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Abstract

This paper compares the capability of interest rate rules, namely, inflation targeting (IT), price-level targeting (PT) and a combination of the two regime in a hybrid rule (HT) to improve social welfare in a small-open-economy, DSGE-based, New-Keynesian model. Allowing for some inflation inertia, we develop a small-open-economy version of the Calvo sticky-price model to investigate the relative ability of IT, PT and HT to minimize the variability in domestic inflation and the output gap. Our analyses show that hybrid targeting outperforms other specifications and produces quantitatively good results, compared to those regimes that target only price levels or inflation rates.

Keywords: Small-Open Economy, Monetary Policy, Hybrid Targeting

JEL classification: E31, E52, E58.

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1 Introduction

Over the past two decades, many developed economies have been radically transformed. These countries, after shifting to a new monetary policy regime, now show a low rate of inflation, a declining public and external debt, and the private sector is more concerned about costs as well as more productive and efficient than during the 1990's. Because of unsatisfactory monetary policy performance, countries such New Zealand, Canada, Australia, Sweden and U.K. introduced policies targeting inflation rate to achieve price stability. Still controversial is the definition of the price stability and how to achieve it. Indeed, The definition of price stability remains unclear. The debate has mainly focused on whether the inflation rate or the price-level path should be the policy target. More specifically, under inflation targeting (hereafter, IT), the central bank tries to bring the inflation rate to the target, while it aims to bring the price level to the initial level of the price index at the time the regime is established with price-level targeting (hereafter, PT). An alternative method considers a hybrid target (hereafter, HT), based on a weighted average of an inflation target and price-level target. This paper addresses this particular issue in a small open economy setting.

The difference between the three regimes can be captured in their effects on price level. The IT regime aims to maintain a stable path for future inflation even if this leads to a unit root (non stationarity) in the price level. The PT regime imply a stable path for price level leading at the same time to a stationary price level around the targeted value and a stationary inflation rate around zero. The hybrid regime combines the characteristics of IT and PT by incorporating an average of inflation and price level target, this policy (HT) targets an average inflation of several forthcoming periods rather than targeting one-period ahead (IT) or infinite horizon (PT).

The present work lays out a small-open-economy model with Calvo-type staggered price setting. Moreover, the benchmark model allows for some inflation inertia by including price indexation to past inflation. Introducing price indexation results in a lagged inflation term in the price equation and, therefore, a better fit for inflation persistence. The resulting specification enables us to focus on the monetary-policy implications of different regimes, namely inflation targeting, price-level targeting and hybrid targeting. We also address the welfare implications of these policy regimes.

Our results suggest that allowing for some base drift in the price level (HT), small-open-economy welfare is improved. Indeed, these findings are consistent with the fact that hybrid inflation/price-level targeting performs well and provides an alternative method for conducting successful monetary policy in the case of a small-open economy, without the shortcomings of the other monetary-policy regimes considered in this work (IT and PT). Following a hybrid targeting rule, a central bank generates lower variabilities in domestic inflation and output gap, and reports significant benefits when adopting this regime.

Inflation Rate Versus Price-Level Target: The Debate

Throughout the last decade, inflation targeting was widely adopted as a framework for monetary policy. Several industrialized countries formally or informally adopted IT targeting and, thus far, most enjoy low inflation,[1] price stability and satisfactory real-growth records.[2] In contrast, 'conventional wisdom', as Svensson (1999) called it, has been sceptical of price-level targeting. The main argument against PT is that it induces both higher short-run inflation and output variability compared to IT (see Fischer, 1994, Haldane and Salmon, 1995). However, Dittmar et al. (1999) and Svensson (1999) argue that PT has advantages over IT, since, with PT inflation, variability becomes lower, assuming output variability is at least moderately persistent.[3] The controversy mainly concerns the definition of price stability and more particularly how price stability can be maintained in practice. For instance, monetary authorities should choose paths for either price level or the inflation rate allowing, in the latter case, for a base drift in the price level.[4]

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

[2] Canada, Australia, New Zealand, Sweden, the United Kingdom (UK) and other industrialized countries have adopted an IT regime.

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

[4] 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 and Vestin (2000) and Nessen (2002) suggest the central bank should target average inflation over several periods. Batini and Yates (2003), Cecchetti and Kim (2003) and Kobayashi (2004) investigate another novel proposal that combines IT and PT in a mixed regime, called hybrid inflation/price-level targeting. In this proposal, inflation volatility becomes lower when compared to PT and IT regimes. Indeed, Batini and Yates (2003) introduce a new perspective on the analysis of price-level and inflation targets by considering a hybrid target, which is a weighted average of an inflation target and a price-level target. They do not, however, use a utility-based, welfare-loss function as an evaluation criterion. In their analysis of price-level versus inflation targeting under different model specifications, policy rules, and loss functions of the central bank, Batini and Yates (2003) find that the more forward-looking the model, the less noticeable the difference between the reaction functions of inflation and price-level targeting, thus making the performance of such rules highly dependent on the degree of forward-looking behaviour. Using Fuhrer and Moore (1995)'s model to explore the implications of these regimes for the United Kingdom, Batini and Yates (2003) examine both a set of simple rules feeding back from alternative combinations of price-level and inflation deviations from a given target and a set of optimal control rules obtained under the assumption that policy makers minimize a loss function which penalizes a mixed price-level/inflation target.[5] Despite the contribution of these theoretical works, however, few studies have directly evaluated the HT regime using open-economy models. An analysis of HT in a small-open-economy environment is relevant, especially given the IT- and PT-regimes' shortcomings, as well as the implications of these weaknesses for central banks.

Our work departs from the above-mentioned literature in at least two dimensions, extending the works of Batini and Yates (2003) and Kobayashi (2004). First, we consider a New-Keynesian environment combined with inflation inertia where the model's dynamics are enriched by allowing for price indexation rather than considering them only in a pure Calvo-staggered fashion. Second, we use a utility-based, welfare-loss

[5]Batini and Yates (2003) explored the implications of the HT regime using a reduced form of the Fuhrer and Moore (1995) model which is not built on microfoundations that are as compelling as the Calvo model. Like the original Taylor model, the Fuhrer-Moore model is based on some arbitrary but superficially plausible assumptions about the form of labour contracts (Mankiw, 2001).

function as an evaluation criterion to evaluate the hybrid monetary-policy regime. By combining these new features, we obtain new insights on the price-level versus inflation targeting debate. We discuss the potential implications of these insights later in this paper.

In line with previous research on monetary-policy analysis, we adopt the New-Keynesian framework frequently adopted in this literature.[6] The most important feature of this model is the appearance of terms that reflect the forward-looking behaviour of representative agents. This leads, for example, to a stabilization-bias problem that occurs if monetary authorities apply discretionary monetary policy (Clarida et al, 2000). Most of the literature to date uses the new classical model to assess the properties of the HT regime and confirms its advantages (Kobayashi, 2004). However, the use of New-Keynesian models in analyzing the HT regime is only in its early stages.[7] In this paper, we investigate this framework and provide evidence that assists in discriminating between hybrid regimes and other kinds of monetary-policy targeting.

The small-open-economy representation considers the possibility that international trade and financial assets affect the evolution of the domestic economy. Thus, foreign shocks, such as changes in the terms of trade, can alter domestic business-cycle fluctuations, giving rise to further dynamics within the model. This, in turn, may lead the monetary authority to explicitly take these kinds of fluctuations into account (Lubik and Schorfheide, 2003).[8]

Recent developments in New-Open-Economy Macroeconomics, originating with Obstfeld and Rogof (1995), have led to a wealth of literature in which micro-founded and optimization-based models are used for policy analysis in the open economy.[9] These studies highlight the role of the terms of trade in the transmission of business cycles (see Corsetti and Pesenti, 2001).

[6]See for example McCallum and Nelson (2000), Clarida et al. (2000), Ball (1999) and Svensson (2000) for a discussion of this framework.

[7]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.

[8]Domestic policy decisions do not impact the rest of the world, allowing us to abstract from strategic interactions between the domestic economy and the rest of the world.

[9]See Lane (2001) for a survey.

Galí and Monacelli (2005)[10] consider a small-open-economy version of the Calvo sticky-price model and show how equilibrium dynamics are reduced to a simple representation in domestic inflation and the output gap. The model used here further explores this avenue and extends Gali and Monacelli's (2005) framework to account for HT targeting. We use the resulting setting to analyze the macroeconomic implications of three alternative rule-based policy regimes for the small-open economy: A CPI-inflation-based Taylor rule, pure price-level targeting, and a hybrid- inflation/price-level-based rule.

In our empirical work, we use the New Keynesian framework in a calibrated DSGE model, applying the hybrid monetary-policy rule. We calibrate key parameters to match some broad characteristics of the Canadian data. Since analytical solutions are often not available for this regime and empirical literature has not reached a consensus about key parameters, we rely on a calibrated model. Subsequently, we conduct a welfare analysis of the various monetary-policy regimes considered in this study and compare their impulse-response functions.

The paper proceeds in the following manner: Section 2 sketches the model's derivation as suggested by the microfoundations presented by Gali and Monacelli (2005). Section 3 provides details on the quantitative methodology and discusses the results. Section 4 introduces welfare analysis, provides the results, and conducts a sensitivity analysis over various parameter configurations. Section 5 presents the concluding remarks.

2 The Model

We construct a model that is a variant of a dynamic New-Keynesian model applied to a small-open economy, following Clarida et al (2002) and Gali and Monacelli (2005). In order to make this paper self-contained, key structural equations are presented in this section.

The model has three sectors: 1) a continuum of profit-maximizing, monopolistically-competitive firms

[10]The authors develop a tractable optimizing model of a small open economy with staggered price setting à la Calvo to analyze three interest rate rule: the domestic-inflation-based Taylor rule, the CPI-based Taylor rule, and an exchange rate peg.

(owned by consumers who include their shares in their portfolios) operating a constant return-to-scale technology and making staggered price decisions in the spirit of Calvo (1983); 2) an infinitely-lived representative household which maximizes a utility function defined over a composite consumption-good and labour supply;[11] and 3) a central bank which sets the monetary policy through an interest rule that targets both the price level and the inflation rate in a hybrid formula.[12]

This section introduces the main log-linearized equilibrium conditions of the model as well as the price setting scheme. The equilibrium dynamics for the small-open economy in terms of output gap ($\bar{x}_t$), domestic inflation ($\hat{\pi}_{H,t}$) and real interest rate ($\hat{r}_t$) can be completed by writing a version of the 'IS curve'. In a stationary setting, log-linearized version of this equation has the following form

$$\bar{x}_t = E_t\{\bar{x}_{t+1}\} - \frac{1}{\sigma/[(1-\alpha)+\alpha\omega]}(\hat{r}_t - E_t\{\hat{\pi}_{H,t+1}\} - \overline{rr}_t\,), \tag{1}$$

where $\omega = \xi\sigma + (\sigma\theta - 1)(1-\alpha)$, α is the degree of openness of the economy ($0 < \alpha < 1$), θ is the elasticity of substitution between domestic and imported goods ($\theta > 0$) and ξ is the elasticity of substitution among goods within each category ($\xi > 1$). $\bar{x}_t$ define the output gap[13] which is a deviation of domestic output ($\hat{y}_t$) from its 'natural' level ($\bar{y}_t$). Formally, $\bar{x}_t = \hat{y}_t - \bar{y}_t$, where the small-open economy natural output is the level of output that would prevail under flexible prices. E_t is the expectations operator conditional on time t set of agent's information. This IS equation relates the output gap in a forward-looking equation to the interest rate, domestic inflation and the natural interest rate ($\overline{rr}_t$).

2.1 Price Setting

Price-setting behaviour follows Calvo (1983) and Yun (1996) in that only a fraction $(1-\psi)$ of firms adjust their prices each period. Indeed, firms are not allowed to change their prices unless they receive a signal

[11] To solve the household's optimization problem, we introduce the following functional form for the utility function $U(C_t, N_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\phi}}{1+\phi}$.

[12] Detailed derivations and descriptions of the model are available from the corresponding author upon request. The reader is referred to Clarida et al (2002) and Gali and Monacelli (2005) for a general discussion about this model.

[13] In our model, we have to handle three definitions of output: a measure of output, 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.

allowing them to re-optimize prices. Following Christiano, Eichenbaum and Evans (2005), prices set by firms that do not receive a random price-change signal are indexed to past inflation.[14] Furthermore, Christiano et al. (2005) assume that prices are fully indexed to past inflation, but empirical models that allow for partial indexation (following Smets and Wouters, 2003) often find that the best-fitting value for the degree price indexation is positive but less than one. The partial indexation allows us to have some inflation inertia, leeway which can make the model more robust for policy and welfare analysis, especially if we are interested in welfare evaluation of inflation costs. Erceg, Henderson and Levine (2000) use indexation to the steady-state inflation rate, allowing them to compute a linearized equation for inflation combining expected future inflation and lagged inflation. This equation differs from the forward-looking inflation process obtained under the standard Calvo model.

Let $P^n_{H,t}$ be the price set by firm i adjusting its price in period t and facing a probability ψ^k of keeping its price unchanged for k periods (for $k = 0, 1, 2, ...$). $P^b_{H,t}$ defines the price chosen by the remaining fraction ψ of firms not optimally adjusting their prices at time t. The (log) price $\hat{p}^b_{H,t}$ is set according to the simple, backward-looking rule $\hat{p}^b_{H,t} = \hat{p}_{H,t-1} + \gamma_p \hat{\Pi}_{H,t-1}$, while the new price must satisfy the following equation

$$P^n_{H,t} = \mu + (1 - \beta\psi) \sum_{k=0}^{\infty} (\beta\psi)^k E_t\{mc_{t+k} + P_{H,t+k}\}, \tag{2}$$

where γ_p is the coefficient of price indexation, μ is the steady-state markup and β is the discount factor.[15] The dynamics of the domestic price index are then given by

$$P_{H,t} = [\psi(P^b_{H,t-1})^{1-\xi} + (1 - \psi)(P^n_{H,t})^{1-\xi})]^{\frac{1}{1-\xi}} \tag{3}$$

which can be loglinearized to obtain an expression for the domestic inflation as follows:

$$\hat{\pi}_{H,t} = \psi\gamma_p \hat{\pi}_{H,t-1} + (1 - \psi)(\hat{p}^n_{H,t} - \hat{p}_{H,t-1}). \tag{4}$$

[14] Price indexation makes the price dispersion between individual prices of the monopolistic firms much smaller compared with constant price-setting behaviour, a factor which has important consequences for monetary-policy evaluation. See Rabanal and Rubio-Ramírez, 2005, for a general discussion about price indexation.

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

Combining (4) with the differentiated version of (3) yields the aggregate supply equation

$$\hat{\pi}_{H,t} = \frac{\beta}{1+\beta\psi\gamma_p} E_t\{\hat{\pi}_{H,t+1}\} + \frac{\gamma_p}{1+\beta\psi\gamma_p}\hat{\pi}_{H,t-1} + \kappa \hat{mc}_t \tag{5}$$

where $\kappa = (1-\beta\psi)(1-\psi)/\psi(1+\beta\psi\gamma_p)$, $\hat{mc}_t$represents the log-deviation of the real marginal cost. Equation (5) shows that the domestic inflation dynamic has both forward-looking and backward-looking components. The real marginal costs faced by the firms are also an important determinant of domestic inflation. Note that with $\gamma_p = 0$, this equation reverts to the standard open-economy supply equation. Moreover, assuming that the degree of price stickiness ψ is identical across economies, the firms in the rest of the world (ROW) face simple Calvo-style price-setting behaviour. For simplicity and without loss of generality, we assume, throughout our analysis, that the degree of price indexation in the ROW γ_p^* is equal to zero.[16]

2.2 Monetary Policy

To close the model, we assume that the central bank sets the nominal interest rate following a Taylor-type interest-rate rule. In its simple version introduced by the influential work by Taylor (1993), an interest rate feedback from output and inflation is used to approximate monetary policy. Recently Woodford (2000) demonstrated that the interest rate rule is consistent with nominal demand determinacy for forward-looking models. In addition, in an open-economy model, the exchange rate is affected by the difference between domestic and foreign nominal interest rates and expected future exchange rates, via an interest rate parity condition (Svensson, 1998). The real exchange rate will then affect the relative price of domestic and foreign goods, which in turn affects both domestic and foreign demand for domestic goods and hence contributes to movements in CPI inflation. Likewise, the exchange rate affects the domestic currency prices of imported final goods included in the CPI price. In this way, monetary policy can affect both the CPI price and the CPI inflation rate. Consequently, when analyzing our model under HT targeting, we consider a monetary rule that incorporates both the price level and the inflation rate.

[16]Setting γ_p^* so that it is equal to the domestic price-indexation coefficient (or $\gamma_p^* \neq 0$) does not significantly change the policy-evaluation results.

In the present paper, we analyze the macroeconomic implications of three alternative monetary-policy regimes for the small-open economy: a policy that aims at fully stabilizing CPI inflation (IT), a policy that stabilizes CPI price level (PT) and a policy that combines price-level and inflation targeting (HT).

As a means of focusing on these target rules, we first begin by defining each rule. We next turn to the quantitative results of the model.

Inflation Targeting

Inflation targeting is the policy which responds to deviations of the CPI inflation rate from the target and acts to stabilize the CPI inflation rate around the inflation-target path. IT involves, then, price-level drift and consequently price non stationarity. We adopt a Taylor rule representation (Taylor 1993) where the interest rate ($\hat{r}_t$) reacts to inflation deviations from its target ($\hat{\pi}_t$) and output deviations from potential (output gap, $\bar{x}_t$), that is $\hat{r}_t = \rho + \phi_\pi \hat{\pi}_t + \phi_y \bar{x}_t$, where ρ, ϕ_π and ϕ_y are policy parameters. We analyze the properties of the equilibrium of the small open-economy when this policy rule is used and compare its performance with PT and HT.

Price-Level Targeting

Price-level targeting itself is a policy that systematically responds to deviations of the CPI price index from a predetermined long-run path. PT is then a policy stabilizing the price level ($\hat{p}_t$) around the target path, which implies stationarity for the price index and an inflation rate around zero inflation. In our analysis, we consider PT with a fixed price-level target (steady-state price level, $\bar{P}$), i.e. $P_t = \bar{P}$ or in log deviation $\hat{p}_t = 0$. Thus PT yields price-level stability around the steady-state price and zero inflation.

Hybrid Targeting

A hybrid inflation/price-level targeting policy combines elements of both previous regimes. This regime embeds both an inflation target and a price-level target, allowing therefore for some base drift in the price path. As in Batini and Yates (2003), we assume that the monetary policy follows the generalized hybrid inflation/price-level target

$$\hat{r}_t = E_t\{\hat{\pi}_{t+1}\} + \phi_p(E_t\hat{p}_t - \chi\hat{p}_{t-1}) + \phi_y\bar{x}_t, \tag{6}$$

where $\hat{r}_t$ denotes the short-term nominal interest rate, $\hat{\pi}_t$, $\hat{p}_t$ are defined in the same way as above, and $\bar{x}_t$ is the output gap. $\chi \in [0, 1]$ is the key parameter that defines the spectrum of targets between price-level and inflation targeting. For $0 < \chi < 1$ the target is a hybrid regime targeting both the price-level and the inflation-rate level.[17]

The degree of price-level drift, χ, in Batini and Yates' [2003] model is treated as a choice variable for the government and no optimal value for this parameter is derived by the authors. However, Røisland (2006) shows that, within a model with inflation inertia due to price indexation, an HT regime can be adopted to achieve optimal policy identical to the optimal policy under commitment if the monetary authority sets the degree of price-level drift equal to the degree of price indexation. Hence, the optimal degree of price-level drift in the HT rule is equal to the degree of price indexation.

As in Galí and Monacelli (2005), we assume that the world monetary authority succeeds in fully stabilizing world prices and the output gap; hence, we assume $\hat{y}_t^* = \pi_t^* = 0$ for all t which is an optimal policy for the closed economy under our assumptions.[18]

2.3 Deriving the New Keynesian Phillips Curve (NKPC)

Price stickiness is the only source of suboptimality in the equilibrium allocation. Indeed, as shown by Galí and Monacelli (2005), 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. Inflation inertia is also introduced in the model by the price behaviour.

[17] We only consider this scheme in our analysis, i.e. $0 < \chi < 1$. We then study the welfare implications of varying χ in the unit interval.

[18] The reader is referred to Clarida et al. (2000 and 2002) and Galí and Monacelli (2005) for the derivation of such a rule and its optimality for closed economy version of the model.

The resulting model is then consistent with what has been termed the NKPC. The determination of the real marginal cost as a function of domestic output ($\hat{y}_t$) and foreign output ($\hat{y}_t^*$) is complex due to the wedge between some aggregate variables, namely output versus consumption and domestic price versus consumer price indexes. We indeed have

$$\begin{aligned}\hat{mc}_t &= -\nu + \hat{w}_t - \hat{p}_{H,t} - \hat{a}_t \\ &= -\nu + \phi\hat{y}_t + \sigma\hat{y}_t^* + \hat{s}_t - (1+\phi)\hat{a}_t, \end{aligned} \tag{7}$$

where $\hat{w}_t$, $\hat{s}_t$ and $\hat{y}_t^*$ stand respectively for the deviation of wage rate from its steady-state value, the deviations of the terms-of-trade and the foreign output from their steady-state values. $\hat{p}_{H,t}$ is the log-deviation of domestic price level and $\hat{a}_t$ is a total-factor productivity index driven by an $AR(1)$ exogenous stochastic process, $\hat{a}_t = \rho_a \hat{a}_{t-1} + \varepsilon_{a,t}$, where $\varepsilon_{a,t}$ is a white noise with mean 0 and variance σ_ϵ^2. $\nu = -\log(1-\tau)$, where τ is an employment subsidy created to exactly compensate for the monopolistic competition distortion. The employment subsidy exactly offsets 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 small-open-economy model, namely sticky prices.

According to (7), real marginal cost is increasing as concerns the terms of trade, domestic output and world output and is decreasing with regards to technology. Hence, the wealth and employment effects on real wages, combined with the changes in the product wage and then the impacts on real wages lead to changes in marginal cost through its direct effect on labour productivity. Real marginal cost is then, given by

$$\hat{mc}_t = (\sigma_\alpha + \phi)\bar{x}_t, \tag{8}$$

which we can combine with equation (5) to derive a NKPC in terms of the output gap

$$\hat{\pi}_{H,t} = \frac{\beta}{1+\beta\psi\gamma_p} E_t\{\hat{\pi}_{H,t+1}\} + \frac{\gamma_p}{1+\beta\psi\gamma_p}\hat{\pi}_{H,t-1} + \delta\bar{x}_t, \tag{9}$$

where $\delta = \kappa(\sigma_\alpha + \phi)$. Notice that with the degree of openness (α) and the coefficient of price indexation γ_p set to zero (i.e. $\alpha = 0$ and $\gamma_p = 0$), equation (9) reverts to the standard, purely forward-looking, NKPC. The relation (9) also makes it clear that the standard formulation of NKPC based on the output gap assumes no price indexation to past inflation, and hence there is no inflation inertia in the model.

Furthermore, we assume that the foreign country pursues an optimal policy, implying a constant foreign-price level at equilibrium.[19] The model's dynamics can be stable in this case, even with non-stationary prices.

In the following sections, we will first set the model parameters as calibrated to the Canadian economy, and before analyzing the welfare implications of each regime, compute the impulse response functions and second-moment statistics .

3 Quantitative Results

3.1 Model Calibration

Baseline calibration of the model is based on recent literature and closely follows Galí and Monacelli (2005). The parameter values used in this study reflect Canadian data.

We use a labour supply elasticity of about $1/3$ which sets $\phi = 3$ and a steady-state markup $\mu = 1.2$, meaning that the elasticity of substitution between different domestic goods ξ is 6. Following Galí and Gertler (1999), we use the standard value of 0.75 to calibrate the sticky-price parameter ψ this implies an average price adjustment period of 4 quarters. The degree of openness of the economy α is set to 0.4. The discount factor β is assumed to equal 0.99 and the elasticity of substitution between domestic and foreign goods θ takes the value 1.5 according to Backus et al. (1995).

The remaining parameters are somewhat difficult to determine, due to lack of consensus amongst 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 (2005) calibrate their models with $\sigma = 1$. We follow Erceg et al. (2000) and set this parameter to 1.5.

The price indexation parameter characterizes the backward-looking component in the NKPC. A 0.5 value

[19]See Galí and Monacelli (2004) for a discussion of optimal policy in the foreign-country and SOE cases.

for this parameter is frequently found in empirical estimates of the NKPC (see for example Smets, 2003). Christiano, Eichenbaum and Evans (2005) and Galí, Gertler and López-Salido (2001) use indexation to the past period's inflation rate, but set the indexation parameter to one (i.e. full indexation). In contrast, estimates reported by Smets and Wouters (2003) and Sahuc (2004) using U.S. and Euro area data show that γ_p ranges from 0.40 to 0.64 with larger values for the U.S. case.[20] The latter authors argue that partial indexation is data consistent and appears to capture inflation dynamics. Following Justiniano and Preston (2007), who estimated a small-open-economy model similar to one we study in this paper (using Canadian data), this parameter is set at $\gamma_p = 0.55$, so that the backward-looking coefficient is 0.40 and the forward-looking term is 0.71 in the price equation.

Parametrization of the policy-rule set ϕ_p, ϕ_y[21] and ϕ_π to 0.5. As discussed in Batini and Yates, setting a value to the χ parameter is quite difficult. Using a range of values within the interval [0,1] the authors show that the value of χ depends on the size of the inflation tax, the cost of indexation and the length of nominal contracts but they do not however derive an optimal value for this coefficient. As stated above, we set χ equal to the degree of price indexation to past inflation.

Using Canadian labour productivity for the period 1963Q01 - 2002Q04 as a proxy for domestic productivity, Galí and Monacelli (2005) estimate the stochastic properties of technology shock to be $\rho_a = 0.66$ with a standard deviation of about one percent. Finally, we use these estimates and set the residual correlation to zero, i.e. $corr(\varepsilon_{a,t}, \varepsilon_{a^*,t}) = 0$. See Table 1 for a summary of model-parameter values.

3.2 Impulse Response Functions and Second Moment Analysis

Impulse response functions (IRFs) play an important role in describing the impact that shocks have on macroeconomic variables. To further understand this role, we simulate the IRFs of the main variables using three

[20] Leith and Malley (2003) estimate an open-economy NKPC for the G7 countries, using a model with backward-looking behaviour. They find that this parameter ranges from 0.54 in some countries up to as high as 0.87 in others.

[21] In the original Taylor rule, the weights on the output gap and inflation are set to the standard weight of 0.5, which is common in the literature.

rules : IT, PT and HT. The results are reported in Figures 1 to 3, and display impulse responses up to 15 quarters. Figure 1 displays the impulse responses to a one percent positive technology shock under HT, IT and PT regimes. The output gap response function exhibits the same patterns for all three regimes, with a hump-shaped pattern and initial negative responses ranging from -1.4 (IT) to -0.3 percent (PT). The peaks are reached after three to five quarters, and then the IRFs revert slowly to steady-state. Inflation responses (domestic and CPI-based inflation) display different patterns depending on the policy targeted. While domestic inflation has approximately the same response as the output gap under HT and IT, the IRF under PT is quite different. Domestic inflation shows a small variation under PT, starting with an initial value of -0.3, reaching a 0.2 percent peak in about 1.5 periods and then rapidly reverting to the steady-state. The response of CPI inflation under PT is flat at the steady-state level. This is because the price targeting rule imposes a path for the price level at its steady-state value, which prevents both CPI and domestic inflation from displaying more variability when the model is hit by a transitory technology shock. The main difference occurs when the initial response to the shock is highlighted. The initial value is zero for CPI inflation under the HT regime and negative under IT with hump-shaped responses. Therefore, the monetary authority has the same response under all three rules, stabilizing inflation when the technology shock occurs.

The same patterns are displayed by the domestic and CPI price-level responses with a hump-shaped domestic price response under HT and IT. 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 quite different during HT and IT targeting, where after a while the path reverts to initial values. The initial fall in the domestic and CPI price responses under HT and IT are followed by hump-shaped patterns (more pronounced for IT targeting) with a slow increase toward steady-state values. Furthermore, the impact on foreign aggregates is negligible by construction, implying that the world interest rate remains unchanged. An anticipated domestic currency appreciation is induced by the uncovered parity (UIP). Thus, the exchange rate depreciation explains the paths followed by the inflation rates that rise in the shock period and then revert back to initial levels.

The nominal interest rate shows a different response. With an initial negative response to the shock, it increases in a hump-shaped pattern to attain a peak in about five periods and then returns to steady-state values under all regimes. Intuitively, this means that after the economy has been hit by a technology shock, the optimal monetary authority response increases the nominal interest rate by a larger amount than the increase in inflation, resulting in an initial increase in the real interest rate level.

The terms of trade and net exports display similar paths, with initial positive responses and decreases persistently to reach steady-state values. This yields to a stationary behaviour for those variables, which is defined as a property of the model. The nominal exchange rate moves in the wrong direction, especially under HT and PT.[22]

The dynamic effects of foreign technology shocks are displayed in Figure 2. In this case, the foreign monetary authority reacts to shocks by lowering the world interest rate to stabilize inflation. The domestic authorities react in the same way by reducing their own interest rate to counteract the real appreciation caused by the foreign policy,[23] followed by a gradual depreciation until both interest rates converge to their steady-state levels.

The output gap and domestic inflation responses display hump-shaped patterns under all targeting rules. CPI inflation responses are different given the rule followed by the monetary authority. While the terms-of-trade variable is more stable under HT and PT targeting, responses persistently remain above initial levels under IT targeting. The same patterns are displayed for net exports under the three regimes.

Under IT, the decline in domestic and CPI prices is more accentuated. The nominal interest rate response takes the hump-shaped form and then reverts to the initial value. The main difference between home and foreign technology shock responses is registered for the exchange rate while the response under all regimes persistently remains above the initial levels.

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

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

Finally, the response functions of the macro variables to unit innovations in the policy shocks reveal that all variables display approximately the same patterns under HT and PT targeting. However, the initial domestic and CPI price responses under IT targeting persistently remain above the steady-state levels for more than 10 periods and then revert to the steady-state. Interestingly, the figure shows persistent exchange rate responses slightly below the initial values for all regimes. This is explained by the negligible effect of the policy innovations on foreign variables. A rise in the nominal interest rate is followed by an instant currency appreciation and an anticipated depreciation since the world interest rate remains unchanged. Asset and goods generate such movements in exchange rate and price levels.

In order to conclude the quantitative analysis for the three regimes, the second moments for some macro variables are shown in Table 2. For each variable, we report standard deviation in percentage points.

The second moment analysis confirms the IRF visual analyses. The IT regime requires more volatility in CPI and domestic price levels compared to the other regimes. Terms of trade are more stable under IT. Their volatility is about two times lower than that for the PTs. Intuitively, under IT the price level should follow the I(1) process. Hence, price adjustment after the occurrence of shocks is carried out very sluggishly, leading to sluggish inflationary behaviour. In fact, lagged price levels have little direct influence on current price levels. Upon shocks the price adjustment inevitably experiences sharp inflation fluctuation. Furthermore, the hybrid target can be set taking into account both inflation and its corresponding price level, such that past price levels affect current price levels, but their influence is not as strong as under IT. The price level path will lie between those under IT and PT. As pointed out by Kobayashi (2004), implementing hybrid targeting leads to 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. These findings align with the results obtained by Galí and Monacelli (2005).

4 Welfare Analysis of Alternative Regimes

The analysis of welfare implications under different monetary policy rules has become an important field of study (Taylor, 1999). Investigating the welfare implications of the hybrid regime and comparing them to other monetary-policy targeting schemes considered in this work would thus be worthwhile.

A welfare-maximizing central bank may target CPI inflation, CPI price or a combination of specific price and inflation paths. The key difference in approaches to inflation/price-level targeting concerns a stable, long-run price level compared to maintaining a particular rate of inflation. These rule-based approaches have different welfare implications. Devereux and Engel (2000) and Aoki (2001) show that in a closed economy with sticky prices and backward-looking behaviour, optimal policy entails the perfect stabilization of the inflation rate. In fact, Svensson (1999) shows that if the monetary authority has a price-level targeting objective, inflation variability may be reduced 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 a price-level targeting objective, the central bank appears to improve welfare if expectations are forward-looking or if there is substantial endogenous persistence. Vestin (2000) argues that in a purely forward-looking model, price-level targeting provides more efficient outcomes than inflation targeting. Concerning a closed-economy model, Nessen and Vestin (2000) suggest that hybrid targeting leads to better outcomes than targeting inflation only, if the Philips curve has forward-and backward-looking components.

Our study focus on a small open economy model with a Phillips curve showing both backward and forward looking behaviour. The evaluation of household welfare in this case can be expressed as a fraction of steady-state consumption.[24] Here we follow Galí and Monacelli (2005), who derive a second-order approx-

[24] The application of the quadratic approximation of the objective function is complex and cannot be simply derived in an open-economy model with sticky prices. A popular measure thus uses inflation and output gap volatility, in addition to the utility function.

imation to the domestic consumer utility function in a SOE model.[25] This second order approximation,[26] expressed as a fraction of steady-state consumption, reveals that the expected welfare losses of any policy in terms of domestic inflation and output gap variances are then given by

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

Using this expression,[27] we can compare different monetary policies to assess their welfare implications and highlight welfare costs among regimes.

Table 3 shows welfare losses associated with three different regimes: HT, IT and PT. We assume that the central bank wants to minimize variations in domestic inflation ($\hat{\pi}_{H,t}$). 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 compared to the CPI inflation targeting regime (IT in the text). Entries for loss functions are percentage units of steady-state consumption.

In this Table, we report welfare losses under our benchmark parametrization, we present some sensitivity analysis in Table 4. The results show that under our benchmark case, the reduction in welfare loss results from a decrease in output and domestic inflation volatility varying from an IT to an HT regime. On the other hand, CPI inflation targeting leads to a much higher level of losses in the welfare-loss function than obtained by the two other regimes. As usually found in the literature,[28] welfare losses are quantitatively small for all regimes.

[25] See Appendix 4 in Galí and Monacelli (2004) for details on the welfare-loss function derivations. However, the derivation is restricted to the special case of log utility and unit elasticity of substitution between different goods (i.e. $\sigma = \eta = \theta = 1$) in deriving an exact expression; otherwise, its derivation is more complex. We use this approximation for the purpose of comparing different regimes without loss of generality. For more discussion about welfare analysis in the loglinearized model, refer to Kim and Kim (2003) and Schmitt-Grohe and Uribe (2004).

[26] After dropping terms independent of policy and those of high order and computing the unconditional expectation of this approximation.

[27] Recently, Røisland (2006) has shown that under the HT regime the central-bank loss function should be modified to take the form $L = (\hat{p}_t - \chi\hat{p}_{t-1})^2 + \bar{\lambda}\bar{x}_t^2$, where χ is as in the text and $\bar{\lambda}$ is a modified weight on the output gap. This assumption cannot be used here since we aim to compare various targeting regime. We relay this case to future work.

[28] Kollman (2002) and Smets and Wouters (2003) are recent examples of papers in which monetary-policy welfare implications are investigated.

The welfare analysis can be sensitive to the parametrization of the model. We then perform a sensitivity analysis with respect to various key parameters. Results are shown in Table 4 which have four panels. In each panel, we report welfare losses under different policy parameter values (χ) and of lowering, respectively, the degree of economy openness (α), the steady-state mark-up (μ) and the elasticity of labour supply (ϕ).

Compared to the benchmark case, and using different policy parameters, the HT regime implies substantially larger welfare losses as one gets closer to extreme values corresponding either to high value of χ (with $\chi = 0.85$) or low value of χ (with $\chi = 0.25$). As one gets closer to the extremes, the PT targeting performs well, lowering both inflation and output gap variabilities. This finding is in line with recent studies of monetary policy which show PT targeting outperforming IT targeting (see for example Svenson 1998, Vestin, 2000 and Røisland, 2006).

We next consider the effect of lowering the degree of economy openness. This has a general effect of decreasing both domestic inflation and output gap volatilities, leading to low welfare losses under all regimes. We can interpret this to suggest that the decrease in volatilities and the resulting welfare values are essentially generated by movements in small-open-economy variables such as terms of trade and exchange rate which have low effects in a 'quasi-open economy' (with small α). In this case, HT and PT deliver lower welfare losses than the IT regime.

Finally, we explore the effects of lowering both the mark-up to 1.1, which leads to a larger penalization of inflation variability in the loss function, and the elasticity of labour supply to 0.1, which implies a larger penalization of output gap volatility. This leads to similar output gap volatility compared to the other scenarios, which in turn leads to an amplification of the volatility of domestic inflation, further implying higher welfare losses for all three regimes. Interestingly, the IT leads to a significantly larger loss compared to the two other regimes and gives a loss function value up to 10 times higher than with HT and PT. In comparison with PT, an HT regime leads to a larger welfare loss meaning that the results may be sensitive to the model assumption, as pointed out by Galí and Monacelli (2005) and Schmitt-Grohé and Uribe (2001).[29]

To conclude our welfare evaluation, we conduct a sensitivity analysis of welfare loss to the parametrization of the key policy parameter χ in the hybrid rule (6). Figure 4 displays the effect in the Ξ function of varying this parameter from zero to one. The figure represents the peaks of welfare losses when we change this parameter in the unit interval. In fact, the welfare-loss function takes values ranging from -4 (for χ with small values around 0) to -0.1 (for χ with value around and up to 1). We can conclude that this occurs because at the limiting case of $\chi = 0$ (or $\chi = 1$) and using rule (6), the price level (inflation rate) is targeted and the inflation inertia due to price indexation does not play a stabilizing role in the model. Thus, as shown by Røisland (2006), this is similar to the complete indexation case where the optimal monetary policy is flexible inflation targeting.

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 produces a higher welfare gain (see for instance Goodfriend and King, 2001). In open-economy models, the different dynamics of the terms of trade, exchange rate and other foreign variables may affect the domestic agent's welfare given a monetary policy regime. We assume that this leads to different results if the open-economy analysis is adopted to assess welfare-maximizing monetary policy.

[29] The authors argue that the welfare ranking among different monetary policies may be sensitive to distortions in the economy.

5 Summary and Concluding Remarks

This paper investigates hybrid inflation/price-level targeting from a New-Keynesian perspective. To this end, we calibrate generalizations of the models proposed by Monacelli (2003) and Galí and Monacelli (2005) to the Canadian economy. Both papers develop a small-open-economy (SOE) 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) 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 affects the evolution of the domestic economy. This gives rise to richer dynamics within the model, given our assumption of complete security markets. Moreover, and as shown by Galí and Monacelli (2005), the equilibrium dynamics of the SOE model have a canonical representation, in terms of domestic inflation and output gap, analogous to that of its closed economy conterpart.[30]

In light of the considerable attention paid in recent macroeconomic literature to monetary-policy formulations in terms of interest rate rules, we adopt this formulation to construct three regimes. In addition, we compare the hybrid regime to the IT and PT regimes. Our results show that hybrid targeting can lead to a successful monetary policy strategy, without any major loss in the welfare function.

Overall, an HT regime seems to be an appropriate method of conducting monetary policy if monetary authorities seek price stability. In fact, the long-run anchor for a central bank is clearly price stability. The problem is then whether it should target price level or variations in this price level (inflation rate) or a combination of the two. Notice that an inflation-price-level targeting (HT) has mainly reasonable benefits in that planning and contracting become easier as nominal values approaches real values. Also, the transfers of wealth from the private sector to the government using inflation device (especially under IT) is wiped out under both PT and HT.

Recent literature on PT shows that anchoring the price level to a long-run price-level path is a good idea

[30]The authors argue that the closed economy version of the model is nested in the small open economy model, as a limiting case.

given agents' expectations (forward and/or backward looking). However, since conservative central bankers seem to need more time to reach this point, we believe that an intermediate way should be hybrid targeting, and suggest more research is needed before PT can be implemented or even considered for implementation, as is the case for example in Canada.

Likewise, in this kind of model, including more nominal rigidities, particularly sticky wages or some type of wage indexation, should change the results obtained significantly. Further research is therefore necessary to establish the manner in which these frictions would likely alter this finding.

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Table 1: Model Parametrization

Parameters	μ	ϕ	ξ	θ	σ	α	ψ	χ	ϕ_p	ϕ_π	ϕ_y	ρ_A	σ_A
Values assigned	1.2	3	6	1.5	1.5	0.4	0.75	0.55	0.5	0.5	0.5	0.66	1%

Table 2: Volatility Under Alternative Policy Regimes
(**Standard Deviations in %**)

	HT Regime	IT Regime	PT Regime
Output Gap	0.115531	0.292549	0.221236
Domestic Inflation	0.208678	0.425783	0.248183
CPI Inflation	0.151996	0.231277	$0.9386e^{-15}$
Nominal Interest Rate	0.174683	0.115639	0.071611
Exchange Rate	4.028806	1.472007	4.576895
CPI Price Level	0.247563	2.272017	0.000000
Domestic Price Level	0.599330	2.369227	0.693747
Terms of Trade	1.110025	0.898438	1.734369

Table 3: Welfare Losses Under Alternative Policy Regimes: Benchmark

	HT Regime	IT Regime	PT Regime
Benchmark $\mu = 1.2$, $\phi = 3$, $\alpha = 0.4$ and $\chi = 0.55$			
Var(Domestic Inflation)	0.043546	0.181292	0.061595
Var(Output Gap)	0.013347	0.085585	0.048945
Welfare Loss (Ξ)	-0.929222	-3.904543	-1.350430

Table 4: Sensitivity of Welfare Losses to Key Parameter Values

	HT Regime	IT Regime	PT Regime
$\mu = 1.2$, $\phi = 3$, $\alpha = 0.4$ and $\chi = 0.25$			
Var(Domestic Inflation)	0.067517	0.222545	0.057849
Var(Output Gap)	0.001193	0.004340	0.001566
Welfare Loss (Ξ)	-1.417321	-4.672170	-1.215020
$\mu = 1.2$, $\phi = 3$, $\alpha = 0.4$ and $\chi = 0.85$			
Var(Domestic Inflation)	0.001255	0.035528	0.019625
Var(Output Gap)	0.048605	1.295282	1.238130
Welfare Loss (Ξ)	-0.084637	-2.299402	-1.897320
Low degree of openness $\mu = 1.2$, $\phi = 3$, $\alpha = 0.25$ and $\chi = 0.55$			
Var(Domestic Inflation)	0.026702	0.141287	0.025688
Var(Output Gap)	0.005782	0.047865	0.019376
Welfare Loss (Ξ)	-0.708635	-3.775443	-0.702432
Low steady-state mark-up and Low elasticity of labour supply $\mu = 1.1$, $\phi = 10$, $\alpha = 0.4$ and $\chi = 0.55$			
Var(Domestic Inflation)	0.177927	1.400579	0.118844
Var(Output Gap)	0.009838	0.070990	0.011315
Welfare Loss (Ξ)	-3.763743	-29.60564	-2.529602

Figure 1: Impulse Responses to a Domestic Productivity Shock Under HT, IT and PT Regimes

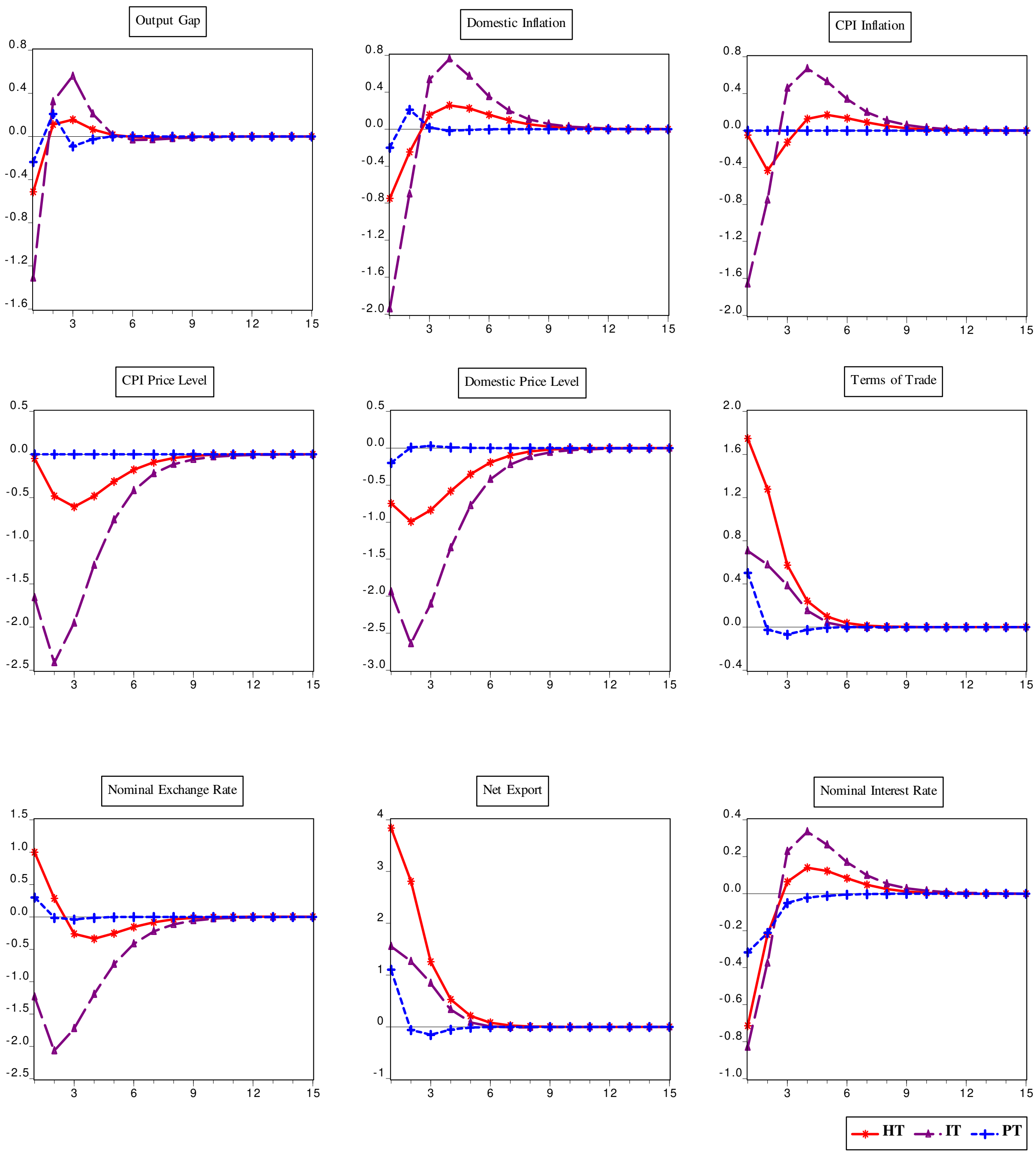

Figure 2: Impulse Responses to a Foreign Productivity Shock Under HT, IT and PT Regimes

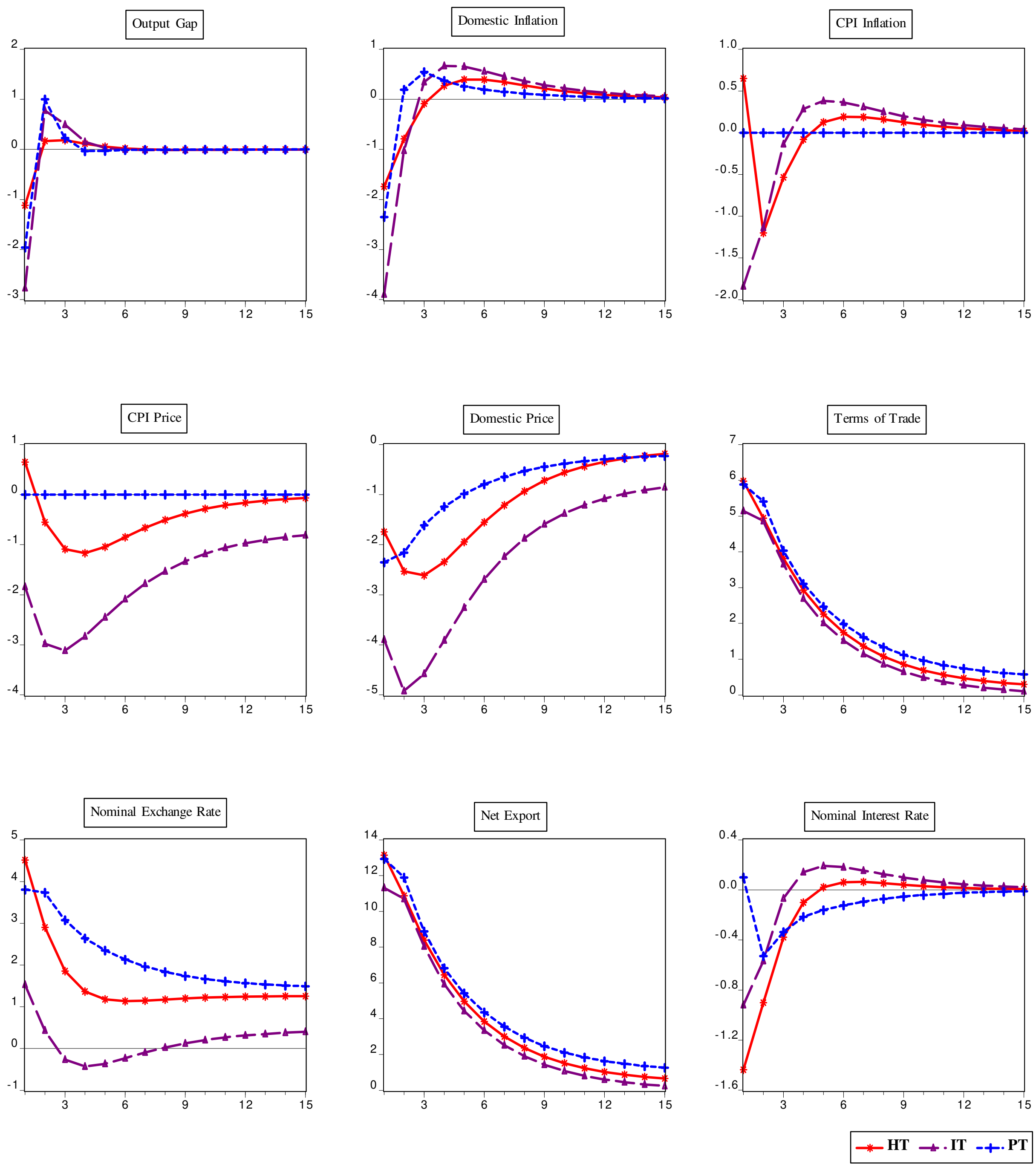

Figure 3: Impulse Responses to Interest Rate Rule Innovations Under HT, IT and PT Regimes

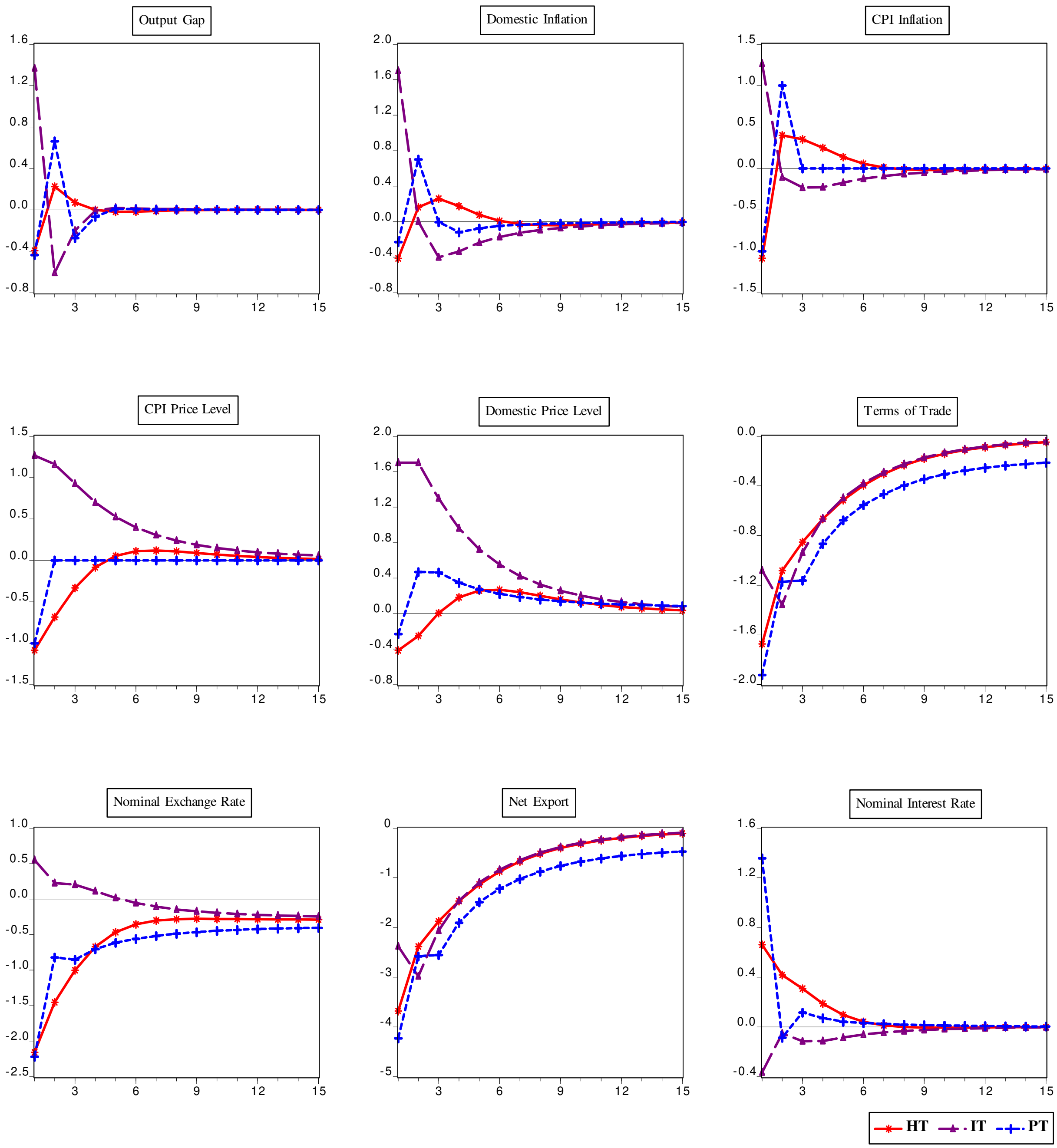

Figure 4: Welfare Losses with Policy Parameter Changes