

THE MAKING OF CONTEMPORARY AUSTRALIAN MONETARY POLICY – FORWARD OR BACKWARD LOOKING?

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Abstract: Monetary authorities rarely disclose their true reasons for their policy reactions. Tracing the policy reaction function to see if the monetary authority is using simple rules would offer profound insight into the past behavioral relationship between the monetary authority and economic agencies. A reasonable body of knowledge about the direction of monetary policy would assist economic agencies' expectations, which would in turn, be useful for the monetary authority in anticipating the likely trends for the general economy. The main objective of this study is to extend de Brouwer and Gilbert (2005) as from the Australian financial deregulation era (from 1983 to 2002) to the present. Empirical findings show that the Reserve Bank of Australia (RBA) is forward looking when formulating monetary policy rather than backward looking, and that inflation targeting plays a significant role in stabilizing the output of the economy.

Keywords: backward looking, forward looking, generalized method of moments

JEL code: E52

1. Introduction

According to RBA charter, monetary policy is the central instrument for maintaining low, stable inflation, stabilizing the home currency, preserving full employment level, maintaining the economic prosperity and welfare of the citizen and maximizing the sustainability of economic growth. Most major central banks use an overnight cash rate¹ as the tool of policy. An important question is how to set up the cash rate to achieve the objectives of policy. Many methods have been used to set up the cash rate, and the most popular methodology is known as the Taylor rule. From a historical aspect, the Taylor rule has been widely used as a benchmark for inspecting

¹ Bank rate also known as Official Bank Rate in UK, Official Cash Rate in New Zealand and Federal Funds Rate in the United States.

monetary policy achievement.

A number of simple interest rate feedback rules have been proposed to assess the overnight cash rate. These are the nominal income level rule, nominal income growth rule, price level rule, Taylor rule, inflation only rule, change rule and constant real interest rate rule. After examining the above rules, de Brouwer and O'Regan (1997) indicated that none of the efficient frontiers for any of the rules reduce the variability in inflation or output to zero. But the policy that unambiguously makes the best effort is the Taylor rule. The Taylor rule clearly leads to a lower variability of output and inflation. They suggested that inflation is caused by recent domestic excess demand. Therefore, reacting to the strength of demand, indicated by the output gap, would lower the variability of inflation. Orphanides (2007) reviews the theoretical studies of monetary rules and argues that the simplest policy rule was Milton Friedman's k -percent rule. Friedman (1960) advises that the constant growth rate of money supply should be similar to the growth rate of potential output, and he also proposes a constant growth of money supply. This rule only requires a small amount of information to implement the policy, which implies that Friedman's rule ignores the importance of the interest rate instrument. In contrast, Taylor (1993) argues that creating and maintaining target inflation would stabilize not only the financial market but also macroeconomic performances. He advocates the direct linkage between interest rate, inflation, and economic activities. Hence, his rule provides a convenient framework for analyzing monetary policy that neglects the effects of money supply and demand.

This paper investigates the RBA's reaction functions in setting the cash rate in the post-exchange rate float period after 1984, and in particular, focuses on the period after 1993 when the RBA introduced inflation targeting. The full sample period commences from quarter 1, 1984 until quarter 4, 2014. The subsample or inflation targeting period starts from quarter 1, 1993 until quarter 4, 2014. The target approach allows monetary policy to intervene and stabilize the fluctuations in output over the business cycle. Achieving the target rate would provide a discipline for monetary policymakers, and would be treated as an anchor for private-sector expectation of inflation. Further, our main goal is to investigate whether RBA policy emphasizes a specific rule. While many

empirical studies have been published which gauge the efficiency and behaviour of major central banks in making their monetary policy, there has been a lack of systematic empirical analysis of how RBA sets their monetary policy to sustain the Australian economy. The latest empirical paper was de Brouwer and Gilbert (2005), which used data until 2002.

Several important choices were made before the study. First, Orphanides (1998) suggests that policymakers should use real time data. This study uses final release data because they are easy to use and more likely to represent the precise economic activities. There are two unobservable variables in the Taylor rule which are target inflation and potential output. We utilize the Hodrick-Prescott (HP) filter to generate the potential GDP and thus output gap. The HP filter is extensively used in empirical macro-economic research to isolate the cyclical element of a time series from raw data. We assume 2.5% of inflationary target which is the average of the target band (2-3%). Third, we distinguish between backward-looking and forward-looking reaction functions. The backward-looking function uses historical data to figure out the cash rate, while the forward-looking function specifies the forecast profile for both inflation and output gap one year ahead. We estimate and compare both rules. To estimate the parameters in the forward-looking rule, we use the generalized method of moments (GMM). A key in GMM is a set of population moment conditions that are derived from the assumptions of the econometric model.

Overall, this paper will investigate the following questions: Whether the RBA make variables other than inflation and output gap? What are the implications of inflation targeting on monetary policy? What is the natural interest rate implied by the model? Comparing the backward-looking and forward-looking functions, which one is more efficient and gives a better outlook of monetary policy reaction function? Is Australian monetary policy sensitive to other developed economy policies or other main trading partner policies?

The structure of this paper is as follows: Section 2 provides the literature review of the study. Section 3 introduces the simple reaction function of the Taylor rule followed by a description of the data and variables that are used in Ordinary Least Square (OLS)

and the GMM model in Section 4. Section 5 is based on the equation in Section 3 and uses OLS to estimate parameters under the backward-looking reaction function. Section 6 derives the equation for the forward-looking reaction function and uses the GMM routine for obtaining the empirical results. Section 7 composes the out-of-sample forecasts for both backward- and forward-looking specification. The main findings of this project, directions of future study and the answers to the questions given above, are provided in Section 8.

2. Literature Review

Taylor (1993) states that policy rules that concentrate on exchange rates or money supply do not convey a good output and price variability as policies that target price level and real output directly. He advocates for monetary policies where the short-term cash rate is increased or decreased when price level and real income deviate from their targets. The uncertainty is how much the cash rate should change to meet central bank purposes. While Taylor (1993) investigated the economic performance of the US, this empirical study will focus on Australian economic conditions.

On the basis of the original paper by Taylor (1993), Clarida et al. (1998) derive a forward-looking version of the simple backward-looking reaction function. They estimate the reaction function with expectation variables and suggest that targeting inflation is effective and a major component for output stabilization. By targeting inflation, monetary authorities would be able to increase the nominal rate effectively to raise the real rate of interest if expected inflation exceeds its target in the long run.

Taylor (1993) indicates that under the floated exchange rate system, the central bank can easily adjust the short-term cash rate in relation to deviations in price level and real output from their potential level. Yet in fixed exchange rate regimes, countries cannot adjust their interest rate independently since they have to consider the shift in other countries monetary policy to maintain its pegged exchange rate. Output and inflation perform better under a floated exchange rate scheme compared with a fixed exchange rate scheme. Clarida et al. (1998) state that building credibility through a fixed

exchange rate regime is tough due to the failure of monetary control, which puts pressure on the economy. Edey (2006) finds that the Taylor rule gave an accurate explanation of the federal funds rate in the US since 1987. The most recent empirical paper about Australian monetary policy reaction function was published by de Brouwer and Gilbert (2005). They examine the backward-looking and forward-looking Taylor rule using Australian data up to 2002.

Orphanides (1998, 2000) argues that policymakers use real-time data that is available at the moment they made their decision, while studies such as Taylor (1999) and Clarida et al. (1998) prefer to utilize final release data. Orphanides (2004) indicates that estimated output gaps are effective for explaining subsequent fluctuations in inflation. Gruen et al. (2005) and Orphanides (2001) implement the Phillips Curve, a theoretical model to generate the output gap, which dominates the HP filter. deBrouwer and Gilbert (2005) indicate that the standard errors from regression and implied cash rates are not distinguished under these different data sets and technical approaches. They all explain central bank decisions similarly. So, there is no optimal data set or technique.

Lee et al. (2011) establish a novel methodology of the Taylor rule. They advocate that instead of using one rule to formulate the cash rate, central banks should estimate several rules, weight them and take the average interest rate to adjust monetary policy. A reasonable weighting would be when higher weights are given to the rules which performed better than others in the past. As with Taylor rules, they apply to several methods using different measurements of inflation and different techniques to derive the output gap, weight them and then imply the fitted cash rate to evaluate central banks policies. They call the resulting rule the “meta Taylor rule” and employ the Meta Taylor rule to investigate US monetary policy. Lee et al. (2012) do the same with UK and Australia monetary policies. The results demonstrate that the novel approach is useful and applicable in terms of both behavioral modelling and inference perspective, offering a highly flexible instrument with which to model and describe policymaker’s decisions. The novel model can not only adjust the uncertainties of parameter estimates and unexpected shocks, but it can further adjust the uncertainties on the measures of

variables used in making decisions. Their results indicate that a ‘meta’ Taylor rule offers a flexible but reliable prescription of monetary policy in those countries.

However, according to Bernanke (2010), the limitation of the Taylor rule is that in a given episode, such as when the US short-term nominal interest rate hits the zero lower bound (ZLB), the cash rate cannot be reduced further, and therefore using the Taylor rule as a framework of monetary policy is not reasonable. At the ZLB, monetary policy cannot be set with a nominal interest (Orphanides, 2007). Since Australia has not experienced such a case, unlike the US economy, applying the Taylor rule to examine RBA decisions is reasonable and effective.

3. Simple Reaction Function

The Taylor rule is regularly known as a simple monetary policy rule that describes how central banks change the short-term nominal cash rate in response to inflation movements and macroeconomic fluctuations. It brings a useful, simple and transparent framework for the study of historical policy and for the econometric assessment of alternative strategies that central banks can use as an anchor for their interest rate policy. The rule is also adopted as a tool for review of the policy and has simplified the analysis of monetary policy in practice and in empirical research. The primary formulation of the simple policy reaction function applied in monetary literature is widely known as the Taylor rule:

$$i_t = \bar{i} + \beta(\pi - \pi^*) + \gamma(y - y^*)$$

where i_t is the short term nominal cash rate, \bar{i} is the neutral rate of interest, π is the inflation rate, and y is the real output. The value t indicates the period of investigation, and the value (*) indicates the target or potential value of the variables. β and γ are parameters representing the weight of inflation and output, respectively, by policymakers.

This equation states that policymakers make the change in interest rate in response to the deviations from the target or potential value of the variables. Taylor (1993)

suggests that β being greater than 1 means that the nominal cash rate should be adjusted to stabilize inflation. β being greater than 1 is commonly known as the “Taylor principle”. If it is less than 1, the nominal cash rate adjusts to accommodate the divergence of inflation. If the estimated value of β is significantly higher than γ , the central banks consider inflation variability as more important than output gap variability and vice versa. Following Taylor (1999), previous periods of inflation and output should be used as the primary information set for guiding the instrument path. The backward-looking reaction function is computed on the basis of historical data, while the forward-looking reaction function is computed on the basis of a one year forecast profile of inflation and output gap.

4. Data Description

The data was collected from the Australian Bureau of Statistic (ABS). The inflation rate is measured by the change in CPI. The target inflation is assumed to be 2.5% - average of the target range (2-3%). While Taylor (1993) originally used the GDP deflator as an inflation measurement, we prefer CPI to measure the inflation rate. The GDP deflator contains only goods and services manufactured domestically, while the CPI covers further imported goods and services. This indicates that the CPI will more accurately specify changes in the price level in response to average consumption. This is especially appropriate in Australia, as we import more than export and the major export base is raw materials which are not consumable goods. Changes in imported goods and services prices would heavily influence the degree of inflation in Australia. Further, the GDP deflator contains the prices of capital goods while the CPI ignores them, implying that the GDP deflator is less likely to capture the inflation rate precisely compared to the CPI². The GDP level employs real GDP, not nominal GDP, since nominal GDP does not eliminate the GDP deflator or inflation index. The figure below shows the results of using the HP filter to determine potential GDP and the output gap.

²For example, changes in price of BHP shares or Boeing aeroplanes are not relevant to the changes in household consumption level

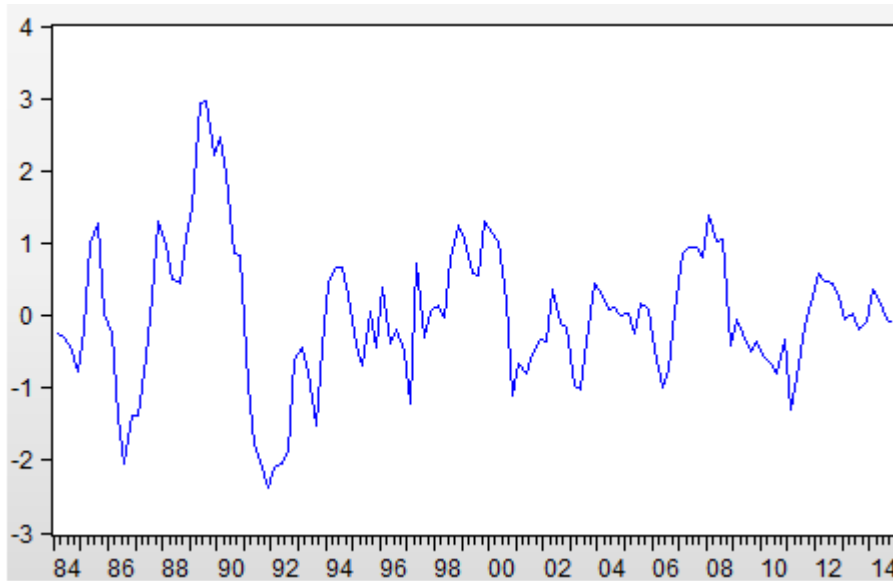


Figure1: Output Gap

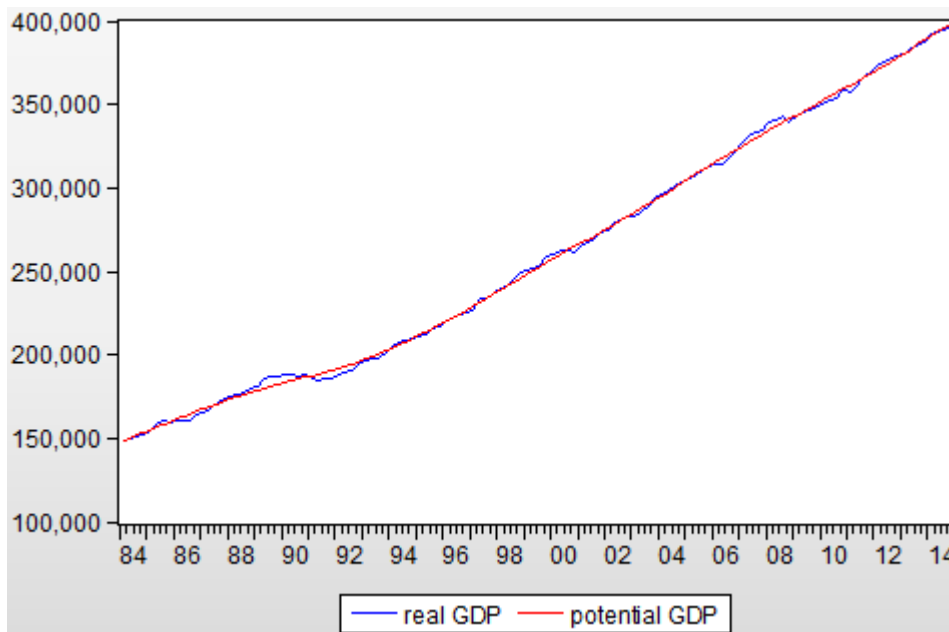


Figure 2: Real GDP versus Potential GDP derived from HP filter

The striking feature of Figures 1 and 2 is the recession in the early 1990s when the Australian economy was affected by the saving and loans crisis in North America. The crisis began when Japan and Germany increased their interest rates heavily, pressuring US cash rates to also rise, leading to a massive sell off of shares in the US market. Share prices declined by 25% on average globally, but Australia saw a 40% collapse in its

share market. Most of the major OECD economies experienced an economic downturn in the early 1990s. Real output collapsed below the potential level. Further, in 2008, we can see that real output exceeded its potential level. Meanwhile, the Global Financial Crisis (GFC) led to recessions in many developed countries. This was because of the economic boom in China, resulting in large demand for raw materials from Australia. Thus, Australian economy was spared from the collapse of the global economy.

Rather than just the output gap and inflation, the forward-looking function also considers the unemployment rate, exchange rate and world interest rate. The federal funds rate is used to measure the world interest rate since US monetary policy significantly influences the world economy and also the economic information set of the RBA. This does not mean that RBA decisions are heavily dependent on US policy but that the RBA considers the change in US interest rate as an important element to determine its actions. Therefore, the exchange rate also specifies the Australian dollar in terms of the US dollar. Figure 3 shows the federal funds rate, where we can see that the rate has hit the ZLB since 2008. The Federal Reserve had to do this in order to recover their economy. In this case, the Taylor rule is not applicable. Figure 4 shows that in the period between 2009 and 2010, our home currency depreciated deeply but then appreciated until it hit a peak in 2012.

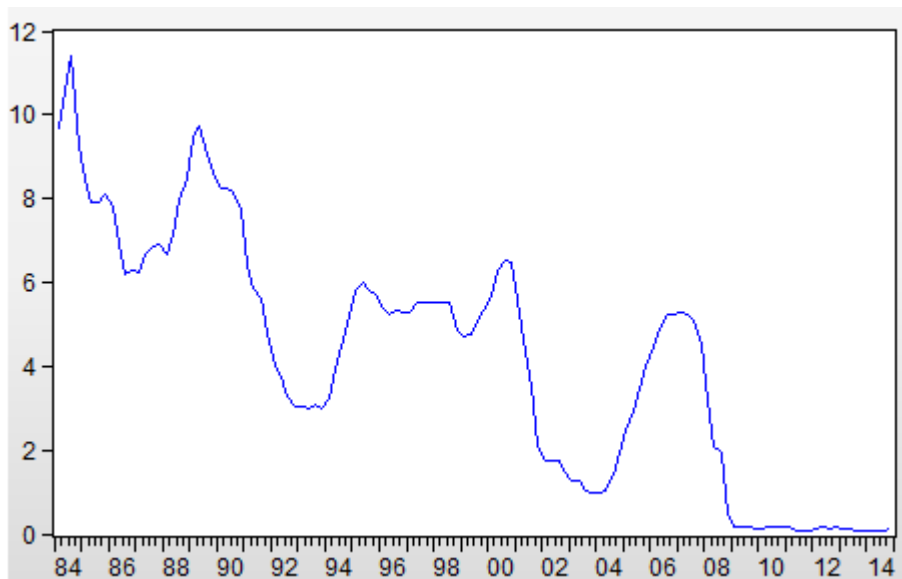


Figure 3: The US Federal Funds Rate

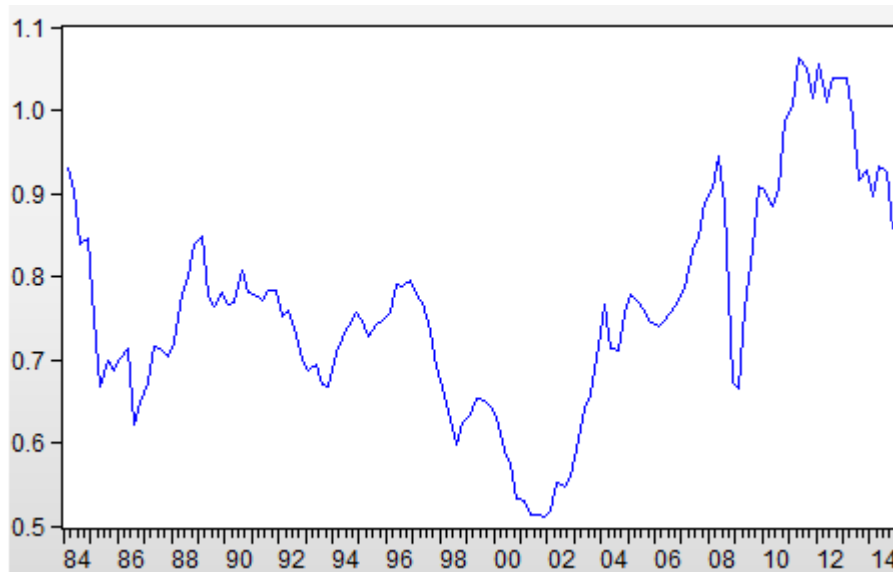


Figure 4: USD/AUD Exchange Rate

The unemployment rate is positively related to output level, representing an outlook of the entire economy. Including the unemployment rate would produce a better performance of the reaction function. Figure 5 shows the domestic unemployment rate. The increase in unemployment rate in 2009 is in line with the effects of the GFC. Unemployment surging from 2012 onwards explains the recent cash rate cut. Figure 6 represents the deviation of inflation from its target. Since 1993, when the RBA adopted target inflation, we have experienced a period of stable inflation, as it contributed to maintain inflation within its target band as well as stabilizing economic activities. Figure 7 represents the actual cash rate generated by the RBA. During the inflation targeting period, interest rates moved in a quite flat direction as a result of inflation and output stabilization.

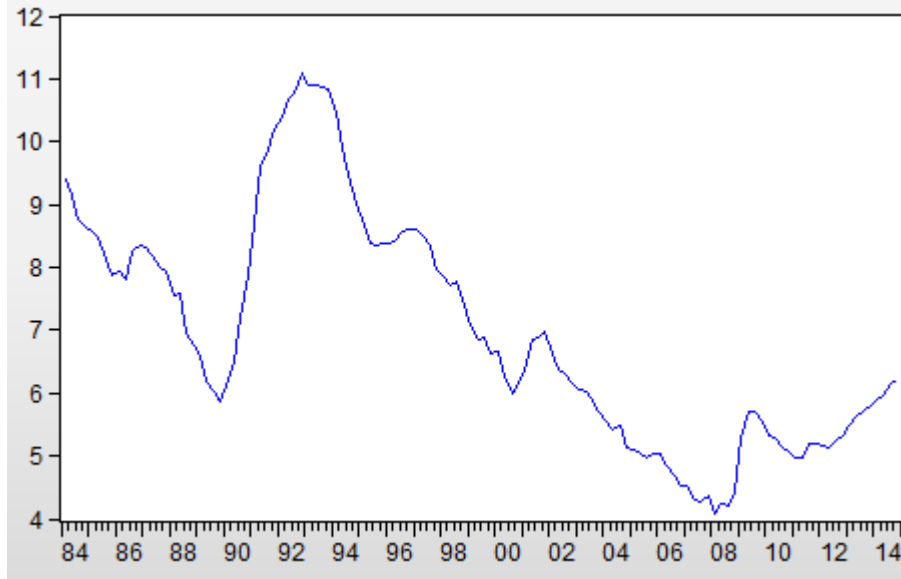


Figure 5: The Australian Domestic Unemployment Rate

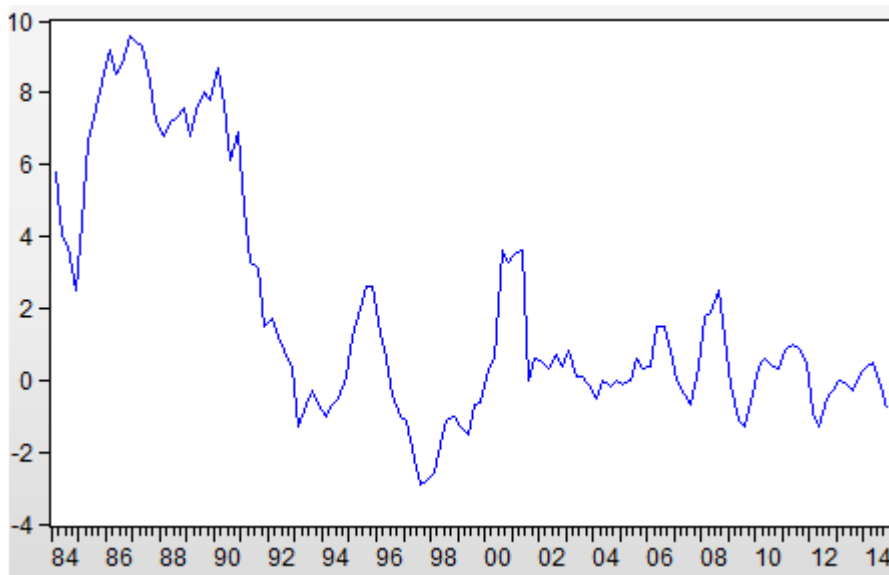


Figure 6: Deviations from the Inflation Target

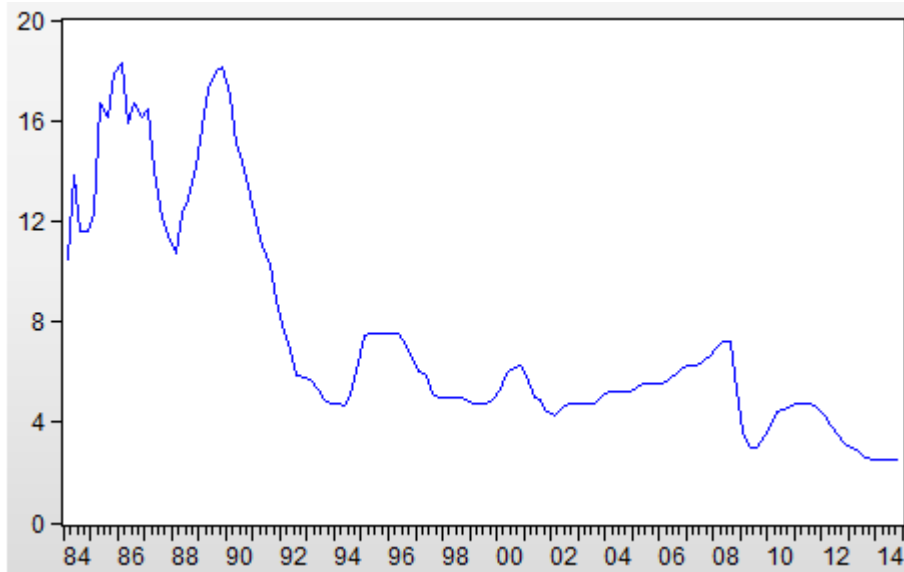


Figure 7: RBA Actual Cash Rate

5. Backward-Looking Reaction Function

The Taylor rule is generally recognized as a backward-looking reaction function since people assume that monetary authority decisions rely on the current and lags inflation diversion and output gap. In this section, we use the value of inflation deviation and output gap lagged one period. The Taylor rule with backward-looking function is estimated using the Ordinary Least Square (OLS) estimation.

Table 1: Estimated Backward-Looking Reaction Functions (post floated period of exchange rate):

1984Q2 – 2014Q4:				
Constant	Inflation gap (t-1)	Output gap (t-1)	Standard error	Adjusted R²
5.23 (0.00)	1.17 (0.00)	0.5 (0.00)	1.89	0.81

Table 1 shows the estimated coefficients of inflation deviation and output gap using the backward-looking function. The model uses one quarter lagged values of the

inflation gap and output gap. The outcomes from the full sample period show that both inflation parameter β and output parameter γ are significant. β is greater than 1, which indicates that the Australian monetary authority adjusts the target nominal interest rate to stabilize inflation within the target range. Yet it is lower than de Brouwer and Gilbert (2005) estimated value because they only investigate the data up to 2002, whilst this study includes more recent periods. Figure 3 shows that after 2002, the inflation deviation became less volatile, meaning that inflation is captured well and might be a reason for policymakers to reduce the weight on inflation.³ The output gap parameter is significant, but less than 1, which means that the RBA still treats inflation variability as more important than output gap variability. Compared to previous findings, the weight on the output gap is significantly lower, however the weight is positive. Hence, policymakers still consider the role of the output gap when making decisions.

Table 2: Estimated Backward-Looking Reaction Functions (inflation targeting period):

1993Q2 – 2014Q4 (87 observations)				
Constant	Inflation gap (t-1)	Output gap (t-1)	Standard error	Adjusted R2
5.0 (0.00)	0.36 (0.00)	0.40 (0.06)	1.23	0.12

Table 2 shows the subsample period results, in which output and inflation parameters are still statistically significant but the coefficient of inflation is smaller than the output coefficient. β is less than 1, and the standard errors are higher than previous studies, partly because the sampling period is different and our period cover a longer time, including the period of the GFC. During this period, there were many fluctuations in the cash rate series. Figure 7 shows the actual movement of the short-term nominal

³Recall that excess demand is a major driver of inflation but in the last decade real output and potential output almost match each other except in 2008 (see Figure 2).

cash rate. The striking feature is that after 1993 when the RBA adopted target inflation, interest rate movement is much flatter than in the past. This explains why the adjusted R2 is much lower in the sub-sample period and also the much lower values of inflation and output variability.

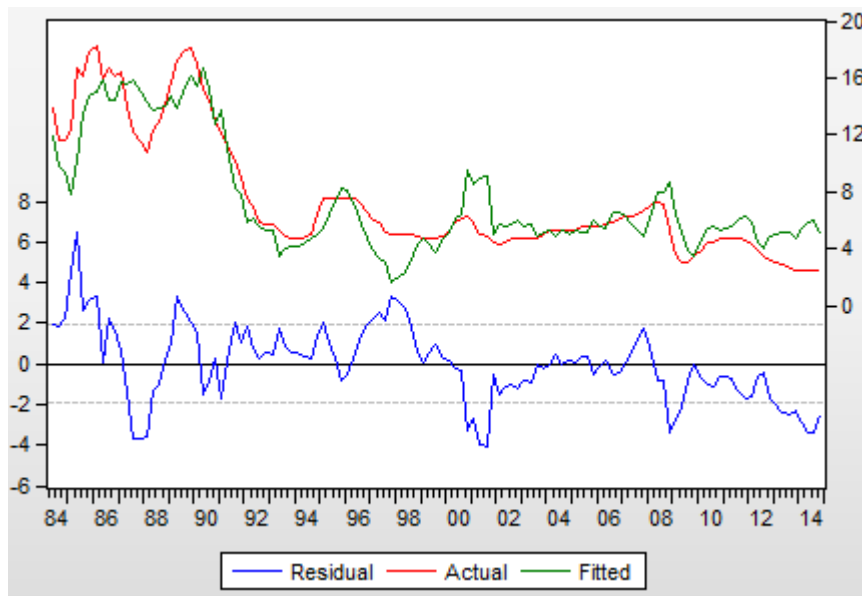


Figure 8: Predicted versus Actual Cash Rate

Figure 8 indicates that under the backward-looking function, the fitted cash rate is in line with the actual cash rate. The model prediction significantly overstated RBA actions in the early 2000s and 2008 with an unpredicted global financial crisis that forced the RBA to cut the interest rate deeply. In addition, the implied cash rate greatly understated the actual rate in the beginning of the post-floated period, late 1980s and second half of the 1990s.

The simple backward-looking reaction function seems easy to understand and serves as a benchmark for investigating monetary policy. On the other hand, since the rule is too simple, by considering inflation and the output gap, it forgoes many other crucial economic variables such as the unemployment rate, exchange rate and world interest rate.

6. Forward-Looking Reaction Function

The simple backward-looking reaction function described above is straightforward and easy to interpret as it depends on lagged values of deviation of inflation from the target and output gap. However, it neglects one important aspect – the forward-looking monetary policy formulation perspective. In practice, monetary policy makers often tend to base their monetary policy decision making on a rational outlook – expectation of future values of policy variables, available information, and past experiences. Empirical studies, including Clarida et al. (1998), Batini (1999), de Brouwer and Gilbert (2005), and so forth, suggest that the forward-looking reaction function specification outperforms the backward-looking one in evaluating monetary policy behavior.

Clarida et al. (2000) cast the Bryant-Hooper-Mann rule (1993) in a forward-looking framework and proposed a simple baseline forward-looking specification for the policy reaction function in which the target interest rate (i_t^*) relies on a neutral nominal interest rate (\bar{i}), the expected deviation of inflation from the target [$E(\pi_{t+n}|\Omega_t) - \pi^*$] as well as the expected output gap [$E(y_t|\Omega_t) - y^*$]:

$$i_t^* = \bar{i} + \beta[E(\pi_{t+n}|\Omega_t) - \pi^*] + \gamma[E(y_{t+m}|\Omega_t) - y^*] \quad (1)$$

Where Ω_t is the information set available to the monetary authority at time t when it sets the interest rate.

Since the monetary authority often tends to avoid a loss of credibility from impulsive large changes in policy instrumental variables, it is assumed that it smooths interest rates by adjusting it partially to the target:

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

where ρ is a smoothing factor, $0 < \rho < 1$. Larger values of ρ actually reduce the level of smoothing, and in the limiting case with $\rho = 1$, the cash rate series is just the same as the original series with lag one time unit. Hence, values of ρ close to 1 have less of a smoothing effect and give greater weight to recent changes in the data, while values of ρ closer to 0 have a greater smoothing effect and are less responsive to recent changes.

Letting $\alpha \equiv \bar{i} - \beta\pi^*$ and $x_t \equiv y_t - y_t^*$ and substituting equation (2) into (1) yield

$$i_t = (1 - \rho)[\alpha + \beta E(\pi_{t+n}|\Omega_t) + \gamma E(x_{t+m}|\Omega_t)] + \rho i_{t-1} + v_t \quad (3)$$

where $v_t \in \Omega_t$ which is orthogonal to ε_t . Assuming rational expectations, equation (3) can be written in terms of realized variables as

$$i_t = (1 - \rho)\alpha + (1 - \rho)\beta\pi_{t+n} + (1 - \rho)\gamma x_{t+m} + \rho i_{t-1} + \varepsilon_t \quad (4)$$

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

Let u_t be the monetary authority's instrument set at the time it chooses the interest rate. This information set is orthogonal to the error term in the base line equation (4); i.e., $E(\varepsilon_t|u_t) = 0$. Equation (4) implies the following orthogonality condition:

$$E[i_t - (1 - \rho)\alpha - (1 - \rho)\beta\pi_{t+n} - (1 - \rho)\gamma x_{t+m} - \rho i_{t-1} | u_t] = 0 \quad (5)$$

The estimation issue arising from equation (4) is that the conventional ordinary least square (OLS) estimation will give inconsistent estimates because π_{t+n} is correlated with ε_t . To circumvent this issue, Clarida et al. (1998) suggest estimating the unknown parameters (α , ρ , β , γ) in equation (4) via the GMM method with a vector of instrumental variables that belongs to the information set t and is orthogonal to ε_t . In other words, this vector of instrumental variables comprises the monetary authority's information set at the time they determine the interest rate and that it should not be correlated with v_t .

Given equation (1), an equilibrium relation for the real interest rate can be written as

$$r_t^* = \bar{r} + (\beta - 1) [E(\pi_{t+n}|\Omega_t) - \pi^*] + \gamma [E(y_{t+m}|\Omega_t) - y^*] \quad (6)$$

where \bar{r} is the equilibrium interest rate independent of monetary policy. Equation (6) illustrates the critical role of parameter β . If $\beta > 1$, the target real interest rate is adjusted to stabilize inflation. If $0 < \beta < 1$, it moves to accommodate inflation; that is, the monetary authority raises the nominal rate in response to an expected rise in inflation, but it does not increase it sufficiently to keep the real rate from declining. Clarida et al. (2000) show that $0 < \beta < 1$ is consistent with the possibility of persistent,

self-fulfilling fluctuations in inflation and output. Hence, $\beta = 1$ is crucial discriminatory criterion to judge central bank behavior.

Finally, it is possible to use the fitted values for the parameters α and β to recover an estimate of the monetary authority's constant target inflation rate π^* . Although the empirical model does not separately identify the equilibrium inflation rate and the equilibrium real interest rate, it does provide a relation between them conditional upon α and β . Given that $\alpha \equiv \bar{i} - \beta\pi^*$ and $\bar{r} = \bar{i} - \pi^*$, the target inflation rate

$$\pi^* = \frac{\bar{r} - \alpha}{\beta - 1} \quad (7)$$

establishes a relation between the target inflation rate and the equilibrium real interest rate defined by the parameters α and β in the policy rule. Clarida et al. (1998) set the real interest rate to the average in the sample and use equation (7) to recover the implied value for π^* .

Forward-Looking Reaction Function – Empirical Results

Following de Brouwer and Gilbert (2005), the forward-looking reaction functions were run for the full sample period (1984Q1 – 2014Q4) as well as for the subsample period (1993Q1 – 2014Q4). In order to obtain GMM estimates in Eviews, the moment conditions must be written as an orthogonality condition between an expression including the parameters and a set of instrumental variables. Moreover, there has to be at least as many instruments as there are parameters for estimates of the GMM estimator to be identified. For the full sample period (1984Q1–2014Q4), the instrumental variables chosen are the constant, the second lag of cash rate, the first lag of inflation, the first lag of output gap, the second lag of the AUD to USD exchange rate, the first four lags of the federal funds rate, and the first four lags of the Australian unemployment rate. This base set of instruments is in line with de Brouwer and Gilbert (2005) except that the unemployment rate is included as a valid instrument since there is always a link between unemployment and inflation. Inflation is forecast 4 quarters

ahead and output is forecast at 1 quarter ahead. The following table reports estimation results:

Table 3: Estimated Forward-Looking Reaction Functions (post floated era):

1984Q1 – 2014Q4						
Constant	Cash rate (t-1)	Inflation (t+n)	Output gap (t+m)	Standard error	Adjusted R ²	J-Test
6.21 (0.00)	0.88 (0.00)	1.36 (0.00) (n=4)	2.32 (0.00) (m=1)	0.89 (0.90)	0.96	0.79 (2)

Note: The instrument list includes cash rate (-2), inflation rate (-1), output gap (-1), exchange rate (-2), federal funds rate (-1 to -4) and unemployment rate (-1 to -4). The numbers in the brackets next to the standard error are the standard errors from the backward-looking response function when I added the cash rate lagged one period in the regression model. The significant level of parameters is 5 per cent. The test statistic shows the over-identification, indicating whether the model's moment conditions match the data well or not. The numbers in the brackets next to the test statistic are the degrees of freedom which equals the number of instruments subtract the number of parameters estimated.

The four parameter estimates are $\hat{\alpha} = 6.21$, $\hat{\rho} = 0.88$, $\hat{\beta} = 1.36$, and $\hat{\gamma} = 2.32$. Apart from the longer sampling period, the estimates, as a whole, are in line with those obtained by de Brouwer and Gilbert (2005). The magnitude of the parameter β is critical here. Since $\hat{\beta} > 1$, the target real rate is adjusted to stabilize inflation and output (for $\hat{\gamma} > 0$), also if inflation goes up by 1%, monetary authorities will raise interest rate by 1.36%. In order to examine the validity of the model (i.e. the validity of instruments), the J-test is conducted and is asymptotically Chi-squared with 4 degrees of freedom (8 instruments minus 4 parameters). The J-test statistic is 0.788687 with the corresponding p-value of 0.852171. Since the p-value is very large, the validity of the instrument and

overall specification of the model cannot be rejected.

In addition, the standard error of estimate is 0.89 and smaller than de Brouwer and Gilbert (2005), implying a better fit of the estimated model to the cash rate data. The results indicate that the output gap tends to dominate inflation in the reaction function of the post floated period. Recall that excess demand is a main driver of inflation, thus if output is above its potential level, inflation tends to increase.

Another GMM estimation is performed over the subsample period (1993Q1 – 2014Q4). This subsample period marks the era when the RBA first set this inflation target rate in 1993. Presented below are the estimation results for the subsample period:

Table 4: Estimated Forward-Looking Reaction Functions (inflation targeting period):

1993Q4 – 2013Q4 (81 observations)						
Constant	Cash rate (t-1)	Inflation (t+n)	Output gap (t+m)	Standard error	Adjusted R²	Implied neutral cash rate
2.52 (0.01)	0.93 (0.00)	1.09 (0.0) (n=4)	3.40 (0.00) (m=1)	0.46 (0.43)	0.86	5.25

Note: The instrument list includes cash rate (-2), inflation rate (-2), output gap (-1), fed funds rate (-2), trade weighted index (-1,-2), oil price (-1), commodity price (-1) and unemployment rate (-1). The numbers in the brackets next to the standard error are the standard errors from the backward looking response function when I added the cash rate lagged one period in the regression model. The significant level of parameters is 5 per cent.

The four parameter estimates are $\hat{\alpha} = 2.52$, $\hat{\rho} = 0.93$, $\hat{\beta} = 1.09$, and $\hat{\gamma} = 3.40$. Apart from the longer sampling period, the magnitude of the parameter estimate for β is greater than 1. The estimate of γ is significantly higher. The GFC caused an increase in the output gap, and it is reasonable that our output gap parameter is greater compared to de Brouwer and Gilbert (2005) in which their study investigates a period of stable

economic activity. Since $\hat{\beta} > 1$, target real rate is adjusted to stabilize inflation and output (for $\hat{\gamma} > 0$), and also if inflation goes up by 1%, monetary authorities will raise interest rates by 1.09%. The J-test statistic is 1.073352 and is asymptotically Chi-squared with 3 degrees of freedom (7 instruments minus 4 parameters). The corresponding p-value is 0.783511. Since the p-value is very large, the validity of the instrument and overall specification of the model cannot be rejected.

Last but not least, the standard error of estimate is smaller than that of the full sample period. Since the subperiod fits the model better than the full sample period, inflation targeting on monetary policy does provide an anchor for expectations about future inflation. Policymakers would rely on the basis of this target to formulate the cash rate and stabilize the price level, avoid an insecure money supply, control the financial market and not obstruct ongoing economic growth. Inflation and output gap parameters are fairly close which means in terms of the inflation targeting period, the RBA considers the weights of these two variables equally in order to stabilize the economy.

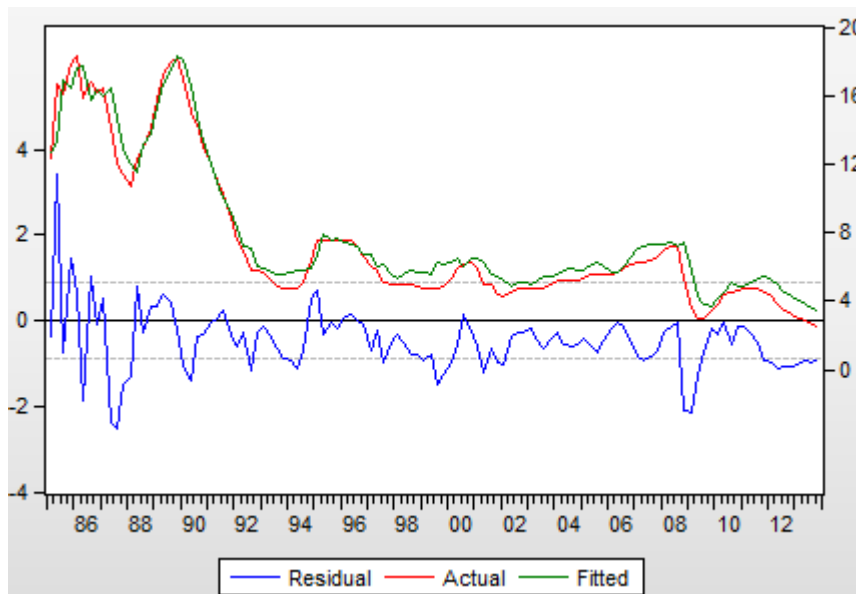


Figure 9: Predicted Cash Rate by the Forward Looking Reaction Function versus RBA Cash Rate

Figure 9 shows the actual, fitted and residual values of cash rate with respect to GMM estimated results in Table 3. The striking feature is that the forward-looking

reaction function generates the implied cash rate which is fairly close to RBA decisions. The high interest rate in the late 1980s was unexpected in response to the rational expectation one year ahead forecast profile. The big jump in the cash rate of late 1994 and early 1995 was also not expected regarding the rational expectation of the forecast profile. In the first half of the 2000s, the fitted cash rates were in line with the actual rate. At the end of 2008 and the beginning of 2009, the big drop in nominal interest rates as an impact of the GFC was not predictable on the basis of rational expectations one year ahead forecasts. These outcomes indicate that the Taylor forward-looking rule broadly matches policy rates during periods of low volatility of inflation and business cycle fluctuations. On the other hand, the forward-looking reaction function may overestimate or underestimate policy rules in the case of unpredictable shocks, but it will rapidly adjust the forecast profile of inflation and output fluctuations so as to capture the movement of the RBA cash rate. Overall, the results in Figures 8 and 9 suggest that forward-looking describes the actual interest rate better than the backward specification.

The final goal is to calculate the implied neutral rate of interest from the forward-looking model. As mentioned in section 6, $\alpha \equiv \bar{i} - \beta\pi^*$. Given the constant value in Table 3 and a constant target inflation of 2.5%, the average of the target band, the implicit neutral cash rate \bar{i} is calculated as $2.52 + (2.5 \times 1.09) = 5.25$. Note that all the estimated parameters are statistically significant at the 10% level.

6. Out-of-Sample Forecasts

The previous sections examined monetary policy under the backward- and forward-looking specification using in-sample fit. In this section, we examine the backward- and forward-looking function in term of out-of-sample fit. We will use the HP filter to generate the potential output and output gap in two steps. First, the in-sample period is defined from quarter 2, 1984 until quarter 4, 2007. Second, for the out-of-sample prediction of interest rate, we use the output gap from the previous estimation from quarter 1, 2008 to quarter 4, 2014. Then, the first period output gap is substituted into the model, again running the ordinary least square (OLS) and generalised method of

moment (GMM) to compute the estimated parameters of inflation and output gap for the backward- and forward-looking functions, respectively. These estimated parameters are applied in the out-of-sample period to investigate how fitted cash rates from the backward- and forward-looking specification fit the actual cash rate from the RBA.⁴ This section addresses how the forecast profile in the forward-looking specification assists to capture the true movement of the RBA cash rate. Then it will be compared with the backward-looking specification where there is no forecast procedure.

After computing the fitted cash rate, we derive the standard error (SE) of the out-of-sample model. From this, we compare the in-sample and out-of-sample SE between and across two reaction functions. The out-of-sample standard error is calculated from the equations:

$$\text{Mean Square Error (MSE)} = \frac{1}{28} \sum_{t=2008Q1}^{2014Q4} (i_t - \hat{i}_t)^2 \quad (8)$$

$$SE = \sqrt{MSE} \quad (9)$$

The number of observations in the out-of-sample period is 28 quarters.

Backward-Looking Reaction Function – Out-of-Sample Forecasts

Table 5 shows the estimated parameters for the in-sample period, and they are all statistically significant. Further, the in-sample model represents a much smaller standard error (SE) than the out-of-sample. Recall, the smaller the SE, the better the fit of the estimated model to the cash rate data. Figure 10 shows the out-of-sample fit of the backward looking specification using in-sample estimated parameters. It depicts that past information cannot observe the unpredictable shock in the future. From the beginning of the GFC, the fitted cash rates are always overestimated in RBA decisions. Therefore, historical data are inconsistent with the expected movement of inflation and output.

⁴The reason we choose the out-of-sample period starting at 2008 quarter 1 is that year 2008 is the inception of GFC. There was an unpredictable movement in GDP, inflation, and cash rate as well.

Table 5: Out-of-sample Backward-Looking Reaction Functions:

1984Q2 – 2007Q4					
Constant	Inflation gap (t-1)	Output gap (t-1)	Standard error (in-sample)	Standard error (out-of-sample)	Adjusted R2
5.86 (0.00)	1.09 (0.00)	0.56 (0.00)	1.81	2.43	0.83

Note: Empirical results from in-sample model and standard error calculated from out-of-sample model.

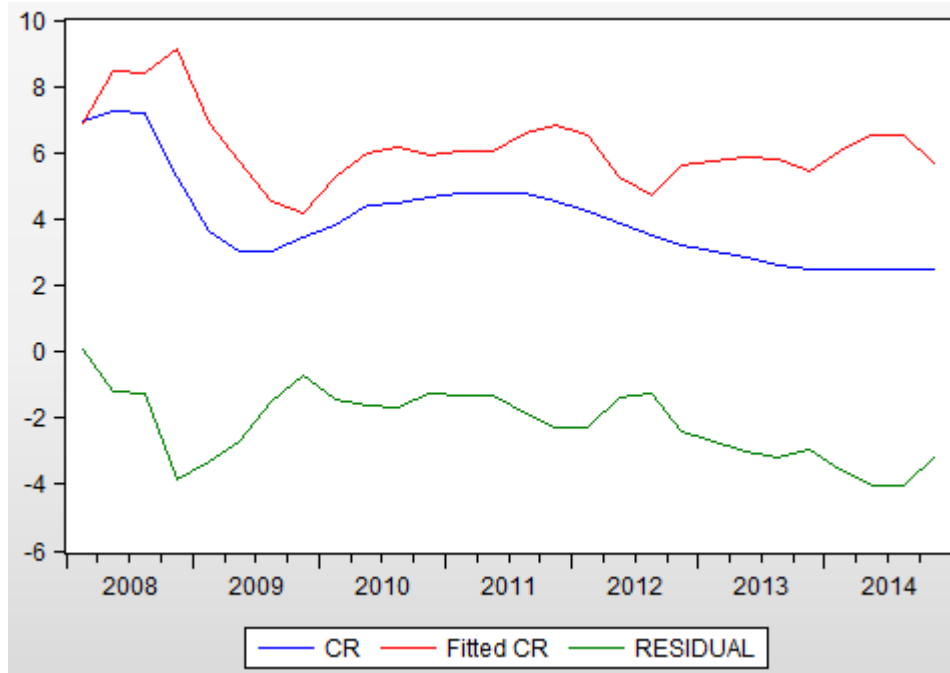


Figure 10: Fitted cash rate computed by out-of-sample backward looking reaction function

Forward-Looking Reaction Function – Out-of-Sample Forecasts

Table 6 represents the findings of the in-sample model and the estimation of the out-of-sample model. Except for the constant parameter, the rest are statistically significant. Unlike, the out-of-sample fit of the backward-looking specification, the forward-looking function shows that the out-of-sample model fits the cash rate data better than the in-sample model as it generates a smaller standard error, which is the standard deviation of the estimated model. From tables 5 and 6, comparing the backward-looking and forward-looking out-of-sample standard errors, we can strongly conclude that the backward-looking reaction function falls short of the forward-looking rule, which means monetary authorities explicitly consider the importance of the forecast profile,

treating it as the major component of policy input when they decide the changes in nominal interest rate. Figure 11 shows the forward-looking out-of-sample fitted cash rate versus the real interest rate. Even though, sometimes, the forward-looking rule still over or underestimates the cash rate due to the consequences of unobservable shocks, but overall, it still provides an outlook of how the RBA sets up monetary policy on the basis of economic rational expectation.

Table 6: Out-of-sample Forward-Looking Reaction Functions:

1984Q2 – 2007Q4 (90 observations)						
Constant	Cash rate (t-1)	Inflation (t+n)	Output gap (t+m)	Standard error (in- sample)	Standard error (out-of- sample)	Adjusted R²
0.17 (0.66)	0.87 (0.00)	2.24 (0.00) (n=4)	2.57 (0.00) (m=1)	0.83	0.63	0.96

Note: Empirical results from in-sample model and standard error calculated from out-of-sample model.

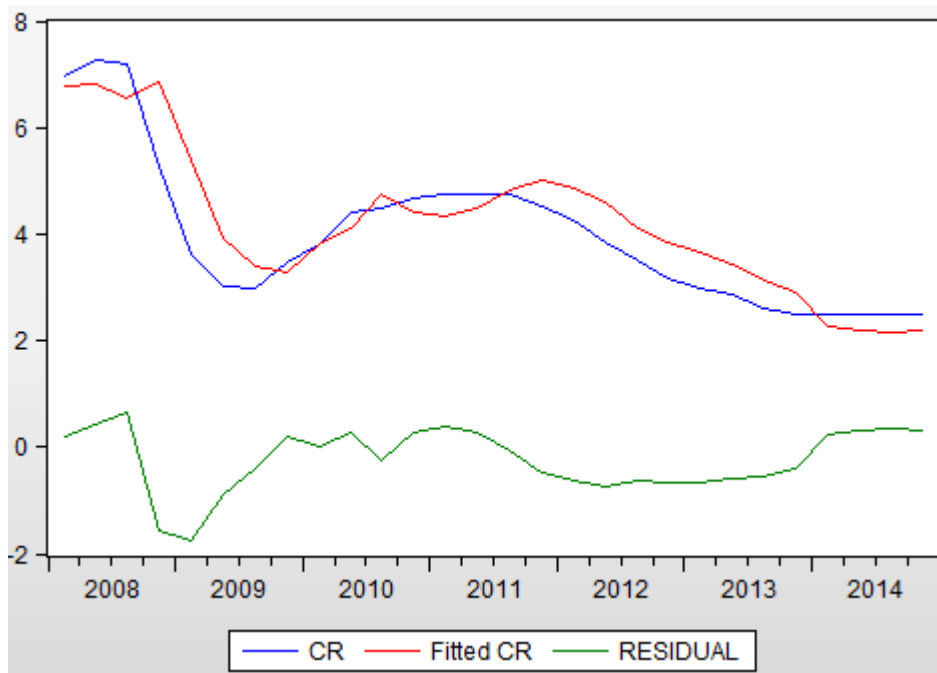


Figure 11: Fitted cash rate computed by out-of-sample forward looking reaction function

7. Conclusion and Future Research

Estimation of the monetary policy reaction function can enhance our understanding of components affecting central bank decisions. While there is only limited empirical research on Australian monetary policy, there are many empirical papers for OECD countries. The empirical studies indicate that differences exist among countries as to whether monetary authority actions only focus on expected inflation or also concern expected output growths. This paper addresses the question of how the RBA implements its policy to maintain price stability and conserve domestic economic wellbeing. In this study, we consider two specifications of Taylor's rule and fit them to Australian economic conditions. We have looked at the estimations of the backward-looking response function based on Taylor's original paper and the forward-looking response function from Clarida *et al.* (1998) and de Brouwer (2005). We extend our discoveries into economic components utilized in different response functions of Taylor's rule to analyze the monetary policy and RBA implementation in the post-

floated stage and the inflation targeting stage.

Overall, after addressing both models, there is empirical evidence to show that the forward-looking outperforms the backward-looking reaction function. The backward-looking function provides a brief interpretation of how the RBA implements the short-term nominal interest in response to changes in inflation and output. However, due to its simplicity, it ignores the future expectation of policy variables and also many other valid instruments that can affect inflation and output fluctuation. The forward-looking approach, which combines the lagged values of variables and one year ahead forecasting, is more likely to capture the appropriate movement of the cash rate. Kahn, Koenig and Leeson (2012) say that Ben Bernanke, who is the chairman of the Federal Reserve, promoted the forward-looking approach since it is a true real time policy that formulates the reaction function with respect to available forecasted information when monetary decisions are made. The forward-looking version is explicitly preferred because it considers the role of forecasting macroeconomic movements in finalizing decisions.

Both the exchange rate of the Australian dollar in terms of the US dollar, as well as the Fed Funds rate, were included in the forward-looking specification because the RBA is sensitive to the adjustment of the US Federal Reserve. However, this does not mean that the domestic cash rate is dependent on the movement of the US interest rate. Fed's actions provide a general vision of the world's largest economy; changes in Fed funds rate, therefore, would affect the global economy and the global financial market as well as the economic input of the RBA when they formulate their decisions.

Future research will focus on the forward-looking reaction function and also consider the lagged values of inflation and output with rational expectation of these two variables, hence achieving a direct investigation of the forward-looking versus backward-looking specification. The subsequent study may further include more instruments which are significantly related to inflation, output and nominal cash rate. These additional instruments will generate a more detailed estimation of the reaction function and provide a comprehensive outlook of monetary policy in Australia.

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