Hybrid Inflation-Price-Level Targeting in an Estimated Small-Open-Economy New-Keynesian Framework*

Mohamed Douch†

Department of Economics

CIRPÉE - UQAM

April, 2006

Preliminary, Comments Welcome

Abstract

In this paper we use a small open economy version of the Calvo sticky price model to investigate hybrid inflation/price-level targeting. We explore the proprieties of this kind of targeting regime within a Bayesian estimated structural general equilibrium model. We consider monetary policy in terms of Taylor interest rate rules and conduct a welfare analysis on various specifications. Our analysis shows that the hybrid targeting performs well and produces quantitatively good results compared to the regimes targeting only price levels or inflation rates. A hybrid regime thus appears to provide a successful way of conducting monetary policy in a small open economy.

Keywords: Small Open Economy, Monetary Policy, Hybrid Targeting, Bayesian Analysis

JEL classification: E31,E52, E58, C32

*I gratefully acknowledge the invaluable support of Steve Ambler and Louis Phaneuf. I would like to thank Alain Guay and the participants at the summer seminar held by the Department of Economics (UQAM).

†Correspondence to: Mohamed Douch. University of Quebec at Montreal (UQAM), Department of Economics, P.O Box 8888, Downtown Station, Montreal, Canada, H3C 4R1, E-mail: Douch.mohamed@uqam.ca, URL: http://www.er.uqam.ca/nobel/k15000

1 Introduction

Inflation targeting has been widely adopted as a framework for monetary policy throughout the last decade. Indeed, several industrialized countries, including Canada, Australia, New Zealand, Sweden and the United Kingdom (UK), have formally or informally adopted inflation targeting (hereafter, IT), and thus far most of them appear to be enjoying a good inflation performance[1], price stability and satisfactory real growth records.

In contrast, "conventional wisdom" has been skeptical of price-level targeting (hereafter, PT). The main argument against PT is that it induces both higher short-run inflation and also output variability than does IT (see Fischer, 1994, Haldane and Salmon, 1995). However, Dittmar et al. (1999) and Svensson (1999) argue that PT has more advantages than IT, since with PT inflation variability becomes lower , assuming that output persistence is at least moderate[2]. The controversy mainly concerns price stability definition and more particularly how price stability can be maintained in practice. For instance, monetary authorities should choose paths for either the price level or for the inflation rate, allowing in this case for a base drift in price level. The first known example of an implicit target for price stability was in terms of price level targeting, as adopted by Sweden in the 1930s (see Berg and Jonung, 1999).

More recently, Nessen (2002), and Nessen and Vestin (2000) suggested that the central bank targets an average inflation over several periods. Batini and Yates (2003), Cecchetti and Kim (2003) and Kobayashi (2004) investigate another novel proposal which is the combination of IT and PT in a mixed regime, called hybrid inflation/price-level targeting (hereafter, HT), showing that inflation volatility under this regime becomes lower when compared to PT and IT regimes.

[1] A survey of literature on economic performance of inflation-targeting countries is presented in Svensson (1995) Haldane (1995) and Bernanke et al. (1999).

[2] Svensson (1999) and Vestin (2000) argue that price-level targeting yields better output-inflation variability trade-off and price stability than does inflation targeting.

However, despite this thriving theoretical literature, little work has been done on directly evaluating this kind of regime (HT) in open economy modeling cases. An analysis of HT in a small open economy environment is relevant, especially, given IT and PT regime shortcomings, as well as the implications of this policy's weakness for central Banks. This work therefore attempts to investigate this targeting type in an estimated small open economy model using Canadian, Australian, New Zealand and United Kingdom data.

The small open economy version implies that foreign variables may be included in each equation of the model, and that the treatment of foreign sector variables is different from that used for the closed version. These differences may result in contrasting policy advice or may confirm results obtained in the literature for the HT regime. Moreover, analyzing the small open economy takes into consideration the possibility that international trade and financial assets would affect the evolution of the domestic economy. Thus, foreign shocks such as the terms of trade can alter domestic business cycle fluctuations, giving rise to much more dynamics in the model, which may lead the monetary authority to explicitly take these kind of fluctuations into account (Lubik and Schorfheide, 2003). Further, the recent development of the New Open Economy Macroeconomics originated by Obstfeld and Rogof (1995) and Lane (2001) lead to a rich literature where micro-founded and optimization-based models are used for policy analysis in the open economy. It particularly highlighted the role of the terms of trade in the transmission of business cycles (see Corsetti and Pesenti, 2001).

In line with previous research on monetary policy analysis, we adopt the new Keynesian framework, a model that many macroeconomic studies have indeed frequently employed[3]. The most important feature of this model is the appearance of terms that reflect the representative agents' forward-looking behavior. This lead for example to stabilization bias problem that occurs if monetary authorities undertake to apply discretionary monetary policy (Clarida et al., 2000). Most of the

[3] See for example McCallum and Nelson (2000), Clarida et al. (2000), Ball (1999) and Svensson (2000) for a discussion of these kinds of models.

literature to date uses the new classical model to assess the property of the HT regime and confirms its advantages (Kobayashi, 2004). However, the use of New Keynesian models when analyzing the HT regime is only in its first stages[4]. In this work we attempt to investigate this framework and try to provide evidence to help discriminate between hybrid regime and other kind of monetary policy targeting.

In our empirical work, we use the Bayesian approach to estimate the DSGE model structural parameters, based on contributions of Schorfheide (2000) and Lubik and Schorfheide (2003). Although different estimation methods have been adopted by macroeconomists in estimating DSGE models[5], most of these modeling techniques have to deal with potential model misspecification and identification problems[6]. In fact, the Bayesian approach is a system based and fits the DSGE model to a vector of time series. Also, prior distributions play an important role by enabling the inclusion of available information, in addition to the estimation sample. Furthermore, estimation involves Markov-Chain Monte-Carlo (MCMC) techniques which work with marginal densities rather than gradient methods (see Geweke, 1999, Schorfheide, 2000, Smets and Wouters, 2003, Justiniano and Preston, 2004 and An and Schorfheide, 2005).

Subsequently, we conduct a welfare analysis between different monetary policy regimes considered in this study and then compare their impulse response functions.

Our results are consistent with the fact that the hybrid inflation/price-level targeting performs

[4]Dittmar et al. (1999) Cecchetti and Kim (2003) and Kobayashi (2004) analyzed the Hybrid regime using a model similar to Svensson's (1999) model. Batini and Yates (2003) explored the implications of this regime using the Fuhrer and Moore' (1995) model.

[5]Some standard procedures are Maximum Likelihood (ML), Generalized Method of Moments (GMM), Simulated Method of Moments (SMM), the Indirect Inference procedure proposed by Smith (1993) and finally the Bayesian techniques.

[6]Taking into account this model misspecification, many authors use the calibration approach. This approach along the line of Kydland and Prescott (1982) is by far the most common approach found in the literature for examining the empirical properties of DSGE models (An and Schorfheide, 2005).

well and provides an alternative way of conducting successful monetary policy in the case of a small open economy without having to worry about shortcoming of the other monetary policy regimes considered in this work. Our estimates also show that the small open economies considered in this work follow monetary policies that allow for some temporary base drift in prices (HT targeting), even if publicly announced policy by central banks in those countries is focused more on targeting inflation.

The paper proceeds in the following manner. Section 2 sketches the model's derivation as implied by the microfoundations presented by Galí and Monacelli (2004). Section 3 provides details on estimation methodology and discusses the results. Section 4 introduces welfare analysis and provides some results. Section 5 concludes.

2 The Model

We construct a model that is a variant of a dynamic New Keynesian Model applied to the small open economy following Clarida et al. (2002) and Galí and Monacelli (2004).

The model has three sectors. There are a continuum of profit maximizing monopolistically competitive firms (owned by the consumers who have shares of it in their portfolios) operating a constant return to scale technology and facing staggered price setting a la Calvo (1983).

An infinitely-lived representative household maximizes a utility function defined over a composite consumption good and labor supply, and finally a central bank who sets the monetary policy throughout an interest rule targeting both price-level and inflation rate in an hybrid formula.

2.1 Firms' Problem

The production function for a typical firm (i) in home economy that produces a differentiated good is:

$$Y_t(i) = A_t N_t(i), \text{ i} \in [0, 1] \tag{1}$$

where $Y_t(i)$ and $N_t(i)$ are the firm (i) specific output and labor input respectively, and A_t is a total factor productivity shifter that follows an $AR(1)$ process (in $\log$ deviation):

$$\hat{a}_t = \rho_a \hat{a}_{t-1} + \varepsilon_{a,t},$$

with $\varepsilon_{a,t}$ is a white noise with mean 0 and variance σ_ϵ^2.

The cost minimization problem leads to express real marginal cost $\widehat{mc}_t$, which is common across domestic firms, in terms of home prices, by the relation:

$$\widehat{mc}_t = -\nu + \hat{w}_t - \hat{p}_{H,t} - \hat{a}_t \tag{2}$$

where $\nu = -\log(1-\tau)$, with τ being an employment subsidy[7], and $\hat{p}_{H,t}$ and $\hat{w}_t$ are respectively the deviations of domestic price and wage rate from their steady state values.

Let Y_t defines the aggregate index for domestic output and N_t the aggregate employment:

$$Y_t = [\int_0^1 Y_t(i)^{\frac{\zeta-1}{\zeta}} di]^{\frac{\xi}{\xi-1}},$$

$$N_t = \int_0^1 N_t(i)\, di = \int_0^1 \frac{Y_t(i)}{A_t}\, di,$$

where $\xi > 1$ is the elasticity of substitution among goods within each category. Moreover, defining $Z_t = \int_0^1 \frac{Y_t(i)}{Y_t} di$ yields:

$$N_t = \frac{Y_t Z_t}{A_t},$$

in log-linear form (up to first order approximation) this yields:

$$\hat{y}_t = \hat{a}_t + \hat{n}_t \tag{3}$$

where the variables $\hat{y}_t, \hat{a}_t$ and $\hat{n}_t$ are the deviations of output, technology shifter and employment from a symmetric steady state.

2.1.1 Price Setting

The price setting-behavior follows Calvo (1983) and Yun (1996), in that only a fraction $(1-\psi)$ of firms adjust their price each period, while a fraction ψ of randomly selected firms keep their price unchanged. This leads to a forward-looking pricing decision.

We follow Galí and Monacelli (2004) to determine the new price-setting strategy[8]. Let $P^n_{H,t}$ be the price sets by a firm (i) adjusting its price in period t and facing a probability ψ^k to keep their price unchanged for k period (for k=0,1,2,...).

[7] The employment subsidy offsets exactly the combined effects of the firm's market power and the terms of trade distortions in the steady state. In this case, there is only one effective distortion left in the SOE, namely, sticky prices.

[8] See Gali and Monacelli (2004) -Appendix 2- for more details.

The new price must satisfy:

$$P^n_{H,t} = \mu + (1-\beta\psi)\sum_{k=0}^{\infty}(\beta\psi)^k E_t\{mc_{t+k} + P_{H,t+k}\} \tag{4}$$

where μ is the steady state markup[9]. The dynamic of the domestic price index is then:

$$P_{H,t} = [\psi P^{1-\xi}_{H,t-1} + (1-\psi)(P^n_{H,t})^{1-\xi})]^{\frac{1}{1-\xi}} \tag{5}$$

which can be log-linearized to get an expression for the domestic inflation:

$$\hat{\pi}_{H,t} = (1-\psi)(\hat{p}^n_{H,t} - \hat{p}_{H,t-1})$$

Combining this expression with the differenced version of (5) gives the following aggregate supply equation:

$$\hat{\pi}_{H,t} = \beta E_t\{\hat{\pi}_{H,t+1}\} + \kappa \widehat{mc}_t \tag{6}$$

where $\kappa = \frac{(1-\beta\psi)(1-\psi)}{\psi}$ and $\widehat{mc}_t$ represents the log-deviation of the real marginal cost.

The firms in the rest of the world (ROW) face the same price setting problem with the assumption that the degree of price stickiness is identical for both economies.

2.2 Households

Our small open economy is inhabited by a continuum of infinitely-lived households where the representative household seeks to maximize the expected utility:

$$E_t\sum_{t=0}^{\infty}\beta^t U(C_t, N_t), \tag{7}$$

where N_t is hours worked and C_t is a composite consumption index defined by:

$$C_t = [(1-\alpha)^{\frac{1}{\theta}}(C_{H,t})^{\frac{\theta-1}{\theta}} + \alpha^{\frac{1}{\theta}}\ (C_{F,t})^{\frac{\theta-1}{\theta}}]^{\frac{\theta}{\theta-1}} \tag{8}$$

[9]The forward-looking pricing decision is related to the fact that firms that adjust their price in any period do that for a random number of periods. The price is then set as a markup over the average of expected future marginal costs.

where the elasticity of substitution between the indices of home and foreign goods is given by $\theta > 0$, $C_{H,t}$ is the consumption index of j domestic goods defined by the CES aggregator:

$$C_{H,t} = [\int_0^1 (C_{H,t}(j))^{\frac{\xi-1}{\xi}} dj]^{\frac{\xi}{\xi-1}}$$

and $C_{F,t}$ is the index of imported goods:

$$C_{F,t} = [\int_0^1 (C_{F,t}(j))^{\frac{\xi-1}{\xi}} dj]^{\frac{\xi}{\xi-1}}$$

where the elasticity of substitution among goods within the two indices is given by the scalar $\xi > 1$.

The maximization of the expected utility is subject to the sequence of budget constraints of the form:

$$\int_0^1 P_{H,t}(j)C_{H,t}(j)dj + \int_0^1 P_{F,t}(j)C_{F,t}(j)dj + E_t\{O_{t,t+1}D_{t+1}\} \leqslant D_t + W_tN_t + T_t,$$

with $P_{H,t}(j)$ is the price of the domestic good j and $P_{F,t}(j)$ is the price of imported good j expressed in home currency. D_{t+1} is the nominal payoff in period $t+1$ of the portfolio held at the end of period t (including firms' share), W_t is the nominal wage rate and T_t is the lump-sum transfers/taxes. $O_{t,t+1}$ is the stochastic discount factor for one period ahead nominal payoff relevant to the domestic household.

The demand function for the domestic and foreign goods can be written as:

$$C_{H,t}(j) = (\frac{P_{H,t}(j)}{P_{H,t}})^{-\xi}\, C_{H,t},$$

$$C_{F,t}(j) = (\frac{P_{F,t}(j)}{P_{F,t}})^{-\xi}\, C_{F,t},$$

which define the quantities consumed of each type of goods, with $P_{H,t}$ and $P_{F,t}$ are the domestic and foreign price index expressed in domestic currency, defined as:

$$P_{H,t} = [\int_0^1 (P_{H,t}(j))^{1-\xi} dj]^{\frac{1}{1-\xi}},$$

$$P_{F,t} = [\int_0^1 (P_{F,t}(j))^{1-\xi} dj]^{\frac{1}{1-\xi}}.$$

Those definitions can be combined to obtain:

$$\int_0^1 P_{H,t}(j) C_{H,t}(j) dj = P_{H,t} C_{H,t},$$

$$\int_0^1 P_{F,t}(j) C_{F,t}(j) dj = P_{F,t} C_{F,t}.$$

Moreover, the optimal allocations between domestic and imported goods are given by:

$$C_{H,t} = (1-\alpha)(\frac{P_{H,t}}{P_t})^{-\theta} C_t,$$

$$C_{F,t} = \alpha(\frac{P_{F,t}}{P_t})^{-\theta} C_t,$$

where the consumer price index is given by:

$$P_t \equiv [(1-\alpha)(P_{H,t})^{1-\theta} + \alpha(P_{F,t})^{1-\theta}]^{\frac{1}{1-\theta}}$$

with the log-linearized form:

$$\hat{p}_t = (1-\alpha)\, \hat{p}_{H,t} + \alpha\, \hat{p}_{F,t}.$$

We can then compute the total consumption expenditures by the domestic households:

$$P_{H,t}\, C_{H,t} + P_{F,t}\, C_{F,t} = P_t\, C_t, \tag{9}$$

which help us to write the period budget constraint given by:

$$P_t\, C_t + E_t\{O_{t,t+1} D_{t+1}\} \leqslant D_t + W_t N_t + T_t. \tag{10}$$

In order to study the properties of this model, we will evaluate them using specific functional form for the period utility function that takes the form:

$$U(C_t, N_t) = \frac{C^{1-\sigma}}{1-\sigma} - \frac{N^{1+\phi}}{1+\phi},$$

the Lagrangian for this problem is then:

$$\underset{C_t,N_t,D_{t+1}}{Max} E_0\{\sum_{t=0}^{\infty}\beta^t[\frac{C^{1-\sigma}}{1-\sigma}-\frac{N^{1+\phi}}{1+\phi}+\lambda_t(D_t+W_tN_t+T_t-P_tC_t-E_t(O_{t,t+1}D_{t+1}))]\}. \quad (11)$$

The intratemporal optimally condition follows from the household problem :

$$C_t^{\sigma}N_t^{\phi}=\frac{W_t}{P_t}, \quad (12)$$

when the intertemporal optimization (for all states and dates) implies:

$$O_{t,t+1}=\beta(\frac{C_{t+1}}{C_t})^{-\sigma}(\frac{P_t}{P_{t+1}}). \quad (13)$$

When defining the gross return on riskless period discount bond paying off one unit of domestic currency in $t+1$ as $R_t=\frac{1}{E_tO_{t,t+1}}$ and taking conditional expectation on equation (13) we get the standard Euler equation:

$$\beta R_tE_t\{(\frac{C_{t+1}}{C_t})^{-\sigma}(\frac{P_t}{P_{t+1}})\}=1 \quad (14)$$

which is in log-linearized form:

$$\hat{c}_t=E_t\hat{c}_{t+1}-\frac{1}{\sigma}(r_t-E_t\hat{\pi}_{t+1}-\rho)$$

where $\rho\equiv-\log\beta$ is the time discount factor.

In the rest of the world a representative household faces a similar problem as the one outlined above. We assume here that the size of small open economy is negligible relative to the ROW economy[10].

2.2.1 Some Identities

We assume that the law of one price holds for all goods (including imported goods) at all times implying that:

$$P_{F,t}(j)=\epsilon_tP_{F,t}^F(j) \text{ for all } j\in[0,1],$$

[10]This assumption allows us to treat the ROW economy as a closed economy.

where ϵ_t is the bilateral nominal exchange rate[11] , $P^F_{F,t}(j)$ is the price of the good (j) produced in foreign country in term of foreign currency.

By substituting this in the definition of $P_{F,t}$:

$$P_{F,t} = \epsilon_t [\int_0^1 (P^F_{F,t}(j))^{1-\xi} dj]^{\frac{1}{1-\xi}},$$

if we define the foreign price index as:

$$P^*_t = [\int_0^1 (P^F_{F,t}(j))^{1-\xi} dj]^{\frac{1}{1-\xi}},$$

we can write the relation between the home price of imported goods and the foreign price index in log-linearized form around a steady state:

$$\hat{p}_{F,t} = \hat{e}_t + \hat{p}^*_t. \tag{15}$$

The term of trade is defined by:

$$S_t = \frac{\epsilon_t P^*_t}{P_{H,t}},$$

log-linearized form around a symmetric steady state of this relation is:

$$\hat{s}_t = \hat{e}_t + \hat{p}^*_t - \hat{p}_{H,t}. \tag{16}$$

While the real exchange rate is defined as (log-linearized form):

$$\hat{q}_t = \hat{e}_t + \hat{p}^*_t - \hat{p}_t,$$

using equation (16) we get:

$$\hat{q}_t = \hat{s}_t + \hat{p}_{H,t} - \hat{p}_t.$$

Using the price indices definition we can compute:

$$\frac{P}{P_H}\hat{p}_t - \frac{P}{P_H}\hat{p}_{H,t} = [(1-\alpha) + \alpha(S)^{1-\theta}]^{\frac{1}{1-\theta}} S^{1-\theta} \alpha \hat{s}_t,$$

[11] The price of foreign country currency in term of domestic currency.

we suppose that the purchasing power parity (PPP) holds at steady state that is: $S = \frac{P_F}{P_H} = 1$ this yields:

$$\hat{p}_t - \hat{p}_{H,t} = \alpha \hat{s}_t, \tag{17}$$

and the domestic inflation is then related to the CPI inflation according to:

$$\hat{\pi}_t = \hat{\pi}_{H,t} + \alpha \Delta \hat{s}_t. \tag{18}$$

Finally, the real exchange rate can now be written as:

$$\hat{q}_t = (1-\alpha)\hat{s}_t \tag{19}$$

which set a relation between real exchange rate and terms of trade depending on the degree of openness of the SOE.

2.2.2 International Risk Sharing

In our work we assume that there is a complete securities market in the world so that the Euler equation holds also for foreign representative household[12]:

$$O_{t,t+1} = \beta E_t \{ (\frac{C^*_{t+1}}{C^*_t})^{-\sigma} (\frac{P^*_t}{P^*_{t+1}}) (\frac{\epsilon_t}{\epsilon_{t+1}}) \}, \tag{20}$$

combining this equation with its domestic counterpart yields the following equality:

$$\beta(\frac{C_{t+1}}{C_t})^{-\sigma}(\frac{P_t}{P_{t+1}}) = \beta(\frac{C^*_{t+1}}{C^*_t})^{-\sigma}(\frac{P^*_t}{P^*_{t+1}})(\frac{\epsilon_t}{\epsilon_{t+1}})$$

replacing $Q_t = \frac{\epsilon_t P^*_t}{P_t}$ and manipulating to get:

$$C_t = Q_{t+1}^{-\frac{1}{\sigma}} \frac{C_{t+1}}{C^*_{t+1}} C^*_t Q_t^{\frac{1}{\sigma}}. \tag{21}$$

[12]In term of domestic currency.

Hence, the optimal allocation for imported good is given by:

$$C_t^* = \alpha Q_t^{-\theta} C_t, \tag{22}$$

that is, the relation (21) can be written as:

$$C_t = \Phi_o C_t^* Q_t^{\frac{1}{\sigma}}$$

where Φ_o depends on initial condition on asset position. If we assume symmetric initial conditions between home and foreign country with zero foreign asset holding for the small open economy we can get without loss of generality that $\Phi_o = 1$ so that the log-linearized form leads to:

$$\hat{c}_t = \hat{c}_t^* + \frac{1}{\sigma}\hat{q}_t. \tag{23}$$

Using the fact that: $\hat{q}_t = (1-\alpha)\hat{s}_t$ we can write:

$$\hat{c}_t = \hat{c}_t^* + \frac{1-\alpha}{\sigma}\hat{s}_t. \tag{24}$$

2.2.3 Uncovered Interest Parity

With our assumption of complete market securities, the Euler equation holds either for foreign households:

$$\beta R_t^* E_t\{(\frac{C_{t+1}^*}{C_t^*})^{-\sigma}(\frac{P_t^*}{P_{t+1}^*})\} = 1$$

rearranging terms to get:

$$R_t^{*-1} = \beta E_t\{(\frac{C_{t+1}^*}{C_t^*})^{-\sigma}(\frac{P_t^*}{P_{t+1}^*})\},$$

introducing this relation in equation (20) we can get the price of riskless bond dominated in foreign currency:

$$R_t^{*-1}\epsilon_t = E_t\{O_{t,t+1}\epsilon_{t+1}\},$$

we know by definition that $R_t^{-1} = E_t O_{t,t+1}$ combining both equations we can write:

$$E_t\{O_{t,t+1}[R_t - R_t^*(\epsilon_{t+1}/\epsilon_t)]\} = 0, \tag{25}$$

log-linearizing around steady state we get the asset pricing equation for nominal bounds which implies that the interest rate differential is related to expected exchange rate depreciation :

$$\hat{r}_t - \hat{r}_t^* = E_t\{\Delta \hat{e}_{t+1}\} \tag{26}$$

where $\hat{e}_t$ is the deviation of the nominal exchange rate from its steady state value.

2.3 Monetary Policy

We suppose that a central bank sets the interest rate rule in this way we can obtain closure of the general equilibrium model. However, the money does not appear in either the household utility function or the budget constraint. Indeed, the recent research on monetary policy adopt this modeling strategy (Galí and Monacelli, 2004). In this kind of models the money play the role of a unit of account only.

Moreover, the influential work by Taylor (1993) use the interest rate feedback from output and inflation to approximate the monetary policy. Recently Woodford (2000) demonstrated that interest rate rule is consistent with nominal demand determinacy for forward-looking models even when money demand is not present in the model.

In the spirit of Taylor (1993, 1996) we assume that the monetary policy follows generalized Taylor rule of the form:

$$\hat{r}_t = E_t\{\hat{\pi}_{t+1}\} + \phi_p(E_t\hat{p}_t - \chi\hat{p}_{t-1}) + \phi_y\bar{x}_t, \tag{27}$$

where $\hat{r}_t$ denotes the short-term nominal interest rate and $\hat{\pi}_t$, $\hat{p}_t$ are defined in the same way as above, and $\bar{x}_t$ is the output gap. $\chi \in [0, 1]$ is the parameter that defines the spectrum of targets between price level and inflation targeting. When $\chi = 0$, the policy makers target the price level and when $\chi = 1$, the level of the inflation rate is targeted. For $0 < \chi < 1$ the target is an hybrid regime targeting both price level and inflation rate level.

2.4 Equilibrium Determination

2.4.1 Aggregate Demand

World output and consumption

The market clearing condition for the ROW economy requires:

$$\hat{y}_t^* = \hat{c}_t^*,$$

where the Euler equation for the household in this case can be written as:

$$\hat{c}_t^* = E_t \hat{c}_{t+1}^* - \frac{1}{\sigma}(r_t^* - E_t \hat{\pi}_{t+1}^* - \rho)$$

which combined with the clearing condition leads to a version of the new IS equation in the case of sticky price models:

$$\hat{y}_t^* = E_t \hat{y}_{t+1}^* - \frac{1}{\sigma}(r_t^* - E_t \hat{\pi}_{t+1}^* - \rho),$$

this IS equation demonstrates that the foreign output is related negatively to the world interest rate and positively to the expected foreign CPI inflation.

Small open economy output, consumption and trade balance

Market clearing for domestic goods requires:

$$Y_t(i) = C_{H,t}(i) + C_{H,t}^*(i),$$

where $Y_t(i)$, $C_{H,t}(i)$ and $C^*_{H,t}(i)$ are ,respectively, the production , home and foreign demand for home produced good (i). Moreover, we suppose that there is symmetric preferences between home and foreign country which imply that:

$$C^*_{H,t} = \alpha(\frac{P_{H,t}(i)}{P_{H,t}})^{-\xi}(\frac{P_{H,t}}{\epsilon_t P^F_{F,t}})^{-\xi}(\frac{P^F_{F,t}}{P^*_t})^{-\theta}C^*_t,$$

replacing this equation in the market clearing condition above, we get:

$$Y_t(i) = (\frac{P_{H,t}(i)}{P_{H,t}})^{-\xi}\{(1-\alpha)(\frac{P_{H,t}}{P_t})^{-\theta}C_t + \alpha(\frac{P_{H,t}}{\epsilon_t P^F_{F,t}})^{-\xi}(\frac{P^F_{F,t}}{P^*_t})^{-\theta}C^*_t\}$$

for all $i \in [0,1]$ and for all t.

The aggregate output can then be computed in the following way:

$$Y_t = (\frac{P_{H,t}}{P_t})^{-\theta}C_t[(1-\alpha) + \alpha(\frac{\epsilon_t P^F_{F,t}}{P_{H,t}})^{\xi-\theta}Q_t^{\theta-\frac{1}{\sigma}}],$$

using the fact that $S_t \equiv \frac{\epsilon_t P^F_{F,t}}{P_{H,t}}$ this yields:

$$Y_t = (\frac{P_{H,t}}{P_t})^{-\theta}C_t[(1-\alpha) + \alpha S_t^{\xi-\theta}Q_t^{\theta-\frac{1}{\sigma}}].$$

The log-linearized form of this expression is given by:

$$\hat{y}_t = \alpha\theta\hat{s}_t + \alpha(\xi-\theta)\hat{s}_t + \hat{c}_t + \alpha(\theta - \frac{1}{\sigma})\hat{q}_t$$

where we use the fact that $\hat{p}_{H,t} - \hat{p}_t = \alpha\hat{s}_t$. Thus we get:

$$\hat{y}_t = \hat{c}_t + \alpha\xi\hat{s}_t + \alpha(\theta - \frac{1}{\sigma})\hat{q}_t,$$

here we can use the relation: $\hat{q}_t = (1-\alpha)\hat{s}_t$ to get:

$$\hat{y}_t = \hat{c}_t + \frac{\alpha\omega}{\sigma}\hat{s}_t, \quad (28)$$

where $\omega = \xi\sigma + (\sigma\theta - 1)(1-\alpha)$. Using the fact that: $\hat{c}_t = \hat{y}^*_t + (\frac{1-\alpha}{\sigma})\hat{s}_t$, yields:

$$\hat{y}_t = y^*_t + \frac{1}{\sigma_\alpha}\hat{s}_t \quad (29)$$

where $\sigma_\alpha = \frac{\sigma}{(1-\alpha)+\alpha\omega}$ and where the subscript in σ_α meant to emphasize the dependence of this parameter on the degree of openness of the economy (α). Finally we can compute a version of the new IS equation for the SOE by combining the Euler equation (14) with (28):

$$\hat{y}_t = E_t\{\hat{y}_{t+1}\} - \frac{1}{\sigma}(\hat{r}_t - E_t\{\hat{\pi}_{t+1}\} - \rho) - \frac{\alpha\omega}{\sigma}E_t\{\hat{s}_{t+1}\},$$

this leads to derive a difference equation for output which is related to domestic interest rate, world output and domestic inflation:

$$\hat{y}_t = E_t\{\hat{y}_{t+1}\} - \frac{1}{\sigma_\alpha}(\hat{r}_t - E_t\{\hat{\pi}_{t+1}\} - \rho) + \alpha(\omega - 1)E_t\{\Delta\hat{y}^*_{t+1}\}, \qquad (30)$$

this SOE equation is different from its closed economy version because it depends on the degree of openness of the small economy and on the foreign output[13].

Moreover, the net exports (nx) is related to the domestic output in terms of steady state output (Y) through the following equation:

$$nx_t = (\frac{1}{Y})(Y_t - \frac{P_t}{P_{H,t}}C_t),$$

this yields in linearized form:

$$\hat{nx}_t = \hat{y}_t - \hat{c}_t - \hat{p}_t + \hat{p}_{H,t},$$

which combined with (17), (24) and (28) gives:

$$\hat{nx}_t = (1 - \Lambda)(\hat{y}_t - \hat{y}^*_t)$$

with $\Lambda = \frac{\sigma_\alpha[(1-\alpha)+\alpha\sigma]}{\sigma}$, then the relationship between the net exports and the output differential is ambiguous and depends on the value of Λ. If $-1 < \Lambda < 1$, a positive output differential generates a trade surplus favorable to the small open economy and with $\Lambda > 1$ or $\Lambda < -1$ the trade surplus is favorable to the foreign country. Following Galí and Monacelli (2004) we need $-1 \leq \Lambda \leq 1$ to satisfy the Marshall-Lerner conditions[14].

[13] It's easy to see that with $\alpha = 0$, one can get the closed economy version.

[14] The Marshall-Lerner conditions apply if and only if the sum of the import and export elasticities is greater than one.

2.4.2 Deriving The New Keynesian Phillips Curve (NKPC)

Price stickiness is the main friction in the model developed above[15]. Those fluctuations make the model consistent with what has been termed the NKPC. Indeed, using the equation (2) which relates the relation between marginal cost and macro variables it can be shown that:

$$\begin{aligned} \overset{\wedge}{mc}_t &= -\nu + \hat{w}_t - \hat{p}_{H,t} - \hat{a}_t \\ &= -\nu + \phi\hat{y}_t + \sigma\hat{y}_t^* + \hat{s}_t - (1+\phi)\hat{a}_t, \end{aligned}$$

using (3) and (24) in the last equality. We also use equation (29) to compute:

$$\overset{\wedge}{mc}_t = -\nu + (\sigma_\alpha + \phi)\hat{y}_t + (\sigma - \sigma_\alpha)\hat{y}_t^* - (1+\phi)\hat{a}_t. \tag{31}$$

In the other hand we can define the output gap[16] as the difference between the domestic output and the 'natural' output:

$$\bar{x}_t = \hat{y}_t - \bar{y}_t \tag{32}$$

where the natural output is computed by imposing the restriction[17]: $\overset{\wedge}{mc}_t = -\mu$ for all t in equation (31) and solving for domestic output:

$$-\mu = -\nu + (\sigma_\alpha + \phi)\bar{y}_t + (\sigma - \sigma_\alpha)\hat{y}_t^* - (1+\phi)\hat{a}_t,$$

[15]The price stickiness is the only source of suboptimality in the equilibrium allocation. Indeed, as shown by Gali and Monacelli (2004), the employment subsidy neutralizes the market power distortion and by not assigning any explicit value to monetary holding balances, the monetary distortion, that would pull monetary policy towards the Friedman rule, is eliminated.

[16]In our model we have to handle with three definitions of output: A measure of output, the natural output (which we get in an economy with no imperfection or nominal rigidity) and finally the output gap which is the difference between the output and the natural output.

[17]We impose the restriction that the marginal cost is equal to its steady state value (markup) to compute the natural level of output.

which yields after some algebraic manipulations:

$$\bar{y}_t = \Omega + \Gamma \hat{y}_t^* + \Psi \hat{a}_t, \tag{33}$$

with $\Omega = \frac{\nu-\mu}{\sigma_\alpha+\phi}$, $\Gamma = \frac{\sigma_\alpha-\sigma}{\sigma_\alpha+\phi}$ and finally $\Psi = \frac{1+\phi}{\sigma_\alpha+\phi}$. This states that the natural output for the small open economy is determined by world output and productivity, as well as domestic markup. In addition we can derive a relationship between real marginal cost and output gap:

$$\overset{\wedge}{mc}_t = -\nu + (\sigma_\alpha + \phi)\bar{x}_t + (\sigma_\alpha + \phi)(\Omega + \Gamma y_t^* + \Psi \hat{a}_t) + (\sigma - \sigma_\alpha)\hat{y}_t^* - (1+\phi)\hat{a}_t,$$

where we replace the natural output by its value in (33) in the last equality. This yields:

$$\overset{\wedge}{mc}_t = (\sigma_\alpha + \phi)\bar{x}_t. \tag{34}$$

Replacing the marginal cost with this value in equation (6) we get:

$$\hat{\pi}_{H,t} = \beta E_t\{\hat{\pi}_{H,t+1}\} + \kappa[(\sigma_\alpha + \phi)\ ]\bar{x}_t,$$

then the NKPC can be written in this case as:

$$\hat{\pi}_{H,t} = \beta E_t\{\hat{\pi}_{H,t+1}\} + \delta \bar{x}_t, \tag{35}$$

where $\delta = \kappa(\sigma_\alpha + \phi)$. Notice that only the degrees of openness (α) affect the small open economy version of the NKPC, and with $\alpha = 0$, we can easily see that the Phillips equation is exactly equivalent to that of the closed economy.

The equilibrium dynamics for the small open economy in terms of output gap and domestic inflation can be completed by writing a version of the IS equation in terms of output gap. Indeed, using (30) and (33) we can derive:

$$\bar{x}_t = E_t\{\bar{x}_{t+1}\} - \frac{1}{\sigma_\alpha}(\hat{r}_t - E_t\{\hat{\pi}_{H,t+1}\} - \rho) + \Gamma(\rho_a - 1)\hat{a}_t + \alpha(\Psi + \Theta)E_t\{\hat{y}_{t+1}^*\}, \tag{36}$$

with $\Theta = (\omega - 1)$. If we define the natural interest rate as:

$$\bar{rr}_t \equiv \rho - \sigma_\alpha \Gamma(\rho_a - 1)\hat{a}_t + \alpha\sigma_\alpha(\Psi + \Theta)E_t\{\hat{y}^*_{t+1}\},$$

where the degree of openness and the expected world output affect the natural rate of interest and then the new IS equation which has the following form:

$$\bar{x}_t = E_t\{\bar{x}_{t+1}\} - \frac{1}{\sigma_\alpha}(\hat{r}_t - E_t\{\hat{\pi}_{H,t+1}\} - \bar{rr}_t), \tag{37}$$

which relates Output gap in forward-looking equation to interest rate, domestic inflation and natural interest rate.

To solve this model we take a log-linear approximation of the equilibrium conditions around a balanced-trade zero-inflation steady state[18]. The dynamic properties of the model depends in a crucial manner on the monetary policy used. Indeed, with the Taylor where the parameter χ taking value 1, the persistent response of inflation to technology chock imply a permanent effect of the shock on the price level and then a unit root on it, which can be mirrored by a unit root in the nominal exchange rate. In this case, and following Galí and Monacelli (2004) when targeting inflation rate, the monetary authority seeks to stabilize CPI inflation. Such policy requires only to set :

$$\hat{r}_t - E_t\{\hat{\pi}_{t+1}\} = \phi_p(E_t\hat{\pi}_t) + \phi_y\bar{x}_t,$$

for all t. Moreover, and following Woodford (1999) and Bullard and Mitra (2003), our analysis focusses on the case where ϕ_p and ϕ_p have non negative values. Thus, the necessary and sufficient condition for a stable path allocation[19] is given by:

$$\delta(\phi_p - 1) + (1 - \beta)\phi_y \neq 0. \tag{38}$$

[18] The markup is also assumed to be constant at steady state ($\mu = \frac{\xi}{\xi - 1}$) in order to derive the equilibrium conditions.

[19] As shown by Bullard and Mitra (2003), This condition rules out eigenvalues on the unit circle.

Furthermore, we assume that the foreign country pursues an optimal policy implying a constant foreign price level at equilibrium[20]. The dynamic of the model can be stable in this case even with non stationary prices. Otherwise, with $0 \leqslant \chi < 1$ the price level is I(0) and the condition (38) holds also in this case.

In what follows, we, first estimate the model parameters and then compute the impulse response functions and second moments statistics before analyzing the welfare implications of each regime.

3 Estimation Procedure

We use Bayesian estimates of the structural parameters. As in previous studies, some parameters should be set prior to the estimation, since there values are commonly used in the literature. The discount factor,β, is set equal to 0.99, which implies an annual steady-state real interest rate of 4 per cent, matching the value observed in the data.All other parameters are estimated using the Bayesian method of estimation.

3.1 GMM Estimation of the Monetary Rule

In order to establish a point of comparison with our structural estimates and then get some priors for our monetary policy parameters, the Taylor rule is estimated first using GMM method of estimation. Clarida, Galí and Gertler (2000) advocated this estimation procedure since it potentially incorporates information from underlying economic structure. Using quadratic Canadian data over the sample period 1983:01 to 2004:03, we estimate equation (27). Indeed, the HP-detrended real output is used as a measure for the output gap, the Overnight Money Market rate as nominal interest rate and annualized CPI inflation rate as inflation. The list of instruments includes lagged values of variables in the regression.

[20] See Gali and Monacelli (2004) for a discussion about the optimal policy in the foreign country and in the SOE case.

The GMM estimates are reported in Table (3). All coefficients estimates are insignificants. The estimation of the monetary rule revealed very large price coefficient (ϕ_p) but not statistically different from zero[21]. Lagged price coefficient (χ) is negative, while the output gap coefficient is in line with what is found in the literature but the estimate is also not significant for this parameter.

Lubik and Schorfheide (2003) report GMM estimates for a monetary policy rule[22] in the case of SOE (for several country). They found that the estimates for Canada are dramatic and insignificant even when the linearly detrended output gap measure is used instead of HP-detrended output.

3.2 Bayesian Estimation

3.2.1 Econometric methodology

We estimate a structural model for our small open economy using a Bayesian approach. Following Lubik and Schorfheide (2003), we restrict the estimated model to five equations rather than estimating the whole reduced form. Indeed, using this strategy permit us to focus on structural model parameters which yields consistent estimates.

Specifically, the structural model is determined by the following equations: The small open economy IS-curve (eq. 36), The NKPC equation (eq. 35), the monetary policy rule (eq. 27), the CPI inflation versus domestic inflation (eq. 18) and finally a combination of differenced version of equation (18) and (29) yielding an endogenous terms of trade[23]. We assume that the foreign output follows an AR(1) process[24].

---

[21] All parameters are expected to belong the unit interval [0,1].

[22] The monetary policy rule they estimate is different than the one used in our work. In their interest rate rule the central bank adjust its behavior in response to deviations of inflation and output from their targets. They include the nominal exchange rate depreciation and lagged interest rate persistence term in the rule.

[23] Lubik and Schorfheide (2003) assume an AR(1) process for the terms of trade rather than endogenous specification. Their assumption is not fully consistent with the fact that the firms have certain market power, making the traded market product prices endogenous to the economy and then the terms of trade.

[24] We, also, estimate our model following their specification (exogenous terms of trade following AR(1) process) but

The linear rational expectations model provides a state-space representation for the vector of observable Y_t. Let ς be a vector of the parameters and Y^T the data used to estimate the model parameters. Given a prior distribution with density $p(\varsigma)$, the posterior density of the model coefficients ,ς, is given by:

$$p(\varsigma/Y^T) = \frac{L(\varsigma/Y^T)p(\varsigma)}{\int L(\varsigma/Y^T)p(\varsigma)d\varsigma},$$

where $L(\varsigma/Y^T)$ is the likelihood function[25] conditional on observed data Y^T that can be evaluated using the Kalman filter.

The model has three shock processes. The technology shock innovations, the foreign output innovations and finally the monetary policy rule innovations[26]. In order to identify them we use the same number of data series for Canada, UK, New Zealand and Australia obtained from DRI International Database. The series consist of real output growth (GDPR), CPI inflation in annualized terms (CPINS) and nominal interest rate[27] in quarterly frequencies, and cover the period 1983:1 to 2004:4. All series are seasonally adjusted and demeaned prior to estimation. The estimation is conducted using the Metropolis-Hastings algorithm implemented in the Dynare code[28].

3.2.2 Quantitative Results

The SOE model is solved and the parameter draws are generated from the posterior distribution using the Dynare code. We first set prior means and distributional forms before estimating the model.

---

results (available upon request) are not presented in this work.

[25] The likelihood function is computed assuming normality distribution for the model disturbances.

[26] Here we add innovations term to the policy rule which is an exogenous policy shock that can be interpreted as the unsystematic component of the decision rule.

[27] Following Lubik and Schorfheide (2003), we use the Interbank Cash Rate for Australia (DRI series RMOCSH), RMBANK for New Zealand, the Repo Rate (DRI series RM) for UK and finally the Overnight Money Market Rate for Canada as nominal interest rate. The reader is referred to this study for more details about data series.

[28] The Dynare code can be found at : http://www.cepremap.cnrs.fr/dynare/.

Priors

We choose priors for estimated parameters based on recent literature. Table (2) provides means, distributional form and prior standard deviations. We, also assume that prior distributions are independent and impose restrictions on parameters such as non-negativity by truncating the distributions. Indeed, beta distribution is selected for coefficients we wanted to restrict to lie within [0,1), Gamma and Inverted Gamma distributions are imposed to guarantee real positive values for parameters such as elasticity coefficient or standard deviation estimates.

The priors for the parameters of the policy rule follows Batini and Yates (2003) since our GMM estimates yield non consistent or statistically insignificant values. We set the prior mean for ϕ_p and ϕ_y at the values commonly used in the literature 0.5 and 0.4 with standard deviations of 0.125 and 0.02 respectively. Furthermore, our study focuses on hybrid targeting, and as discussed in Batini and Yates the value to assign to χ is quite difficult to find. Indeed, using a rang of values within the interval [0,1] the authors found that the optimal value of χ depends on the size of inflation tax, the cost of indexation and the length of nominal contracts. Following this study we set the prior mean of χ to 0.6 and standard deviation equal to 0.20.

Moreover, the other parameters are parameterized following Galí and Monacelli (2004). We use a labor supply elasticity of about $\frac{1}{3}$ which set the prior mean of $\phi = 3$ and a steady state markup $\mu = 1.2$ which means that the elasticity of substitution between different domestic goods ξ has a prior mean value of 6. The average period of price adjustment by firms is set to 4 quarters then we set the sticky price parameter ψ to 0.75. While the degrees of openness of the economy α is set to prior mean equal to 0.4 with standard error of 0.10. The elasticity of substitution between domestic and foreign goods θ take a mean value of 1.5 according to Backus et al. (1995), Galí and Monacelli use the special case where $\theta = \sigma = 1$ for their calibrations of the model.

The remaining parameters are somewhat difficult to determine. Indeed, there is no consensus among open economy researchers about the values attributed to the intertemporal rate of substitution σ. Cochrane (1997) uses values between one and two, Yun (1996) and Galí and Monacelli (2004) calibrate their models with $\sigma = 1$. We follow Erceg et al. (2000) and set this parameter mean to 1.5 with standard deviation of about 0.20. The exogenous processes parameters are set to prior values following Galí and Monacelli (2004) and Lubik and Schorfheide (2003) for all countries. Indeed, ρ_A is set to prior mean of 0.76 with standard error of 0.05 for Canada. For all other countries this parameter take a mean prior value of 0.20 with standard error of 0.10. We set ρ_{y*} to be equal to 0.86 with standard error of 0.05 in Canadian case and to be equal to 0.90 and standard error of 0.05 for all other countries.

Posterior Computation

Using different Taylor rule specifications in a DSGE model with time series macroeconomic data from four small open economies: Canada, Australia, New Zealand and UK, we estimate the structural parameters with the Bayesian approach. The posterior estimates of our model[29] are reported in Tables 4 to 6. In addition to the 90% confidence intervals we report posterior means as point estimates for all countries.

The monetary policy parameter estimates are in line with what was expected and tend to be similar to those found in the literature[30]. Indeed, ϕ_p ranges from 0.769 for New Zealand to 0.888 for UK considering the HT regime. The output gap parameter has an estimate of 0.251 for Canada which means a low reaction to deviations of output gap from target. This parameter is estimated to be around 0.5 for Australia which means that the monetary authority responds more aggressively to

[29]Our estimates are compatible with the stability condition 38 which means that our model is stable under the regimes considered in this paper.

[30]See for example Taylor (2001) for a general discussion.

output gap deviations in this country. The estimation of the key parameter of the hybrid inflation price level targeting, χ, is in the line of what was reported by Batini and Yates (2003). This parameter range from 0.03 to 0.36 with a mean estimate of about 0.2 for Canada and New Zealand. The estimate for Australia and UK is about 0.32 and 0.4 respectively. In this case the monetary authority[31] has as target an hybrid regime stabilizing both inflation rate and price level at the same time allowing for some temporary base drift in price. Similar results are obtained for the other regimes apart from χ which is fixed to value 1 and 0, respectively, prior to estimation of the model with IT and PT specifications.

All the other parameters are broadly in line with the common values used in the empirical and theoretical studies of small open economy (Galí and Monacelli, 2004 Monacelli, 2003, Lubik and Schorfheides, 2003). The estimated degree of price stickiness suggests price are changed every 3 quarters on average for Canada, Australia and UK and every 5 quarters for New Zealand, Woodford (2003) state that survey evidence suggests prices are set slightly less frequently than twice a year, Bils and Klenow (2002) report evidence that consumer prices are adjusted on average considerably more frequently than once a year. The degree of openness of the economy is estimated to be around 0.36 for Canada, Australia and UK and around 0.25 for New Zealand, somewhat similar to the value obtained from national accounts data[32]. Of the disturbances, posterior estimates of the volatility of shocks indicate that the policy rule shocks are most important, having the largest standard deviations, followed by the technology chocks, with the latter being most persistent, independently of the targeting regime adopted.

Data, However, is found not fully informative with respect to some parameters. Indeed, the

[31]Note that the historical estimated Taylor rule for Canada is an inflation targeting one with moderate concern for output stabilization (Bergin, 2003, Kollmann, 2002 and Ambler, Dib and Robei, 2004).

[32]This parameter takes as proxy the import/GDP ratio which range from 12% for Australia to 40 % for Canada. To be noted that this kind of model lacks non tradable goods which makes harder the comparison between α and this ratio (Justiniano and Preston, 2005).

parameters μ and θ have the same patterns between the prior and posterior distributions which means that the actual data are little informative about these parameters.

Furthermore, in order to evaluate the importance of the individual shocks we compute variance decompositions. The results for Canada (under HT regime) are reported in Table (7). Canadian GDP is totally driven by the technology shock which is in line with evidence from VAR studies (Lubik and Schorfheide, 2003). Interestingly, foreign output shocks contribute significantly to price level and interest rate volatility. Although the technology shock do not play a substantial role in price level and interest rate volatility with later variable movements largely determined by policy shock, and to a smaller degree by the world output shock. The results for other countries are quantitatively similar to the Canadian case.

3.3 Impulse Response Functions and Second Moment Analysis

Impulse response functions (IRFs) play an important role in describing the impact that shocks have on economic variables. Since the dynamic responses are quantitatively similar we only present results for Canada under the three regimes[33]. Figure (2) displays the impulse responses to a positive technology shock of 1% under HT, IT and PT regimes. The output gap response function have the same patterns for HT and PT regimes, with an initial positive response of about 12% then it falls within the next two periods to reach negative values and then revert to steady state. The IRF under IT has the same initial response and then go down to reach study state values within 5 periods. The response of inflation (both domestic and CPI based inflation) have the same path as the one displayed by output gap response under the three policies targeting.

The nominal interest rate presents a different response. With an initial negative response to shock, it increases to attain steady state in about 20 periods. Intuitively, this means that after the

[33] Results for the other countries are quiet similar and available upon request.

economy is hit by a technology shock, the optimal response of monetary authority is to increase the nominal interest rate by a large amount than the increase in inflation, bringing to an initial increase in the real interest rate level.

The terms of trade and net exports display similar paths with initial positive response and decrease to reach steady state values persistently. This yields to a stationary behavior for those variables which is a property of the model. The nominal exchange rate move in the wrong direction[34] with a persistent decline more pronounced for PT and HT. The same patterns are displayed by the domestic and CPI price responses with a hump-shaped response of domestic price under HT and PT. The unit root in the price level is then mirrored by the unit root in the exchange rate. However, the responses of those three variables are quiet different under HT and PT targeting where the path revert to initial values after a while. The initial fall in the responses of domestic and CPI prices under HT and PT are followed in a hump-shaped patterns (more pronounced for HT targeting) with a flat rise toward steady state values. Furthermore, the impact on foreign aggregates is negligible, by construction, implying that the world interest rate remains unchanged. There is an anticipated appreciation of the domestic currency induced by the uncovered parity (UIP). Thus, the depreciation of the exchange rate explains the paths followed by the inflation rates that jump up in the period of shocks and then revert back to initial levels.

The dynamic effects of foreign technology shocks are displayed in Figure (3). In this case, the foreign monetary authority reacts to shocks by lowering the world interest rate to stabilize inflation. The domestics react in the same way by reducing their own interest rate to counterpart the real appreciation caused by the foreign policy[35], followed by a gradual depreciation until both interest

[34] One can believe that monetary contraction generates an appreciation of the domestic currency. Thus, capital outflows cause demand for foreign exchange to increase and not to fall as is the case here.

[35] With our earlier assumption about the foreign monetary policy that stabilizes price levels at equilibrium, a reduction in world interest rate implies an appreciation of home currency.

rates converge to their steady state levels.

Moreover, the responses of output gap, domestic and CPI inflations display a hump-shaped patterns for both HT and PT targeting. While the terms of trade is more stable under HT and PT targeting, the responses remain persistently above the initial levels for this variable. The same patterns are displayed for net exports under the 3 regimes.

The fall in domestic and CPI prices is more accentuated with this shock under IT. The response of nominal interest rate takes the hump-shaped form and then reverts to the initial value. The main difference between home and foreign technology shocks' responses is registered for the exchange rate with the response under all regimes remaining persistently bellow the initial levels.

Finally the response functions of the macro variables to unit innovations in the policy shocks reveal that all variables display the same patterns under the 3 regimes. However, the responses of domestic and CPI price levels under IT targeting is also persistent bellow the steady state levels. Interestingly, the figure shows a persistent responses of the exchange rate above the initial values for all regimes. This can be explained by the negligible effect of the policy innovations on foreign variables. Indeed, the rise in nominal interest rate is followed by an instant appreciation of the currency and an anticipated depreciation since the world interest rate remains unchanged. The movements in assets and goods generate such movements in exchange rate and price levels.

In order to conclude the quantitative analysis, the second moments of some macro variables under the three monetary policy regimes are reported in Table (8). For each variable we report standard deviation beginning with a benchmark model where the monetary authority targets a pure domestic inflation targeting by simply setting $\hat{\pi}_{H,t} = \bar{x}_t = 0$.

The second moment analysis confirms the visual analysis of IRFs. Indeed, the IT regime requires more volatility in price levels and exchange rate than what is given under the other regimes. The terms of trade is more stable under HT where its volatility is about a half the IT's one. Intuitively, Under IT the price level follows I(1) process. Hence, price adjustment after the occurrence of shocks is carried out very sluggishly, which leads to a slothful inflation behavior. In fact, the lagged price levels have little direct influence on current price level. In this case, the price adjustment made after the occurrence of shocks inevitably entails a sharp inflation fluctuation. Furthermore, the hybrid target can be set taking into account both the inflation and its corresponding price level so that past price level affects current price level, but its influence is not as strong as it is under IT. In this case, the path of price level will lie between those under IT and PT. As pointed out by Kobayashi (2004), it can be said that implementing hybrid targeting can achieve, relatively, moderate inflation volatility by appropriately incorporating both the sluggish nature of inflation adjustment under IT and the rapid nature of inflation response under PT. More generally, and as shown in Galí and Monacelli (2004), we find that, across regimes, the higher the terms of trade volatility, the lower the volatility of inflation and output gap, and therefore the higher the resulting welfare score.

4 Welfare Analysis of Alternative Regimes

The analysis of welfare implications of different monetary policy rules has become an important field of study (Taylor, 1999). The main idea concerns the importance for policy makers to have a set of tools that allows them to predict the effects of switching from one policy rule to another. Then, it will be worthwhile to investigate the welfare implications of the hybrid regime compared to other monetary policy targeting considered in this work. Whereas, the quadratic approximation of the objective function is not simple to derive in an open economy model with sticky prices. A popular measure uses then the volatility of inflation and output gap besides the utility function.

Furthermore, a welfare maximizing central bank may target CPI inflation, CPI price or a combination of specific price and inflation path. In fact, the key difference in approaches to inflation/price level targeting is between a stable, long-run price level and maintaining a particular rate of inflation. Those rule-based approaches have different welfare implications. Aoki (2001) and Devereux and Engel (2000) show that in a closed economy with sticky prices and backward-looking behavior, the optimal policy entails perfect stabilization of inflation rate. In fact, Svensson (1999) shows that if monetary authority has price-level-targeting objective this may reduce inflation variability without affecting output variability. This 'free-lunch' result depends on substantial endogenous output persistence in the New-Classical Philips curve. Dittmar and Gavin (2000) extend this analysis to the case where expectations are forward-looking in a New-Keynesian Philips curve. They show that the free-lunch argument applies without the need for persistence terms. Thus, assigning the central Bank a price level targeting objective appears to improve welfare if expectations are forward-looking or if there is substantial endogenous persistence. Likewise, Vestin (2000) argues in a purely forward-looking model that price level targeting will provide more efficient outcomes than inflation targeting. Nessen and Vestin (2000), in a closed economy model, suggest that a hybrid targeting will provide better outcomes than only targeting inflation if the Philips cure has forward-and backward-looking components. In purely forward-looking models They show that hybrid targeting is dominated by price level targeting.

The evaluation of the household's welfare in the small open economy can be expressed as a fraction of steady state consumption. Indeed, Galí and Monacilli (2004) derive a second-order approximation to the utility function of the domestic consumer in a SOE model similar to the one we study here[36]. This second order approximation[37], expressed as a fraction of steady state consump-

[36]See Appendix 4 in Gali and Monacelli (2004) for the details of derivations of the welfare loss function. However, the derivation is restricted to the special case of log utility and unit elasticity of substitution between different goods (i.e., $\sigma = \eta = \theta = 1$) to derive an exact expression, otherwise, it's more complicated to derive it. We use this approximation for comparison purpose between different regimes without loss of generality. For more discussion about welfare analysis in the log-linearized model the reader is referred to Kim and Kim (2003) and Schmitt-Grohe and Uribe (2004).

[37]After dropping terms independent of policy and those of high order.

tion, can be written as:

$$\Xi = -\frac{(1-\alpha)}{2}\sum_{t=0}^{\infty}\beta^t[\frac{\xi}{\kappa}\hat{\pi}_{H,t}^2 + (1+\phi)\bar{x}_t^2]. \quad (39)$$

Hence, the welfare measure of our economy can be computed by taking an unconditional expectation on (39), the expected welfare losses of any policy in term of the variances of domestic inflation and the output gap is then:

$$F = -\frac{(1-\alpha)}{2}[\frac{\xi}{\kappa}var(\hat{\pi}_{H,t}) + (1+\phi)var(\bar{x}_t)],$$

using this expression we can compare different monetary policies to assess their welfare implications and highlight welfare cost among regimes.

In Table (8) we report the standard deviations and the welfare losses associated with various regimes: HT regime, IT regime and finally PT regime. We assume that central bank wants to minimize variation in domestic inflation ($\hat{\pi}_{H,t}$). Indeed, since most of the countries that use inflation targeting are likely to target CPI inflation rather than home inflation (namely producer price inflation), HT has been essentially compared to CPI inflation targeting regime (IT in the text). We use parameter estimates presented in Tables (4 to 6) to compute losses in utility function. Entries for loss function are percentage units of steady state consumption.

The results show that the reduction in the welfare loss results from a decrease in output and domestic inflation volatility varying from IT to PT regime. On the other hand, the CPI inflation targeting leads to a level of losses in the welfare loss function much higher than one obtained by the two other regimes. Likewise, the loss of the two targeting regime, HT and PT, is significantly similar. In fact, as usually found in the literature[38], the welfare losses are quantitatively small for all regimes.

[38] Kollman (2002) and Smets and Wouters (2003) are recent examples of papers where the welfare implications of monetary policy are investigated for small open economy.

Moreover, in closed-economy models, the case for price stability is quite robust. Its desirability is associated with the possibility of reproducing the fluctuations that would arise in a flexible-price world which produce higher welfare gain (see for instance Goodfriend and King, 2001). In the open economy models, the different dynamics of the terms of trade are associated with a welfare loss, relative to the monetary policy regime. Indeed, as shown in the quantitative evaluation of the second moments conducted above, the terms of trade dynamics imply a substantially larger deviation on the welfare function as the associated volatility increases. Intuitively, this can lead to different results if the open economy analysis is adopted to assess welfare-maximizing monetary policy.

5 Concluding Remarks

This paper investigates the hybrid inflation/price-level targeting in a New Keynesian perspective. To this end, we estimate generalizations of the models proposed by Galí and Monacelli (2004) and Monacelli (2003). Both papers develop a small open economy model incorporating many of the microfoundations appearing in a closed economy within the New Keynesian framework (see, for instance, Clarida, Galí, and Gertler, 2000 and Woodford, 2003) as was recently used for the analysis of monetary policy. The model's open economy version allows for the possibility that international trade in goods and financial assets affect the evolution of the domestic economy, thus giving rise to richer dynamics in the model, including our assumption of complete market securities.

Following the contributions of Schorfheide (2000) and Smets and Wouters (2003) this paper adopts a Bayesian methodology. Regarding other recent approaches for inference in DSGE models, by simulating posterior distributions, this method makes it possible to take into consideration a characterization of all uncertainty surrounding the estimates of structural parameters. The present analysis is however more closely related to the analysis made by Lubik and Schorfheide (2003) in order to estimate a simplified version of the Galí and Monacelli (2004) model. In our empirical work, we use Australian, Canadian, New Zealand and UK data for our estimation.

Furthermore, in light of the considerable attention in recent macroeconomic literature given to monetary policy formulations in terms of interest rate rules, we adopt this formulation to construct three regimes. In addition for the purpose of comparison to the hybrid regime, we analyze the IT and PT regimes. Our results chow that the hybrid targeting can lead to a successful monetary policy strategy that lies between the two extremes, yet without any major loss in the welfare function. Likewise, in this kind of model, including more nominal rigidities, particularly sticky wages or the type of indexation are expected to change the results obtained here in a crucial manner. Further research is then necessary to establish the way these frictions are likely to alter this finding.

References

An, S. and Schorfheide, F., 2005, 'Bayesian analysis of DSGE models', *Manuscript*, University of Pennsylvania.

Ambler, S., Dib, A. and Rebei, N. 2004, 'Optimal Taylor Rules in an Estimated Model of a Small Open Economy', *Bank of Canada Working Paper,* 2004-36.

Aoki, K., 2001, 'Optimal Policy Responses to Relative-Price Changes', *Journal of Monetary Economics* 48, pp. 55-80.

Ball, L., 1999, 'Policy Rules for Open Economies', in: *John B. Taylor (ed.), Monetary Policy Rules, University of Chicago Press*, Chicago.

Backus, D., Kehoe, P.K and Kydland, F. E., 1995, 'International Business Cycles: Theory and Evidence', *in Frontiers of Business Cycle Research*, *Edited by Thomas F. Cooley*, Princeton University Press.

Batini, N. and Yates, A., 2003, 'Hybrid inflation and price level targeting', *Journal of Money, Credit and Banking*, 35, pp. 283–300.

Bergin, P., 2003. 'Putting the 'New Open Economy Macroeconomics' to a Test', *Journal of International Economics,* 60, pp. 3-34.

Berg, C. and Jonung, L., 1999, 'Pioneering price level targeting: the Swedish experience 1931–1937', *Journal of Monetary Economics*, 43, pp. 525–51.

Bernanke, B. S., Laubach, T., Mishkin, F. S. and Posen, A. S., 1999, 'Inflation Targeting Princeton', *Princeton University Press*.

Bils, M. and Klenow, P. J., 2002. 'Some Evidence on the Importance of Sticky Prices', *NBER working paper,* no 9069, 2002.

Calvo, G., 1983, 'Staggered Prices in a Utility Maximizing Framework', *Journal of Monetary Economics*, 12, pp. 383-398.

Cecchetti, S. G. and Kim, J., 2003, 'Inflation targeting, price path targeting and output variability', *NBER Working Paper,* no 9672.

Clarida, R., Galí, J. and Gertler, M., 2000, 'Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory', *Quarterly Journal of Economics,* 115(1), pp. 147-180.

Clarida, R., Galí, J. and Gertler, M., 2002, 'A Simple Framework for International Monetary Policy Analysis', *Journal of Monetary Economics*, vol., 49, no. 5, pp. 879-904.

Cochrane, J. H., 1997, 'Where is the Market Going? Uncertain Facts and Novel Theories' *NBER Working Paper,* 6207.

Corsetti, G., and Pesenti, P., 2001, 'Welfare and Macroeconomic Interdependence', *Quarterly Journal of Economics*, 421-445.

Devereux, M., Engel, C., 2000, 'Monetary Policy in the Open Economy Revisited: Price Setting and Exchange Rate Flexibility', *NBER Working Paper,* no 7665.

Dittmar, R., Gavin, W. T. and Kydland, F. E., 1999, 'Price level uncertainty and inflation targeting', *Federal Reserve Bank of St. Louis Review*, July/August, pp. 23–33.

Dittmar, R. and Gavin, W.T., 2000, 'What Do New-Keynesian Phillips Curves Imply for Price-Level Targeting?', *Federal Reserve Bank of St. Louis Review,* vol. 82 (2), pp. 21–30.

Erceg, C. J., Henderson, D.W. and Levine, A.T., 2000, 'Optimal Monetary Policy with Staggered Wage and Price Contracts', *Journal of Monetary Economics,* 46 pp. 281-313.

Fischer, S., 1994, 'Modern Central Banking', *In The Future of Central Banking: The Tercentenary Symposium of the Bank of England*, F. Capie, C. Goodhart, S. Fischer, and N. Schnadt, pp. 262–308. Cambridge: Cambridge University Press.

Fuhrer, J. C. and Moore, G. R., 1995, 'Inflation persistence', *Quarterly Journal of Economics* 111 (1), pp. 127-159.

Galí, J. and Monacelli, T., 2004, 'Monetary Policy and Exchange Rate Volatility in a Small Open Economy', *The Review of Economic Studies*, Volume 72, Number 3.

Geweke, J., 1999, 'Using Simulation Methods for Bayesian Econometric Models: Inference, Development, and Communication', *Econometric Reviews*, 18, pp. 1-126.

GOODFRIEND, M. S., and KING, R. G., 2001, 'The Case for Price Stability', *NBER Working Paper,* no 8423.

Haldane, A., 1995, 'Targeting Inflation', *London: Bank of England.*

Haldane, A.G. and Salmon, C.K. 1995, 'Three Issues in Inflation Targets', *In Targeting Inflation, edited by A.G. Haldane*, pp. 170–201. London: Bank of England.

Justiniano, A. and Preston, B., 2004, 'Small Open Economy DSGE Models-Specification, Estimation, and Model Fit', *Manuscript*, International Monetary Fund and Department of Economics, Columbia University.

Justiniano, A. and Preston, B., 2005, 'Can structural small open economy models account for the influence of foreign disturbances?', *Manuscript*, Columbia University.

Kim, K.S. and Kim, J., 2003, ’SpuriousWelfare Reversals in International Business CycleModels’, *Journal of International Economics* 60, pp. 471-500.

Kobayashi, T., 2004, ’Hybrid Inflation-Price-Level Targeting in an Economy With Output Persistence’, *Scottish Journal of Political Economy, Scottish Economic Society*, vol. 51(5), pp. 641-653.

Kollmann, R., 2002, ’Monetary Policy Rules in the Open Economy: Effects on Welfare and Business Cycles’, *Journal of Monetary Economics*, 49, pp.989-1015.

Kydland, F. and Prescott, E., 1982, ’Time to Build and Aggregate Fluctuations’, *Econometrica*, 50, pp. 1345-70.

Lane, P. R., 2001, ’The New Open Economy Macroeconomics: A Survey’, *Journal of International Economics,* 54, 235-266.

Lubik, T. A. and Schorfheide, F., 2003, ’Do Central Banks Respond to Exchange Rate Movements? A Structural Investigation’, *Mimeo,* Department of Economics, Johns Hopkins University

McCallum, B. T. and Nelson, E., 2000, ’Monetary Policy for an Open Economy: An Alternative Framework with Optimizing Agents and Sticky Prices’, *Oxford Review of Economic Policy*, Vol. 16, pp. 74-91.

Monacelli, T., 2003, ’Monetary Policy in a Low Pass-Through Environment’ *Working Papers No. 228, IGIER.*

Nessen, N. M., 2002, ’Targeting inflation over the short, medium and long term’, *Journal of Macroeconomics*, 24, pp. 313–29.

Nessen, M. and Vestin, D., 2000, ’Average inflation targeting’, *Sveriges Riksbank Working Paper Series* no. 119.

Obstfeld, M. and K. Rogof, 1995 ’Exchange Rate Dynamics Redux’, *Journal of Political Economy*, 103, 624-660.

Schmitt-Grohe, S. and Uribe, M., 2004, ’Optimal Operational Monetary Policy in the Christiano-Eichenbaum-Evans Model of the U.S. Business Cycle’, *mimeo* Duke University.

Schorfheide, F., 2000, ’Loss Function-Based Evaluation of DSGE Models’, *Journal of Applied Econometrics*, 15, pp. 645-670.

Smets, F. and Wouters, R., 2003, ’An Estimated Stochastic Dynamic General Equilibrium Model of the Euro Area’, *Journal of the European Economic Association,* 1, pp. 1123-75.

Smith, A. A., 1993, ’Estimating Nonlinear Time-Series Models using Simulated Vector Autoregressions’, *Journal of Applied Econometrics* 8, pp. 63-84.

Svensson, L. E. O., 1995, ’Optimal Inflation Targets, ’Conservative’ Central Banks, and Linear Inflation Contracts’, *CEPR Discussion Papers 1249, C.E.P.R. Discussion Papers*.

Svensson, L. E. O.,1999, ’Price-Level Targeting versus Inflation Targeting: A Free Lunch?’ Journal of Money, Credit and Banking 31 (3) Part 1, pp. 277–95.

Svensson, L. E. O., 2000, ’The Zero Bound in an Open Economy: A Foolproof Way of Escaping from a Liquidity Trap’, *NBER Working Paper,* 7957.

Taylor, J. B., 1993, ’Macroeconomic Policy in a World Economy’ *New York : W. W. Norton*.

Taylor, J. B., 1996, ’Policy Rules as a Means to a More Effective Monetary Policy’, *Bank of Japan Monetary and Economic Studies*, Vol. 14(1), pp. 28-39.

Taylor, J. B., 1999, ’A Historical Analysis of Monetary Policy Rules’, *in J.B. Taylor ed., Monetary Policy Rules*, Chicago: U. of Chicago Press.

Taylor, J. B., 2001, 'The Role of the Exchange Rate in Monetary-Policy Rules', *American Economics Review*, 91 (2) pp. 263-267.

Vestin, D., 2000, 'Price level targeting versus inflation targeting in a forward looking model', *Sveriges Riksbank Working Paper Series* no. 106.

Woodford, M., 2000, 'Pitfalls of Forward-Looking Monetary Policy', *American Economic Review,* 90(2), pp. 100-104.

Woodford, M., 2003, 'Interest and Prices: Foundations of a Theory of Monetary Policy', *Princeton University Press*.

Yun, T., 1996, 'Monetary Policy, Nominal Price Regidity, and Business Cycles', *Journal of Monetary Economics*, 37, pp. 345-70.

Table 1: PRIOR DISTRIBUTION

(For Canada)

Parameters	Range	Density	Mean	Prior Std Deviation
μ	$\mathbb{R}^+$	Gamma	1.2	0.0200
ϕ	$\mathbb{R}^+$	Gamma	3	0.0200
ξ	$\mathbb{R}^+$	Gamma	6	0.2000
θ	$\mathbb{R}^+$	Gamma	1.5	0.1000
σ	$\mathbb{R}^+$	Gamma	1.5	0.2000
α	[0,1)	Beta	0.4	0.1000
ψ	[0,1)	Beta	0.75	0.2000
χ	[0,1]	Beta	0.6	0.2000
ϕ_p	[0,1)	Beta	0.5	0.1250
ϕ_y	[0,1)	Beta	0.4	0.0200
ρ_A	[0,1)	Beta	0.76	0.0500
ρ_{y*}	[0,1)	Beta	0.86	0.0500
σ_A	$\mathbb{R}^+$	InvGamma	1.89	4.0000*
σ_{y*}	$\mathbb{R}^+$	InvGamma	1.89	4.0000*
σ_r	$\mathbb{R}^+$	InvGamma	0.50	4.0000*

$Note$: * For the Inverse Gamma distribution we display priors for s and v.

Table 2: PRIOR DISTRIBUTION

(For Other Countries)

			Australia		New Zealand		United Kingdom	
Parameters	Range	Density	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation
ρ_A	[0,1)	Beta	0.20	0.1000	0.20	0.1000	0.20	0.1000
ρ_{y*}	[0,1)	Beta	0.90	0.0500	0.90	0.0500	0.90	0.0500
σ_A	$\mathbb{R}^+$	InvGamma	1.50	4.0000	1.50	4.0000	1.50	4.0000*
σ_{y*}	$\mathbb{R}^+$	InvGamma	1.50	4.0000	1.50	4.0000	1.50	4.0000*
σ_r	$\mathbb{R}^+$	InvGamma	0.50	4.0000	0.50	4.0000	0.50	4.0000*

$Note$: All other parameters are given the same prior means and standard deviations as in Table (2).

* For the Inverse Gamma distribution we display priors for s and v.

Table 3: GMM ESTIMATION RESULTS

$(Canada)$

Parameters	Point Estimates	Std-Error	T-Stat	P-Value
ϕ_p	1.885110	45.404452	0.0400	0.9669
χ	-0.535269	37.271694	-0.01000	0.9885
ϕ_y	0.548058	21.282058	0.03000	0.9795

Notes: The table reports GMM estimates for the parameters of the monetary policy rule (27). We use Cliff 's GMM and MINZ matlab packages to compute the estimations. This computer package is available at: http//:mcliff.cob.vt.edu/

Table 4: PARAMETER ESTIMATION RESULTS

(Hybrid Targeting Regime for all Countries)

	Canada		Australia		New Zealand		United Kingdom	
Parameters	Mean	90% Interval	Mean	90% Interval	Mean	90% Interval	Mean	90% Interval
μ	1.202	[0.8733,1.5217]	1.196	[0.8689,1.5232]	1.201	[0.8668,1.5142]	1.204	[0.9191,1.523]
ϕ	2.847	[2.5298,3.1706]	2.844	[2.5239,3.1175]	2.827	[2.5088,3.1382]	2.863	[2.5398,3.124]
ξ	5.931	[5.6047,6.2490]	5.942	[5.6233,6.2731]	5.956	[5.6347,6.2821]	5.941	[5.6592,6.244]
θ	1.488	[1.3279,1.6553]	1.491	[1.3338,1.6714]	1.491	[1.3305,1.6519]	1.489	[1.3360,1.656]
σ	0.862	[0.6826,1.0310]	1.010	[0.8172,1.2123]	2.209	[1.8372,2.4851]	0.875	[0.6890,1.039]
α	0.359	[0.2748,0.4498]	0.356	[0.2681,0.4250]	0.253	[0.1608,0.3390]	0.372	[0.2799,0.443]
ψ	0.611	[0.6110,0.6113]	0.611	[0.6110 0.6112]	0.807	[0.7761,0.8397]	0.611	[0.6110,0.612]
χ	0.205	[0.0390,0.3650]	0.323	[0.1692,0.4630]	0.194	[0.0386,0.3400]	0.395	[0.2231,0.566]
ϕ_p	0.854	[0.7780,0.9345]	0.885	[0.8150,0.9597]	0.769	[0.6498,0.8955]	0.888	[0.8190,0.949]
ϕ_y	0.251	[0.2510,0.2514]	0.506	[0.4709,0.5509]	0.415	[0.3728,0.4552]	0.345	[0.3448,0.345]
ρ_a	0.954	[0.9223,0.9854]	0.920	[0.8693,0.9673]	0.864	[0.8008,0.9303]	0.957	[0.9266,0.996]
ρ_{y*}	0.928	[0.8871,0.9741]	0.936	[0.8934,0.9740]	0.867	[0.8105,0.9263]	0.936	[0.8957,0.976]
σ_A	0.698	[0.6123,0.7854]	0.758	[0.6619,0.8573]	1.115	[0.9454,1.2769]	0.563	[0.4866,0.631]
σ_r	2.317	[2.0323,2.6227]	3.549	[3.5418,4.0835]	4.481	[3.8099,5.1840]	2.548	[2.2966,2.850]
σ_{y*}	0.291	[0.2248,0.3580]	0.321	[0.2439,0.3971]	0.317	[0.2383,0.3938]	0.292	[0.2205,0.356]

$Note$: The table reports posterior means and 90% probability intervals. We use Dynare Code to compute estimations. The Code can be downloaded from : $http://www.cepremap.cnrs.fr/dynare/$

Table 5: PARAMETER ESTIMATION RESULTS

(Price Targeting Regime)

	Canada		Australia		New Zealand		United Kingdom	
Parameters	Mean	90% Interval	Mean	90% Interval	Mean	90% Interval	Mean	90% Interval
μ	1.201	[0.8734,1.5834]	1.204	[0.8864,1.5280]	1.198	[1.1665,1.2293]	1.199	[1.1685,1.231]
ϕ	2.825	[2.5269,3.2041]	2.717	[2.4083,3.0261]	3.005	[2.9803,3.0427]	2.778	[2.4616,3.092]
ξ	5.944	[5.6328 6.2935]	5.913	[5.6049,6.2511]	6.111	[5.8294,6.5131]	5.999	[5.9680,6.033]
θ	1.492	[1.3384,1.6458]	1.481	[1.3224,1.6351]	1.519	[1.3750,1.7086]	1.494	[1.3344,1.656]
σ	0.914	[0.7248,1.0804]	0.820	[0.6829,0.9760]	2.209	[1.8372,2.4851]	1.489	[1.4560,1.521]
α	0.363	[0.2779 0.4475]	0.161	[0.1350,0.1967]	0.267	[0.2314,0.3827]	0.346	[0.2692,0.425]
ψ	0.611	[0.6112,0.6112]	0.839	[0.8203,0.8613]	0.659	[0.6219,0.6904]	0.816	[0.7874,0.845]
χ	0.000	–	0.000	–	0.000	–	0.000	–
ϕ_p	0.879	[0.8062,0.9551]	0.834	[0.7345,0.9361]	0.022	[0.0184,0.0224]	0.816	[0.7155,0.910]
ϕ_y	0.510	[0.4701,0.5474]	0.516	[0.4750,0.5549]	0.138	[0.0869,0.1793]	0.428	[0.3891,0.470]
ρ_A	0.9543	[0.9253,0.9890]	0.921	[0.8733,0.9696]	0.662	[0.6479,0.6709]	0.958	[0.9261,0.997]
ρ_{y*}	0.921	[0.8766,0.9774]	0.883	[0.8354,0.9308]	0.868	[0.8669,0.8835]	0.831	[0.7782,0.887]
σ_A	0.6982	[0.6113,0.7862]	0.758	[0.6598,0.8576]	0.176	[0.1764,0.1764]	0.562	[0.4885,0.632]
σ_r	2.6867	[2.4141,2.8130]	5.655	[4.9059,6.4185]	0.907	[0.7182,1.0198]	3.871	[3.3604,4.390]
σ_{y*}	0.299	[0.2223,0.3596]	0.303	[0.2267,0.3749]	0.181	[0.1764,0.1878]	0.215	[0.1863,0.239]

Table 6: PARAMETER ESTIMATION RESULTS

(Inflation Targeting Regime)

	Canada		Australia		New Zealand		United Kingdom	
Parameters	Mean	90% Interval	Mean	90% Interval	Mean	90% Interval	Mean	90% Interval
μ	1.178	[0.8762,1.5061]	1.196	[1.1554 1.2354]	1.174	[0.9174,1.3353]	1.200	[1.1678,1.234]
ϕ	2.905	[2.6302,3.2907]	3.065	[2.8348 3.4165]	3.617	[3.3456,3.7418]	2.735	[2.3987,3.048]
ξ	5.914	[5.6356,6.2749]	6.001	[5.9820 6.0426]	6.196	[6.1467,6.2295]	5.999	[5.9668,6.032]
θ	1.455	[1.3264,1.6469]	1.466	[1.3452 1.6587]	1.445	[1.4363,1.4453]	1.494	[1.3316,1.653]
σ	0.831	[0.6858,1.0402]	1.484	[1.4612 1.5212]	1.571	[1.5639,1.5710]	1.489	[1.4569,1.521]
α	0.423	[0.3265,0.4887]	0.496	[0.2314,0.3827]	0.627	[0.6207,0.6241]	0.364	[0.2733,0.455]
ψ	0.611	[0.6111,0.6113]	0.611	[0.6110 0.6112]	0.611	[0.6115,0.6118]	0.830	[0.7996,0.861]
χ	1.000	–	1.000	–	1.000	–	1.000	–
ϕ_p	0.896	[0.8159,0.9476]	0.849	[0.8276 0.9534]	0.684	[0.6857,0.6863]	0.816	[0.6965,0.931]
ϕ_y	0.251	[0.2514,0.2514]	0.373	[0.3496 0.4293]	0.534	[0.5332,0.5339]	0.432	[0.3901,0.475]
ρ_A	0.950	[0.9220,0.9840]	0.677	[0.6737 0.6964]	0.205	[0.2049,0.2053]	0.696	[0.6968,0.697]
ρ_{y*}	0.948	[0.8919,0.9696]	0.944	[0.9077 0.9706]	0.961	[0.9609,0.9625]	0.789	[0.7312,0.846]
σ_A	0.722	[0.6093,0.7815]	1.148	[0.9663 1.2401]	2.203	[2.2634,2.5486]	0.945	[0.8322,1.060]
σ_r	2.021	[1.7625,2.3397]	2.533	[2.4029 2.6668]	1.401	[1.3901,1.6700]	4.048	[3.4785,4.677]
σ_{y*}	0.292	[0.2226,0.3511]	0.240	[0.2001,0.2651]	0.241	[0.2036,0.2651]	0.213	[0.1863,0.238]

Table 7: POSTERIOR THEORETICAL VARIANCE DECOMPOSITION

$(Canada)$

	Output	Price Level	Interest Rate
Policy Shock	0.0000	0.4260	0.6170
	[0.000,0.000]	[0.283,0.617]	[0.477,0.767]
Technology Shock	1.0000	0.0010	0.0000
	[1.000,1.000]	[0.000,0.010]	[0.000,0.000]
World Output Shock	0.0000	0.5730	0.3830
	[0.000,0.000]	[0.383,0.716]	[0.233,0.523]

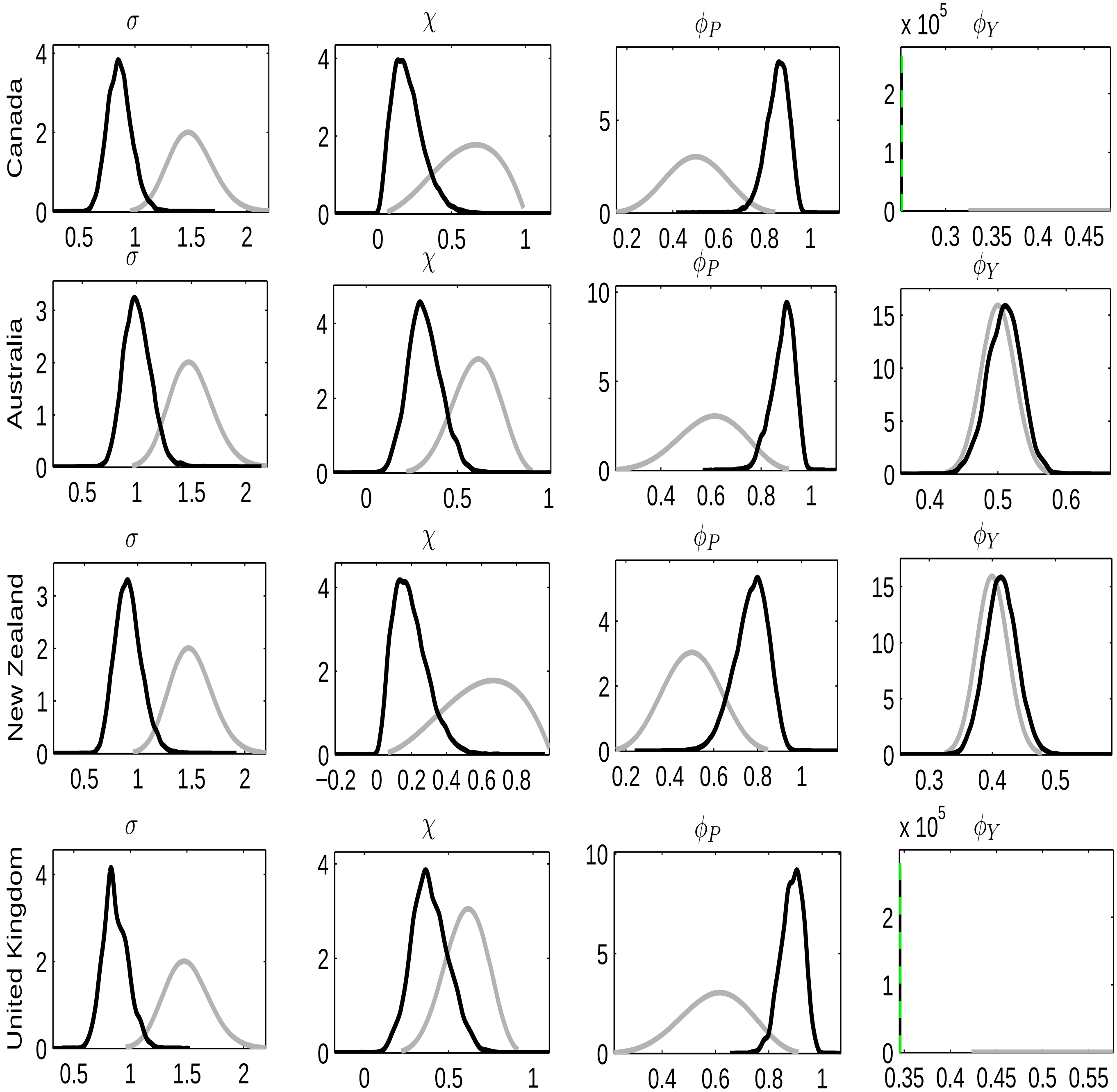
Note: Posterior means and 90% probability intervals are reported in this table.

Table 8: THE VOLATILITY AND WELFARE LOSS UNDER ALTERNATIVE POLICY REGIMES (CANADA)

(Standard Deviations in %)

	HT Regime	IT Regime	PT Regime
Output Gap	0.020058	0.033944	0.015211
Domestic Inflation	0.020492	0.030867	0.016340
CPI Inflation	0.011335	0.018448	0.011090
Nominal Interest Rate	0.011889	0.019834	0.011653
Exchange Rate	13.13689	13.47787	13.29337
CPI Price Level	0.012846	1.626283	0.010661
Domestic Price Level	0.076807	1.505952	0.067407
Terms of Trade	0.195639	0.453456	0.178466
Var(Domestic Inflation)	0.041992	0.095278	0.026701
Var(Output Gap)	0.040232	0.115221	0.023137
Welfare Loss (F)	-0.367348	-0.777836	-0.229519

Figure 1: PRIOR AND POSTERIOR DISTRIBUTIONS OF THE SHOCK PARAMETERS



Note: We use Dynare code to generate the Posterior estimations using 500.000 iterations with 5 replications for the MH-Algorithm.

Figure 2: IMPULSE RESPONSE FUNCTIONS TO A 1% SHOCK IN HOME TECH. INNOVATIONS

$(Canada)$

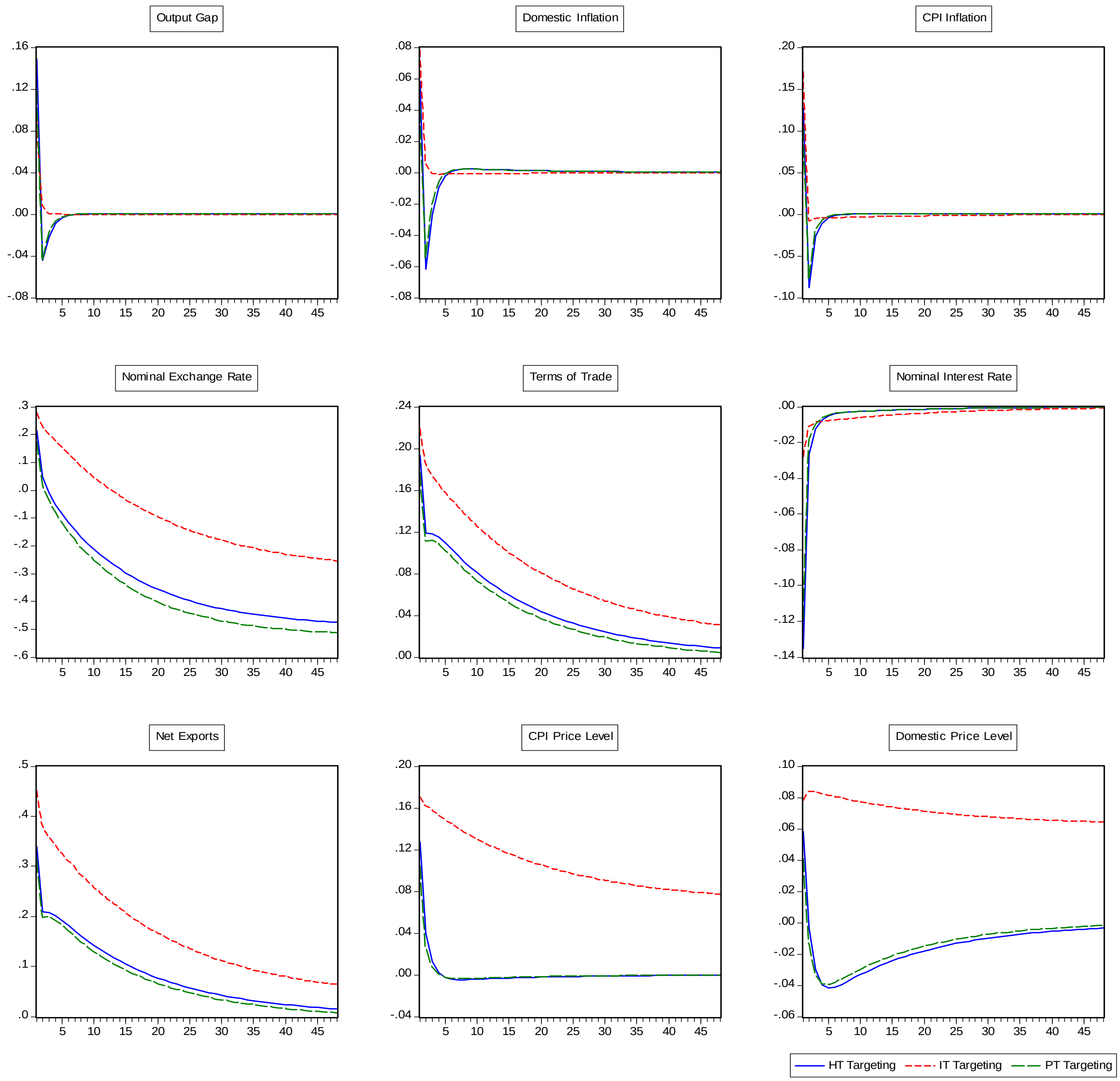


Figure 3: IMPULSE RESPONSE FUNCTIONS TO A 1% SHOCK IN FOREIGN TECH. INNOVATIONS

$(Canada)$

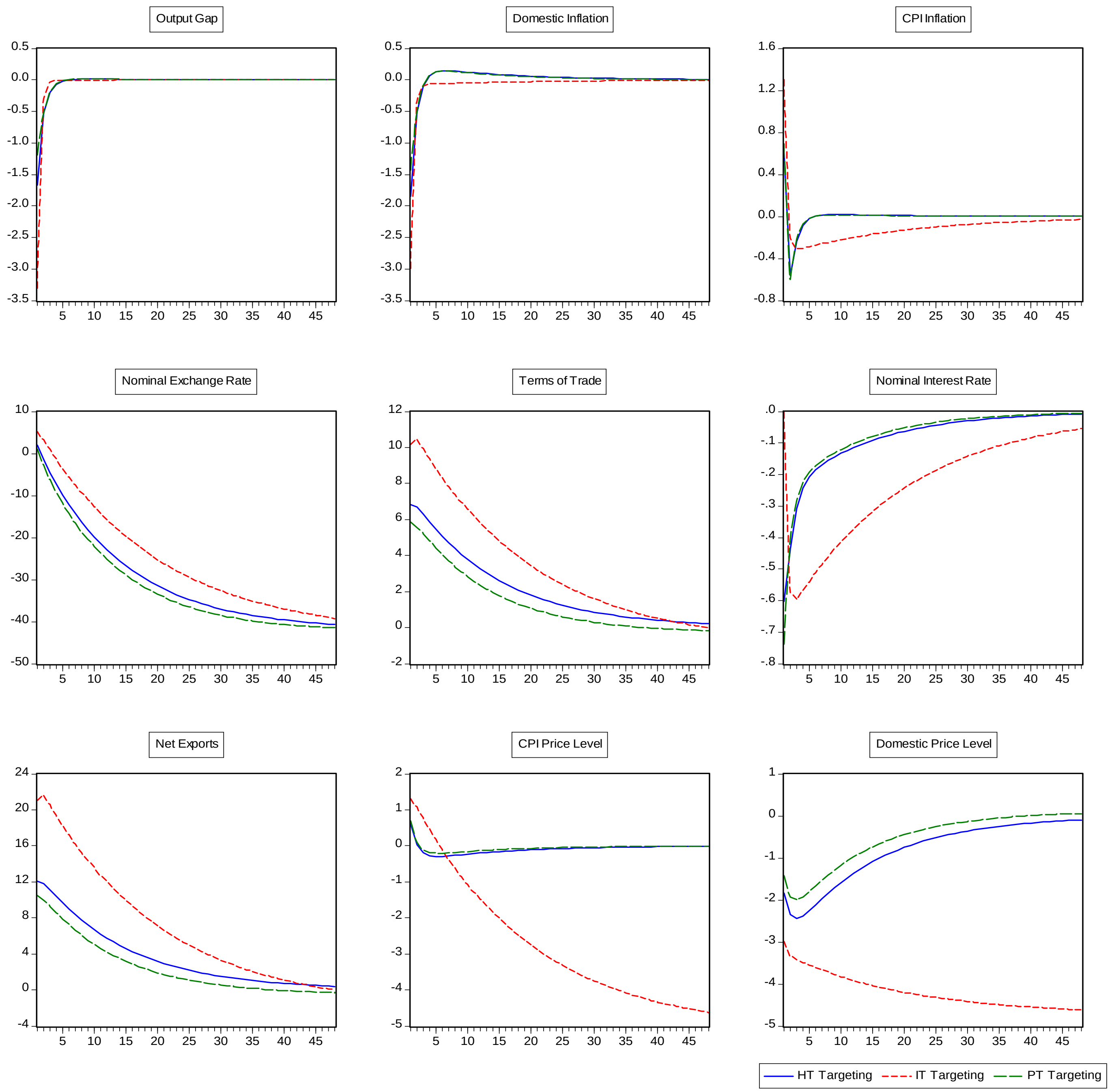


Figure 4: IMPULSE RESPONSE FUNCTIONS TO A 1% SHOCK IN INTEREST RATE RULE INNOVATIONS

$(Canada)$