Testing Optimal Monetary Policy in the New Keynesian Model

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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 optimality conditions or Euler equations and test whether they hold at different horizons, i.e. with respect to different information sets. In this paper we examine whether the predictions of the standard New Keynesian model of optimal monetary policy are satisfied for Australia, Canada and the US. Our results suggest that central banks in all three countries are flexible inflation targeters and that their behavior is more consistent with optimal policy under commitment rather than with discretionary optimization.

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1 Introduction

Inflation targeting was initially developed by central banks as a credible and transparent means of implementing monetary policy. It can be described by three principles: (1) a numerical target for inflation; (2) forward-looking policy decisions; and (3) transparency and accountability for policy decisions. Subsequent theoretical research has recast inflation targeting as an optimal monetary policy rule; that is, as the outcome of a central bank setting monetary policy to maximize social welfare. Woodford (2003) provides a detailed treatment of the issues and models.

Optimal monetary policy can be analysed in terms of instrument rules and targeting rules. An instrument rule is a function linking controllable policy instruments (such as the Federal Funds rate) to current economic conditions. The Taylor rule is a well-known example of an instrument rule, although it is not necessarily an optimal policy rule (Taylor, 1993). In general instrument rules can be atheoretical statistical-based models (Clarida,Gali′and Gertler, 1998) or they can be an optimal interest rate rule that is implied by solving an optimization problem for the central bank (Dennis, 2006).

Svensson (2003) is a strong advocate of the use of optimal targeting rules. A specific targeting rule is an optimality condition for a central bank implied by a specific objective function and a model of the economy. It essence it is an Euler equation for the central bank. Svensson (2005) draws an analogy with the Euler equation for optimal consumption. Svensson (2003, 2005) and McCallum and Nelson (2005) discuss the relative merits of each approach for the implementing monetary policy.

While there is a large literature on estimating and evaluating interest rate rules, relatively little empirical research has directly focused on estimating and testing optimal targeting rules. Favero and Rovelli (2003) is the only paper we are aware of that employs an Euler equation approach. In this paper we examine whether the optimal targeting rules implied by the basic forward-looking New Keynesian model are satisfied in the data. In order to keep the Euler equations tractable we initially assume that only inflation-target deviations and output gap deviations enter into central bank's loss functions. The validity of this assumption can be tested in a straightforward manner. The model is tested using data for Australia, Canada and the United States (US). The first two of these countries have officially adopted policies of inflation targeting. In contrast the US does not officially pursue inflation targeting. Our primary objective is to see whether the theories of optimal monetary policy describe actual policy behavior. Were this to be true, then these models are arguably useful tools for analysis. A further objective is to explore how policy behavior departs from predicted optimal behavior, which may provide information as to how monetary policy might be improved, or as to how models of monetary policy might be improved.

A particular focus of our analysis concerns the horizon over which central banks choose to target inflation. Central banks often couch inflation targets in terms of the medium term, say 1-2 years. Implicit in this type of target is an acceptance that the target may not be met in the near-run. Theory, however, suggests that optimal policy should be as focused on the nearer term. This is made most explicit in the discussion in Woodford (2004). Finally we also examine the issue of whether central banks appear to engage in discretionary optimization or commitment.

2 Theory

Models of optimal monetary policy in New Keynesian environments typically provide conditions restricting the conditionally expected path of variables targeted by the central bank. As a very simple example, consider a central bank that uses a policy instrument to target only inflation — a pure inflation target. Given an understanding of the underlying economy, the central bank will adjust its policy instrument to ensure that inflation will not deviate from target. Since in most instances, the central bank does not have immediate control of inflation, it will in fact operate to ensure that expected inflation — at an horizon for which it can control inflation — will not differ from target. If we suppose for the moment that relative to time t, the horizon under its control is $t+j,\ j \geq k$ for some k, then optimal policy should ensure;

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

where π_{t+j} is inflation at time $t+j$. A condition like (1) arises in a standard New Keynesian model of optimal monetary policy for a central bank that is concerned only about inflation, Gali′ (2008).

In most presentations of conditions such as (1), the focus is on the single horizon that is under the control of the central bank. For example, if we suppose that the structure of the economy is such that $k = 2$, the focus would be;

$$E_t(\pi_{t+2} - \pi^*) = 0 \tag{2}$$

However Woodford (2004) notes that optimal monetary policy also constrains all future conditional expectations of the target variable after the date $t+k$. This provides additional restrictions on the behavior of the policy target variables that can be tested.

Condition (1) is highly restrictive. Most central banks do not claim to be pure inflation targeters. However analogous conditions arise in models where central bank's loss function depends upon other target variables, such as some measure of output deviations. As we move to more general models of central bank behavior, the optimality conditions will also depend upon the underlying structure of the economy. In this paper our starting point is a central bank whose loss function only depends upon deviations of inflation from its target level and deviations of output from some efficient level, subject to a New Keynesian Phillips curve.

If a central bank takes a purely discretionary approach to policy then its optimality condition (or Euler equation) is given by,

$$E_t(\pi_{t+j} + \phi x_{t+j} - \pi^*) = 0 \tag{3}$$

whereas if it is able to achieve a commitment solution in the sense of Woodford's "timeless perspective" its Euler equation is given by;

$$E_t(\pi_{t+j} + \phi \Delta x_{t+j} - \pi^*) = 0 \tag{4}$$

for some $j \geq k$. The value of k depends upon the exact structure of the economy, in particular the number of periods it takes for central bank's policy instrument to affect its policy targets. The parameter $\phi = \frac{\lambda}{\gamma}$ in the above conditions is the ratio of the weight the central bank places on output gap variations (λ) to the slope of the Phillips curve (γ). If $\lambda = 0$ these flexible inflation targeting conditions reduce to pure inflation targeting.

Conditions (3) and (4) provide simple and intuitive descriptions of policy outcomes. A central bank that is concerned about inflation and the output gap will balance-off deviations in these variables based upon the respective weighting in the loss functions. This involves adjusting the policy instrument(s) in such a way that if inflation is expected to be above target, this will be balanced against a negative expected output gap and vice versa. One attractive feature these conditions is that they do not directly depend on the means by which the central bank implements policy.

The conditions (3) and (4) 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 $j \geq k$. Thus we can consider a system of Euler equations such as,

$$
\begin{gathered}
E_t(\pi_{t+k} + \phi x_{t+k} - \pi^*) = 0 \\
E_t(\pi_{t+k+1} + \phi x_{t+k+1} - \pi^*) = 0 \\
\dots\dots\dots\dots\dots\dots\dots\dots \\
E_t(\pi_{t+k+m} + \phi x_{t+k+m} - \pi^*) = 0
\end{gathered}
$$

where m is some upper bound on the conditions we wish to consider. As a practical matter we can think of m as being roughly the equivalent of two years, since this is the longest horizon about which central banks are generally concerned. In theory the ϕ and π^* parameters should be constant across the moment conditions. This is a testable restriction. Another testable restriction implied by theory is that $\phi \geq 0$. If $\phi = 0$ then we could reasonably conclude that the central bank is a strict inflation targeter. A positive value for ϕ indicates the central bank is a flexible inflation targeter. While the two parameters in ϕ are not separately identified, given an independent estimate of γ we can recover an estimate of the central bank's preference parameter λ.

An implication of the above Euler equations is that 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 $(\pi_{t+k} + \phi x_{t+k} - \pi^*)$ should be uncorrelated with *any* variable known to the central bank at time (t). Thus in the following regression

$$
(\pi_{t+k} + \phi x_{t+k} - \pi^*) = \alpha + \delta Z_t + v_{t+k} \tag{5}
$$

we expect to find $\alpha = \delta = 0$. To implement this test can we use a subset of Z_t, call it z_t, as instruments to estimate the model and then use $(\pi_{t+k} + \widehat{\phi} x_{t+k} - \widehat{\pi}^*)$ and other components of Z_t to run the above regression.

The choice of instruments used to estimate the Euler equations is an important one. The precise form of the Euler equations (3) and (4) is dependent upon what variables are assumed to enter a central bank's objective function and on the structure of the economy. For example the central bank may care about variables other than inflation and the output gap. A standard generalization would be to assume the central bank cares about nominal interest rate volatility. In this case neither (3) or (4) would be the valid Euler equations. However equation (5) suggests a simple specification test for any set of Euler equations. Use as instruments in estimating (3) and (4), variables that are unlikely to directly enter a central bank's loss function. Then conditional on these estimates use (5) as a means of checking if interesting variables have been omitted from the central bank's Euler equation.

3 Empirical Results

We consider three countries: Canada, Australia, and the United States. 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 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.[1] Australia adopted an inflation target of 2-3 percent in 1993, so the Australian sample is 1993-2007.[2] 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). [3] 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. A potential proxy for GDP is available monthly, the industrial production index. For Australia, both GDP and the CPI are only available on a quarterly basis. For purposes of comparison, we estimate quarterly models for all three countries. We also estimate monthly models for Canada and the United States.

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. As a check on these results we also use the growth rate of real output Δy_t as a proxy for the change in the output gap.

The moment conditions stipulate that inflation forecasts or indices of inflation and output are

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

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

[3] Each of these central banks has the ability to change policy between meetings if required.

orthogonal to any information at time t. To estimate these conditions, we need to choose a set of instruments z_t. One concern that guides our choice of instruments is that our Euler conditions may be mis-specified. In particular, if the central bank is concerned about variables other than inflation and the output gap, then these should form part of the index. From this perspective, possibly omitted variables are changes in interest rates (due to interest smoothing), the exchange rate, and other relevant measures of inflation (for example, Giannoni and Woodford (2003) include wage inflation). Because of this, we do not view these as suitable instruments. Instead, we focus on a relatively small set of instruments that is common across all three countries — commodity price inflation constructed using the IMF's non-fuel commodity price index. 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.

For the models using quarterly data, the instrument set is $z_t = \{\pi_t^{cx}, \pi_{t-1}^{cx}, \pi_{t-2}^{cx}\}$ and for the monthly models, $z_t = \{\pi_t^{cx}, \pi_{t-3}^{cx}, \pi_{t-6}^{cx}\}$. In either case, inflation is defined as year-on-year percentage changes in commodity prices. (See Table 8 for precise details.)

The empirical results are presented in Tables 1 to 5. Tables 1 to 3 report estimates based on quarterly data for Australia, Canada and the US, while Tables 4 to 5 report estimates using monthly data for Canada and the US. In estimating the Euler equations we consider (four) forecast horizons equivalent to six months, one year, eighteen months and two years.

We initially estimate a version of the strict inflation targeting condition (see Model 1 in the Tables). In no case can we reject the existence of constant value for the inflation target π^*across all forecast horizons. The estimates of $\pi^*$from the quarterly data are 2.87 for Australia, 1.83 for Canada and 2.68 for the US.

Turing to the more general models we consider estimates of the Euler equation implied by discretionary optimization (Model 2 in the Tables). For Canada the estimates of ϕ are negative and hence at odds with the theory. In fact the evidence against discretion is particularly strong for Canada. For both quarterly and monthly data and at all forecast horizons the estimates of ϕ negative and statistically significant. Rather than setting policy to *lean against the wind* the estimates suggest that the Bank of Canada *leans with the wind*. For the US the point estimates of ϕ vary with the forecast horizon; they are negative at horizons of 6 to 12 months and positive at horizons of 18 to 24 months. However the point estimates are generally not statistically significant. On the basis of the quarterly data one might conclude that the US is a strict inflation targeter, since we cannot reject $\phi_2 = ... = \phi_8 = \phi = 0$. The results for Australia actually provide some support for the Euler equation under discretion. While point estimates of ϕ tend to vary with the forecast horizon, the restriction of equal parameters is not rejected by the data, and we obtain a common $\widehat{\phi} = 0.42$. This figure suggests that if the RBA forecasts inflation to be one percent above target in six months time, they would they seek to adjust current policy settings so as to also have a negative output gap of 2.5 percent six months hence.

Woodford (2003) makes the case that central banks can 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 is not possible if central banks engage in purely discretionary optimization. Thus Model 3 represents the Euler equation that is implied if a central bank follows a commitment solution. Interestingly the data for all three countries provide some support for the Euler equation under commitment. Estimates of ϕ_2 (a six month horizon) from the quarterly data are positive and statistically significant. Although estimates for ϕ at longer horizons tend to decline in magnitude and are generally not statistically significant. If we impose a common value for ϕ across all forecast horizons then we obtain sensible results for all three countries. The respective estimates of ϕ are 0.53 for Australia, 0.85 for Canada, and 1.27 for the US. The significantly higher estimated value of ϕ for the US is potentially interesting. While it may reflect a steeper US Phillips curve (i.e. a low value of γ), it may also reflect a relatively greater concern by the US Fed to output variability, compared to the Bank of Canada and the RBA. While both of the latter central banks have formal inflation targets, the Fed does not. Model 4 uses the growth rate of real output as a proxy for the change in the output gap. The results are broadly similar to those obtained from using HP filtered data.

Results for Canada and the US based on monthly data are reported in Tables 4 and 5. For Canada the estimates from the monthly data are essentially consistent with the quarterly estimates. This is not the case for the US where the monthly estimates are frequently not statistically significant. This may well reflect the fact that we have had to use industrial production rather than GDP to measure real output.

Table 6 reports the results of some preliminary specification tests on the models. We focus on Models 3 and 4 and estimate a version of (5) using the first-difference of a country's respective policy rate as the explanatory variable. Conditional on our parameter estimates we are asking if the current change in the policy rate can predict the residuals from (4) at various horizons. There is some evidence that this is the case and this might indicate the omission of an interest rate term form the central bank's Euler equation. To some degree their is stronger evidence against the restricted version of the model than the unrestricted version.

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 find that some support in the data for Australia, Canada and the US for the Euler equation implied by optimal policy under commitment.

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Table 1: Quarterly Results for Australia

Sample: 1993:Q1-2007:Q4

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

Model 1: $E_t(\pi_{t+j} - \pi_j^*) = 0, \quad j = 2, 4, 6, 8$

π_2^*	π_4^*	π_6^*	π_8^*	J^{UR}		π^*	J^R	$J^R - J^{UR}$
2.7533	2.9606	3.1214	2.9487	8.9170		2.8728	10.1102	1.1932
(0.1201)	(0.1600)	(0.1388)	(0.1311)	(0.7100)		(0.0648)	(0.8128)	(0.7546)

Model 2: $E_t(\pi_{t+j} + \phi_j x_{t+j} - \pi_j^*) = 0, \quad j = 2, 4, 6, 8$

ϕ_2	ϕ_4	ϕ_6	ϕ_8	π_2^*	π_4^*	π_6^*	π_8^*	J^{UR}
0.4667	−0.2266	0.3332	3.3858	2.7749	2.7611	2.7604	2.4663	8.1728
(0.4073)	(0.3555)	(0.6015)	(0.1693)	(0.2135)	(0.2279)	(0.2097)	(0.3079)	(0.4168)

ϕ	π^*	J^R		$J^R - J^{UR}$
0.4244	2.6124	10.3686		2.1958
(0.2073)	(0.0951)	(0.7348)		(0.9008)

Model 3: $E_t(\pi_{t+j} + \phi_j \Delta x_{t+j} - \pi_j^*) = 0, \quad j = 2, 4, 6, 8$

ϕ_2	ϕ_4	ϕ_6	ϕ_8	π_2^*	π_4^*	π_6^*	π_8^*	J^{UR}
0.8044	−1.0735	-0.6775	-0.0893	2.5222	2.4033	2.6524	2.6830	9.3139
(0.4409)	(1.7527)	(0.9702)	(1.3790)	(0.1535)	(0.2391)	(0.2315)	(0.1797)	(0.3165)

ϕ	π^*	J^R		$J^R - J^{UR}$
0.5284	2.7039	8.6889		0.6250
(0.2164)	(0.0661)	(0.8504)		(0.9960)

Model 4: $E_t(\pi_{t+j} + \phi_j \Delta y_{t+j} - \pi_j^*) = 0, \quad j = 2, 3, 4, 8$

ϕ_2	ϕ_4	ϕ_6	ϕ_8	π_2^*	π_4^*	π_6^*	π_8^*	J^{UR}
0.9742	−1.7706	-0.3960	0.1119	3.1359	1.0885	2.3542	2.8015	8.6954
(0.4411)	(3.5042)	(0.9607)	(1.0054)	(0.4277)	(3.0191)	(0.8957)	(0.8373)	(0.3686)

ϕ	π^*	J^R		$J^R - J^{UR}$
0.6604	3.2223	8.7742		0.0788
(0.2202)	(0.1860)	(0.8542)		(0.9999)

Notes: The second set of estimates for each model restrict the parameters to be constant across moments. J^{UR} and $J^R$are Hansen's J-statistic for the unrestricted and restricted models. These are distributed $\chi^2(r-k)$, where r is the total number of moment conditions and $k = k^{UR}$ or k^R is the number of estimated parameters. The difference if distributed as $k^{UR} - k^R$. Numbers in parentheses are standard errors except for the reported statistics, which are marginal significance levels. The covariance matrix is estimated following Newey and West (1987) using a truncation parameter of 2.

Table 2: Quarterly Results for Canada

Sample: 1994:Q1-2007:Q4

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

Model 1: $E_t(\pi_{t+j} - \pi_j^*) = 0, \quad j = 2, 4, 6, 8$

π_2^*	π_4^*	π_6^*	π_8^*	J^{UR}		π^*	J^R	$J^R - J^{UR}$
2.1662	1.9642	1.7512	1.9557	8.4446		1.8315	10.0431	1.5985
(0.0945)	(0.1151)	(0.0894)	(0.0893)	(0.7495)		(0.0706)	(0.8170)	(0.6597)

Model 2: $E_t(\pi_{t+j} + \phi_j x_{t+j} - \pi_j^*) = 0, \quad j = 2, 4, 6, 8$

ϕ_2	ϕ_4	ϕ_6	ϕ_8	π_2^*	π_4^*	π_6^*	π_8^*	J^{UR}
-0.5400	−0.6378	−0.6684	−0.4734	2.1162	2.1610	2.1072	2.0454	4.1977
(0.2720)	(0.2037)	(0.1856)	(0.1979)	(0.1134)	(0.0884)	(0.0989)	(0.0997)	(0.8389)

ϕ	π^*	J^R		$J^R - J^{UR}$
-0.6475	2.1316	4.6557		0.4580
(0.1063)	(0.0607)	(0.9901)		(0.9983)

Model 3: $E_t(\pi_{t+j} + \phi_j \Delta x_{t+j} - \pi_j^*) = 0, \quad j = 2, 4, 6, 8$

ϕ_2	ϕ_4	ϕ_6	ϕ_8	π_2^*	π_4^*	π_6^*	π_8^*	J^{UR}
0.8339	0.2291	-0.4169	-0.3260	1.9318	1.9070	1.8478	1.9111	7.3968
(0.3040)	(0.3542)	(0.9055)	(1.9598)	(0.1456)	(0.1279)	(0.1042)	(0.1139)	(0.4945)

ϕ	π^*	J^R		$J^R - J^{UR}$
0.8501	1.7655	10.2251		2.8283
(0.2332)	(0.0670)	(0.7455)		(0.8300)

Model 4: $E_t(\pi_{t+j} + \phi_j \Delta y_{t+j} - \pi_j^*) = 0, \quad j = 2, 4, 6, 8$

ϕ_2	ϕ_4	ϕ_6	ϕ_8	π_2^*	π_4^*	π_6^*	π_8^*	J^{UR}
0.2382	0.0947	-0.0743	-0.2857	2.6282	2.1647	1.6156	1.0362	6.7227
(0.0541)	(0.1025)	(0.1851)	(0.3930)	(0.1204)	(0.2741)	(0.5315)	(1.2371)	(0.5668)

ϕ	π^*	J^R		$J^R - J^{UR}$
0.6329	2.3073	9.8559		3.1332
(0.1933)	(0.1435)	(0.7726)		(0.7920)

Notes: The second set of estimates for each model restrict the parameters to be constant across moments. J^{UR} and $J^R$are Hansen's J-statistic for the unrestricted and restricted models. These are distributed $\chi^2(r-k)$, where r is the total number of moment conditions and $k = k^{UR}$ or k^R is the number of estimated parameters. The difference if distributed as $k^{UR} - k^R$. Numbers in parentheses are standard errors except for the reported statistics, which are marginal significance levels. The covariance matrix is estimated following Newey and West (1987) using a truncation parameter of 2.

Table 3: Quarterly Results for the United States

Sample: 1990:Q1-2007:Q4

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

Model 1: $E_t(\pi_{t+j} - \pi_j^*) = 0, \quad j = 2, 4, 6, 8$

π_2^*	π_4^*	π_6^*	π_8^*	J^{UR}		π^*	J^R	$J^R - J^{UR}$
2.8943 (0.1104)	2.7253 (0.1139)	2.6169 (0.1113)	2.5563 (0.1020)	8.4243 (0.7512)		2.6817 (0.0788)	10.8262 (0.7648)	2.4019 (0.4932)

Model 2: $E_t(\pi_{t+j} + \phi_j x_{t+j} - \pi_j^*) = 0, \quad j = 2, 4, 6, 8$

ϕ_2	ϕ_4	ϕ_6	ϕ_8	π_2^*	π_4^*	π_6^*	π_8^*	J^{UR}
-0.2377 (0.3290)	−0.0982 (0.2834)	0.3216 (0.4409)	2.0211 (1.5867)	2.9183 (0.1154)	2.7833 (0.1115)	2.6071 (0.1455)	2.2097 (0.2832)	6.8520 (0.5527)

ϕ	π^*	J^R		$J^R - J^{UR}$
-0.0576 (0.2292)	2.6874 (0.0834)	10.6427 (0.7138)		3.7907 (0.7050)

Model 3: $E_t(\pi_{t+j} + \phi_j \Delta x_{t+j} - \pi_j^*) = 0, \quad j = 2, 4, 6, 8$

ϕ_2	ϕ_4	ϕ_6	ϕ_8	π_2^*	π_4^*	π_6^*	π_8^*	J^{UR}
2.5563 (1.3815)	0.6533 (0.9573)	-0.2342 (0.4686)	-2.0549 (2.9787)	2.8546 (0.1735)	2.7113 (0.1043)	2.6258 (0.1104)	2.6534 (0.1787)	2.2039 (0.9741)

ϕ	π^*	J^R		$J^R - J^{UR}$
1.22695 (0.4397)	2.5411 (0.0535)	9.1427 (0.8218)		6.9388 (0.3265)

Model 4: $E_t(\pi_{t+j} + \phi_j \Delta y_{t+j} - \pi_j^*) = 0, \quad j = 2, 4, 6, 8$

ϕ_2	ϕ_4	ϕ_6	ϕ_8	π_2^*	π_4^*	π_6^*	π_8^*	J^{UR}
2.3047 (0.9759)	0.5702 (0.6921)	-0.1587 (0.4670)	-1.3492 (2.2056)	4.5299 (0.7001)	3.1372 (0.4832)	2.5166 (0.3481)	1.6557 (1.7066)	2.8339 (0.9443)

ϕ	π^*	J^R		$J^R - J^{UR}$
1.3550 (0.4244)	3.6372 (0.2917)	8.3585 (0.8698)		5.5246 (0.4785)

Notes: The second set of estimates for each model restrict the parameters to be constant across moments. J^{UR} and $J^R$are Hansen's J-statistic for the unrestricted and restricted models. These are distributed $\chi^2(r-k)$, where r is the total number of moment conditions and $k = k^{UR}$ or k^R is the number of estimated parameters. The difference if distributed as $k^{UR} - k^R$. Numbers in parentheses are standard errors except for the reported statistics, which are marginal significance levels. The covariance matrix is estimated following Newey and West (1987) using a truncation parameter of 2.

Table 4 : Monthly Results for Canada

Sample: 1994:M1-2007:M12

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

Model 1: $E_t(\pi_{t+j} - \pi_j^*) = 0, \quad j = 6, 12, 18, 24$

π_6^*	π_{12}^*	π_{18}^*	π_{24}^*	J^{UR}		π^*	J^R	$J^R - J^{UR}$
2.1405	1.9806	1.8677	1.9964	17.9657		1.9752	19.6849	1.7192
(0.0844)	(0.0921)	(0.0879)	(0.0782)	(0.1167)		(0.0473)	(0.1844)	(0.6327)

Model 2: $E_t(\pi_{t+j} + \phi_j x_{t+j} - \pi_j^*) = 0, \quad j = 6, 12, 18, 24$

ϕ_6	ϕ_{12}	ϕ_{18}	ϕ_{24}	π_6^*	π_{12}^*	π_{18}^*	π_{24}^*	J^{UR}
-1.2157	-1.0997	-1.1194	-0.8781	2.0968	2.1767	2.1269	2.1174	2.3077
(0.3675)	(0.3494)	(0.3694)	(0.3967)	(0.1057)	(0.0929)	(0.1148)	(0.0966)	(0.9701)

ϕ	π^*	J^R		$J^R - J^{UR}$
-1.1380	2.1493	3.4726		1.1649
(0.1984)	(0.0468)	(0.9979)		(0.9786)

Model 3: $E_t(\pi_{t+j} + \phi_j \Delta x_{t+j} - \pi_j^*) = 0, \quad j = 6, 12, 18, 24$

ϕ_6	ϕ_{12}	ϕ_{18}	ϕ_{24}	π_6^*	π_{12}^*	π_{18}^*	π_{24}^*	J^{UR}
1.3296	-0.8435	-0.7941	0.2453	1.9408	1.9858	1.8588	1.9609	13.5117
(0.3838)	(0.5996)	(0.9914)	(0.9174)	(0.1119)	(0.1118)	(0.0930)	(0.0862)	(0.0954)

ϕ	π^*	J^R		$J^R - J^{UR}$
0.6365	1.9112	19.5870		6.0753
(0.2678)	(0.0534)	(0.1437)		(0.4148)

Model 4: $E_t(\pi_{t+j} + \phi_j \Delta y_{t+j} - \pi_j^*) = 0, \quad j = 6, 12, 18, 24$

ϕ_6	ϕ_{12}	ϕ_{18}	ϕ_{24}	π_6^*	π_{12}^*	π_{18}^*	π_{24}^*	J^{UR}
1.0618	-0.4575	-0.7777	-0.1904	2.7784	1.6372	1.2959	1.8550	11.6723
(0.2373)	(0.3920)	(0.6773)	(0.6664)	(0.1647)	(0.2800)	(0.5085)	(0.4993)	(0.1664)

ϕ	π^*	J^R		$J^R - J^{UR}$
0.5432	2.3361	20.0113		8.3390
(0.1775)	(0.1277)	(0.1298)		(0.2143)

Notes: The second set of estimates for each model restrict the parameters to be constant across moments. J^{UR} and $J^R$are Hansen's J-statistic for the unrestricted and restricted models. These are distributed $\chi^2(r-k)$, where r is the total number of moment conditions and $k = k^{UR}$ or k^R is the number of estimated parameters. The difference if distributed as $k^{UR} - k^R$. Numbers in parentheses are standard errors except for the reported statistics, which are marginal significance levels. The covariance matrix is estimated following Newey and West (1987) using a truncation parameter of 2.

Table 5 : Monthly Results for United States

Sample: 1990:M1-2007:M12

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

Model 1: $E_t(\pi_{t+j} - \pi_j^*) = 0, \quad j = 6, 12, 18, 24$

π_6^*	π_{12}^*	π_{18}^*	π_{24}^*	J^{UR}		π^*	J^R	$J^R - J^{UR}$
2.8240	2.6988	2.6050	2.5444	16.6486		2.6412	19.3455	2.6969
(0.0849)	(0.0764)	(0.0749)	(0.0754)	(0.1633)		(0.0531)	(0.1985)	(0.4408)

Model 2: $E_t(\pi_{t+j} + \phi_j x_{t+j} - \pi_j^*) = 0, \quad j = 6, 12, 18, 24$

ϕ_6	ϕ_{12}	ϕ_{18}	ϕ_{24}	π_6^*	π_{12}^*	π_{18}^*	π_{24}^*	J^{UR}
-0.4333	−0.0215	0.0522	0.6293	2.9177	2.7113	2.6244	2.5482	9.6680
(0.2277)	(0.1290)	(0.1463)	(0.3829)	(0.0981)	(0.0791)	(0.0803)	(0.1115)	(0.2891)

ϕ	π^*	J^R		$J^R - J^{UR}$
-0.0621	2.6444	18.9749		9.3068
(0.1058)	(0.0517)	(0.1659)		(0.1570)

Model 3: $E_t(\pi_{t+j} + \phi_j \Delta x_{t+j} - \pi_j^*) = 0, \quad j = 6, 12, 18, 24$

ϕ_6	ϕ_{12}	ϕ_{18}	ϕ_{24}	π_6^*	π_{12}^*	π_{18}^*	π_{24}^*	J^{UR}
0.4680	−0.1088	-0.0106	-0.1514	2.7435	2.6515	2.6134	2.5919	15.2180
(0.4256)	(0.2534)	(0.2176)	(0.3554)	(0.0948)	(0.0830)	(0.0814)	(0.0844)	(0.0550)

ϕ	π^*	J^R		$J^R - J^{UR}$
0.0545	2.6322	19.3246		4.1066
(0.1728)	(0.0537)	(0.1529)		(0.6623)

Model 4: $E_t(\pi_{t+j} + \phi_j \Delta y_{t+j} - \pi_j^*) = 0, \quad j = 6, 12, 18, 24$

ϕ_6	ϕ_{12}	ϕ_{18}	ϕ_{24}	π_6^*	π_{12}^*	π_{18}^*	π_{24}^*	J^{UR}
1.5412	0.2312	0.0093	0.0209	3.9830	2.8772	2.6524	2.6496	5.4583
(0.9523)	(0.2489)	(0.1578)	(0.1826)	(0.7680)	(0.2071)	(0.1317)	(0.1550)	(0.7077)

ϕ	π^*	J^R		$J^R - J^{UR}$
0.0901	2.7013	19.2015		13.7432
(0.1328)	(0.1098)	(0.1574)		(0.0326)

Notes: The second set of estimates for each model restrict the parameters to be constant across moments. J^{UR} and $J^R$are Hansen's J-statistic for the unrestricted and restricted models. These are distributed $\chi^2(r-k)$, where r is the total number of moment conditions and $k = k^{UR}$ or k^R is the number of estimated parameters. The difference if distributed as $k^{UR}-k^R$. Numbers in parentheses are standard errors except for the reported statistics, which are marginal significance levels. The covariance matrix is estimated following Newey and West (1987) using a truncation parameter of 2.

Table 6: Specification Tests											
Australia				**Canada**				**United States**			
j=**2**	j=**4**	j=**6**	j=**8**	j=**2**	j=**4**	j=**6**	j=**8**	j=**2**	j=**4**	j=**6**	j=**8**
Model 3: $(\pi_{t+j} + \widehat{\phi}_j \Delta x_{t+j} - \widehat{\pi}_j^*) = \alpha + \delta \Delta i_t + \upsilon_{t+j} \quad j = 2, 4, 6, 8$											
Unrestricted Model											
0.32	0.27	0.00	0.00	0.39	0.35	0.09	0.35	0.57	0.18	0.83	0.87
Restricted Model											
0.00	0.00	0.12	0.17	0.04	0.04	0.07	0.01	0.02	0.15	0.37	0.37
Model 4: $(\pi_{t+j} + \widehat{\phi}_j \Delta y_{t+j} - \widehat{\pi}_j^*) = \alpha + \delta \Delta i_t + \upsilon_{t+j} \quad j = 2, 4, 6, 8$											
Unrestricted Model											
0.00	0.00	0.19	0.16	0.16	0.17	0.12	0.75	0.18	0.07	0.89	0.98
Restricted Model											
0.00	0.00	0.19	0.32	0.03	0.06	0.08	0.02	0.03	0.23	0.88	0.86

Notes: Figures are p-values for test of joint significance of constant and slope coefficients.

Table 7: Data and Sources

Variable	Description	Source
Australia		
Y	GDP SA at annual rates: chained 2005-06 dollars	RBA Bulletin Tab. G10, ABS 5206
P	CPI All Groups	RBA Bulletin Tab. G02, ABS 6401
Canada		
Y	Qrt: GDP SA at annual rates: chained 2000 dollars	CANSIM Tab. 3800002, V1992067
	Monthly:	
P	CPI All, 2005 Basket, Qrt = ave. of monthly nos.	CANSIM Tab. 3260020, V42690973
United States		
Y	Qrt: GDP SA at annual rates: chained 2000 dollars	BEA GDPC96
	Monthly: Industrial Production Index, SA	BGFRS INDPRO
P	CPI All Urban, All Items, Qrt=ave. of monthly nos.	BLS CPIAUCSL
Commodity Prices		
P^{cx}	Non-Fuel Index, Qrt=ave. of monthly nos.	IFS Series 00176NFDZF...

Table 8: 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, $\lambda = 1600$,Sample 1981:Q1-2007:Q4
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, $\lambda = 14400$,Sample 1981:M1-2007:M12
x_t	$100 \cdot (\ln Y_t - \overline{y}_t^M)$	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, %