Asymmetric monetary policy rules for open economies: Evidence from four countries

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Abstract

This study presents an analytical framework to examine the policy reaction function of a central bank in an open economy context while allowing for asymmetric preferences. The paper then empirically examines the policy rule obtained from this framework using quarterly data for the US, Canada, Japan, and the UK. The results, based on GMM approach, provide evidence that domestic policy is affected by changes in the foreign interest rate and exchange rate. We also provide evidence of the presence of asymmetries in response to the inflation rate and output gap for all the sample countries.

Keywords: Monetary policy rule; asymmetric preferences; open economy.

JEL: E52; E58; F41.

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1 Introduction

It is well accepted that monetary policy plays an essential role in providing a stable macroeconomic background which facilitates the efficient allocation of resources. To demonstrate that such an economic environment can be achieved by adopting an optimal monetary policy framework, researchers have proposed several alternative models leading to the development of a vast literature. For instance, a large number of studies advocate the adoption of inflation targeting and its implementation through variants of Taylor rule.[1] Yet many (recent) studies including McCallum and Nelson (2000), Clarida et al. (2001), Taylor (2001), Clarida et al. (2002), Batini et al. (2003), Dennis (2003), Leitemo and Söderström (2005), and D'Adamo (2011) argue that the impact of foreign factors on the domestic policy is small, and therefore their effects can be excluded.[2]

However, in an open economy context, it is somewhat surprising to discount the role of exchange rate movements on the monetary transmission mechanism: exchange rates which respond to foreign disturbances do affect domestic prices. To that end, Ball (1999b) shows that although Taylor rules are optimal in a closed economy context these policies perform poorly in an open economy framework unless they are modified to account for the movements in the exchange rates. Svensson (2000) argues that the optimal reaction function in an open economy accounts for more information in comparison to a closed economy Taylor rule. He discusses the presence of various direct and indirect channels through which the exchange rate can affect monetary policy and shows that CPI-inflation responds to foreign variables including foreign inflation, foreign interest rate, exchange rate and shocks from the rest of the world. More recently Gali and Monacelli (2005), Lubik and Schorfheide (2007), and Adolfson et al. (2008) implement open economy DSGE models to investigate whether central banks respond to exchange rate movements. In this framework, Chen and MacDonald (2012) move a step further by incorporating parameter instability into a small scale open economy DSGE model.

It is also important to note that the recent literature in monetary economics has challenged

[1] Researchers have examined different variants of the Taylor rule by introducing backward or forward looking components while allowing the policy makers to have linear or nonlinear objective functions. Among others see for instance Taylor (1993), Svensson (1997), Ball (1999a), Rudebusch and Svensson (1999), Ireland (1999), Clarida et al. (2000), Ruge-Murcia (2003b), Dolado et al. (2004), and Surico (2007).

[2] For instance Taylor (2001) argue that the exchange rate changes are implicitly incorporated through prices therefore the closed economy models are well representative of an open economy scenario. Similarly, Clarida et al. (2001) document that the open economy models are isomorphic to the closed economy models.

the assumption that policy makers minimize a quadratic loss function subject to a linear IS equation and a Philips curve —the assumption that the vast majority of research on optimal policy rules has used. Cukierman and Gerlach (2003) suggest that a central bank responds strongly to inflation when the economy is in expansion and to output gap when the economy is in contraction. Dolado et al. (2005) relax the assumption of a linear Phillips curve while allowing both inflation and the loss function to be convex functions of the output gap. In particular, Nobay and Peel (1998), Ruge-Murcia (2000), Ruge-Murcia (2003a), Dolado et al. (2004), Surico (2007) and Surico (2003) assume that central banks have a linear exponential (i.e. linex) loss function. The use of this function allows the monetary policy authorities to have an asymmetric response towards inflation and/or output gap as actual inflation or output level exceeds or falls short of the target. In this approach since the quadratic loss function corresponds to a special case where the asymmetry parameter of the linex loss function is equal to zero, one can test the null hypothesis of quadratic preferences against the alternative of asymmetric preferences.

In this paper, different from the existing literature, we model the optimal monetary policy rule of a central bank in an open economy framework while we allow for asymmetric preferences such that the policy makers can weigh positive and negative deviations of inflation and output gap from their corresponding targets differently. To achieve our purpose, we use an open economy New-Keynesian model where aggregate demand and supply depend on the real exchange rate while we assume that policy makers have a linex loss function. The latter assumption implies that the certainty equivalence does not hold and uncertainty will induce a prudent behavior on the part of the central bank. Thus, in this set up, minimization of the loss function subject to the IS equation and the Philips curve lead to an optimal reaction function which respond not only to the deviation of inflation and output gap from their respective targets but also to changes in the exchange rate and to the volatility of inflation and output gap. Therefore, within this framework while we discuss the effect of changes in exchange rate and foreign monetary policy on the domestic interest rate, we can also examine whether policy makers have asymmetric response towards inflation and/or output gap across different phases of the business cycles.

We estimate the resulting optimal policy rule from our model using quarterly data for four major industrialized countries including Canada, Japan, the United Kingdom (UK) and the

United States (US). Our dataset spans the period over 1979q1-2010q1, while for each country the starting point of the empirical analysis depends on the specific factors that affected the behavior of each central bank to implement independent monetary policy. Our empirical findings, based on the generalized method of moments approach, provide evidence that central banks follow an active monetary policy and control for the impact of real exchange rate on output and inflation. We show that policy makers in all four countries have asymmetric preferences with respect to both inflation and output gap such that they weigh positive and negative deviations of inflation and output gap differently. We also find that the domestic interest rate reacts positively with respect to changes in foreign interest rate.

The rest of the paper is organized as follows: Section 2 presents the model. Section 3 discusses the empirical issues and the data. Section 4 lays out the empirical results while Section 5 concludes.

2 The Model

In this section we present a New-Keynesian model for an open economy whose variants are implemented in, among others, Ball (1999b), Svensson (2000), Clarida et al. (2001) and Leitemo et al. (2002). The economic structure we present below differs from that of Ball (1999b) as our model contains forward looking elements. The structure we present here is also different from that of Leitemo et al. (2002) as the forward looking element in their model is embedded only in the behavior of the exchange rate which is determined by the uncovered interest parity (UIP) condition. Furthermore, different from both studies we allow the policy makers to have asymmetric response towards inflation and output gap as their actual levels exceeds or falls short of the corresponding targets. We obtain the policy rule for our proposed framework by solving an intertemporal optimization problem.

2.1 Economic Structure

The dynamics of the open economy are given by the following three equations which describe the behavior of the output gap, inflation and the exchange rate, respectively.

$$
\begin{aligned}
y_t &= \alpha_1 E_t y_{t+1} - \alpha_2(i_t - E_t\pi_{t+1}) + \alpha_3 q_t + \varepsilon^y_{t+1} && (1)\\
\pi_t &= \beta_1 E_t\pi_{t+1} + \beta_2 y_t + \beta_3(E_t q_{t+1} - q_t) + \varepsilon^\pi_{t+1} && (2)\\
q_t &= E_t q_{t+1} - (i_t - E\pi_{t+1}) + (i^f_t - E\pi^f_{t+1}) && (3)
\end{aligned}
$$

Equation (1) is an open economy forward looking aggregate demand curve (IS-curve). At any point in time t, the output gap is denoted by y_t, the domestic nominal interest rate is i_t and inflation is π_t. Expected value of variable x_{t+1} given the information set at time t is denoted by $E_t x_{t+1}$. This equation implies that the expected course of real interest rate has a negative impact on the output gap. Equation (1) also assumes that the real exchange rate, q_t, which is defined as the domestic currency price of foreign currency, has a positive effect on the output gap. ϵ^y_t depicts demand shocks.

Equation (2) describes an open-economy Phillips curve. This equation allows the price setters to adjust the current prices accounting for future marginal costs. In that sense this equation captures the Calvo-type world in which the price adjustment takes place with a constant probability by each firm in a given period of time. Here, inflation is a positive function of the output gap. We also assume that the real exchange rate affects inflation positively as suggested by Svensson (2000) who argues that the current exchange rate has a direct impact on the CPI inflation rate.[3,4] In this equation ϵ^π_t captures cost disturbances.

Equation (3) suggests that the real exchange rate is determined according to the UIP conditions. The foreign interest rate and the foreign expected inflation rate are denoted by i^f_t and π^f_{t+1}, respectively. Hence, the first and the second parenthesized terms capture the domestic and the foreign real interest rates at time t. Equation (3) shows that an increase in the domestic real interest rate leads to an appreciation of the exchange rate as the domestic assets become more attractive. This equation also shows that an increase in the foreign real interest rate will result in depreciation of the exchange rate (due to capital flight from the home country).

[3]Several other researchers, including Ball (1999b) and Leitemo et al. (2002), relate inflation to changes in real exchange rate. Ball (1999b) argues that changes in the real exchange rate affects the inflation rate by the import price pass through mechanism which constitute an indirect impact of exchange rate on domestic inflation.

[4]Introducing difference of the expected exchange rates in Equation (2) rather than the level of exchange rate does not change our results.

2.2 Objective Function

Following the earlier research, we assume that the policy makers choose interest rate at the beginning of time t based upon the information available at the end of the previous period before the economic shocks are realized. The policy authorities therefore minimize the following intertemporal loss function:

$$\text{Min } E_{t-1} \sum_{\tau=0}^{\infty} \delta^{\tau} L_{t+\tau} \tag{4}$$

subject to the dynamics described in Equations (1-3). In Equation (4), δ is the discount factor and L_t stands for the period t loss function of the central bank. The objective of the central bank is to choose a path for its instrument, the short term interest rate, to minimize the expected loss.

Here, we use a linear exponential (linex) loss function that allows policy makers to weigh positive and negative deviation of output gap and inflation from their respective targets differently. The linex loss function was proposed by Varian (1974). Subsequently, Zellner (1986), Granger et al. (1996) and Christoffersen and Diebold (1998) used this function in the context of optimal forecasting. Nobay and Peel (2003) use the linex loss function to study optimal policy reaction function under both discretion and commitment.[5] The loss function that we implement for our purposes takes the following form:

$$L(\pi_t, y_t) = \frac{e^{\mu(\pi_t - \pi^*)} - \mu(\pi_t - \pi^*) - 1}{\mu^2} + \lambda \frac{e^{\gamma y_t} - \gamma y_t - 1}{\gamma^2}$$

where the parameters μ and γ capture any asymmetry in the objective function with respect to inflation and output gap respectively. The policy preference towards inflation stabilization is normalized to one and λ represents the relative aversion of the policy maker towards output fluctuations around its long run level. The inflation target set by the central banker is denoted by π^*. The output gap target is set to zero.

The significance of μ and γ identifies whether the policy makers have asymmetric response towards inflation and output gap, respectively, in different economic situations. For instance, a positive value for μ implies that the central bank is more worried about inflation exceeding the set target level π^* because the cost of high inflation exceeds that of low inflation. This is

[5] Following Nobay and Peel (2003) several researchers used linex form including Ruge-Murcia (2000), Ruge-Murcia (2003a) and Surico (2003) among others.

so because if $\mu > 0$ then the exponential term ($e^{\mu(\pi_t - \pi^*)}$) will rule over the linear component. Thus, positive deviations from the inflation target will have dominant effects on policy makers' loss function than negative deviations. The reverse is true if $\mu < 0$. In a similar vein, we can argue that should the central bank place more weight to output contractions ($y < 0$), then γ must take a negative value such that the exponential in the second term ($e^{\gamma y_t}$) plays the dominant role. However if the policy maker is more worried that the economy overshooting its long run growth ($y > 0$), then we should observe a positive value for γ. Hence, this framework can provide us information whether the business cycle fluctuations have welfare effects beyond the first order or not.

Besides the idea that the policymakers can have asymmetric weights depending on the stance of inflation and output gap with respect to their targets, the linex function also allows discretion on the part of the central bank so that higher moments of inflation and output gap might play an important role in designing optimal policy rules (see Kim et al. (2005)). Furthermore, the evidence of asymmetry implies that certainty equivalence does not hold. Thus, uncertainty about inflation and output gap will induce a prudent behavior on the part of the central bank. This is so because uncertainty raises the expected marginal cost of inflation and output gap from their respective targets. Finally, the model nests the quadratic preferences as a special case. The loss function reduces to symmetric parametrization when both μ and γ are equal to zero, which can be empirically tested.

2.2.1 Solution of the model

To solve the model, we first substitute Equation (3) into (1) and (2). After rearranging the terms, we obtain:

$$y_t = \alpha_1 E_t y_{t+1} - (\alpha_2 + \alpha_3)(i_t - E_t \pi_{t+1}) + \alpha_3 E_t q_{t+1} + \alpha_3 (i_t^f - E_t \pi_{t+1}^f) + \varepsilon_{t+1}^y \tag{5}$$

$$\begin{aligned}\pi_t = {} & \beta_1 E_t \pi_{t+1} + \alpha_1 \beta_2 y_{t+1} - [\beta_2(\alpha_2 + \alpha_3) - \beta_3](i_t - E_t \pi_{t+1}) + \\ & + (\beta_2 \alpha_3 - \beta_3)(i_t^f - E_t \pi_{t+1}^f) + \beta_2 \alpha_3 E_t q_{t+1} + \beta_2 \varepsilon_t^y + \varepsilon_t^\pi\end{aligned} \tag{6}$$

Next, we minimize Equation (4) subject to (5) and (6) with respect to the current interest rate i_t and obtain the following first order condition:

$$\begin{aligned} E_{t-1}\frac{\partial L(\pi_t, y_t)}{\partial i_t} &= \frac{-(\beta_2\alpha_2 + \beta_2\alpha_3 - \beta_3)}{\mu}E_{t-1}[e^{\mu(\pi_t-\pi^*)} - 1] - \\ & \frac{\lambda(\alpha_2 + \alpha_3)}{\gamma}E_{t-1}[e^{\gamma y_t} - 1] = 0 \end{aligned} \tag{7}$$

We assume that the demand and supply shocks (ε_t^y and ε_t^π) are normally distributed. Hence, the exponential terms in Equation (7) are log normally distributed with conditional means $e^{[\mu(\pi_{t|t-1}-\pi^*+\frac{\mu}{2}\sigma^2_{\pi,t})]}$ and $e^{(\frac{\gamma^2}{2}\sigma^2_{y,t})}$, respectively.[6] Here, $\sigma^2_{\pi,t}$ and $\sigma^2_{y,t}$ denotes the conditional variance of inflation and output gap, respectively. Thus, we can rewrite Equation (7) in the following form:

$$\begin{aligned} E_{t-1}\frac{\partial L(\pi_t, y_t)}{\partial i_t} &= \frac{-(\beta_2\alpha_2 + \beta_2\alpha_3 - \beta_3)}{\mu}[e^{(\mu(\pi_{t|t-1}-\pi^*)+(\frac{\mu^2}{2})\sigma^2_{\pi,t})} - 1] - \\ & \frac{\lambda}{\gamma}(\alpha_2 + \alpha_3)[e^{(\frac{\gamma^2}{2}\sigma^2_{y,t})} - 1] = 0 \end{aligned} \tag{8}$$

Linearizing the expression in Equation (8) by taking a first-order Taylor approximation and solving for expected inflation we arrive at:

$$E_{t-1}\pi_t = \pi^* - \frac{\mu}{2}\sigma^2_{\pi,t} - \frac{\lambda(\alpha_2 + \alpha_3)}{(\beta_2\alpha_2 + \beta_2\alpha_3 - \beta_3)}[(\frac{\gamma}{2})\sigma^2_{y,t}] \tag{9}$$

Taking the conditional expectation of Equation (6) with respect to information set available at time $t-1$ and substituting $E_{t-1}\pi_t$ into (9), we can show that the policy variable takes the following form:

$$\begin{aligned} i_t = \varphi_0 + \varphi_1 E_{t-1}y_{t+1} + \varphi_2 E_{t-1}\pi_{t+1} + \varphi_3 E_{t-1}q_{t+1} \\ + \varphi_4 E_{t-1}(i_t^f - \pi_{t+1}^f) + \varphi_5\sigma^2_{\pi,t} - \varphi_6\sigma^2_{y,t} + (error) \end{aligned} \tag{10}$$

Equation (10) depicts the forward looking policy rule of the central bank with asymmetric preferences in an open economy framework. The associated coefficients of the equation are the reduced form parameters (φ_i) which measure the response of monetary policy with respect to

[6] Recall that output gap is a zero mean normally distributed variable so that we have $E_{t-1}\exp(\gamma y_t)$ is equal to $e^{\frac{\gamma^2}{2}\sigma^2_{y,t}}$.

those variables in the policy rule. In particular, given the parameters in Equations (1-4), each coefficient (φ_i) in Equation (10), can be written as follows:

$$
\begin{aligned}
\varphi_0 &= \frac{-\pi^*}{(\alpha_2\beta_2+\alpha_3\beta_2-\beta_3)},\ \varphi_1 = \frac{\alpha_1\beta_2}{(\alpha_2\beta_2+\alpha_3\beta_2-\beta_3)},\ \varphi_2 = \frac{\beta_1+\alpha_2\beta_2+\alpha_3\beta_2+\beta_3}{(\alpha_2\beta_2+\alpha_3\beta_2-\beta_3)} \\
\varphi_3 &= \frac{\alpha_3\beta_2}{(\alpha_2\beta_2+\alpha_3\beta_2-\beta_3)},\ \varphi_4 = \frac{\alpha_3\beta_2+\beta_3}{\alpha_2\beta_2+\alpha_3\beta_2-\beta_3},\ \varphi_5 = \frac{-\mu/2}{\alpha_2\beta_2+\alpha_3\beta_2-\beta_3} \\
\varphi_6 &= \frac{\lambda(\alpha_2+\alpha_3)(\gamma/2)}{(\alpha_2\beta_2+\alpha_3\beta_2-\beta_3)^2}.
\end{aligned}
$$

The policy rule given in Equation (10) by construction differs from the standard Taylor rule on three facets. First, it incorporates the forward looking expressions of output gap and inflation rate. Second, it introduces exogenous variables such as the exchange rate and foreign interest rate. Third, it captures asymmetric preferences by accounting for the volatility of output gap and inflation rate.

3 Empirical Issues

The policy rule in Equation (10) contains expected future output gap, inflation, the exchange rate and the foreign real interest rate. We proxy for the expected exchange rate by using twelve-month ahead forward exchange rates. To compute the expected output gap and inflation rate we first construct an autoregressive model based upon the Akaike information criterion (AIC) and Bayesian Information criterion (BIC). The selected model is then used recursively to compute the h-step ahead out-of-sample forecasts for both series.[7] The foreign real interest rate is calculated as the deviation of nominal interest rate from the expected inflation rate of the corresponding country.

We estimate Equation (10) implementing the generalized method of moments (GMM) technique as we replace the unobserved expectations with their forecasts and the volatility terms with proxies derived from GARCH models as described below. In doing so we face two major issues concerning the instruments employed in the GMM estimation. First, the reliability of our econometric methodology depends crucially on the validity of the instruments which we

[7] We compute the h-step ahead forecast for y_t implementing $\widehat{y}_{t+h|t} = \widehat{\phi_0} + \sum_{i=1}^{p} \widehat{\phi_i}\widehat{y}_{t+h-i|t}$ where $\widehat{\phi_i}$ are the estimated coefficients based on in-sample information. Then $\widehat{\phi_i}$ are used to forecast out-of-sample y_{t+h}.

evaluate by computing the the Sargan–Hansen J test of overidentifying restrictions, asymptotically distributed as χ^2 in the number of restrictions. A rejection of the null hypothesis that instruments are orthogonal to errors would indicate that the estimates are not consistent. We also test for the presence of first and second order serial correlation so as to determine the correct lag structure of the instrument set. In each of the models presented below, the Hansen J statistic for overidentifying restrictions and the autocorrelation tests show that our instruments are appropriate and our models do not suffer from serial correlation problem, respectively.

Another important issue in implementing the GMM methodology is the possibility that the instruments could be weak; that the instruments could be weakly correlated with the endogenous variables. Weak instruments will distort the distribution of the estimators and the test statistics will lead to misleading statistical inference.[8] Therefore, for the reliability of the instrumental variable approach, the instruments should be relevant and strongly correlated with the endogenous variables. Indeed, a measure of the strength of the instruments can be determined by the concentration parameter (see Anderson (1977)).[9] We can test for weak instruments either by testing for rank deficiency of the concentration statistic or using the reduced rank regression technique developed by Anderson and Rubin (1950) which is later extended for the presence of autocorrelated errors by Cragg and Donald (1997), Robin and Smith (2000), and Kleibergen and Paap (2006). Here, we follow the latter approach and report the p-values of the reduced rank test suggested in Kleibergen and Paap (2006).

In view of the fact that our model employs expected variables which are generated by the use of autoregressive models, one may be concerned about the use of lags of these series as instruments in estimation. We address these concerns by investigating the forecast performance of the models that we employed. If the models perform well, lags of the series can be used as proper instruments in our investigation. We test for forecast rationality checking whether the forecast minimize the loss function of the decision maker. It should be noted that forecast rationality must be evaluated in consideration of the decision maker's loss function. If a forecaster has a quadratic loss function (QLF) then forecast rationality requires forecast to be unbiased implying that the forecast errors are not on average significantly different from zero. We test

[8]For a review of weak instruments see Stock et al. (2002). For the impact of weak instruments on statistical inference see Mavroeidis (2004) and Hansen et al. (1996).

[9]Intuitively, it is possible to interpret the concentration statistic as a portmanteau F-test on the significance of instruments which are regressed on an endogenous variable.

for forecast being unbiased by regressing the forecast error on a constant.[10]

To further investigate forecast rationality, we next relax the assumption that the forecasters have a QLF and employ another forecast evaluation test which is optimal for any loss function. We do so by using the density forecast criterion introduced by Diebold et al. (1998). The density forecast criterion allows us to test whether the forecasting model used by the researcher is not significantly different from the model that generated the actual data. If this is the case then obviously the forecasting model will be optimal for any loss function. Diebold et al. (1998) show that if a sequence of density forecasts are correctly conditionally calibrated then the sequence of the probability integral transform of standardized forecast errors are iid and U(0,1). Berkowitz (2001) suggests an alternative goodness-of-fit test where under the null, the sequence of standardized forecast errors is iid $N(0,1)$.[11] However, he also argues that to test for normality more powerful tools can be employed than testing uniformity.[12] Under the null the likelihood ratio test suggested in Berkowitz (2001) follows a χ^2_3. We use both tests but for the sake of brevity we present results only from the Berkowitz's test.

Figure 1 here

Figure 2 here

Figure 1 presents visual evidence that in all cases forecasts are unbiased. Thus, the naive autoregressive models that we use for the out-of-sample forecasting exercise do not systematically under-predict or over-predict the target variables. In Figure 2, we present recursive estimates of density forecasts which implement the naive autoregressive model for all the countries. However, Figure 2 shows that the naive autoregressive models does not represent the true data generating process (DGP) for the UK and Japan as the density forecast criterion fails either the distributional or independence assumption. Although such evidence may raise doubts

[10] An h-step ahead forecast is autocorrelated of order h-1. We account for autocorrelation by using the heteroscedasticity and autocorrelation consistent variance covariance matrix suggested by Newey and West (1987). In our investigation, we adopt uniform weights.

[11] The density forecast is constructed as follows. We assume that disturbances are i.i.d. Gaussian and compute the stantardized forecast errors as $\{z^*_{t+1}\} = \{(\frac{y_{t+1}-\widehat{y}_{t+1}}{\widehat{\sigma}_{t+1}})\}$ where $\widehat{y}_{t+1}$ is the one-step-ahead forecast of y_{t+1} made at time t and $\widehat{\sigma}_{t+1}$ is the standard deviation of $\widehat{y}_{t+1}$. Then the probability integral transform values are given by $\{z_{t+1}\} = \{\Phi(z^*_{t+1})\}$ where Φ is the Normal CDF. Here, instead of testing for uniformity and independence of $\{z_{t+1}\}$ we follow Clements and Smith (2000) and test for normality and independence of $\{z^*_{t+1}\}$.We do so by employing the Doornik and Hansen (1994) normality test and the Ljung-Box for autocorrelation test.

[12] The Berkowitz test is computed as $z^*_t = c + \rho z^*_{t-1} + \varepsilon_t$, $LR_B = -2[L(0,1,0) - L(\widehat{c}, \widehat{\sigma}^2, \widehat{\rho})]$ where $L(\widehat{c}, \widehat{\sigma}^2, \widehat{\rho})$ is the value of the exact maximum likelihood function of an AR(1) model.

concerning the use of lags of inflation as an instrument, Kleibergen and Paap (2006) show that lags of these variables are not subject to the problem of weak identification.

The last issue that needs to be addressed is the volatility terms that appear in Equation (10). To generate these two series (inflation volatility and output gap volatility), we implement a GARCH(1,1) model. As Pagan (1984) and Pagan and Ullah (1988) point out, the use of generated regressors may lead to some problems in estimation and statistical inference. According to Pagan (1984) although one may overcome these problems by using instrumental variables approach, the use of lagged series as instruments may not be possible when the variable under consideration is a function of the entire history of the available data. In such cases, Pagan and Ullah (1988) suggest testing the validity of the underlying assumptions of the model that generates the proxy. For instance, Ruge-Murcia (2003) follows these suggestions and uses lagged conditional volatility of unemployment obtained from a GARCH(1,1) model as an own instrument after checking for any remaining heteroscedasticity in the standardized squared residual. Here, we, too, follow a similar route. We generate output gap and inflation volatility measures implementing GARCH(p,q) and ARCH(p) models after we carefully check whether these models are well specified and whether there is any neglected heteroscedasticity. We then use the lags of these proxies as instruments to estimate our model.

3.1 Data Sources and Definition of Variables

In our empirical investigation we use quarterly data which cover the period between 1979q1-2010q1. We estimate the policy rule given in Equation (10) for Canada, Japan, the UK and the US where the starting point of the empirical analysis slightly differs for each country depending on the specific factors that have affected the behavior of each central bank. To that end we start the analysis for the UK on 1979q1 as the bank of England increased its emphasis on controlling inflation. In the case of Japan we begin the analysis as of 1979q1, too, as she went through a period of financial market deregulation in 1979 where all capital controls were removed and the Bank of Japan began to use the interbank lending rate to conduct monetary policy.[13] In the case of Canada our starting date is 1980q1 as the bank of Canada began to float the bank rate. Last, for the US, our investigation begins as of 1983q4. In fact a large body of literature is devoted to empirically evaluating the monetary policy of the FED by classifying FED's policy preferences

[13]See Batten (1990).

for pre and post 1979 to capture the role of Volcker period. However, Surico (2007) and Ilbas (2008) argue that the period between 1979–1983 is a period of frequent shifts in the monetary policy and high uncertainty, and suggest to use the post 1983 period for analysis. Bernanke and Mihov (1998) also document that during the period 1979q4 -1982q3 the operating procedure of Fed switched from federal funds rate to non-borrowed reserves targeting. Similarly, Dolado et al. (2004) conclude that post-1983 period portrays the US policy preferences well. Therefore, we use the data between 1983q4 and 2010q1 to examine the behavior of the FED's monetary policy.

The end date of our empirical analysis of each country is twelve months prior to the latest available data due to the fact that our investigation uses four quarter ahead out of sample forecast of inflation rate and output gap. In our empirical modeling we use the CPI inflation rate to estimate optimal policy rules as suggested in Svensson (2000).[14] Leitemo and Söderström (2005) also argue that imported inflation is considered as one of the components of inflation while setting the target for inflation. To generate the output gap from the log of GDP for all the countries, we implement the HP (Hodrick and Prescott (1997)) filter.[15]

We use the respective short term interest rate of the each country such as the overnight interbank rate for the UK and the overnight money market rate for Canada, the call-money rate for Japan as the policy variable.[16] For the US, we use the Federal-Funds rate as the appropriate policy instruments as argued by researchers including Bernanke and Mihov (1998) and Clarida et al. (1998). Since our model embodies the foreign monetary policy instrument, the US is taken as the foreign country when we estimate the policy rule for the UK, Canada and Japan. The UK, on the other hand, is considered as the foreign country when we evaluate the policy rule for the US. The exchange rate appears in our model within a forward looking framework as suggested in Svensson (2000).

The data are collected from the international financial statistics (IFS) database published by the International Monetary Fund(IMF). The 12-month forward exchange rate for the UK is

[14]The domestic inflation is more relevant when estimating the policy rule for closed economy.

[15]Alternatively, it is possible to generate a proxy for output gap by linear de-trending approach. For instance, while Taylor (1993) uses linear de-trending to compute the output gap series, Taylor (1999) employs HP filter for computation of output gap series.

[16]Among others Miyao (2002), Miyao (2000), Kasa and Popper (1997), Morgan (1993) use call money rate as an instrument of monetary policy for the bank of Japan. Miyao (2002) prefers call money rate over monetary aggregates as an appropriate measure of monetary policy because interest rate is predetermined for monetary aggregates. De Andrade and Divino (2005) also argue in favor of call rate as a policy instrument.

accessed from the bank of England data sources whereas for the US, Canada and Japan data are obtained form the datastream database.

4 Discussion of Results

In what follows, we present for each country several different variants of Equation (10) in Tables 1-4 where we use four quarter ahead forecast horizon to proxy the forward looking variables. We must note that while our main results are based on four quarter ahead forecast horizon, for robustness check, we also estimate all models using one quarter ahead forecast horizon as a proxy for the forward looking variables. Results from this set, which are available from the authors upon request, provide similar observations.

Table 1 presents results for Canada, Table 2 for Japan, Table 3 for the UK and Table 4 for the US. Each table provides estimates for six different models. The first column depicts results for the full open economy model (Equation (10)) which assumes that the policy makers use an asymmetric loss function with respect to both inflation and output gap. In columns 2, 3 and 4, we still allow for the open economy framework, while the model in column 2 relaxes the assumption of asymmetry for inflation only, that in column 3 relaxes the assumption of asymmetry only for output gap and that in column 4 relaxes the assumption of asymmetry for both inflation and output gap. In column 5, we maintain the assumption of asymmetry but we assume closed economy. Finally, the last column presents results for a simple forward looking Taylor rule by relaxing both asymmetry and open economy assumptions where policy makers are assumed to have quadratic loss function.

4.1 General Observations

We have three sets of key results. First, we observe that the monetary policy aims to stabilize the economic environment by reacting to inflationary pressures driven by both domestic and foreign factors. That is the central bank not only reacts to movements in expected inflation but also to movements in real exchange rate and foreign interest rate. Second, we provide empirical evidence that central banks have asymmetric preferences concerning the positive or negative deviation of inflation and output gap, respectively. We show that the central bank reacts more strongly to positive deviations of inflation from its target level than to negative deviations from the target. Furthermore, although our findings generally confirm that that the policy makers dislike negative output gap, there are some instances that the policy makers respond to positive output gap. We interpreted this observation as that the central bank is mainly concerned about inflation and considers a positive output gap as an indicator of future inflation. Third, our findings provide evidence towards the importance of the use of an open economy framework in discussing monetary policy rules. Our claim is not only due to the significance of foreign policy variables in Equation (10) but it is also because of sign changes on the asymmetry parameters beyond our expectations as the open economy assumption is relaxed.

4.2 Bank of Canada

Table 1 provides our results for Canada. In all columns of this table, as expected, we observe that the impact of expected output gap and expected inflation (captured by φ_1 and φ_2) on the monetary policy rule is positive and significant. In fact, the impact of expected inflation is greater than unity indicating that an increase in expected inflation leads to a more than one-for-one increase in the nominal interest rate. This finding implies that the model is stable and has a unique equilibrium.

We next focus on the impact of the real exchange rate and that of the real foreign interest rate on the domestic monetary policy. The table shows that the coefficient associated with the real exchange rate is negative ($\varphi_3 < 0$) and that with the real foreign interest rate is positive ($\varphi_4 > 0$). These two coefficients play a key role in identifying the type of policy rule pursued by the central bank (i.e. active or passive). To have the above sign structure, inspecting the components of φ_3 and φ_4, we should have $(\alpha_2\beta_2+\alpha_3\beta_2-\beta_3) > 0$, $(\alpha_3\beta_2) < 0$ and $(\alpha_3\beta_2+\beta_3) > 0$. These requirements suggest that the central bank follows an active monetary policy where the nominal interest rate must increase more in proportion to the expected inflation which changes as a consequence of movements in the foreign policy variables. In particular, note that the first term of $(\alpha_2\beta_2 + \alpha_3\beta_2 - \beta_3)$ captures the reaction of domestic interest rate to expected inflation and to output changes. The remaining two terms reflect the impact of real exchange rate changes on output gap and inflation. The positive sign associated with the third component above ($(\alpha_3\beta_2 + \beta_3) > 0$), which appears as the numerator of (φ_4), implies that the total impact (current and expected) of real exchange rate on inflation is positive. However, to obtain $(\alpha_2\beta_2+\alpha_3\beta_2-\beta_3) > 0$ we must have $(\alpha_2\beta_2) > (\alpha_3\beta_2-\beta_3)$. Thus, an expected depreciation will increase current and expected inflation but it will also increase nominal interest rate above expected inflation. This is consistent with the coefficient of expected inflation being above one in all columns ($\varphi_2 > 1$).

When we turn to inspect the coefficients that capture the presence of asymmetric preferences of the policy makers regarding inflation and output gap, we arrive at the following observations. The first column of Table 1 shows that the coefficient of inflation volatility (φ_5) is positive and significant. This observation provides further support to the view that the bank of Canada (BOC) is inflation averse. This is so because the significance of inflation volatility implies that the marginal cost of inflation will increase as inflation deviates from its target level. Thus, inflation uncertainty will induce a prudent behavior on the part of BOC which sets the interest rate accounting both for the expected inflation and its uncertainty. In doing so BOC increases nominal interest rate more than is required by the expected inflation. In column 2, this parameter is still significant and positive when we relax the assumption of asymmetry with respect to the output gap. However, in column 5, the same coefficient becomes negative and significant when we assume a closed economy framework. The change in sign may be due to the exclusion of the open economy elements from the subsequent models, suggesting that the closed economy framework is not desirable.

As we explore the output gap asymmetry coefficient (φ_6), we see from column 1 that the coefficient of output gap volatility is negative but insignificant. However, when we turn to column 3, which relaxes the assumption of inflation asymmetry, the coefficient of output gap volatility becomes positive and significant at the 10% level. Although positive output gap asymmetry is not consistent with our expectations and the significance level is rather weak, this observation provides support for the view that the main focus of BOC is to keep inflation below target. In this context, one can argue that BOC considers output gap as a predictor of inflation. Nevertheless, results for the closed economy model presented in column 5, show that the same coefficient, takes a negative and significant sign at the 1% level. Although this is consistent with the view that central banks under-predict growth to reduce inflationary pressure, evidence of negative φ_5 points to the direction of mispecification error driven by the strong assumption of Canada being a close economy.

In column 6, we provide results for the closed economy framework where the model lacks the asymmetry effects as well as the open economy elements. In that sense this column presents the standard model where policy makers use quadratic loss function. Here, although the coefficient estimates appear to be reasonable, compared to the model depicted in column 1, this model is misspecified in the light of the Wald tests which verifies joint significance of inflation and output gap volatilities.

4.3 Bank of Japan (BOJ)

We, next, focus on the estimates for the bank of Japan which are presented in Table 2. In line with those findings reported in the literature, the coefficients of both expected inflation and expected output gap are positive and significant.[17] Similar to BOC, the monetary policy adopted by BOJ satisfy the Taylor principle as the estimated coefficient of expected inflation is greater than 1 ($\varphi_2 > 1$). This finding implies that the model is stable and has a unique equilibrium.

Moving on to explore the impact of the real exchange rate and the real foreign interest rate on domestic monetary policy, we see that the coefficients associated with these two variables (φ_3 and φ_4, respectively) take the expected signs as they are both positive and significant at the 1% level in all models. This finding suggests that currency depreciation will lead the central bank to increase the interest rate as a loss in the value of the currency induces inflationary pressures on the economy. Likewise, the domestic interest rate follows the movement in the foreign interest rate.

When we turn to the influence of output gap volatility and inflation volatility on the policy measure, we find that both measures exert a significant impact. Different from the case of Canada, we observe that inflation volatility exerts a negative and significant effect on the policy rule while output volatility has a significant and positive effect. These findings suggest that an increase in inflation volatility leads to a reduction whereas an increase in output volatility causes an increase in the interest rate. However, it should be noted that the total impact of inflation and output gap uncertainty on nominal interest rate is positive ($\varphi_5 + \varphi_6 > 0$). Considering the implication of the estimates on the parameters of the model given in Equations (1-4), we argue that policy makers at BOJ are more concerned about inflation undershooting

[17] See for instance Miyao (2000); Miyao (2002) and Clarida et al. (2000).

its target than overshooting it. In column 2 once we exclude the impact of output gap volatility the asymmetry parameter of inflation turns positive ($\varphi_5 > 0$). In column 3, we see that the asymmetry parameter of output gap is still positive. These findings can be explained taking into account the long deflationary period that Japan went through in the 90s which still affects her economy.[18] In particular, Miyao (2000) argue that the Japanese economy experienced a stagnation after the bubble economy burst.[19] This led to a substantial decline in the short term interest rates such as the discount rate and call money rate to push the economy back to its long run track.

Interestingly, we should note that BOJ reacts more when output overshoots its long run target than when it falls short of it, as captured by the positive sign of the output gap volatility coefficient. Hence, the interest rate is tightened more in periods of expansion as compared to easing of the interest rate when output contracts by the same magnitude. We argue that this observation is an outcome of the fact that Japan experienced a stagnant economy in most of the period under investigation. Results in column 5 for the closed economy case show that BOJ under-predict both expected inflation and output growth but at the same time BOJ follows an active monetary policy by fighting rather than accommodating inflation. This is consistent with the inflation averse policy followed by the BOJ prior to the financial crisis in the early 90s and after the long-lasting stagnation following the burst of the real estate bubble.[20]

It is also worth noting that we conduct the Wald test and verify that inflation and output gap volatility coefficients are significantly different from zero. This observation suggests that the Bank of Japan has asymmetric preferences towards movements in inflation and output.

4.4 Bank of England (BOE)

Table 3 presents our results for the UK. In columns 1-6, we see that the impact of expected output gap and expected inflation is positive. In particular, the impact of expected inflation on interest rate is positive ($\varphi_2 > 1$) and stronger than that of the expected output gap suggesting

[18] Bec et al. (2002) found similar results for France where the deflationary pressures were weighted more than the inflationary pressures.

[19] Japan experienced a bubble economy following the strong economic boom in the late 80s as the asset prices increased substantially.

[20] BOJ followed an expansionary monetary policy in the late 80s to mitigate the effects of Yen's appreciation. The expansionary monetary policy accompanied with current account surplus led to excess liquidity in the financial system fueling asset prices. To counteract inflationary pressure the BOJ doubled the bank rate. The increase in the bank rate led to the burst of assets prices and increase the number of loan defaults. The by-product of loan defaults was a long-lasting stagnation.

that the model is stable and has a unique equilibrium.

As we inspect the effects of the exchange rate and the foreign interest rate, we see that the results are similar to that of Japan. The expected real exchange rate has a positive and sizable impact on the UK interest rate ($\varphi_3 > 0$) reflecting the response of monetary policy to changes in real exchange rate. In addition, the real foreign interest rate has a positive ($\varphi_4 > 0$) and significant impact on domestic interest rate.[21] Yet, the size of this coefficient is smaller than that associated with the real exchange rate. In that context, the results presented in column 5 provide further support to the view that the BOE accounts for changes in the monetary policy of the US.

We next observe that the impact of inflation and output gap volatility on domestic interest rate is positive and negative, respectively. Accounting for the effects of uncertainty concerning the state variables, it appears that the BOE tend to adopt a precautionary policy regarding the behavior of inflation as the signs associated with φ_2 and φ_5 are both positive and greater than one. While at the same time BOE, as depicted by the coefficients φ_1 and φ_6 under-predict output gap and respond less than one-for-one to output gap changes. In this context, our findings suggest that the BOE will increase the interest rate above the conditional mean of inflation but the under-prediction of output-growth will lead to low interest rate which is preferred in periods of recession. In doing so, we argue that the BOE aims to strengthen its anti-inflationary credibility. Thus, although the BOE is inflation averse, it responds to real economic activity independently of its concerns about inflation. The Wald test statistics show that inflation and output gap volatility coefficients are significantly different from zero providing further evidence that the Bank of England has asymmetric preferences.

Results in column 2-6 are consistent with those presented in column 1. Exception to this is column 3 where the sign of output gap asymmetry is positive at the 10% significance level. Although this observation might be due to the restrictions imposed on the model, it is possible that the positive sign is reflecting that the BOE use output gap as an indicator to forecast inflation. In column 5, where we entertain a closed economy model with asymmetric loss function, both inflation and output gap volatility attain significant coefficients with correct signs.

[21]Similar findings are documented by Clarida et al. (1998) regarding the effect of German interest rate on the UK monetary policy when Germany was used as the foreign country. Clarida et al. (1998) show that one percent increase of German interest rate induce 60 basis points rise in the British interest rate.

4.5 The Federal Reserve (FED)

Last we focus on results for the US which we report in Table 4. Overall, signs of the associated variables estimated for the US are similar to that of Canada. We find that expected output gap (φ_1) and expected inflation (φ_2) have a positive impact on the domestic interest rate. However, in several models, the coefficient associated with the expected inflation is low, in the vicinity of unity or smaller, except for the last model where we assume closed economy with quadratic loss function. Although the coefficient estimates of the expected inflation that we report in columns 1-6 could raise questions about the stability of the model, arguments carried out in Lubik and Schorfheide (2004) as well as in Bullard and Mitra (2002), and Lubik and Marzo (2007) point out that equilibrium is a system property which depends on the linkages between the parameters of the Taylor rule and of the structural parameters.[22] Thus, a low inflation coefficient should be interpreted with caution and should not be taken as evidence for indeterminacy. More concretely, in column 1 the coefficient of expected inflation is marginally above one but the total response of interest rate to inflationary pressure is well above one ($\varphi_2 + \varphi_5 > 1$); there is no evidence of indeterminacy in the full model. However, in columns 2-4 where we gradually remove the assumption of asymmetry, the coefficient associated with inflation variability is estimated to be insignificant while the coefficient of expected inflation is below one. In this case, one can suggest that there is evidence of indeterminancy which might be an outcome of specification error.

When we inspect the coefficients associated with the exchange rate and the foreign real interest rate (φ_3 and φ_4, respectively), we see that these coefficients follow the pattern that we observed for Canada (column 1).[23] The coefficient associated with the real exchange rate is negative ($\varphi_3 < 0$) and that with the real foreign interest rate is positive ($\varphi_4 > 0$). Similar to the case of Canada, these findings suggest that the FED follows an active monetary policy where the nominal interest rate increases more than in proportion to an increase in the expected inflation which changes as a consequence of movements in the foreign policy variables. Thus, an expected depreciation will increase current and expected inflation but it will also increase

[22] Clarida et al. (2000) show that if the policy rule includes only current level of inflation (i.e. $i_t = \varphi_0 + \varphi_2 E_t \pi_t$) then determinancy requires $\varphi_2 > 1$. Alternatively, Bullard and Mitra (2002) and Lubik and Marzo (2007) show that if the policy rules includes forward looking values of inflation and output gap (i.e. $i_t = \varphi_0 + \varphi_1 E_t y_{t+1} + \varphi_2 E_t \pi_{t+1}$) then determinancy is achieved if $0 \leq \varphi_1 < \frac{1}{\alpha_2}$, and $\max\{1 - \frac{1-\beta}{\beta_2}\varphi_1, 0\} < \varphi_2 < 1 + 2\frac{1+\beta}{\beta_2 \alpha_2} - \frac{1+\beta}{\beta_2}$ holds.

[23] Recall that we take the UK as the foreign country for the case of US.

nominal interest rate above expected inflation.

Next, we inspect the coefficients that capture the presence of asymmetric preferences of the policy makers regarding inflation and output gap. We find that both measures exert a significant impact on the policy rule pursued by the FED. We observe that inflation volatility has a positive impact on the domestic interest rate suggesting that the FED increases the interest rate to achieve a stable economic environment. Moreover, as in the earlier cases, the positive and statistically significant association between the volatility of inflation rate and the domestic interest rate suggests that the response of the FED is asymmetric with respect to changes in the inflation rate. In other words, the FED puts more weight to the upward swings of inflation from the target than the downward swings. This finding is consistent with earlier research such as Dolado et al. (2004) and Bec et al. (2002) among others who provide an evidence in favor of asymmetric preference of central bank with respect to inflation rate for the post 1979 period. These authors argue that a nonlinear policy rule for the post 1983 period reasonably portrays the US policy preferences.[24]

We also find that the volatility of output gap is negative and statistically significant at the 1% level. This indicates that the FED is more responsive to output contractions rather than to expansions similar to the case of UK and Canada. In other words, output contractions induce relatively more loosening of the interest rate than an increase in interest rate induced by output expansions of the same size. This finding is in line with Surico (2007) who argues that an output contraction is more important than an expansion in implementation of asymmetric monetary policy rules for the US.

In column 6, we provide results for the closed economy framework where policy makers use quadratic loss function. The model lacks asymmetry effects as well as the open economy elements. Although the closed economy model results are reasonable in terms of the sign and size of the coefficient estimates (the coefficient of expected inflation is positive and greater than 1), the model is too naive as the Wald tests reject the null that the coefficients of asymmetric preferences and of foreign variables are not significantly different from zero.

[24]However, we must also note that Surico (2007) and Surico (2003) document a statistically insignificant response of federal funds rate towards squared inflation and conclude that the preferences of central bank towards inflation are not asymmetric.

5 Conclusion

In this paper we construct an analytical model to investigate the optimal policy rule of a central bank with an asymmetric loss function subject to an open economy forward looking New Keynesian macroeconomic framework. We then estimate the policy rule that we obtain from the above framework along with a number models which we formulate imposing restrictions on the original model. The empirical investigation is carried out on quarterly data for four industrialized countries—Canada, Japan, the UK and the US. The data cover the period between 1979q1-2010q1.

Our empirical results can be summarized in three main categories. First, we provide evidence that the central banks in our study follow an active monetary policy as they account for the impact of foreign policy variable. More concretely, central banks carefully consider the impact that real exchange rate have on output and inflation while setting the interest rate. Our investigation also provides evidence that central banks increase the nominal interest rate more than one-for-one to a change in expected inflation. Overall, estimated coefficients provide support that the models we estimate are stable except for some cases when we discuss the behavior of the FED where the estimated expected inflation coefficient is less than one. Although this could be a result of the omitted variables in that specific case, some researchers (including Lubik and Schorfheide (2004), Bullard and Mitra (2002) and Lubik and Marzo (2007)) point out that equilibrium is a system property which depends on the interrelations between the parameters of the Taylor rule and those of the structural model.

Second, we find evidence suggesting that all central banks whose policy choices we investigate in this paper have asymmetric preferences for their target variables. In particular, we find that the inflation volatility coefficient is positive suggesting that central banks change the nominal interest rate more when inflation exceeds the target level rather than when it falls below. When we look at the presence of asymmetry associated with the output gap we are confronted with differing reactions. Although we expect to see that a central bank should be more concerned when output gap falls below the target, for some cases we find that the central bank can be more reactionary during periods of positive output gap. We address this observation arguing that the central banks may be inflation averse and may take a positive output gap as an indicator of future inflation. Third, in line with the first finding, foreign variables have a significant impact on domestic monetary policy. This view is based not only on the significant effect of the real exchange rate and foreign real interest rate on domestic monetary policy but also on the closed economy models. We find that once we relax the open economy assumption, the sign of asymmetry parameters change providing evidence of specification error which might be driven by an omitted variable problem.

Overall, the findings we present here help us better understand the behavior of policy makers who have an asymmetric response towards inflation and/or output gap under an open economy framework. Yet, for future research, we believe that it would be fruitful to model and empirically investigate the interest rate smoothing hypothesis by implementing a framework as in this paper. We also think that expanding the set of countries under investigation can broaden our understanding. Finally, in line with the recommendation of Lubik and Schorfheide (2007) one can pursue a multivariate approach by estimating the entire structural model using system GMM. Although, Lubik and Schorfheide (2007) argue that full-information maximum likelihood exploit cross-equation restrictions, Ruge-Murcia (2007) show that limited information procedures are more robust to model mispecification. Ruge-Murcia (2007) show that GMM and simulated method of moment deliver more precise estimates than maximum likelihood. Thus, it would be useful to extend the current study employing system GMM approach to account for the recommendations of both Lubik and Schorfheide (2007) and Ruge-Murcia (2007).

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Figure 1: Testing the Forecast Bias

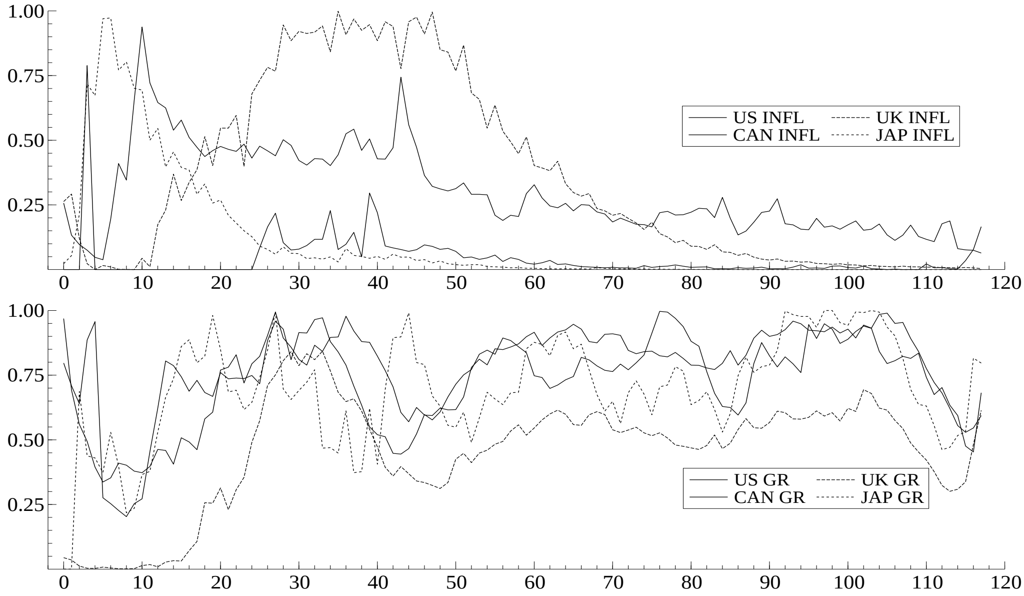

Figure 2: Recursive Forecasts

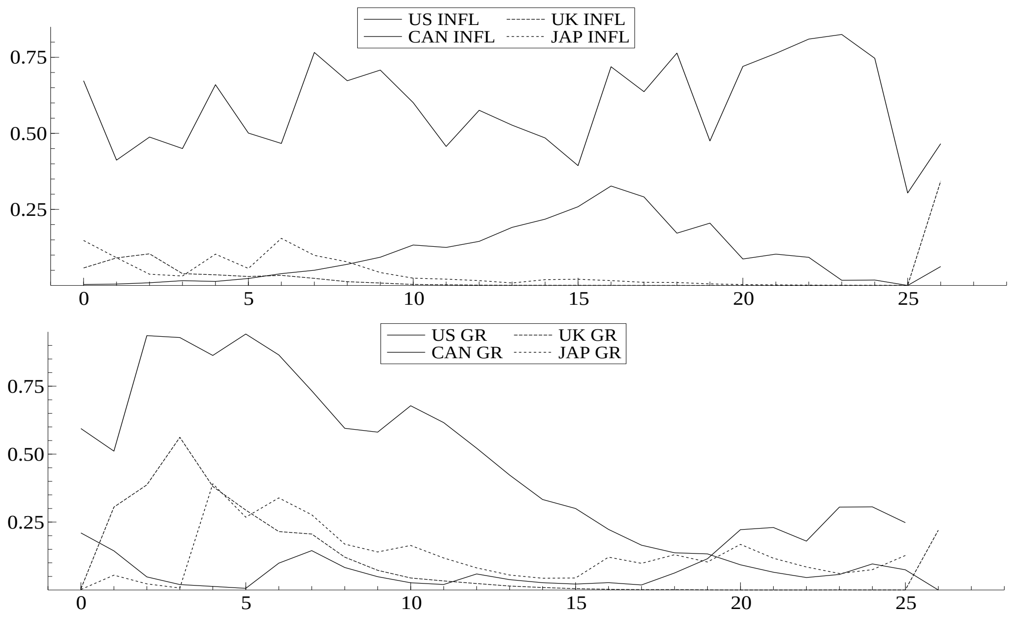

Table 1: **GMM Estimates for Canada**

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Panel A: Estimation Results						
φ_0	6.609***	6.496***	6.758***	6.787***	4.058***	2.177***
	(0.541)	(0.746)	(0.619)	(0.743)	(0.385)	(0.365)
φ_1	0.279***	0.295***	0.291***	0.265***	0.167	0.300**
	(0.057)	(0.071)	(0.064)	(0.069)	(0.117)	(0.152)
φ_2	1.030***	1.244***	1.204***	1.431***	5.220***	5.257***
	(0.179)	(0.229)	(0.207)	(0.228)	(0.268)	(0.322)
φ_3	-3.775***	-3.881***	-3.908***	-3.788***		
	(0.313)	(0.388)	(0.347)	(0.401)		
φ_4	0.529***	0.530***	0.495***	0.477***		
	(0.055)	(0.077)	(0.058)	(0.074)		
φ_5	0.691**	0.904***			-1.921**	
	(0.307)	(0.299)			(0.949)	
φ_6	-0.085		0.290**		-1.995***	
	(0.173)		(0.132)		(0.409)	
Panel B: Diagnostic Tests						
$Observations$	116	117	116	117	122	122
$Under_{ID}test$	63.715	45.713	57.71	40.328	26.247	32.017
$p-value$	0.009	0.000	0.003	0.001	0.035	0.000
$Jstat$	34.027	15.361	27.670	19.362	18.029	6.985
$p-value$	0.696	0.637	0.638	0.250	0.205	0.430
$AR(1)$	0.317	0.318	0.318	0.318	0.317	0.317
$AR(2)$	0.318	0.319	0.318	0.319	0.318	0.318
Panel C: The Wald Test(Joint Significance)						
$H_0 : \varphi_3; \varphi_4 = 0$	931.00***	774.74***	866.06***	791.28***		
$H_0 : \varphi_5; \varphi_6 = 0$	7.56**				44.14***	
$H_0 : \varphi_3; \varphi_4; \varphi_5 = 0$		889.18***				
$H_0 : \varphi_3; \varphi_4; \varphi_6 = 0$			993.41***			
$H_0 : \varphi_3; ...; \varphi_6 = 0$	1131.04***					

Notes: $i_t = \varphi_0 + \varphi_1 E_t y_{t+1} + \varphi_2 E_t \pi_{t+1} + \varphi_3 E_t s_{t+1} + \varphi_4 (i_t^f - E_t \pi_{t+1}^f) + \varphi_5 \sigma^2_{\pi,t}$ - $\varphi_6 \sigma^2_{y,t}$

In Panel A, values in parenthesis are standard errors. ***,**, and * indicate level of significance at 1%, 5%, and 10% level of significance, respectively. Panel C reports the Wald test for testing the joint significance of the underlying coefficients. The time period for estimation is 1980q1-2010q1.

Table 2: **GMM Estimates for Japan**

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Panel A: Estimation Results						
φ_0	-27.506***	-23.107***	-29.890***	-21.23***	0.723	0.981***
	(1.969)	(2.092)	(1.827)	(1.964)	(0.639)	(0.206)
φ_1	0.128*	-0.042	0.160**	-0.077	-0.092	-0.135
	(0.074)	(0.078)	(0.067)	(0.075)	(0.161)	(0.178)
φ_2	1.333***	1.434***	1.013***	1.557***	3.920***	4.159***
	(0.179)	(0.188)	(0.157)	(0.173)	(0.269)	(0.296)
φ_3	5.371***	4.865***	5.876***	4.567***		
	(0.420)	(0.450)	(0.395)	(0.438)		
φ_4	0.192***	0.198***	0.146***	0.173***		
	(0.045)	(0.046)	(0.045)	(0.049)		
φ_5	-1.254**	0.870**			-3.528**	
	(0.507)	(0.377)			(1.618)	
φ_6	3.458***		3.273***		1.871***	
	(0.279)		(0.264)		(0.578)	
Panel B: Diagnostic Tests						
$Observations$	118	117	117	117	121	121
$Under_{ID}test$	67.023	78.476	79.277	76.657	30.120	42.025
$p-value$	0.044	0.046	0.048	0.051	0.036	0.000
$Jstat$	56.716	67.432	70.812	68.170	10.195	10.436
$p-value$	0.182	0.186	0.140	0.150	0.895	0.403
$AR(1)$	0.318	0.318	0.318	0.318	0.339	0.345
$AR(2)$	0.317	0.317	0.317	0.317	0.317	0.317
Panel C: The Wald Test(Joint Significance)						
$H_0 : \varphi_3; \varphi_4 = 0$	761.50***	490.47***	1030.41***	562.54***		
$H_0 : \varphi_5; \varphi_6 = 0$	153.83***				11.32**	
$H_0 : \varphi_3; \varphi_4; \varphi_5 = 0$		703.17***				
$H_0 : \varphi_3; \varphi_4; \varphi_6 = 0$			1140.49***			
$H_0 : \varphi_3, ..., \varphi_6 = 0$	1024.65***					

Notes: $i_t = \varphi_0 + \varphi_1 E_t y_{t+1} + \varphi_2 E_t \pi_{t+1} + \varphi_3 E_t s_{t+1} + \varphi_4 (i_t^f - E_t \pi_{t+1}^f) + \varphi_5 \sigma_{\pi,t}^2$ - $\varphi_6 \sigma_{y,t}^2$

In Panel A, values in parenthesis are standard errors. ***,**, and * indicate level of significance at 1%, 5%, and 10% level of significance, respectively. Panel C reports the Wald test for testing the joint significance of the underlying coefficients.
The time period for estimation is 1979q1-2010q1.

Table 3: **GMM Estimates for UK**

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Panel A: Estimation Results						
φ_0	5.188***	5.501***	4.619***	4.410***	1.332**	1.634
	(0.893)	(0.939)	(0.793)	(0.808)	(0.663)	(1.855)
φ_1	0.794***	0.858***	0.780**	0.591***	0.363	2.403***
	(0.182)	(0.211)	(0.162)	(0.162)	(0.295)	(0.618)
φ_2	1.286***	1.437***	1.664***	1.720***	2.824***	4.493***
	(0.297)	(0.303)	(0.277)	(0.306)	(0.512)	(1.361)
φ_3	6.904***	7.373***	6.169***	5.301***		
	(1.375)	(1.538)	(1.294)	(1.369)		
φ_4	0.522***	0.502***	0.629***	0.640***		
	(0.060)	(0.058)	(0.051)	(0.055)		
φ_5	1.435***	1.020***			4.207***	
	(0.509)	(0.317)			(0.608)	
φ_6	-0.438*		0.349*		-1.616***	
	(0.261)		(0.183)		(0.508)	
Panel B: Diagnostic Tests						
$Observations$	116	119	117	119	117	122
$Under_{ID}test$	54.497	52.527	52.943	53.177	46.749	11.213
$p-value$	0.040	0.012	0.043	0.032	0.000	0.011
$Jstat$	44.093	32.308	45.233	42.263	24.417	3.899
$p-value$	0.197	0.402	0.140	0.186	0.181	0.142
$AR(1)$	0.317	0.318	0.317	0.317	0.318	0.327
$AR(2)$	0.318	0.317	0.318	0.318	0.319	0.325
Panel C: The Wald Test(Joint Significance)						
$H_0 : \varphi_3; \varphi_4 = 0$	155.32***	218.48***	231.99***	210.24***		
$H_0 : \varphi_5; \varphi_6 = 0$	8.66**				48.55***	
$H_0 : \varphi_3; \varphi_4; \varphi_5 = 0$		235.45***				
$H_0 : \varphi_3; \varphi_4; \varphi_6 = 0$			232.47***			
$H_0 : \varphi_3; ...; \varphi_6 = 0$	278.95***					

Notes: $i_t = \varphi_0 + \varphi_1 E_t y_{t+1} + \varphi_2 E_t \pi_{t+1} + \varphi_3 E_t s_{t+1} + \varphi_4 (i_t^f - E_t \pi_{t+1}^f) + \varphi_5 \sigma_{\pi,t}^2 - \varphi_6 \sigma_{y,t}^2$

In Panel A, values in parenthesis are standard errors. ***,**, and * indicate level of significance at 1%, 5%, and 10% level of significance, respectively. Panel C reports the Wald test for testing the joint significance of the underlying coefficients.
The time period for estimation is 979q1-2010q1.

Table 4: **GMM Estimates for US**

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Panel A: Estimation Results						
φ_0	8.468***	5.324***	5.587***	4.111***	1.617**	2.466***
	(0.848)	(0.579)	(0.612)	(0.573)	(0.765)	(0.594)
φ_1	0.842***	1.138***	1.034***	1.205***	1.060***	0.788**
	(0.137)	(0.113)	(0.130)	(0.115)	(0.256)	(0.357)
φ_2	1.024***	0.476*	0.440*	0.498*	1.351***	3.188***
	(0.252)	(0.251)	(0.243)	(0.289)	(0.466)	(0.768)
φ_3	-7.596***	-5.566***	-5.395***	-4.071***		
	(1.067)	(0.997)	(0.915)	(1.010)		
φ_4	0.328***	0.311***	0.344***	0.383***		
	(0.041)	(0.038)	(0.037)	(0.041)		
φ_5	2.524***	-0.217			-3.819***	
	(0.533)	(0.161)			(0.860)	
φ_6	-9.886*		-1.617**		9.176***	
	(1.774)		(0.693)		(2.591)	
Panel B: Diagnostic Tests						
$Observations$	102	104	104	104	106	106
$Under_{ID}test$	53.643	44.853	52.063	39.951	17.394	20.939
$p-value$	0.009	0.004	0.007	0.003	0.002	0.021
$Jstat$	31.930	28.953	34.743	22.387	2.370	11.202
$p-value$	0.420	0.146	0.213	0.215	0.499	0.262
$AR(1)$	0.318	0.317	0.317	0.317	0.317	0.318
$AR(2)$	0.318	0.318	0.318	0.318	0.317	0.317
Panel C: The Wald Test(Joint Significance)						
$H_0 : \varphi_3; \varphi_4 = 0$	189.74***	198.51***	220.59***	184.87***		-
$H_0 : \varphi_5; \varphi_6 = 0$	35.75***				21.34***	-
$H_0 : \varphi_3; \varphi_4; \varphi_5 = 0$		229.95***				-
$H_0 : \varphi_3; \varphi_4; \varphi_6 = 0$			221.91***			-
$H_0 : \varphi_3; ...; \varphi_6 = 0$	228.88***				**	-

Notes: $i_t = \varphi_0 + \varphi_1 E_t y_{t+1} + \varphi_2 E_t \pi_{t+1} + \varphi_3 E_t s_{t+1} + \varphi_4 (i_t^f - E_t \pi_{t+1}^f) + \varphi_5 \sigma^2_{\pi,t}$ - $\varphi_6 \sigma^2_{y,t}$

In Panel A, values in parenthesis are standard errors. ***,**, and * indicate level of significance at 1%, 5%, and 10% level of significance, respectively. Panel C reports the Wald test for testing the joint significance of the underlying coefficients.
The time period for estimation is 1983q4-2010q1