Tests of Simple Targeting Rules for Monetary Policy

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December 2008

Abstract

Models of optimal monetary policy give rise to restrictions on conditionally expected variables such as inflation and the output gap. These conditions have a very natural interpretation. The central bank uses its policy instrument(s) to ensure a weighted combination of its forecasts of the target variables are consistent with its policy objectives. This suggests a simple methodology for testing whether the behavior of central banks is consistent with models of optimal monetary policy. Estimate a central bank's Euler equations and test whether they hold at different forecast horizons. In this paper we test the predictions of the standard New Keynesian model of optimal monetary policy for Australia, Canada and the United States. For all three countries we can reject the hypothesis that central banks pursue a strict inflation target at horizons of 6 to 12 months. For the Canada and the United States there is evidence that central bank behavior is consistent with flexible inflation targeting under pre-commitment, whereas for Australia the data point to discretionary optimization.

JEL Classification: E31, E58.

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The authors thank seminar participants at Griffith University and ESAM08 for their comments.

1 Introduction

Inflation targeting (IT), the practice of specifying a numerical target for inflation and implementing forward-looking policy decisions to achieve the target, was initially developed by central banks as a transparent means of implementing credible monetary policy.[1] Subsequent theoretical work by Svensson (1999), Woodford (2003, 2004), Svensson and Woodford (2005), and Woodford and Giannoni (2005), recasts inflation targeting as an optimal monetary policy rule, that is as the outcome of a central bank setting monetary policy to minimize social welfare losses. A key emphasis of this theoretical work is inflation-*forecast* targeting, where the central bank uses its policy instrument to ensure that the bank's projections or forecasts for its target variables satisfy criteria consistent with minimizing social welfare loss.[2]

In this paper, we ask whether standard theoretical models of inflation forecast-targeting are consistent with the observed behaviour of three central banks, those of Australia, Canada, and the United States. We focus on the target criteria from these models, which restrict the conditionally expected paths of variables targeted by the central bank. In essence, they are the Euler conditions for the central bank. We estimate these conditions, providing a description of monetary policy for each central bank under the maintained hypothesis that monetary policy has been implemented in an optimal manner consistently over the sample. We are then able to test whether these estimated conditions satisfy the predictions of models of optimal monetary policy. A distinct advantage of our approach is that we need not concern ourselves with how the conditions are met; that is, how the policy instrument is adjusted to achieve these conditions. Estimating such policy instrument rules requires a specification for aggregate demand that our analysis does not explicitly require.

Australia and Canada, as two early adopters and to date successful practitioners of inflation targeting, are natural choices for our purposes. The Federal Reserve in the United States (US), in

[1]For a summary of the international experience with inflation targeting, see Roger and Stone (2005) and the earlier work by Bernanke, Laubach, Mishkin, and Posen (1998).

[2]Woodford (2007). Svensson (1997) is the seminal theoretical treatment of inflation forecast targeting. Earlier work by King (1994) discusses the idea as a practical description of monetary policy in the UK.

contrast, is not a declared inflation targeting central bank. Nonetheless, it is of considerable interest to include it in our analysis as its behaviour has been described as being implicitly consistent with inflation targeting and our analysis provides an assessment as to just how accurate is this description.[3] Moreover, the Federal Reserve, with its lack of an explicit inflation target, provides a useful point of comparison with the explicit inflation targeting behaviour of the Reserve Bank of Australia and the Bank of Canada.

A number of issues motivate our analysis. In the first instance, we are interested in whether there is a close correspondence between inflation targeting as it is practiced, explicitly or implicitly, and as it is prescribed by theory. If actual behaviour is consistent with theory, then models of inflation forecast targeting are arguably useful tools for analysis, in the same way that policy instrument rules, such as the Taylor rule, are used in policy analysis (see, Galí and Gertler, 1999 or the more general discussion in McCallum, 1999). A further motivation is to explore how policy behaviour departs from predicted optimal behaviour, which may provide information as to how monetary policy practice might be improved, or as to how models of monetary policy practice might be improved.

An additional motivation is to examine directly the issue of flexible versus pure inflation targeting. Svensson (1999) defines pure inflation targeting as a regime where the target criteria involve only the projected path of inflation. Such a target arises when the central bank places no weight on variation in any variable other than inflation in its loss function. Flexible inflation targeting, in contrast, includes other variables in the target criteria, most commonly the projected path of the output gap.[4] The general consensus is that most inflation targeting central banks practice flexible inflation targeting (though there is still some confusion among some policy makers, see Svensson, 2005).[5] Despite this consensus, there is not much direct empirical evidence in support of flexible

[3]See the discussion in Kuttner (2004).

[4]Giannoni and Woodford (2005) consider in detail a variety of theoretical structures and their implications for target criteria, which in some instances include variables in addition to inflation and the output gap. While theoretically appealing, our focus here on inflation and the output is, we believe, more likely to be consistent with central bank practice.

[5]Buiter (2007), however, is critical of the flexible inflation targeting approach, arguing that most central banks

inflation targeting. The reason being that most empirical descriptions of IT central banks are based upon policy instrument rules, which do not provide a direct means of discriminating between flexible and pure inflation targeting.[6]

A third motivation concerns what Woodford (2007) refers to as the intertemporal consistency of inflation forecast targets. Loosely put, optimal inflation-forecast targeting specifies a sequence of conditional expectations over different horizons. So, for example, a pure inflation targeting regime would restrict the conditional expectations of inflation at, say, the two to eight quarter ahead horizons all to be equal to the target rate of inflation. This relates to an important aspect of practical inflation targeting, the policy horizon. Most inflation targeting central banks do not specify their inflation targets in terms consistent with Woodford's notion of intertemporal consistency.[7] In general terms, inflation targets are usually specified in terms of achieving the target at some point in the future, typically within two years. This leaves unspecified what happens in the near term and is an obvious source of departure from optimal models of inflation-forecast targeting. A key contribution of this study is to examine the consistency of inflation forecasts targets over the policy horizon.

Finally, there is a substantive debate in the optimal monetary policy literature as to whether central banks should specify targeting rules or policy instrument rules.[8] Our analysis, which focuses exclusively on targeting rules, does not address this debate directly but it does go some way to demonstrating the usefulness of interpreting and assessing the outcomes of central bank behaviour in terms of targeting rules. McCallum (2000), for instance, argues that the observed behaviour of inflation targeting central banks is best characterized as following policy instrument rules rather than the targeting rules of Svensson, not least of which because there is no evidence that they are

have mandates that are lexicographic in their targets. Price stability is ordered above other objectives. Thus output gap stability is not to be traded-off against price stability, but considered only once inflation is at its target value.

[6]Policy instrument rules in most instances will include measures of output even if the loss function itself does not include output stabilization. See for example Svensson (2003).

[7]An example of one that does is the Norges Bank, as Woodford (2007) discusses.

[8]See Svensson (2003, 2005) and McCallum and Nelson (2005) for different perspectives; see also the discussion in Kuttner (2004) concerning inflation targeting and policy rules.

optimizing in a manner consistent with targeting rules. Our analysis attempts to provide some such evidence.

Ours is not the first empirical study to consider the Euler conditions associated with optimal inflation-forecast targeting. Two earlier studies have similar focuse but differ in important ways from that here. Favero and Rovelli (2003) estimate and test the Euler conditions associated with a particular structural model of central bank behaviour and the aggregate economy using US data. Their objective is to identify the preference parameters of the Federal Reserve, notably the targetted inflation rate, and determine whether there was a significant change in these preferences after the high inflation period of the 1970s. Our approach is much simpler; we focus exclusively on the Euler conditions alone. The principle benefit is that these conditions are easily comparable across countries and we can admit alternative specifications for the behaviour of aggregate supply and demand.[9] But the real difference is one of focus. While we are interested in uncovering the preference parameters of the central banks, we are also concerned with asking whether these conditions, particularly the flexible inflation targeting conditions, hold. Further, we are interested in whether central bank behaviour is inter-temporally consistency. Neither of these concerns are addressed by Favero and Rovelli.

Rowe and Yetman (2000), in their study of the Bank of Canada, consider some of the same issues that we do here. They examine whether deviations of inflation in Canada from the announced target of two percent (actually, the mid-point of the target band of 2–3 percent) are forecastable, which according to strict inflation-forecast targeting should not be the case. The key difference between our study and Rowe and Yetman's study is that we consider more flexible forms of inflation-forecast targeting and we also consider issues of intertemporal consistency. Moreover, we estimate the parameters of the target criteria rather than impose them as these authors do.

The study that shares many of the same objectives as ours is Kuttner (2004). His analysis is based

[9] Favero and Rovelli impose backward-looking aggregate demand and supply conditions on their estimation. With our simpler approach, we can consider different conditions allowing for both forward-looking and backward-looking conditions.

upon a simple interpretation of the Euler conditions restricting inflation and output in an optimal inflation-forecasting framework. In most (but not all) cases, optimal policy should ensure that deviations of inflation from target should be unconditionally correlated with either the output gap or changes in the output gap. (The sign of the correlation depends upon the underlying structure of the economy, as we discuss below). Kuttner, using data for New Zealand, the United Kingdom, and the United States, considers the unconditional correlations between deviations of inflation from target and either the output gap at different horizons. The critical difference between this study and that here is that we consider conditional rather than unconditional correlations and do so in a formal manner, allowing us to both estimate the inflation-forecast parameters and to test the predictions of inflation-forecast targeting.

In the next section, we provide a simple set of conditions drawn from the theoretical literature. These conditions are used to guide the empirical analysis that follows and to provide a basis for interpreting the results. The empirical analysis considers the three countries, Australia, Canada and the United States, using both monthly (where available) and quarterly data, in each case starting in the early 1990s through to the end of 2007. The first stage of the empirical analysis is to estimate the Euler conditions. We do so in two ways; in the first instance, we consider each horizon independently; in the second instance, we estimate a system of Euler conditions implied by optimal inflation-forecast targeting. The second stage of the analysis is to investigate whether or not the Euler condition residuals are in fact orthogonal to current information as predicted by optimal inflation-forecast models. The final section concludes.

2 Monetary Targeting Conditions

2.1 Strict Inflation Targeting

We initially consider the simplest case of a central bank that uses its policy instrument to target only inflation — a strict inflation target (SIT). Given its model of the underlying economy and forecasts, the central bank will adjust the policy instrument to ensure that inflation does not deviate from target. Since in general the central bank's instrument only affects inflation with a lag, it will operate to ensure that expected inflation — at a horizon for which it can control inflation — does not differ from target. If we suppose that relative to time t, the horizon under its control is $t+h,\ h \geq H$, then optimal policy requires;

$$E_t(\pi_{t+h} - \pi^*) = 0, \quad h \geq H \tag{1}$$

where π_{t+h} is inflation at time $t+h$ and π^* is the target rate of inflation. An optimality condition or Euler equation like (1) can be derived using the standard New Keynesian model of optimal monetary policy for a central bank that is concerned only about inflation, Galí (2008). In most presentations of conditions such as (1), the focus is on the first horizon that is under the control of the central bank, that is for projections of π_{t+H}. However Woodford (2004, 2007) notes that intertemporal consistency of monetary policy constrains all future conditional expectations of the target variable from $t+H$ onwards, as specified in condition (1).

It is straight-forward to perform an empirical test of condition (1). Let $\eta_{t+h} = (\pi_{t+h} - \pi^*)$ then we have

$$E_t\eta_{t+h} \quad = \quad 0, \quad h \geq H$$

which implies that for any horizon greater than or to equal to H, deviations of inflation from target should be unpredictable using information available at time t. If the value of π^* is publicly announced by a central bank, it can be imposed and there are no parameters that need to be estimated. This is the principle approach of Rowe and Yetman (2001). Alternatively if π^* is unknown or there is a target band (and the mid-point is not thought appropriate) then it can be estimated from the Euler equation and the estimated residual be used to test the orthogonality conditions.

In testing conditions such as (1), it is necessary to choose a set of variables against which the above orthogonality conditions can be checked. While any variable that is part of the central bank's information set at t is potentially valid, we focus on variables that might also enter a central bank's loss function, e.g. the output gap and interest rates. If such variables have been incorrectly omitted from (1), then checking if they are correlated with future deviations of inflation around its target should provide a relatively powerful specification test of SIT.

2.2 Flexible Inflation Targeting

Few (if any) central banks claim to be strict inflation targeters. However, more general targeting rules can be obtained by allowing the loss function of a central bank to depend on variables other than just inflation (Svensson, 2003). Following the approach of Svensson (2003) we consider a central bank that cares about current and future expected squared deviations of inflation from target $(\pi - \pi^*)$ and the output gap x. Doing so leads to the following two generalizations of (1);

$$E_t\Big(\pi_{t+h} + \phi x_{t+h} - \pi^*\Big) = 0 \quad h \geq H \tag{2}$$

$$E_t\Big(\pi_{t+h} + \phi(x_{t+h} - x_{t+h-1}) - \pi^*\Big) = 0 \quad h \geq H \tag{3}$$

Condition (2) arises in a model with a forward-looking Phillips curve where the central bank takes a purely discretionary approach to monetary policy; see Galí(2008). The optimality condition implies that there will be a negative relationship between the expected output gap and expected deviations of inflation from target.

Condition (3) is consistent with different economic structures. It can arise either with a forward-looking or a backward-looking Phillips curve. With a forward-looking inflation process condition (3) arises from central bank optimization under pre-committment. In comparison to discretion, (3) contains the *change* in the output gap rather than its level. Condition (3) is also the optimality condition for a central bank where the inflation process is backward-looking. The key difference between the backward and forward-looking models concerns the sign of ϕ. The parameter ϕ is positively related to the weight on the output gap in central bank's loss function and inversely related to the slope of the Phillips curve.[10] The sign of ϕ will be negative for a central bank that optimizes subject to a backward-looking Phillips curve and positive in the case of a forward-looking Phillips curve (Kuttner, 2004).

Finally, note that the choice of H implicitly depends upon the underlying model for aggregate demand. For our purposes, we need not specify a particular model of aggregate demand just a reasonable choice for H, which we discuss in the following section.

Conditions (2) and (3) form the basis of our empirical assessment of optimal monetary policy. In using these conditions we note that they must hold for all values of $h \geq H$ so that we have in effect a system of Euler equations for each model (under discretion and commitment). For example, the discretionary conditions are:

$$E_t\Big(\pi_{t+H+j} + \phi x_{t+H+j} - \pi^*\Big) = 0, \quad j = 1 \ldots m$$

where m is some upper bound on the conditions we wish to consider. As a practical matter we think of m as being roughly the equivalent of two years, since this is the longest horizon about which central banks typically express concern. Theory predicts that ϕ and π^* should be constant across the moment conditions. This is a testable restriction. Another testable restriction implied by flexible inflation targeting is that $\phi \neq 0$. If $\phi = 0$ then we could reasonably conclude that the central

[10] The parameter ϕ also depends upon the rate of time preference; see Svensson (2003) for details.

bank is a strict inflation targeter. A positive value for ϕ indicates the central bank is a flexible inflation targeter and that it believes inflation expectations are determined in a forward-looking manner. While the structural parameters in ϕ are not separately identified, given an estimate of the slope of the Phillips curve, it may be possible to infer something about the relative weight a central bank gives to output variation.

To estimate the parameters in (2) and (3) we can use as instruments Z_t any variables that are part of the central bank's time (t) information set. To mitigate problems associated with weak instruments, we choose variables that are likely to be good predictors of future inflation and the output gap.

As discussed with the strict inflation targeting model, a strong prediction of Euler equations such as (2) and (3) is that the particular linear combinations of inflation and the output gap (or its first-difference) should be orthogonal to lagged information sets. For example the linear combination $(\pi_{t+H} + \phi x_{t+H} - \pi^*)$ should be uncorrelated with *any* variable known to the central bank at time t. Thus in the following regressions

$$(\pi_{t+h} + \phi x_{t+h} - \pi^*) = \alpha + \delta Z_t + v_{t+h}, \quad h \geq H \tag{4}$$

we expect to find $\alpha = \delta = 0$. To implement this test can we use $(\pi_{t+h} + \widehat{\phi} x_{t+h} - \widehat{\pi}^*)$ and Z_t (the instruments used to estimate the model), or we can use other time t variables in the above regression models.

The precise form of the Euler equations (2) and (3) depends upon what variables are assumed to enter a central bank's objective function and on the structure of the economy. For example, in addition to inflation and the output gap, the central bank may care about other variables. A standard generalization would be to assume the central bank is concerned to limit interest rate volatility. In this case neither (2) or (3) would be the valid Euler equations. Equation (4), though, suggests a simple specification test for any set of Euler equations: use as instruments in estimating (2) and (3) variables that are unlikely to directly enter a central bank's loss function. Then conditional on these estimates use (4) as a means of checking if interesting variables have been omitted from the central bank's Euler equation.

3 Empirical Results

We consider data for three countries: Canada, Australia, and the United States (US). The first two have operated monetary policy with well-defined inflation targets since the early 1990s. The US, in contrast, does not have an explicit inflation target though its behavior may in fact be consistent with an implicit inflation target.

We set the samples for estimation based upon the dates at which inflation targeting was adopted or, in the case of the US, a comparable period. Canada effectively adopted its current inflation target of 1–3 percent in December 1993, so the Canadian sample is 1994–2007.[11]. Australia adopted an inflation target of 2-3 percent in 1993, so the Australian sample is 1993-2007.[12] The sample for the United States is 1990–2007, which is a comparable period to the other two countries. Since we are not restricted to a specific period, we start somewhat earlier to include the recession of the early 1990s in our sample.

All three countries set monetary policy at a relatively high frequency. In the case of Canada and the US, policy interest rates are set roughly every six weeks. In Australia, it is every month (with the exception of January).[13] Ideally, one should use data that matches most closely this frequency. This requires monthly measures of output (GDP) and the consumer prices (CPI). Both of these are available for Canada. For the US, the CPI is available on a monthly basis but GDP is not. For Australia, both GDP and the CPI are only available on a quarterly basis. To ensure comparability

[11] Bank of Canada webpage: www.bank-banque-canada.ca/en/backgrounders/bg-i3.html

[12] Reserve Bank of Australia webpage: www.rba.gov.au/MonetaryPolicy/about_monetary_policy.html. The formal inflation target commenced in 1996; however, inflation targeting has in practice been in effect since 1993.

[13] Each of these central banks has the ability to change policy between meetings if required, as we have witnessed in recent months. For our samples, between meeting changes in policy are rare.

of our results we estimate quarterly models for all three countries. However as part of our robustness checks we also estimate a monthly model for Canada. (See Table A1 for the data sources).

For all three countries, we use a headline measure of inflation, consistent with the definitions of inflation targets at both the Bank of Canada and the Reserve Bank of Australia. For the output gap, we use the Hodrick-Prescott filter to calculate potential GDP. This is a relatively crude means of identifying the output gap but does have the advantage of being easily applied across the three countries in a systematic manner.[14] Obtaining a good estimate of the output gap is mainly an issue for testing the Euler equation associated with discretionary optimization. For the optimality condition that uses the change in the output gap there is little difference in the results obtained from the use of Hodrick-Prescott filtered data and simply using the growth rate of real output.

The moment conditions stipulate that inflation forecasts or indices of inflation and output are orthogonal to any information at time t. To estimate these conditions, we need to choose a set of instruments Z_t. We focus on a set of instruments that is common across all three countries — commodity price inflation constructed using the IMF's non-fuel commodity price index, inflation, the output gap, the output gap differenced, and the growth rate of output. The instrument set is $Z_t = \{1, \pi_t^{cx}, \pi_{t-1}^{cx}, \pi_{t-2}^{cx}, \pi_{t-1}, \pi_{t-2}, x_{t-1}, \Delta x_{t-1}, \Delta y_{t-1}\}$. Commodity prices are widely used in the empirical monetary policy literature as an exogenous cost shock variable and is a natural choice for our instrument set. We assume that current inflation and output are not part of a central bank's infromation set. Inflation (both commodity price and CPI) are defined as year-on-year percentage changes, while the change in the output gap and the growth rate of real output used in equation (3) are quarterly. (See Table A4 for details.)

The empirical results are presented in Tables 1 to 8. Tables 1 to 4 report estimates of the models based on quarterly data for Australia, Canada and the US, while Table 5 reports estimates using

[14]There are at least two potential disadvantages to our approach. First, the HP filter may not provide a very accurate measure of the central bank's output gap. Second, our output gap is constructed from the entire sample and necessarily differs from that which would be available in real time; see Kuttner (2004) for an attempt to address this. These are directions we hope to look into in further work.

monthly data for Canada. Table 6 to 8 report results for specification tests of the model. In estimating the Euler equations we consider (four) forecast horizons (values for h) equivalent to six months, one year, eighteen months and two years.

3.1 Strict Inflation Targeting

We initially estimate a version of the strict inflation targeting (SIT) condition (1). Table 1 presents quarterly single equation estimates for $h = 2, 4, 6, 8$ for each of the three countries. For each country and each horizon, we report the conditional estimate of the inflation target, π^* and Hansen's J statistics for the over-identifying restrictions. All inference is based on Newey-West (1987) covariance matrices using truncation parameters indicated in the table.[15]

For each of the three countries, there is a reasonable uniformity in the estimates of the inflation target over the different horizons. Canada has the lowest estimates at all horizons and the United States the highest. In principle, the J-statistic provides us with information as to whether the model is correctly specified. In all cases in Table 1, the over-identifying restrictions are not rejected at usual significance levels. We suspect, however, that for our models the J-statistic has low power, which is one motivation for considering the predictability tests, which we discuss below.

Table 1 also presents system based estimates for the strict inflation targeting model. Because of difficulties with estimation, we limit the system to the first two horizons. From a policy perspective, this is reasonable since the two and four quarter horizon are clearly focal when setting monetary policy.[16] The systems are estimated both as an unrestricted form, where the inflation targets are allowed to vary across horizons, and in a form where they targets are restricted to be equal.

[15] The choice of truncation parameter reflects the fact that for a forecast horizon of h, there will be a moving average structure of $h - 1$.

[16] To estimate the models, we follow the usual procedure for GMM of iterating using as the weighting matrix the inverse of successive estimates of the covariance matrix. Iterations were stopped once the value for the objective function converged based on a convergence criteria of 10^{-6}. With systems of more than two equations, we were unable to obtain convergence in estimation. The near term horizons also have the advantage of having stronger instruments. Measures of instrument quality due to Shea (1997) for all models are presented in Tables A3–A4.

For each of the three countries, the estimates of π^* are comparable to the single equation estimates. We can now, however, test formally whether the inflation targets are constant across horizons. For the United States, where the point estimates at the two and four quarter horizon are very close, we cannot reject parameter constancy. And looking at the six and eight quarter horizon in the single equation estimates, which are all quite close together, there seems to be evidence of parameter constancy at the longer horizons as well. For Canada and Australia, however, we reject the parameter constancy hypothesis, evidence against the strict inflation targeting model.

We can test the adequacy of the simple inflation targeting model by considering whether or not the orthogonality condition holds for each of the estimated models. To proceed, we take the estimated GMM residual from the single equation estimates for each country for the two and four quarter horizons. We then regress these on inflation, the output gap, the change in the output gap and the growth in output all lagged one quarter, as well as the current level of the relevant policy interest rate and the current change in the policy interest rate (a constant term is also included). The first four of these variables are chosen as they are consistent with our alternative flexible inflation targeting models; we lag them one quarter since current inflation and output information are not available within the quarter. The two interest rate variables are included to consider the possibility of interest rate smoothing. A simple summary of the predictability is obtained by considering the $\bar{R}^2$ for the prediction regressions; these are presented in Table 1.

For all three countries we find evidence against the orthogonality conditions for the strict inflation targeting model at the two quarter horizon. For the longer horizon, there is evidence against the condition for Australia and the United States while for Canada there is much less evidence of predictability. Overall, the strict inflation targeting hypothesis does not fare too well. While this is certainly consistent with the stated behaviour of these central banks, none of which claims to focus solely on an inflation target, it provides direct evidence that strict inflation targeting is a poor description of their behaviour.

3.2 Flexible Inflation Targeting

3.2.1 Euler Equation Estimates

The results obtained from estimating the flexible inflation targeting (FIT) conditions using quarterly data are reported in Tables 2 to 5. For each country, we report single equation estimates and systems estimates for horizons two and four.

Table 2 reports the estimates of condition (2), which is consistent with discretionary optimisation by a central bank facing a forward-looking Phillips curve. The resulting Euler equation contains a linear combination of inflation and the output gap. For Australia, the single equation estimates of ϕ are positive at all four horizons and except for the estimate for $h = 2$, statistically significant. The estimates of the inflation target are all statistically significant and range from 2.5 to 2.8%. While these results are consistent with discretionary policy, optimal policy also implies that ϕ and π^* should be constant across all horizons, which is clearly not the case as the estimates for Australia show considerable variation (e.g. ϕ ranges from 0.46 to 1.2). Joint estimation of the Euler equations for $h = 2, 4$ allows a formal test of these restrictions, $\phi_2 = \phi_4$ and $\pi_2^* = \pi_4^*$. Consistent with inspection of the unrestricted estimates, these restrictions are strongly rejected by the data.[17]

In contrast to Australia, the estimates of the Euler equations using Canadian and US data in Table 2 provide no support for discretionary optimisation. The point estimates from both the single equation and system estimates are overwhelming negative. Furthermore, in both countries the restriction on the ϕ parameters is not rejected and the resulting estimates are negative and statistically significant. Taken at face value, these estimates suggest that monetary policy in Canada and the US is *leaning with the wind* rather than *leaning against the wind*. If we focus on the single

[17] There are two implications arising from the system estimates relative to the single equation estimates. First, if the restrictions hold across horizons then estimating the model subject to the cross equation restrictions is more efficient. Second, the unrestricted system estimates can differ significantly from the single equation estimates for the same horizons — as they do for Australia in Table 1 — because of the GMM estimation. Both the single equation and system estimates are estimated using a weighting matrix in the objective function that is proportional to inverse of the covariance matrix. With the system estimates, the weighting matrix depends upon the entire system rather than the single equation and so the parameter estimates may differ.

equation estimates, it is evident for the US that the estimates of ϕ are typically small (in absolute magnitude) and statistically insignificant at conventional significance levels. This suggests that the output gap could be dropped from the US Euler equation, thus providing support for a SIT policy against the hypothesis of discretionary optimization. Overall there is some evidence that the Australian data are consistent with the Euler equation implied by discretionary optimisation while this is not the case for the either Canada or the US.

Woodford (2003) shows that central banks may achieve higher levels of welfare if they can influence private sector expectations, not just in the long-run through their inflation target, but also via their short-run policy actions. This will not be possible if central banks engage in purely discretionary optimisation. Equation (3) represents the Euler equation that is implied when a central bank can implement a pre-commitment solution. In this case the target variable is a linear combination of inflation and the *change* in the output gap. Estimates of equation (3) are reported in Table 3.

The first thing to note from Table 3 is that the estimates of ϕ tend to reject the Euler equation implied by a purely backward-looking Phillips curve, which would have $\phi < 0$. While some negative estimates of ϕ are obtained in the single equation results, these estimates are statistically insignificant. For the system estimates, we do observe a statistically significant negative coefficient for ϕ the Australian model for $h = 4$ but this is paired with a positive significant ϕ coefficient for $h = 2$. (The coefficient estimates are of a similar magnitude to the single equation estimates but with smaller standard errors.) These results thus provide little support for the Euler conditions based upon backward-looking Phillips curves.[18]

The Australian data provide the weakest support for this model. The coefficients for both the single equation and system estimates, as previously noted, are either statistically insignificant (single equation estimates) or do not have a common ϕ across different horizons (system estimates). A test of the restrictions across $h = 2$ and $h = 4$ for both a common ϕ and π^* is strongly rejected. It

[18] This is of course only indirect evidence against backward-looking Phillips curves, which do tend to have some support in the empirical literature, see Rudd and Whelan (2005).

is of some interest to note, however, that if one has strong priors that the general model is correct then the restricted estimates do provide a sensible estimate of π^* as well as a statistically significant ϕ parameter; moreover, the ϕ parameter is similar in magnitude to those reported for Canada and the United States where, as we now discuss, the model fairs somewhat better.

For Canada and the US there is more support for the pre-commitment targeting rule. For both countries the single equation estimates of ϕ are positive and statistically significant for $h = 2, 4$, and 8; for $h = 6$ the coefficient is not statistically different from zero for both countries. As well, the coefficient estimates for π_h^* are consistent with expectations and relatively uniform across the different horizons (particularly for the United States).

Similar conclusions arise from the system estimates. For Canada, we again see fairly similar estimates for ϕ_h at $h = 2$ and 4, both positive and statistically significant. And a test of the restriction $\phi_2 = \phi_4$ is not rejected. We do, however, reject the constancy of π_h^* across the two horizons with π_2^* greater than π_4^*. As a descriptive model of the Bank of Canada there are two interesting implications. First, at either horizon the implied inflation target — once a weight has been attached to output gap deviations - is *lower* than the mid-point of the inflation target of $1 - 3\%$. This also implies that the unconditional mean of inflation is below the mid-point as well. Second, the near term target is higher than the longer term target, implying perhaps a less rigorous focus on near term inflation (though in practical terms the differences are still small: $\pi_2^* = 1.8$ compared to $\pi_4^* = 1.6$).

For the United States, the system estimate results are also quite good. The ϕ parameter estimates are positive and significant, 0.83 and 0.47 for the two and four quarter horizon. Moreover, the two inflation estimates are quite similar, roughly 2.7. Taking each restriction individually, we cannot reject the parameter constancy hypothesis so that the restricted model provides us with an estimate of ϕ equal to 0.28 and and target rate of inflation of 2.8 percent. Broadly speaking, the US central bank appears to put less weight on the output gap and targets a higher long run rate of inflation compared to Canada, though this comparison depends upon a common slope for the respective

Phillips curves.

Table 4 reports estimates of the model where output growth is used rather than the output gap. In part, this provides a check on our previous results. It also can be interpreted as an alternative model in its own right, where the central bank uses the readily available and interpretable output growth measure to guide policy. The results in Table 4 tally closely with those of Table 3, which uses the change in the output gap, for all three countries. There are really only two substantive differences. The first concerns the magnitude of the inflation target, π^*, which is larger for all three countries. This is perfectly understandable, however. For models with x and Δx, both of which have an unconditional mean of zero, we get an estimate of the inflation target, π^*. When we use Δy, which does not have a mean of zero then the π^* estimate includes both the target inflation rate as well as the conditional mean of Δy weighted by the ϕ parameter. The other substantive difference, almost certainly related to this previous point, is that we now reject the hypothesis of $\pi_2^* = \pi_4^*$ for the United States.

One purpose of assessing whether or not the flexible inflation forecasts are consistent with the behaviour of central banks is to provide support for the arguments made by Woodford (2007) that central banks should provide forecasts of appropriately weighted flexible inflation targets when discussing and presenting policy options. The results here suggest that for Canada and the US at least such forecasts are meaningful in the sense that they are consistent with past behaviour. Moreover, the results in Table 4 suggest that using output growth, which is much more readily available and interpretable relative to output gap constructions, may provide similar information.

Results for Canada based on monthly data are reported in Tables 5. To conserve space, only the system estimates are reported; the single equation estimates provide very similar information. The method of estimation is the same as with the quarterly data with the following exceptions. We use a smaller set of instruments than with the quarterly data, dropping the commodity price inflation instruments. We do so because with larger sets of instruments the estimation procedures have difficulty converging.[19] The other principle difference lies in the definition of two variables, the change in output gap and change in output. In both instances, we use a three month change rather than a month on month change. The latter is highly volatile; moreover, the parameter estimates will be directly comparable to those for the quarterly data.[20]

Table 5 presents all four models previously considered: strict inflation targeting as well as the three variants of the flexible inflation targeting model. Qualitatively, the monthly models provide the same conclusions as the quarterly data: coefficient estimates are statistically significant and of the same sign. Remarkably, the monthly coefficient estimates, for both ϕ and π^* estimates, are quite close to those of the quarterly model. This is most readily apparent by comparing the restricted coefficient estimates across the monthly and quarterly results. We take this as evidence that the quarterly results, while not structured to coincide with the higher frequency policy making process, are still a good approximation to central bank behaviour. Of course, we do not have direct evidence of this for the US and Australia but the Canadian results are broadly suggestive.

One important departure from the quarterly results is the tests of the intertemporal consistency of the parameter estimates. Unlike the quarterly data, where the restrictions were generally rejected, for the monthly data they are uniformly accepted at standard significant levels. Of the four models we consider, we again favour that with the change in output gap associated with flexible inflation targeting under commitment and in the presence of a forward-looking Phillips Curve. Here we get an inflation target of 1.7%, again lower than the mid-point of the target range of 2–3%, and a weight on the output gap of 0.8.

In summary, we have evidence in favour of the discretionary optimization model for Australia and evidence in favour of the pre-commitment model for both Canada and the United States. For Australia, however, there is strong evidence against parameter constancy of both the weight on the

[19] The problem appears to be with the large number of lags in the NW covariance matrix estimator; consistent with our choice in the quarterly estimation, we use one lag less than the maximum forecast horizon, which in this case is 11.

[20] The output gap is constructed again using the Hodrick-Prescott filter; see the data appendix for details.

output gap and the inflation target. For Canada, we have evidence in favour of parameter constancy for the change in output but not for the inflation target using quarterly data; the monthly data, however, exhibits parameter constancy and very similar estimates to the quarterly data. Given the greater number of observations for the monthly sample, we are inclined to favour these estimates. For the United States, we have evidence in favour of the pre-commitment model and parameter constancy.

3.2.2 Prediction Regressions

We now consider the specification of these models in greater detail. While all of the models presented so far are not rejected based on Hansen's $J-$test of over-identifying restrictions, as we noted earlier we suspect that the test lacks power in the current circumstances. Moreover, we are interested to know whether or not we have inappropriately excluded variables from the conditions. Two particular concerns are addressed: interest rate targets or smoothing and, for Australia and Canada, the role of the exchange rate.

Interest rate targets or smoothing can be motivated both theoretically (Woodford, 2003) and empirically (Clarida, Galí, and Gertler, 1998) so it is natural to ask if current interest rate levels or changes can explain deviations from the estimated target.[21] The logic is most straightforward to see in terms of the change in the policy interest rate. Suppose we consistently observe changes in the current policy interest rate predicting positive Euler equation residuals, meaning the weighted average of inflation and output exceeds the flexible inflation target. The failure to control output and inflation indicates that the change in interest rates is not sufficient and that a greater change in interest rates is required. That this does not happen may be explained by interest rate smoothing. Similar arguments might be made for the level of the policy interest rate and for changes in the exchange rate.

[21] A more direct assessment of the importance of interest rates would involve estimating the appropriate Euler conditions; however, our attempts to do so so far have not been satisfactory.

More generally, we can motivate these variables as being part of the information set at time t and according to the model these should not predict deviations from target. To this end, we also consider additional time t variables: the inflation rate, the output gap, the change in the output gap, and output growth. We also consider lagged values of the GMM residuals themselves. The sets of regressions we run then are as follows:

$$\pi_{t+h} + \hat{\phi}_h \tilde{x}_{t+h} - \hat{\pi}^*_{t+h} = \alpha + Z_t \delta + u_{t+h}$$

where Z_t is one of,

1. $Z_t = (\pi_{t-1} + \hat{\phi}_h \tilde{x}_{t-1} - \hat{\pi}^*_{t-1}, \pi_{t-2} + \hat{\phi}_h \tilde{x}_{t-2} - \hat{\pi}^*_{t-2})$
2. $Z_t = (\pi_{t-1}, x_{t-1}, \Delta x_{t-1}, \Delta y_{t-1}, i_t, \Delta i_t)$
3. $Z_t = (\pi_{t-1}, x_{t-1}, \Delta x_{t-1}, \Delta y_{t-1}, \Delta s_t)$

Here $\tilde{x}_t$ is either x_t or Δx_t depending upon the country considered; i_t is an overnight policy interest rate (see appendix for details); s_t is the nominal US dollar exchange rate in domestic currency terms. Consistent with our estimation, we assume that at time t output and inflation data is known only with a lag. Exchange rate and interest rate data are known within the quarter.

To keep matters simple, for the quarterly models we focus on one model per country and we use the single equation estimates for horizons 2 and 4. For Australia, we use the results from Table 2, the discretionary model. In this case, $\tilde{x}_t = x_t$. For Canada and the US, we use the results from Table 3, the pre-commitment model. The two quarter horizon results are presented in Table 6; the four quarter horizon results in Table 7. Note that we do not present results for the US using the nominal exchange rate. While US dollar rates are natural choices for Canada and Australia, the appropriate choice for the US is less clear. Nor is there much existing evidence that currency values are important concerns for US monetary policy.

For Australia, the GMM residuals are extremely persistent, as evidenced by the coefficient estimates in model (1), the first column of Table 6. The sum of the coefficients on the two lagged residuals are both significant and sum to just less than one. This is a significant departure from the predictions of the model. Moreover, the $\bar{R}^2$ is 0.29 so these residuals explain a substantive component of these future deviations. An equally strong rejection of the model arises in model (2). In this case, lagged inflation and the change in the policy interest rate are both statistically significant and the $\bar{R}^2$ is quite large, 0.40. Similar results hold true for the four quarter horizon as well. As discussed previously, it appears that there may be some interest rate smoothing behaviour underlying Australian monetary policy behaviour, though this conclusion can only be tentative without explicitly incorporating such behaviour into the estimation directly. In model (3), which includes the nominal exchange rate, we find no evidence that it helps predict deviations from target at either the two or four quarter horizon.

For Canada, there is no evidence of persistence in the residuals themselves for the two or four quarter horizon. Where there does seem to be a meaningful departure from the model is for the two quarter horizon where both lagged inflation and the output gap are both significant predictors as is the level of the short term interest rate, as is the level of the interest rate. The $\bar{R}^2$ is 0.18, indicating a significant amount of predictability, though less than the two quarter horizon Australian regressions. At the four quarter horizon, the level of the interest rate is still significant though the $\bar{R}^2$ indicates there is very little information. The change in exchange rate, model (3), has no predictive power at either the two or four quarter horizon. All together, there is clear evidence of predictability at both the two and four quarter horizon, evidence against the model.

For the United States, there is persistence in the residuals at the two quarter horizon. There is also evidence at both horizons that output measures and the change in the interest rate predict departures from target at both the two and four quarter horizon. At the two quarter horizon, the $\bar{R}^2$ is 0.24 while at the four quarter horizon it is 0.10. Again, evidence against the model.

The same prediction regressions are reported in Table 8 but for the monthly Canadian data. We consider the same horizons, 6 and 12 months. As the restrictions imposed on the systems estimates are not rejected, we use these estimates. The results here are much more favourable for the model. The only significant predictor occurs at the six quarter horizon and this the is lagged residual; there exists some mild persistence in the residuals. However, the $\bar{R}^2$ is extremely low, 0.02, indicating that there is very little information available. On this basis, we conclude that the Canadian data at the monthly level provides reasonable support for the pre-commitment inflation forecast targeting by the Bank of Canada.

4 Conclusion

We test two optimality conditions for a central bank implied by a relatively basic version of the New Keynesian model. Surprisingly in light of the relative simplicity of our assumed loss function and purely forward-looking nature of the Phillips curve, we obtain estimates of flexible inflation targeting models that are reasonable, providing measures of flexible inflation targets for each country. For both Canada and the US, there is reasonable support for the flexible inflation targeting model under commitment. For Australia, there is some evidence in favour of the flexible inflation targeting model under discretion. We can, however, reject the strict inflation targeting model for all three countries.

With all three countries, however, there are some indications of important departures from the flexible inflation. First, there is evidence that deviations from target — whether strict or flexible inflation targeting — are predictable at the two quarter horizon and four quarter horizon, using quarterly data. However, there is very little evidence of meaningful predictability of the flexible inflation target for Canada based on monthly data.

We find mixed evidence on parameter constancy. For Australia there is evidence of variation in both the inflation target and the weight on output across all models. For Canada using quarterly data, the intertemporal consistency arises only with the inflation target not the output weight for our preferred commitment model . And intriguingly, when we use monthly data for Canada there is strong support for parameter constancy (and moreover, the coefficients are roughly similar to those of the quarterly data). For the US, again focusing on the commitment model, there is in fact no strong evidence against the intertemporal consistency hypothesis.

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Table 1: Strict Inflation Targetting

Instruments: $z_t = (1, \pi_t^{cx}, \pi_{t-1}^{cx}, \pi_{t-2}^{cx}, \pi_{t-1}, \pi_{t-2}, x_{t-1}, \Delta x_{t-1}, \Delta y_{t-1})$

Single Equation Models: $E_t(\pi_{t+h} - \pi_h^*),\ h = 2, 4, 6, 8$

	Australia		**Canada**		**United States**	
	π_h^*	J	π_h^*	J	π_h^*	J
$h = 2$	2.5515	9.0118	2.0449	12.2604	2.7524	11.7124
	(0.1078)	(0.3413)	(0.0955)	(0.1400)	(0.1022)	(0.1645)
$h = 4$	2.7663	4.8396	1.9383	4.4861	2.9245	7.4618
	(0.1367)	(0.7746)	(0.1065)	(0.8108)	(0.1086)	(0.4877)
$h = 6$	2.6671	4.6363	1.7732	4.9244	2.8039	4.1013
	(0.0789)	(0.7956)	(0.0846)	(0.7656)	(0.1009)	(0.8479)
$h = 8$	2.6331	4.5672	2.0783	4.5138	2.8524	4.7134
	(0.0765)	(0.8027)	(0.0527)	(0.8080)	(0.0955)	(0.7877)

System Model: $E_t(\pi_{t+h} - \pi_h^*),\ h = 2, 4$

	Australia			**Canada**			**United States**		
	π_2^*	π_4^*	J	π_2^*	π_4^*	J	π_2^*	π_4^*	J
Unrestricted	2.6388	2.9638	9.3713	2.0906	1.7903	9.6865	2.9473	2.9058	12.2269
	(0.0737)	(0.0738)	(0.8973)	(0.0620)	(0.0554)	(0.8825)	(0.0832)	(0.0811)	(0.7282)
Restricted	2.5936		11.7141	1.7093		10.1772	2.9316		12.2358
	(0.0613)		(0.8171)	(0.0429)		(0.8960)	(0.0745)		(0.7857)
Tests									
$\pi_2^* = \pi_4^*$		34.8858			16.8241			0.7063	
		(0.0000)			(0.0000)			(0.4007)	

Prediction Regressions

	Australia		**Canada**		**United States**	
	$\pi_{t+2} - 2.5515$	$\pi_{t+4} - 2.7663$	$\pi_{t+2} - 2.0449$	$\pi_{t+4} - 1.9383$	$\pi_{t+2} - 2.7524$	$\pi_{t+4} - 2.9245$
$\bar{R}^2$	0.4828	0.4485	0.3452	0.0428	0.4509	0.1739

Notes: J is Hansen's (1982) J-statistic, distributed $\chi^2(8)$ for the single equation models and distributed $\chi^2(16)$ or $\chi^2(17)$ for the unrestricted and restricted system models respectively. Numbers in parentheses are standard errors except for the reported statistics, which are marginal significance levels. Covariance matrices are Newey and West (1987) using a lag truncation parameter of $h-1$ for the single equation models and 3 for the system models. The numbers reported in the row denoted $\pi_2 = \pi_4$ the appropriate Wald test and marginal significance levels. The prediction regressions regress the estimated residuals from the single equation models on a set of variables known at time t. See text for details.

Table 2: Flexible Inflation Targetting using x

Instruments: $z_t = (1, \pi_t^{cx}, \pi_{t-1}^{cx}, \pi_{t-2}^{cx}, \pi_{t-1}, \pi_{t-2}, x_{t-1}, \Delta x_{t-1}, \Delta y_{t-1})$

Single Equation Models: $E_t(\pi_{t+h} + \phi_h x_{t+h} - \pi_h^*),\ h = 2, 4, 6, 8$

	Australia			Canada			United States		
	ϕ_h	π_h^*	J	ϕ_h	π_h^*	J	ϕ_h	π_h^*	J
$h = 2$	0.4631	2.5469	9.6940	-0.3533	2.1382	8.4692	-0.2576	2.8472	10.2028
	(0.3988)	(0.1020)	(0.2066)	(0.1026)	(0.0908)	(0.2930)	(0.1652)	(0.0946)	(0.1774)
$h = 4$	1.2074	2.8473	3.0228	-0.0832	1.9398	4.5139	0.0002	2.9244	7.4620
	(0.4906)	(0.0790)	(0.8829)	(0.2309)	(0.1295)	(0.7190)	(0.1437)	(0.1166)	(0.3824)
$h = 6$	1.0764	2.7515	2.8299	-0.2439	1.9242	5.3521	-0.0821	2.8175	3.6519
	(0.3520)	(0.1168)	(0.9003)	(0.1788)	(0.0949)	(0.6171)	(0.1337)	(0.1092)	(0.8189)
$h = 8$	0.6102	2.7865	4.2696	-0.3925	2.1709	4.4949	-0.0376	2.8600	4.5521
	(0.2228)	(0.0885)	(0.7483)	(0.1352)	(0.0616)	(0.7213)	(0.1458)	(0.1069)	(0.7144)

System Models: $E_t(\pi_{t+h} + \phi_h x_{t+h} - \pi_h^*),\ h = 2, 4$

	Australia					Canada					United States				
	ϕ_2	ϕ_4	π_2^*	π_4^*	J	ϕ_2	ϕ_4	π_2^*	π_4^*	J	ϕ_2	ϕ_4	π_2^*	π_4^*	J
Unrestricted															
	0.8579	0.3028	2.6645	2.8773	9.0142	-0.2610	-0.2388	2.0502	1.9043	8.2147	-0.2152	-0.3084	2.9327	2.9966	10.5554
	(0.1431)	(0.1993)	(0.0905)	(0.0955)	(0.8301)	(0.0458)	(0.1218)	(0.0499)	(0.0555)	(0.8778)	(0.1485)	(0.0928)	(0.0697)	(0.0708)	(0.7206)
Restricted															
	0.4232		2.8181		10.9367	-0.2337		1.9365		9.3988	-0.3095		2.9587		10.7060
	(0.1343)		(0.0733)		(0.8134)	(0.0458)		(0.0385)		(0.8961)	(0.0788)		(0.0613)		(0.8273)
Tests															
$\phi_2 = \phi_4$			7.4124	(0.0065)				0.0323	(0.8574)				1.4083	(0.2353)	
$\pi_2 = \pi_4$			4.8203	(0.0281)				5.1325	(0.0235)				1.2143	(0.2705)	
$\phi_2 = \phi_4$ $\phi_2 = \phi_4$			12.8140	(0.0016)				5.7468	(0.0565)				2.2386	(0.3265)	

Notes: J is Hansen's (1982) J-statistic, distributed $\chi^2(8)$ for the single equation models and distributed $\chi^2(14)$ or $\chi^2(16)$ for the unrestricted and restricted system models respectively. Numbers in parentheses are standard errors except for the reported statistics, which are marginal significance levels. Covariance matrices are Newey and West (1987) using a lag truncation parameter of $h-1$ for the single equation models and 3 for the system models. The numbers reported in the rows denoted *Tests* are the appropriate Wald test and marginal significance levels.

Table 3: Flexible Inflation Targetting using Δx

Instruments: $z_t = (1, \pi_t^{cx}, \pi_{t-1}^{cx}, \pi_{t-2}^{cx}, \pi_{t-1}, \pi_{t-2}, x_{t-1}, \Delta x_{t-1}, \Delta y_{t-1})$

Single Equation Models: $E_t(\pi_{t+h} + \phi_h \Delta x_{t+h} - \pi_h^*),\ h = 2, 4, 6, 8$

	Australia			Canada			United States		
	ϕ_h	π_h^*	J	ϕ_h	π_h^*	J	ϕ_h	π_h^*	J
$h=2$	0.5931	2.6124	7.6296	1.0038	1.9131	11.4528	0.8791	2.8069	8.8269
	(0.3927)	(0.1084)	(0.3664)	(0.2972)	(0.1208)	(0.1201)	(0.3744)	(0.0975)	(0.2653)
$h=4$	-0.4982	2.7992	4.8260	0.6843	1.9896	2.4506	0.7792	2.7764	3.6074
	(0.5400)	(0.1555)	(0.6812)	(0.3187)	(0.1131)	(0.9308)	(0.3898)	(0.0949)	(0.8237)
$h=6$	0.4271	2.6546	4.5339	-0.2199	1.7856	5.0654	-0.0293	2.8175	4.0699
	(0.5966)	(0.0959)	(0.7166)	(0.3864)	(0.0834)	(0.6520)	(0.3012)	(0.1044)	(0.7717)
$h=8$	-0.3393	2.6907	4.3178	1.3157	2.0403	4.4666	0.5931	2.8461	3.8253
	(0.5413)	(0.0901)	(0.7425)	(0.4723)	(0.0605)	(0.7247)	(0.2781)	(0.0786)	(0.7997)

System Models: $E_t(\pi_{t+h} + \phi_h \Delta x_{t+h} - \pi_h^*),\ h = 2, 4$

	Australia					Canada					United States				
	ϕ_2	ϕ_4	π_2^*	π_4^*	J	ϕ_2	ϕ_4	π_2^*	π_4^*	J	ϕ_2	ϕ_4	π_2^*	π_4^*	J
Unrestricted															
	0.4624	-0.5591	2.6225	2.8859	8.7619	0.9182	0.7204	1.8485	1.5590	8.7293	0.8292	0.4726	2.7336	2.6589	9.1533
	(0.1908)	(0.3560)	(0.0910)	(0.1115)	(0.8460)	(0.1648)	(0.2518)	(0.1020)	(0.0615)	(0.8480)	(0.2862)	(0.2371)	(0.0787)	(0.0670)	(0.8211)
Restricted															
	0.7138		2.6819		10.0942	1.1775		1.7594		9.7085	0.2818		2.7603		11.3823
	(0.0856)		(0.0802)		(0.8617)	(0.1249)		(0.0447)		(0.8814)	(0.1750)		(0.0807)		(0.7853)
Tests															
$\phi_2 = \phi_4$			4.7387	(0.0295)				0.4398	(0.5072)				2.6432	(0.1040)	
$\pi_2 = \pi_4$			11.0863	(0.0009)				8.9577	(0.0028)				1.6976	(0.1926)	
$\phi_2 = \phi_4$ $\phi_2 = \phi_4$			16.6482	(0.0002)				16.0704	(0.0003)				7.0835	(0.0290)	

Notes: J is Hansen's (1982) J-statistic, distributed $\chi^2(8)$ for the single equation models and distributed $\chi^2(14)$ or $\chi^2(16)$ for the unrestricted and restricted system models respectively. Numbers in parentheses are standard errors except for the reported statistics, which are marginal significance levels. Covariance matrices are Newey and West (1987) using a lag truncation parameter of $h-1$ for the single equation models and 3 for the system models. The numbers reported in the rows denoted *Tests* are the appropriate Wald test and marginal significance levels.

Table 4: Flexible Inflation Targetting using Δy

Instruments: $z_t = (1, \pi_t^{cx}, \pi_{t-1}^{cx}, \pi_{t-2}^{cx}, \pi_{t-1}, \pi_{t-2}, x_{t-1}, \Delta x_{t-1}, \Delta y_{t-1})$

Single Equation Models: $E_t(\pi_{t+h} + \phi_h \Delta y_{t+h} - \pi_h^*),\ h = 2, 4, 6, 8$

	Australia			**Canada**			**United States**		
	ϕ_h	π_h^*	J	ϕ_h	π_h^*	J	ϕ_h	π_h^*	J
$h = 2$	0.7913	3.2896	7.4544	0.8276	2.5702	11.0253	0.8369	3.4297	8.7995
	(0.4081)	(0.4062)	(0.3831)	(0.2281)	(0.1665)	(0.1375)	(0.3148)	(0.2585)	(0.2674)
$h = 4$	-0.3702	2.4878	4.7716	0.5236	2.3682	2.6038	0.7581	3.3338	2.8857
	(0.3480)	(0.2539)	(0.8954)	(0.6647)	(0.5246)	(0.6878)	(0.2463)	(0.2286)	(0.9191)
$h = 6$	0.6567	3.2220	4.5614	0.0313	1.7980	4.9019	0.0866	2.8619	4.19143
	(0.5525)	(0.5052)	(0.7133)	(0.2634)	(0.2305)	(0.6719)	(0.2957)	0.1990	(0.7575)
$h = 8$	0.1110	2.7191	4.6613	0.8840	2.7108	3.7155	0.5566	3.2493	3.8292
	(0.7183)	(0.5927)	(0.7012)	(0.3089)	(0.2324)	(0.8119)	(0.2338)	(0.1466)	(0.7992)

System Models: $E_t(\pi_{t+h} + \phi_h \Delta y_{t+h} - \pi_h^*),\ h = 2, 4$

	Australia					**Canada**					**United States**				
	ϕ_2	ϕ_4	π_2^*	π_4^*	J	ϕ_2	ϕ_4	π_2^*	π_4^*	J	ϕ_2	ϕ_4	π_2^*	π_4^*	J
Unrestricted															
	0.4085	-0.4586	2.9100	2.4376	8.6926	0.7316	0.6290	2.4599	2.0858	8.5797	0.7902	0.4130	3.3513	2.9911	8.9926
	(0.1843)	(0.3657)	(0.2253)	(0.2595)	(0.8502)	(0.1358)	(0.2035)	(0.0637)	(0.1699)	(0.8570)	(0.2599)	(0.2189)	(0.2124)	(0.1674)	(0.8315)
Restricted															
	0.7325		3.2643		10.0513	0.8173		2.4753		9.1383	0.2814		2.9732		10.9583
	(0.0931)		(0.1147)		(0.8639)	(0.0975)		(0.0644)		(0.9076)	(0.1523)		(0.1248)		(0.8121)
Tests															
$\phi_2 = \phi_4$			3.2776	(0.0702)				0.1671	(0.6827)				2.7303	(0.0985)	
$\pi_2 = \pi_4$			1.2583	(0.2620)				4.2826	(0.0385)				5.6569	(0.0174)	
$\phi_2 = \phi_4$ $\phi_2 = \phi_4$			16.8380	(0.0002)				15.1505	(0.0005)				8.6515	(0.0132)	

Notes: J is Hansen's (1982) J-statistic, distributed $\chi^2(8)$ for the single equation models and distributed $\chi^2(14)$ or $\chi^2(16)$ for the unrestricted and restricted system models respectively. Numbers in parentheses are standard errors except for the reported statistics, which are marginal significance levels. Covariance matrices are Newey and West (1987) using a lag truncation parameter of $h-1$ for the single equation models and 3 for the system models. The numbers reported in the rows denoted *Tests* are the appropriate Wald test and marginal significance levels.

Table 5: System Estimates for Canadian Monthly Data

Instruments: $z_t = (1, \pi_{t-1}, \pi_{t-2}, x_{t-1}, \Delta_3 x_{t-1}, \Delta_3 y_{t-1})$

Strict Inflation Targetting

	$E_t(\pi_{t+h} - \pi_h^*),\ h = 6, 12$		
	π_6^*	π_{12}^*	J
Unrestricted			
	1.7016	1.6848	8.1208
	((00.934)	(0.0629)	(0.6170)
Restricted			
	1.6876		8.1125
	(0.0599)		(0.7032)
Tests			
$\pi_6 = \pi_{12}$	0.0338	(0.8541)	

Flexible Inflation Targetting

	$E_t(\pi_{t+h} + \phi_h x_{t+h} - \pi_h^*),\ h = 6, 12$					$E_t(\pi_{t+h} + \phi_h \Delta_3 x_{t+h} - \pi_h^*),\ h = 6, 12$					$E_t(\pi_{t+h} + \phi_h \Delta_3 y_{t+h} - \pi_h^*),\ h = 6, 12$				
	ϕ_6	ϕ_{12}	π_6^*	π_{12}^*	J	ϕ_6	ϕ_{12}	π_6^*	π_{12}^*	J	ϕ_6	ϕ_{12}	π_6^*	π_{12}^*	J
Unrestricted															
	-0.4510	-0.3727	1.6714	1.7945	7.3900	0.8955	0.8525	1.7992	1.6213	7.9567	0.7363	0.5922	2.3598	2.0513	8.2815
	(0.1606)	(0.2126)	(0.0629)	(0.0851)	(0.4952)	(0.2656)	(0.3862)	(0.1353)	(0.0961)	(0.4377)	(0.2300)	(0.3072)	(0.2279)	(0.2329)	(0.4065)
Restricted															
	-0.2906		1.7631		7.8343	0.7833		1.7109		8.0868	0.5358		2.1404		8.2056
	(0.1296)		(0.0642)		(0.6450)	(0.1997)		(0.0761)		(0.6204)	(0.1602)		(0.1456)		(0.6088)
Tests															
$\phi_6 = \phi_{12}$			0.2759	(0.5994)				0.0112	(0.9158)				0.1964	(0.6577)	
$\pi_6 = \pi_{12}$			1.7521	(0.1856)				1.7318	(0.1882)				1.4483	(0.2288)	
$\phi_6 = \phi_{12}$ $\phi_6 = \phi_{12}$			1.8100	(0.4045)				2.2077	(0.3316)				3.0417	(0.2185)	

Notes: J is Hansen's (1982) J-statistic, distributed $\chi^2(r-k)$ where r is the number of moment conditions and k is the number of estimated parameters. Numbers in parentheses are standard errors except for the reported statistics, which are marginal significance levels. Covariance matrices are Newey and West (1987) using a lag truncation parameter of 11. The numbers reported in the rows denoted *Tests* are the appropriate Wald test and marginal significance levels.

Table 6: Prediction Regressions for FIT Residuals at 2 Quarter Horizon

Australia

Dep. Var. $res_{t+2} = \pi_{t+2} + \hat{\phi}_2 x_{t+2} - \hat{\pi}_2^*$

$\hat{\phi}_2 = 0.4631$; $\hat{\pi}_2^* = 2.5469$

	(1)		(2)		(3)	
Constant	-0.0853	(0.1932)	1.6679	(1.8106)	3.0807	(1.2871)
res_{t-1}	1.1130*	(0.3864)				
res_{t-2}	-0.8160*	(0.3687)				
π_{t-1}			0.2891*	(0.1323)	0.2608	(0.1770)
x_{t-1}			0.0280	(0.2689)	0.4692	(0.2947)
Δx_{t-1}			2.0102	(1.6921)	4.1102	(2.6038)
Δy_{t-1}			-1.9743	(1.6028)	-4.2290	(2.5874)
i_t			-0.1273	(0.2967)		
Δi_t			1.6560*	(0.4661)		
Δs_t					-0.0014	(0.0305)
$\bar{R}^2$	0.2908		0.4004		0.2037	

Canada

Dep. Var. $res_{t+2} = \pi_{t+2} + \hat{\phi}_2 \Delta x_{t+2} - \hat{\pi}_2^*$

$\hat{\phi}_2 = 1.0038$; $\hat{\pi}_2^* = 1.9131$

	(1)		(2)		(3)	
Constant	0.0940	(0.1563)	1.7858	(1.0876)	0.2691	(1.1206)
res_{t-1}	0.1656	(0.1367)				
res_{t-2}	-0.1683	(0.1211)				
π_{t-1}			-0.3114*	(0.1712)	-0.0193	(0.2133)
x_{t-1}			0.5364*	(0.2443)	0.0507	(0.1795)
Δx_{t-1}			-0.5661	(1.2011)	0.7271	(1.0949)
Δy_{t-1}			0.6380	(1.1494)	-0.2246	(1.1506)
i_t			-0.3853*	(0.1399)		
Δi_t			-0.0103	(0.2287)		
Δs_t					-0.0240	(0.0611)
$\bar{R}^2$	-0.0134		0.1773		0.0148	

United States

Dep. Var. $res_{t+2} = \pi_{t+2} + \hat{\phi}_2 \Delta x_{t+2} - \hat{\pi}_2^*$

$\hat{\phi}_2 = 0.8791$; $\hat{\pi}_2^* = 2.8069$

	(1)		(2)	
Constant	-0.0852	(0.1263)	0.6119	(0.9700)
res_{t-1}	0.3539	(0.1459)		
res_{t-2}	0.0435	(0.1029)		
π_{t-1}			0.1902	(0.1633)
x_{t-1}			-0.0977	(0.1631)
Δx_{t-1}			2.4177*	(1.2543)
Δy_{t-1}			-2.3451*	(1.2398)
i_t			0.1205	(0.1073)
Δi_t			0.6312*	(0.3073)
Δs_t				
$\bar{R}^2$	0.1692		0.2430	

Notes: Standard errors are Newey-West with lag truncation parameter 3. The covariance matrix is constructed using the small sample adjustment suggested in Davidson and Mackinnon (1994). Standard errors are in brackets to the right of point estimates. The dependent variables estimates are from the single equation GMM estimates in Table 3 (Australia) and Table 4 (Canada and the US) for $h = 2$. A * indicates significance at 10% using a two-sided $t-$statistic.

Table 7: Prediction Regressions for FIT Residuals at 4 Quarter Horizon

	Australia						**Canada**						**United States**			
Dep. Var.	$res_{t+4} = \pi_{t+4} + \hat{\phi}_4 x_{t+4} - \hat{\pi}_4^*$						$res_{t+4} = \pi_{t+4} + \hat{\phi}_4 \Delta x_{t+4} - \hat{\pi}_4^*$						$res_{t+4} = \pi_{t+4} + \hat{\phi}_4 \Delta x_{t+4} - \hat{\pi}_4^*$			
	$\hat{\phi}_4 = 1.2074$; $\hat{\pi}_4^* = 2.8473$						$\hat{\phi}_4 = 0.6843$; $\hat{\pi}_4^* = 1.9896$						$\hat{\phi}_4 = 0.7792$; $\hat{\pi}_4^* = 2.7764$			
	(1)		(2)		(3)		(1)		(2)		(3)		(1)		(2)	
Constant	-0.4216	(0.2813)	4.9357*	(1.7464)	6.1377*	(2.4734)	0.0415	(0.1534)	0.8064	(1.2072)	-0.3383	(0.9834)	-0.0865	(0.1384)	1.5283	(1.2520)
res_{t-1}	0.2096	(0.2885)					-0.1190	(0.1742)					0.1014	(0.1375)		
res_{t-2}	-0.4479	(0.3223)					0.2098	(0.1917)					0.0169	(0.1455)		
π_{t-1}			-0.2737	(0.1858)	-0.4633*	(0.1629)			-0.2153	(0.1937)	-0.0170	(0.1932)			-0.0646	(0.2250)
x_{t-1}			-0.0752	(0.3368)	0.3014	(0.3258)			0.3345	(0.3085)	-0.0196	(0.2159)			-0.1955	(0.1792)
Δx_{t-1}			3.3128	(2.3313)	5.8869*	(2.7506)			-1.3988	(1.1365)	-0.6886	(1.0667)			2.6275*	(1.5168)
Δy_{t-1}			-3.2035	(2.1766)	-5.9436*	(2.6573)			0.9966	(1.1625)	0.4910	(1.1555)			-2.5345*	(1.5308)
i_t			-0.3121	(0.3740)					-0.2781*	(0.1588)					0.1035	(0.1287)
Δi_t			1.3410*	(0.7395)					-0.1586	(0.1887)					0.5555*	(0.3147)
Δs_t					-0.0436	(0.0449)					-0.0309	(0.0554)				
$\bar{R}^2$	0.0775		0.2824		0.2093		-0.0075		0.0035		-0.0942		-0.0094		0.1031	

Notes: Standard errors are Newey-West with lag truncation parameter 3. The covariance matrix is constructed using the small sample adjustment suggested in Davidson and Mackinnon (1994). Standard errors are in brackets to the right of point estimates. The dependent variables estimates are from the single equation GMM estimates in Table 3 (Australia) and Table 4 (Canada and the US) for $h = 4$. A * indicates significance at 10% using a two-sided $t-$statistic.

Table 8: Prediction Regressions for FIT Residuals using Canadian Monthly Models

	Canada											
Dep. Var.	$res_{t+6} = \pi_{t+6} + \hat{\phi}_6 \Delta_3 x_{t+6} - \hat{\pi}^*_6$						$res_{t+12} = \pi_{t+12} + \hat{\phi}_{12} \Delta_3 x_{t+12} - \hat{\pi}^*_{12}$					
	$\hat{\phi}_6 = 1.2074$; $\hat{\pi}^*_6 = 2.8473$						$\hat{\phi}_12 = 0.7792$; $\hat{\pi}^*_12 = 2.7764$					
	(1)		(2)		(3)		(1)		(2)		(3)	
Constant	0.2712*	(0.1583)	0.8549	(0.8808)	0.4895	(0.8508)	0.3274*	(0.1754)	0.7478	(0.9721)	0.4542	(0.9216)
res_{t-1}	0.1931*	(0.1127)					-0.1663	(0.1185)				
res_{t-2}	-0.0474	(0.1031)					0.0850	(0.1247)				
π_{t-1}			0.0449	(0.1061)	0.0751	(0.0992)			-0.1266	(0.1171)	-0.0884	(0.1091)
x_{t-1}			0.2054	(0.1741)	0.0355	(0.1401)			-0.0404	(0.2072)	-0.2158	(0.2260)
$\Delta_3 x_{t-1}$			0.3892	(1.1333)	0.8397	(1.0501)			-0.3128	(0.9487)	0.1042	(1.0259)
$\Delta_3 y_{t-1}$			-0.1393	(1.0474)	-0.4087	(0.9749)			0.3338	(0.9431)	0.0513	(0.9856)
i_t			-0.1232	(0.0950)					-0.1070	(0.0968)		
Δi_t			0.0561	(0.2701)					-0.2878	(0.2078)		
$\Delta_3 s_t$					-0.0109	(0.0243)					-0.0072	(0.0282)
$\bar{R}^2$	0.0150		0.0529		0.0424		0.0002		0.0294		0.0149	

Notes: Standard errors are Newey-West with lag truncation parameter 11. The covariance matrix is constructed using the small sample adjustment suggested in Davidson and Mackinnon (1994). Standard errors are in brackets to the right of point estimates. The dependent variables estimates are from the system estimates for Canada reported in Table 5. A * indicates significance at 10% using a two-sided $t-$statistic.

Table A1: Instrument Quality for Single Equation Estimates

Quarterly

Instruments: $z_t = (1, \pi_t^{cx}, \pi_{t-1}^{cx}, \pi_{t-2}^{cx}, \pi_{t-1}, \pi_{t-2}, x_{t-1}, \Delta x_{t-1}, \Delta y_{t-1})$

	Australia		**Canada**		**United States**	
	π_{t+h}	$\tilde{x}_{t+h}$	π_{t+h}	$\tilde{x}_{t+h}$	π_{t+h}	$\tilde{x}_{t+h}$
Model 1						
$h=2$	0.589		0.478		0.591	
$h=4$	0.499		0.231		0.156	
$h=6$	0.672		0.260		0.130	
$h=8$	0.720		0.160		0.147	
Model 2						
$h=2$	0.463	0.294	0.287	0.374	0.574	0498
$h=4$	0.429	0.287	0.261	0.430	0.121	0.383
$h=6$	0.659	0.247	0.316	0.537	0.132	0.524
$h=8$	0.689	0.262	0.200	0.585	0.153	0.474
Model 3						
$h=2$	0.439	0.194	0.431	0.431	0.361	0.166
$h=4$	0.492	0.131	0.166	0.316	0.124	0.146
$h=6$	0.662	0.060	0.262	0.137	0.129	0.101
$h=8$	0.677	0.040	0.115	0.049	0.154	0.159
Model 4						
$h=2$	0.353	0.172	0.415	0.508	0.329	0.211
$h=4$	0.533	0.088	0.168	0.422	0.097	0.171
$h=6$	0.662	0.060	0.263	0.279	0.134	0.191
$h=8$	0.458	0.051	0.149	0.123	0.153	0.249

Notes: Numbers reported are Shea's (1997) partial R^2 measures for instrument quality.

Model 1: $E_t(\pi_{t+h} - \pi_h^*)$; Quarterly: $h = 2, 4$; Monthly: $h = 6, 12$.

Model 2: $E_t(\pi_{t+h} + \phi_h x_{t+h} - \pi_h^*)$, where $\tilde{x}_{t+h} = x_{t+h}$. For quarterly, $h = 2, 4$. For monthly, $h = 6, 12$.

Model 3: $E_t(\pi_{t+h} + \phi_h \Delta x_{t+h} - \pi_h^*)$. For quarterly, $\tilde{x}_{t+h} = \Delta x_{t+h}$ and $h = 2, 4$. For monthly $\tilde{x}_{t+h} = \Delta_3 x_{t+h}$ and $h = 6, 12$.

Model 4: $E_t(\pi_{t+h} + \phi_h \Delta y_{t+h} - \pi_h^*)$ For quarterly, $\tilde{x}_{t+h} = \Delta y_{t+h}$ and $h = 2, 4$. For monthly $\tilde{x}_{t+h} = \Delta_3 y_{t+h}$ and $h = 6, 12$.

Table A2: Instrument Quality for System Estimates

Quarterly

Instruments: $z_t = (1, \pi_t^{cx}, \pi_{t-1}^{cx}, \pi_{t-2}^{cx}, \pi_{t-1}, \pi_{t-2}, x_{t-1}, \Delta x_{t-1}, \Delta y_{t-1})$

	Australia				**Canada**				**United States**			
	π_{t+2}	π_{t+4}	$\tilde{x}_{t+2}$	$\tilde{x}_{t+4}$	π_{t+2}	π_{t+4}	$\tilde{x}_{t+2}$	$\tilde{x}_{t+4}$	π_{t+2}	π_{t+4}	$\tilde{x}_{t+2}$	$\tilde{x}_{t+4}$
Model 1	0.573	0.485			0.406	0.197			0.500	0.132		
Model 2	0.254	0.408	0.201	0.099	0.143	0.231	0.206	0.208	0.368	0.135	0.184	0.137
Model 3	0.342	0.442	0.152	0.100	0.200	0.122	0.268	0.095	0.315	0.127	0.023	0.018
Model 4	0.391	0.461	0.151	0.116	0.209	0.098	0.214	0.091	0.352	0.119	0.027	0.022

Monthly

Instruments: $z_t = (1, \pi_{t-1}, \pi_{t-2}, x_{t-1}, \Delta_3 x_{t-1}, \Delta_3 y_{t-1})$

	Canada			
	π_{t+6}	π_{t+12}	$\tilde{x}_{t+6}$	$\tilde{x}_{t+12}$
Model 1	0.264	0.091		
Model 2	0.080	0.091	0.129	0.143
Model 3	0.039	0.016	0.021	0.006
Model 4	0.005	0.005	0.003	0.001

Notes: Numbers reported are Shea's (1997) partial R^2 measures for instrument quality.

Model 1: $E_t(\pi_{t+h} - \pi_h^*)$; Quarterly: $h = 2, 4$; Monthly: $h = 6, 12$.

Model 2: $E_t(\pi_{t+h} + \phi_h x_{t+h} - \pi_h^*)$, where $\tilde{x}_{t+h} = x_{t+h}$. For quarterly, $h = 2, 4$. For monthly, $h = 6, 12$.

Model 3: $E_t(\pi_{t+h} + \phi_h \Delta x_{t+h} - \pi_h^*)$. For quarterly, $\tilde{x}_{t+h} = \Delta x_{t+h}$ and $h = 2, 4$. For monthly $\tilde{x}_{t+h} = \Delta_3 x_{t+h}$ and $h = 6, 12$.

Model 4: $E_t(\pi_{t+h} + \phi_h \Delta y_{t+h} - \pi_h^*)$ For quarterly, $\tilde{x}_{t+h} = \Delta y_{t+h}$ and $h = 2, 4$. For monthly $\tilde{x}_{t+h} = \Delta_3 y_{t+h}$ and $h = 6, 12$.

Table A3: Data and Sources

Variable	Description	Source
Australia		
Y	GDP SA at annual rates: chained 2005-06 dollars	Tab. G10, ABS 5206, RBA Bulletin
P	CPI All Groups	Tab. G02, ABS 6401, RBA Bulletin
i	Money Market Rate	19360B..ZF..., IFS Series
s	AUD/USD	RBA Bulletin
Canada		
Y	Qrt: GDP SA at annual rates: chained 2000 dollars	Tab. 3800002, V1992067, CANSIM
	Mth: GDP, SA at annual rates: 2002 constant dollars	Tab. 3790027 , V41881478, CANSIM
P	CPI All, 2005 Basket, Qrt = ave. of monthly nos.	Tab. 3260020, V42690973, CANSIM
i	Bank rate	Tab. 1760043, v122530, CANSIM
s	Canada; United States Dollar, noon spot rate, avg.	Tab. 1760064 , v37426 , CANSIM
United States		
Y	Qrt: GDP SA at annual rates: chained 2000 dollars	BEA GDPC96
P	CPI All Urban, All Items, Qrt=ave. of monthly nos.	BLS CPIAUCSL
i	Effective Federal Funds Rate, Qrt = ave. of monthly nos.	Board of Governors, H.15
Commodity Prices		
P^{cx}	Non-Fuel Index, Qrt=ave. of monthly nos.	00176NFDZF..., IFS Series

Table A4: Variable Definitions and Construction

Variable	Construction	Description/Details
Quarterly Series		
π_t	$100 \cdot (P_t - P_{t-4})/P_{t-4}$	Year-on-year qrt. inflation, %
π_t^{cx}	$100 \cdot (P_t^{cx} - P_{t-4}^{cx})/P_{t-4}^{cx}$	Year-on-year qrt. commodity price inflation, %
$\overline{y}_t^Q$	$HP(\ln Y_t, 1600)$	H-P filter, $\lambda = 1600$
x_t	$100 \cdot (\ln Y_t - \overline{y}_t^Q)$	Output gap, %
Δx_t	$x_t - x_{t-1}$	Quarterly first-difference
Δy_t	$100 \cdot (\ln Y_t - \ln Y_{t-1})$	Quarterly growth rate, %
Monthly Series		
π_t	$100 \cdot (P_t - P_{t-12})/P_{t-12}$	Year-on-year monthly inflation, %
π_t^{cx}	$100 \cdot (P_t^{cx} - P_{t-12}^{cx})/P_{t-12}^{cx}$	Year-on-year monthly commodity price inflation, %
$\overline{y}_t^M$	$HP(\ln Y_t, 14400)$	H-P filter, $\lambda = 14400$
x_t	$100 \cdot (\ln Y_t^M - \overline{y}_t^M)$	Output gap %
$\Delta_3 x_t$	$x_t - x_{t-3}$	Monthly third-difference
$\Delta_3 y_t$	$100 \cdot (\ln Y_t - \ln Y_{t-3})$	Monthly third-difference, %