>0} + \varepsilon_t \quad (14)$$

where $\varepsilon_t = -(1-\rho)\left\{\beta_e(E[\pi_{t+m}|\Lambda_t] - \pi^*) + \gamma_e E[\hat{y}_{t+n}|\Lambda_t]\right\} I_{[\Delta\hat{y}_t>0]}$

$$-(1-\rho)\left\{\beta_r(E[\pi_{t+m}|\Lambda_t] - \pi^*) + \gamma_e E[\hat{y}_{t+n}|\Lambda_t]\right\} I_{[\Delta\hat{y}_t>0]} + \nu_t \quad (15)$$

Leu and Sheen estimate equation (13) with a range of values for m and n, and m = n =1 is the only specification that generates sensible results. We will follow their procedure to evaluate our model with m = n =1.

During the expansionary phases of the business cycle, the sensitivity of central bank towards future expected inflation and output gaps are measure by β_e and γ_e respectively. On the contrary, during the contractionary phases of the business cycle, the sensitivity of central bank towards future expected inflation and output gaps are measure by β_r and γ_r. Thus, to answer our research question that whether the RBA considers output gap deviations from its potential value and inflation deviations from its target in recession and expansion equally costly to the economy, we can simply test whether $\beta_e = \beta_r$ and $\gamma_e = \gamma_r$. If we cannot reject the null hypotheses of $\beta_e = \beta_r$ and $\gamma_e = \gamma_r$,the threshold specification (14) collapses back to the classic forward-looking Taylor rule that proposed by Clarida, Gali and Gertler (1999).

Chapter Four: GMM estimation procedure

In this chapter, we briefly discuss the GMM estimation procedure, which our empirical results are based on.

The Generalized Method of Moments (GMM) is a general method for estimating parameters in statistical models, where many estimators, such as Ordinary Least Squares (OLS) estimator, can be seen as special cases of GMM. Hansen states that:

'GMM refers to a class of estimators which are constructed from exploiting the sample moment counterparts of population moment conditions (sometimes known as orthogonality conditions) of the data generating model' (Hansen 2008).

The orthogonality conditions refer to a set of zero-valued population moments. The Ordinary Least Squares estimator may be easily derived from an orthogonality condition between the explanatory variables and residuals. Consider a linear regression model of

$$y_t = x_t'\beta + \epsilon_t$$

where β is a $K \times 1$ diensional vector and x_t' is a $1 \times K$ vector.

Assume that this linear regression represents the conditional expectation:

$$E[y_t | x_t] = x_t'\beta \text{ so that } E[\epsilon_t | x_t] = 0.$$

By Law of Iterative Expectation, we have $E[x_t\epsilon_t]$ =0. This gives us the K unconditional moment conditions, i.e. orthogonality conditions, for the OLS estimation

$$g(\beta) = E[x_t \epsilon_t] = E\left[x_t\left(y_t - x_t'\beta\right)\right] = 0.$$

As for GMM estimators, consider a regression model of

$$y_t = x_t'\beta + \epsilon_t = x_{1t}'\gamma_0 + x_{2t}'\delta_0 + \epsilon_t.$$

where β is a K×1 diensional vector and x_t' is a 1×K vector. We decompose the K variables in x_t into two parts: x_{1t} and x_{2t}. Assume that the K_1 variables in x_{1t} are predetermined, while the $K_2 = K - K_1$ variables in x_{2t} are endogenous. That implies

$$E[x_{1t}\epsilon_t] = 0 \tag{16}$$

and

$$E[x_{2t}\epsilon_t] \neq 0. \tag{17}$$

Notice that we have K parameters in β, but only $K_1 < K$ moment conditions, therefore the parameters are not identified and cannot be estimated consistently. However, suppose there are K_2 new variables, z_{2t}, that are correlated with x_{2t} but uncorrelated with ϵ_t:

$$E[z_{2t}\epsilon_t] = 0. \tag{18}$$

The K_2 moment conditions in (18) can replace (17), giving us K moment conditions:

$$g(\beta) = \begin{pmatrix} E[x_{1t}\epsilon_t] \\ E[z_{2t}\epsilon_t] \end{pmatrix} = E[z_t\epsilon_t] = E\left[z_t\left(y_t - x_t'\right)\right] = 0,$$

where z_t=[x_{1t}, z_{2t}]. Variables in z_t are usually referred to as instrumental variables. The situation here is called exact identification where the number of instruments equals exactly the number of unknown model parameters. The corresponding sample moment conditions are given by

$$g_T(\hat{\beta}) = \frac{1}{T}\sum_{t=1}^{T} z_t\left(y_t - x_t'\hat{\beta}\right) = 0.$$

Alternatively, in the case of over-identification, where the number of instruments is more than model parameters, there is no exact solution to the above equation. The standard procedure is to minimize the distance between $g_T(\beta)$ and zero. The distance is measured by the quadratic form

$$Q_T(\beta) = g_T(\beta)' W_T g_T(\beta).$$

where W_T is an $R \times R$ symmetric and positive definite weighting matrix. The GMM estimator id defined as

$$\hat{\beta}_{GMM} = \arg\min_{\beta} g_T(\beta)' W_T g_T(\beta).$$

The GMM estimator is efficient when W_T equals the inverse of the covariance matrix Ω of the sample moments g_T.

One of the key assumptions of the Ordinary Least Squares model is that the error terms, ε, are conditionally homoskedastic. A sufficient, but not necessary, condition for this restriction is that the errors are independent and identically distributed. Nevertheless, in practice, it is quite often that we need to allow for heteroskedasticity and/or autocorrelation in the error terms and hence, a Heteroskedasticity and Autocorrelation Consistent Covariance (HAC) or Newey-West weighting matrix is needed for estimating.

Andrews and Monahan (1992) state that if $g_t(\hat{\beta})$ is highly serial correlated; a pre-whitening and re-coloring procedure can soak up the correlation in the moment conditions prior to estimation. This procedure works as follow: We first fit a VAR(1) to the sample moments: $g_t(\hat{\beta}) = Ag_{t-1}(\hat{\beta}) + e_t(\hat{\beta})$. The variance $\widehat{\Omega}$ of $g(\beta)$ is estimated by $\widehat{\Omega} = (I - A)^{-1}\widehat{\Omega}^*(I - A)^{-1}$, where $\widehat{\Omega}^*$ is the long-run variance of the residuals $e_t(\hat{\beta})$. The GMM estimator is then obtained by minimizing $g_T(\beta)'\widehat{\Omega}^{-1}g_T(\beta)$.

There are three different approaches for optimization in Eviews 7: two-step efficient GMM, iterated GMM estimator and continuously updated GMM estimator.

a) Two-step efficient GMM:

- We arbitrarily choose an initial weighting matrix, and find a consistent but inefficient first-step GMM estimator $\hat{\beta}_{[1]} = \arg\min_\beta g_T(\beta)'W_{[1]}g_T(\beta)$.
- Find the optimal weighting matrix, $W_{[2]}^{opt}$, based on $\hat{\beta}_{[1]}$ and obtain a new $\hat{\beta}_{[2]} = \arg\min_\beta g_T(\beta)'W_{[2]}^{opt}g_T(\beta)$. But this estimator in not unique, because it depends on the initial weighting matrix $W_{[1]}$. β

b) Iterated GMM estimator:

This approach is step from the estimator $\hat{\beta}_{[2]}$ in the two-step efficient GMM method.. We repeat the step 1 - 2 of a) to update the weights to obtain $W_{[3]}^{opt}$ and $\hat{\beta}_{[3]}$, and stop until convergence. This approach does not depend on the initial weighting matrix.

c) Continuously updated GMM estimator:

This approach is to recognize from the outset that the weighting matrix depends on the parameters, and minimize $Q_T(\beta) = g_T(\beta)'W_Tg_T(\beta)$. This approach is never possible to solve analytically.

In applications of GMM in the literature, the moment conditions are typically derived directly from economic theory. For instance, under rational expectations, the implications of some economic theory can be present as

$$E\left[v\left(\delta_{t+1}, \eta_0\right) \mid I_t\right] = 0,$$

where $v\left(\delta_{t+1}, \eta_0\right)$ is a function of future observations of a variables, δ_{t+1}; I_t is the information set available at time t.

In our models, we assume the RBA is forward-looking and under rational expectation when it was setting cash rate. This indicates that the RBA behaves as a rational expectations agent uses current available information set to forecast the future. Thus, the forecast error, or residual term, ε_t is orthogonal to variables contained in the information set. This implies that the forecast errors of RBA regarding future values of the inflation and output gaps are uncorrelated with the information that assists in the decision-making. However, the variables in our equations are potentially endogenous. Hence, the instrumental variables, such as exchange rate, lagged value of the cash rate, the inflation rate and output gap, are uncorrelated with the forecast error but correlated with the variables. Therefore, we can construct a set of orthogonality conditions to form the centerpiece of the GMM estimation procedure.

Chapter Five: Data

The estimation is conducted using quarterly data that spans the period from 1993Q1 to 2008Q1. This period corresponds to the start of inflation targeting era and ends before the Global Financial Crisis.[6][7]

We use the target policy rate as the cash rate. Potential output is obtained from the Hodrick-Prescott (HP) filter on the Australian real GDP with parameter 1600.[8]Although there are some problems associated with the use of this HP filter to detrend output such as the assumption that the noise in data is approximately normally distributed, and investigation is entirely historical and static, this filter is used broadly in the macroeconomic research. The output gap is computed as the difference between the logarithm of real GDP and its HP trend.[9] Inflation is based on the year-ended change headline consumer price index (CPI) inflation rate, excluded interest and tax changes of 1999-2000. Given the RBA's explicit inflation target between 2 to 3 percent, we use the midpoint 2.5% for target inflation π^* in both estimations. All of the data above can be obtained from the RBA and Australian Bureau of Statistics.

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[6] Because Grenville (1997) points out that the RBA starts to focus internally on an inflation target by 1991, Leu and Sheen (2006) consider this is the starting date of inflation targeting for Australia as well. However, it is until 1993 that the RBA announce this new monetary policy new regime. And a numbers of other papers favor dating early 1993 as the beginning of inflation targeting regime, such as Bernanke *et al.* (1999) and Karagedikli and Lees's (2007). Thus, we start our estimation from 1993Q1.

[7] Australia is a small open economy. Although the cash rate of Australia did not hit the zero lower bound, the 2008 global financial crisis has serious distortions on the Australian monetary policy. Including the crisis period would make the long run preference obscure. Thus, we stop our analysis at 2008Q1.

[8] Appropriate values of the smoothing parameter depend on the periodicity of the raw data. Since we apply quarterly data for analyzing, the smoothing parameter is 1600.

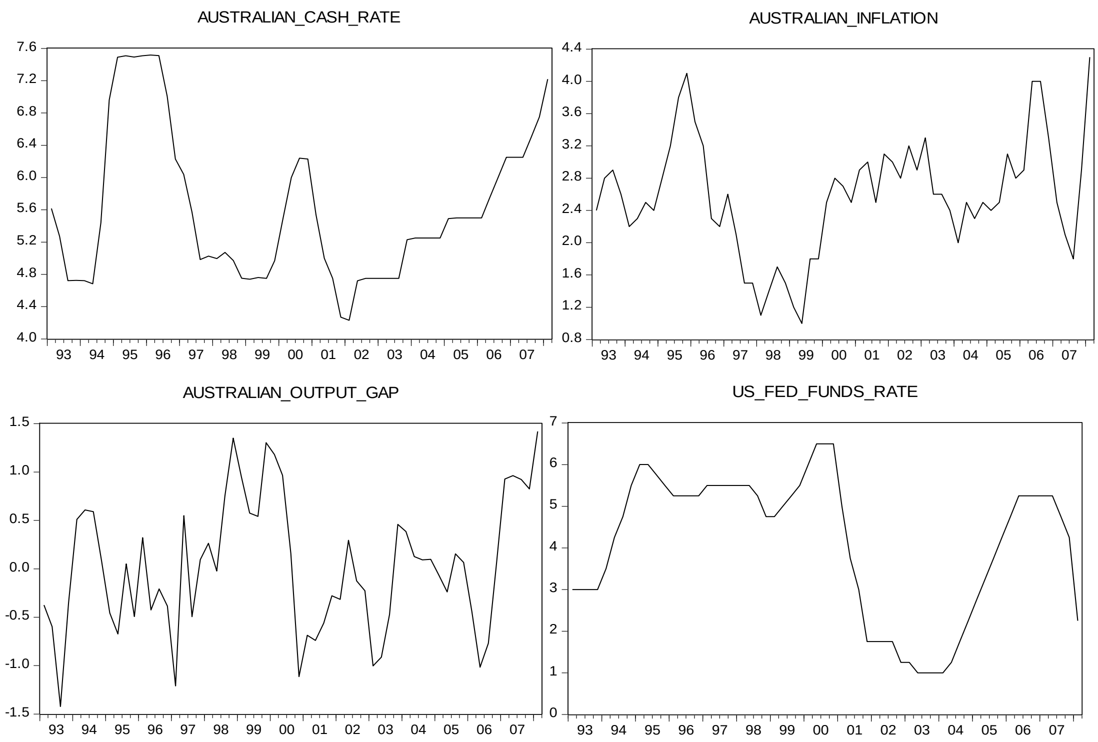
[9] Our output gap is different from Leu and Sheen's, even if we obtain the data from the same place with the same approach; because the RBA regularly review the Australian real GDP.

Table 1 describes the basic statistics of mean and standard deviation of the cash rate, inflation and output gap. Figure 3 shows the principle macroeconomic time series from 1993Q1 to 2008Q1; including the Australian cash rate, Australian inflation, Australian output gap, and the US Fed Funds rate. Please see figures in Appendix II for the dynamics of the instrumental variables. The top left panel of Figure 3 shows the Australian cash rate. The rate increases from the end of 1994 and decreases sharply at the end of 2000. We can observe similar patterns for Australian inflation (the top right panel of Figure 3).

Table 1: Descriptions of the cash rate, inflation and output gap

Descriptive Statistics	Cash Rate	Inflation	Output Gap
Mean	5.61	2.58	0.03
Std. Dev	0.93	0.72	0.68

Figure 3: Principle macroeconomic time series



Chapter Six: Empirical results

In this chapter, we present our empirical results from both the Linex function and the threshold-quadratic specifications. Both results suggest that the RBA responds symmetrically to inflation, but asymmetrically to output gap. Particularly, the RBA places a greater weight on output stabilization in economic contractions than in economic expansions.

6.1 Linex preference

Using the generalized method of moments (GMM) with Newey-West (HAC) weighting matrix that accounts for possible heteroskedasticity and serial correlation in the error terms, we evaluate the preferences of the RBA by estimating the following Linex reaction function:

$$i_t = (1-\rho)\left\{C_0 + C_1(\pi_t - \pi^*) + C_2 y_t + C_3\left(y_t\right)^2 + C_4(\pi_t - \pi^*)^2 + C_5\left[(\pi_t - \pi^*)y_t\right]\right\} + \rho i_{t-1}$$

We choose Bartlett and Newey and West (1994) variable bandwidth for Kernel options. No pre-whitening is used for the estimation. We use the sequential iterate optimization method. A standard set of four lags each of the cash rate, inflation, and output gap, which are the same as Surico (2003) did for analyzing European Central Bank's behavior, are included as instruments for the regression.

As in Leu and Sheen (2006), dummy variables are introduced for the sudden rise in the cash rate for the period from 1994Q3 to 1995Q1 and the sudden fall in the cash rate for the period from 2000Q4 to 2001Q4. Leu and Sheen (2006) argue that the sudden rise in the cash rate in the first period is because RBA believes the early 1990s recession is over and a global expansion is likely; for the second period, the sudden fall of the cash rate are due to the negative sentiments resulted from the September 11 terrorist attack in the U.S, and the burst of dot com bubble that slows down the global economy. Table 2 displays the GMM equation estimation results.

Table 2: GMM Estimates of the Linex function

	ρ	C_0	C_1	C_2	C_3	C_4	C_5
1993Q1 – 2008Q1	0.87	5.76	2.65	4.19	-2.67	0.50	-1.42
p-value	(0.00)	(0.00)	(0.00)	(0.00)	(0.03)	(0.47)	(0.29)

	J-statistic	Q-stat (4 lags)	ARCH(4)-stat	Normality-stat
1993Q1 – 2008Q1	$\chi^2(6)$	$\chi^2(4)$	$\chi^2(4)$	$\chi^2(2)$
	4.30	3.87	2.50	7.26
p-value	(0.64)	(0.42)	(0.65)	(0.03)

Notes: *P*-values are reported in parentheses. The set of instruments are the same as Surico (2003) did for estimating European Central Bank monetary policy: output gap (-1 to -4), inflation (-1 to -4), and cash rate (-1 to -4).

The *J*-statistics indicate that the over-identifying restriction is not rejected at the 5%

significance level. This suggests that the model specification is not rejected by the data. Furthermore, we apply test for autocorrelation, normality and ARCH effects. The diagnostic results suggest there are no serial correlation, no ARCH effects, but the Doornik-Hansen test suggest we cannot reject the null hypothesis of normality with p-value of 0.03.

The estimated coefficients C_4 and C_5 are not significant at 10% significance level, whereas the coefficient on squared output gap, C_3, is significant at 5% significance level. These results have three implications. First, the monetary policy in Australia follows an asymmetric policy in response to output gaps; Secondly, there is no evidence to support a non-linear Phillips curve as the cross-product term C_5 is insignificant and C_1 is significant; Thirdly, no asymmetry can be detected with respect to inflation due to C_4 is not significant. Similar conclusion was drawn in Leu and Sheen (2006) and Karagedikli and Lees (2007). Furthermore, the estimated coefficient C_3 has the expected negative sign suggests that there exists a significant asymmetry that an output contraction relative to the potential level is weighted more severely than an output expansion of the same magnitude.

As we discussed in early chapters, we are not able to identify all structural coefficients, but the reduced-form parameters allow us to recover $\gamma = (2C_3/C_2)$, which measures the asymmetry on the output gap in the loss function of the RBA. This yields $\gamma = -1.274$. Using the delta method yields a standard error of the γ of 0.656. The

χ^2-test with the null hypothesis of the structural parameter is zero is rejected at the significance level 0.0521. Therefore, we can conclude there is asymmetric preference on output gaps for the monetary policy in Australia.

6.2 Threshold quadratic loss function

Following Leu and Sheen's (2006) procedure, we use changes in the output gap to classify the two states of the business cycle. The instruments are the same as those of Leu and Sheen, which are 2 to 5 lagged values of the cash rate and the inflation rate, 1 to 4 lagged value of the first-difference in the output gap, 1 to 4 lagged value of the four-quarter change in the logarithm of the trade-weighted index exchange rate, and 1 to 5 lagged values of the federal funds rate.

The estimation is conducted on the same dataset we used for the Linex preference. We apply the same estimation procedure as before with Bartlett and Newey and West (1994) variable bandwidth for Kernel options. No pre-whitening is used. Sequential iterate optimization algorithm is chosen for the estimation as well. The same dummy variables are used from 1994Q3 to 1995Q1 and from 2000Q4 to 2001Q4. The equation we estimated is the following:

$$
\begin{aligned}
i_t = (1-\rho)\Big\{(\bar{r} + \pi_{t-1}) + \big[\beta_e(\pi_{t+1} - \pi^*) + \gamma_e \hat{y}_{t+1}\big] I_{\Delta\hat{y}_t > 0} \\
+ \big[\beta_r(\pi_{t+1} - \pi^*) + \gamma_r \hat{y}_{t+1}\big] I_{\Delta\hat{y}_t < 0}\Big\} + \rho i_{t-1}
\end{aligned}
$$

Estimation results are presented in Table 3 and 4. Based on the *J*-statistics, the null hypotheses of over-identifying restriction cannot be rejected at 5% level. This suggests that the model specification is not rejected by the data. The diagnostic results suggest we cannot reject the null hypothesis of no serial correlation, no ARCH effects and non-normality at 5% significance level for the residuals.

Table 3: GMM Estimates of threshold model

	$\bar{r}$	ρ	β_e	γ_e	β_r	γ_r
1993Q1 – 2008Q1	3.22	0.87	0.63	0.91	0.95	1.80
	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)	(0.00)

Table 4: Results of hypotheses testing of threshold model

	$\bar{r}$ = sample mean	$\beta e = \beta_r$	$\gamma_e = \gamma_r$	J-stat	Q-stat (4 lags)	ARCH (4 lags)	Normality statistic
1993q1 – 2008q1	F(1, 47)	F(1, 47)	F(1, 47)	$\chi^2(15)$	$\chi^2(4)$	$\chi^2(4)$	$\chi^2(2)$
Sample $\bar{r}$ =3.02	4.20 (0.05)	0.61 (0.44)	3.08 (0.09)	8.69 (0.93)	4.60 (0.33)	2.45 (0.65)	2.71 (0.26)

Notes: *P*-values are reported in parentheses. The set of instruments are the same as Leu and Sheen's which includes: federal funds rate (-1 to -5), four-quarter change in the logarithm of the trade-weighted index exchange rate (-1 to -4), change in the output gap (-1 to -4), inflation (-2 to -5), and cash rate (-2 to -5).

The estimated coefficients ρ, β_e, β_r, γ_e, γ_r and $\bar{r}$ are all possess expected signs and statistically significant with p-values below 2% significance level. Particularly, the estimate of the interest smoothing parameter ρ is 0.87 which is identical to the Linex case. And the high value of ρ indicates that the RBA pays cautious attitude to interest rate changes since the inflation targeting regime. The values of estimated parameters of β_r and γ_r are larger than those of β_e and γ_e respectively, which imply that the RBA response more to both inflation and output gap when it considers the economy is in contractions.

Moreover, to recover an estimate for the 'neutral' real interest rate, we follow Leu and Sheen (2006) that impose an inflation target π^* of 2.5%. And we examine the estimated parameter $\bar{r} = 3.22$ with the sample average real interest rate (3.02%), and find that they are not statistically different from each other at 10% significance level.

Recall that the main purpose of this thesis is to examine whether the RBA considers inflation deviations from the target value (measured by β) and output gaps (measured by γ) during economic expansions and contractions equally. We evaluate this by testing whether $\beta_e = \beta_r$ and $\gamma_e = \gamma_r$ across the two states of the business cycle. The Wald tests show that we can reject the null hypothesis of $\gamma_e = \gamma_r$ at 10% significance level but not for $\beta_e = \beta_r$. This has two implications. First, the RBA has an asymmetric response to output gaps. Particularly, the estimated coefficients γ_e is less than γ_r indicates that the RBA places a greater weight on output stabilization during contractions than during expansions. Second, there is no asymmetric behavior in the RBA's policy response to the inflation. Stevens (2003) argues that inflation is harder to control precisely in the short run, and attempts to do so may trigger unnecessary instability of macro economy. This is why the Reserve Bank of Australia targets the medium-run inflation level. This enables the RBA to have sufficient flexibility to smooth output or employment fluctuations. Indeed, the results from both Linex and threshold model implies a symmetric response to inflation during expansions and recessions.

Given the implications of the two sources of asymmetry – asymmetric preferences or a non-linear aggregate supply curve, our empirical results shows the asymmetry only with regard to the output gaps, thus we conclude that asymmetric preferences provide a plausible explanations.[10]

Figure 4 and Figure 5 show the actual, fitted, and residual series for the cash rate for the Linex and threshold model respectively. Relative to the fitted cash rate of the Linex model, the fitted cash rate of threshold model tracks the actual cash rate very closer.

To summarize, both of the Linex and threshold models suggest that the RBA has asymmetric preferences on output gap during economic expansions and contractions. To be specific, the RBA places a greater weight on output stabilization in contractions than in expansions. Meanwhile, we do not find evidence to support an asymmetric

[10]In the literature review chapter, we discuss that the asymmetric preferences affect the response to both inflation and output gap, whereas the non-linear aggregate supply curve only affects the inflation response.

response to the inflation deviation.

Figure 4: Cash rate fit from the Linex function

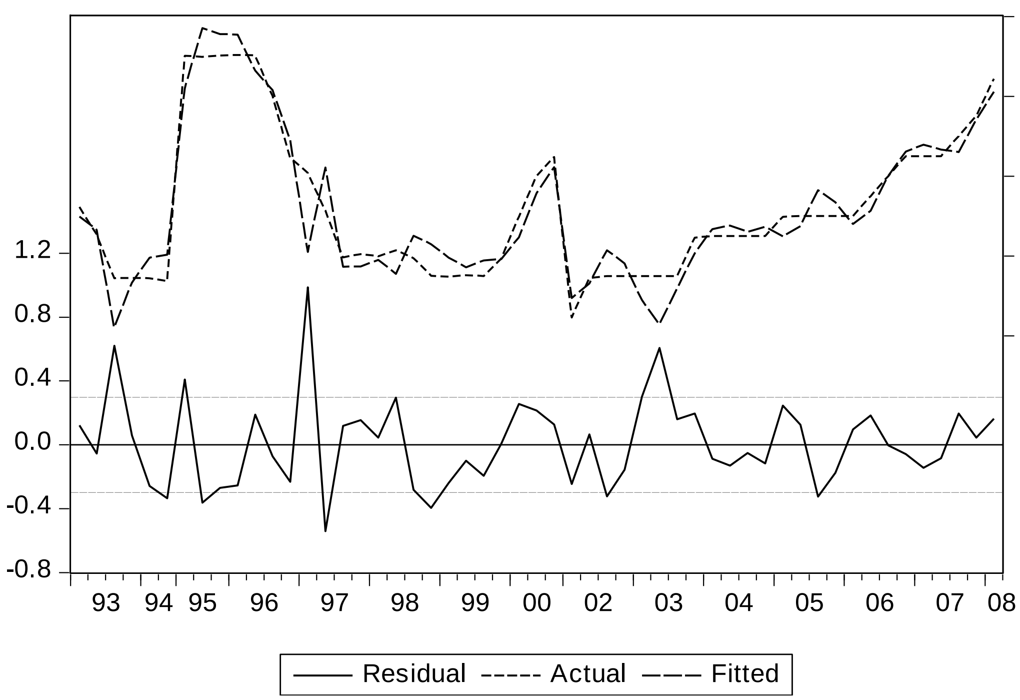
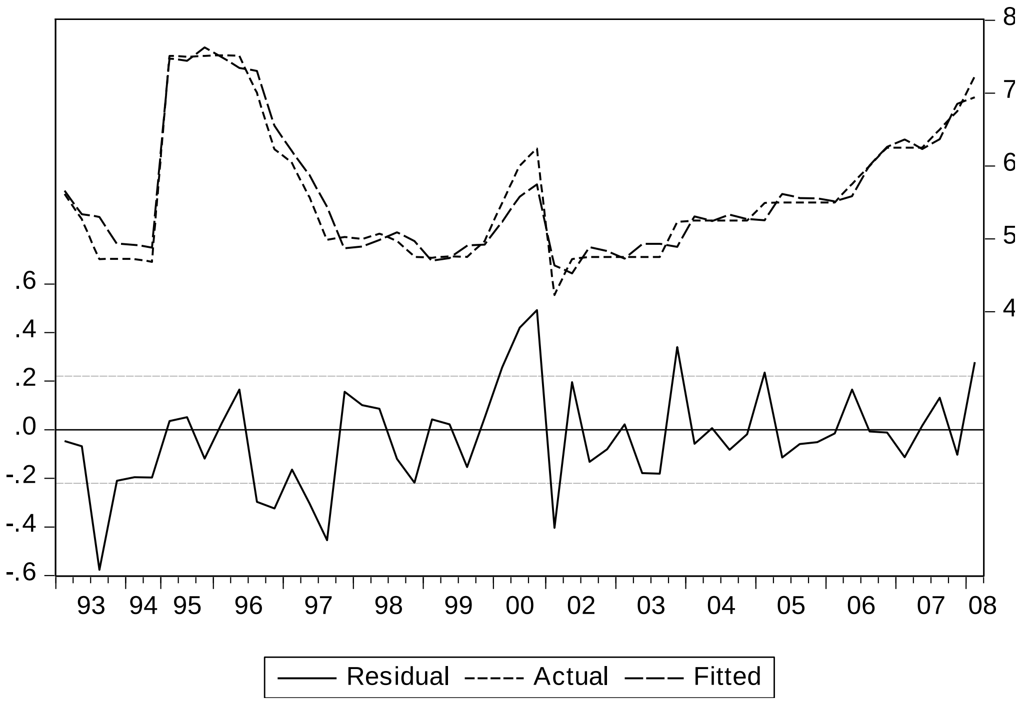


Figure 5: Cash rate fit from the Threshold model



Chapter Seven: Robustness

Our GMM estimation for the Linex model uses instruments to proxy for the two endogeneous variables, π_t and $\hat{y}_t$. If the instruments we applied here are weak then inferences based on the GMM results are seriously undermined. A common way of evaluate whether the instruments are relevant or not is to check the R^2 from the first stage regression. Thus we regress these two endogeneous variables with the whole instrument sets.

Another test for relevance is the first-stage F-test that the coefficients on all the instruments are jointly zero. In the Table 5, we display the F-statistics and the value of adjusted R-square. Obviously, the null hypotheses that the instruments are jointly irrelevant are rejected for both inflation and output gap. The R-square from the first stage regression for inflation is 0.60, and for output gap is 0.37.

Table 5: Results from F-Tests

	π_t		$\hat{y}_t$	
1993:1 – 2008:1	F(11,41)	Adjusted R^2	F(11,41)	Adjusted R^2
	5.95	0.60	3.87	0.37
P-value	(0.00)		(0.00)	

We assess the robustness of our findings that an asymmetric response to the output gap term by considering an alternative instrument set for the Linex model:[11]

Table 6: GMM Estimates of alternative instruments for Linex function

	ρ	C_0	C_1	C_2	C_3	C_4	C_5
1993q1 – 2008q1	0.87	5.75	1.70	1.42	-1.03	0.56	0.80
p-value	(0.00)	(0.00)	(0.00)	(0.01)	(0.04)	(0.20)	(0.16)

Table 6 shows that we re-estimate the Linex specification monetary policy rule with everything equals, but different instrument set. These instruments are 1 to 4 lagged values of the four-quarter change in the logarithm of the trade-weighted index exchange rate; 1 to 5 lagged values of federal funds rate; 1 to 4 lagged values of the first-difference in the output gap; and 2 to 5 lagged values of squared output gap.

The estimated results are similar to our original results that C_3 is the expected negative sign and statistically significant, whereas C_4 and C_5 are not significant. The value of γ yields -1.45 and the standard deviations is 0.861 with delta method. We can reject the null hypothesis that $\gamma = 0$ at 10% significance level.

With different instruments, the coefficient of C_3 is still negative and significant and the parameters of C_4 and C_5 are insignificant as well. Both of the results confirm that the null hypothesis of symmetric preferences of RBA is rejected.

[11] We also try continuously updating weighting matrix for estimating. The results suggest the same that the coefficient C_3 is negative and significant at 5% significance level, and the parameter of C_4 and C_5 are not significant.

Chapter Eight: Conclusions

We employ both a Linex and a threshold quadratic loss functions to study possible asymmetric central bank's preferences during economic expansions and contractions. Our empirical analysis is conducted on quarterly Australian data over the period 1993Q1 to 2008Q1. The GMM estimates suggest that the RBA has an asymmetric preference. In particular, the RBA dislikes a negative output gap more than a positive one. This result is robust to alternative loss functions. In addition, we do not find evidence for a non-linear aggregate supply curve.

We find no evidence to support asymmetric preferences with respect to inflation deviations during the sample period. This outcome is consistent with the objective of inflation targeting regime that the RBA has applied for current monetary policy. The RBA keeps an inflation target band of 2 to 3 percent in a medium run, regardless of the stages of the business cycle.

We compare the fit of the alternative models and argue the Linex loss function fit less well when comparing to the threshold-quadratic loss function. One drawback of this study is that we are not able to identify all the structural parameters. Future studies should also consider potential asymmetries on interest rate smoothing.

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Appendix I: Derivation of optimal monetary policy

This appendix relies heavily on Surico (2003), who demonstrates a solution for the optimal policy in a model of asymmetric central bank preferences provided by a Linex loss function.

The central banks choose policy rates in a discretionary fashion to minimize the following intertemporal criterion

$$\underset{i_t}{\mathrm{Min}}\, E_{t-1} \sum_{\sigma=0}^{\infty} \delta^{\sigma} \mathrm{Loss}_{t+\sigma}$$

where δ is the discount factor and the Loss is:

$$\mathrm{Loss} = \frac{e^{\alpha(\pi_t-\pi^*)} - \alpha(\pi_t-\pi^*) - 1}{\alpha^2} + \lambda\left[\frac{e^{(\gamma\hat{y}_t)} - \gamma(\hat{y}_t) - 1}{\gamma^2}\right] + \frac{\mu}{2}(i_t - i^*)^2 \qquad (3)$$

The parameters α and γ represent the degree of asymmetry with respect to inflation deviations and the output gap, respectively. Quadratic preferences are recovered for α and γ are close to zero.

Because no endogenous state variable enters the model, the intertemporal policy problem reduces to a sequence of static optimization problems. This amounts to choosing in each period the instrument rate such as to minimize the criterion:

$$E_{t-1}\frac{e^{\alpha(\pi_t-\pi^*)} - \alpha(\pi_t-\pi^*) - 1}{\alpha^2} + \lambda E_{t-1}\left[\frac{e^{(\gamma\hat{y}_t)} - \gamma(\hat{y}_t) - 1}{\gamma^2}\right] + \frac{\mu}{2}(i_t - i^*)^2 + E_{t-1}\sum_{\sigma=1}^{\infty} \delta^{\sigma} L_{t+\sigma} \qquad (15)$$

subject to

$$\pi_t = \frac{k\hat{y}_t}{1-k\tau\hat{y}_t} + \theta E_t \pi_{t+1} + \varepsilon_t^s \qquad (5)$$

$$\hat{y}_t = E_t\hat{y}_{t+1} - \varphi(i_t - E_t\pi_{t+1}) + \varepsilon_t^d \tag{4}$$

The first order condition reads

$$-E_{t-1}\left(\frac{e^{[\alpha(\pi_t-\pi^*)]-1}}{\alpha}\right)\frac{k\varphi}{(1-k\tau\hat{y}_t)^2} - E_{t-1}\left(\frac{e^{(\gamma\hat{y}_t)}-1}{\gamma}\right)\lambda\varphi + \mu(i_t - i^*) = 0. \tag{19}$$

Equation (4) implicitly provides a general reaction function derived from which the central bank moves policy rates as the optimal and nonlinear response to the developments in the economy. The task is to estimate the nonlinear reaction function (16) in order to evaluate whether those parameters α, γ and τ are significantly different from zero, for those parameters capture any asymmetry in the objective function of the monetary authorities.

However, because of the exponential function, the reduced-form estimates of equation (16) cannot recover all structural parameters and, especially α and γ which are the main objective of our research. Thus, using a second-order Taylor series expansion around $\pi_t - \pi^* = 0$ and $y_t = 0$, we can get

$$-k\varphi E_{t-1}(\pi_t - \pi^*) - \lambda\varphi E_{t-1}(\hat{y}_t) - \frac{\alpha k\varphi}{2}E_{t-1}[(\pi_t - \pi^*)^2] - \frac{\lambda\varphi\gamma}{2}E_{t-1}(\hat{y}_t^2) -$$
$$2k^2\tau\varphi E_{t-1}\left((\pi_t - \pi^*)\hat{y}_t\right) + \mu(i_t - i^*) + e_t = 0 \tag{20}$$

where e_t is the remainder of the Taylor series approximation.

This condition relates the policy rates with the expected values of the state variables conditioned upon the information available at time t – 1. Replace expected inflation and output gaps with actual values, and include a partial adjustment mechanism for setting interest-rate smoothing, we can get the linearized version of the model:

$$i_t = (1-\rho)\left\{C_0 + C_1(\pi_t - \pi^*) + C_2\hat{y}_t + C_3(\hat{y}_t)^2 + C_4(\pi_t - \pi^*)^2 + C_5\left[(\pi_t - \pi^*) \times \hat{y}_t\right]\right\} + \rho i_{t-1} + v_t \tag{21}$$

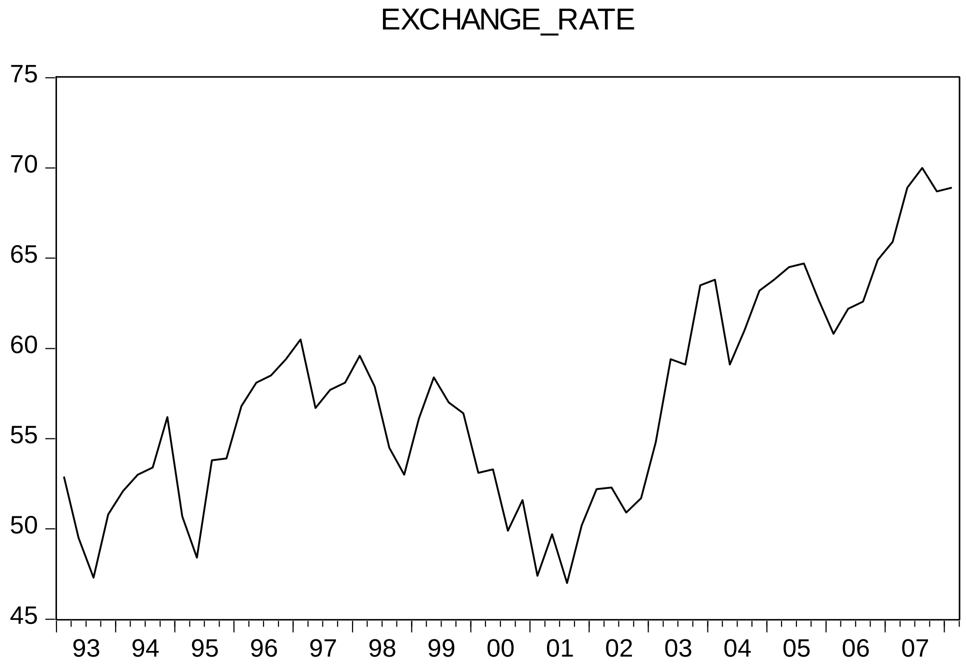
which is linear in the coefficients, and the error term v_t is orthogonal to all variables available at time t.

$$C_0 \equiv i^*, C_1 \equiv \frac{\kappa\varphi}{\mu}, C_2 \equiv \frac{\lambda\varphi}{\mu}, C_3 \equiv \frac{\lambda\varphi\gamma}{2\mu}, C_4 \equiv \frac{\alpha\kappa\varphi}{2\mu} \text{ and } C_5 \equiv \frac{2\tau\varphi\kappa^2}{\mu}.$$

Some interesting facts are worthy to notice. First, the classic Taylor rule can be obtained as a special case by $C_3 = C_4 = C_5 = 0$. Second, the asymmetric preferences parameters of α and γ independently introduce a squared term in inflation and output gap, respectively. Meanwhile, the parameter τ which detects nonlinearity from nonlinear aggregate supply curve, introduce a cross-product term. Third, the reduced-form coefficients can only be interpreted as convolutions of the coefficients representing the central bank's preferences and those describing the structure of economy. Although, it is impossible to identify all structural coefficients, we could identify that $\alpha = 2C_4/C_1$ and $\gamma = 2C_3/C_2$. Using delta method, we can obtain the standard deviations of α and γ respectively. Then we can apply the hypothesis testing of α and γ equal to zero to evaluate whether there exist any asymmetry.

Appendix II: Figure of other instrument variables

The trade-weighted index exchange rate



The first-difference in the output gap