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Price Level Targeting in a Small Open Economy with Financial Frictions: Welfare Analysis

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Abstract

How important are the benefits of low price-level uncertainty? This paper explores the desirability of price-level path targeting in an estimated DSGE model fit to Canadian data. The policy implications are based on social welfare evaluations. Compared to the historical inflation targeting rule, an optimal price level targeting regime substantially reduces the welfare cost of business cycle fluctuations in terms of steady state consumption. The optimal price-level targeting rule performs also better than the optimal inflation targeting rule in minimizing the distortion generated by the presence of nominal debt contracts. The financial shocks, which are shocks to domestic and international intermediation processes, significantly contribute to quantify the welfare gains of price level targeting.

JEL: classification: E31;E32; E52

Keywords: Price-level targeting; Inflation targeting; Financial frictions; Monetary policy.

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1. Introduction

The principal objective of most central banks worldwide is the maintenance of price stability.[1] Inflation targeting, which aims keeping inflation within a target range, has proved successful in sustaining low inflation and low inflation volatility. However, some central banks have recently started investigating the costs and benefits of defining the target in terms of a price level path rather than an inflation rate. Announcing a path for the price level would provide an operational target and be equivalent to targeting a long-run average inflation rate, but would not require central banks to stabilize inflation in the short-run. Under such a regime, the central bank aims at correcting deviations of the price level from the target using inflationary or deflationary policies to bring the price level back to its target in a given period of time.

In order to assess the benefits of low price-level uncertainty, our analysis is based on a medium-scale DSGE model that takes into account several sources of business cycle fluctuations. The model extends the framework adopted in Dib and Christensen (2008) to a multi-sector small open economy with nominal debt contracts in both the domestic and international credit market and credit frictions *à la* Bernanke, Gertler and Gilchrist (1999).[2] In particular, we focus on the role of financial shocks, which are shocks to the domestic and international intermediation processes affecting credit markets, in business cycle fluctuations and optimal monetary policy.[3]

To provide a quantitative assessment of different sources of business cycle fluctuations, we first fit the model to Canadian data using data from 1981:1 to 2007:2. Our findings suggest that financial and investment-specific shocks are the main sources of business cycle fluctuations in the Canadian economy. In particular, approximately 10 percent of the variability in GDP, investment, and the real exchange rate can be attributed to international financial shocks. However, these shocks slightly account for the variability in consumption and asset prices.

Unlike most of the previous literature on price-level versus inflation targeting, the optimal design of monetary policy under the two alternative regimes is based on social welfare evaluations. To maximize welfare, optimal monetary policy rules should aim to minimize the distortions featured in the model. With nominal price and wage stickiness, a strong anti-inflationary stance is needed

[1]Nowadays, Australia, Canada, European Monetary Union, New Zealand, South Africa, Sweden and United Kingdom adopt an explicit target for inflation.

[2]See Iacoviello (2005) and Christiano, Motto and Rostagno (2004, 2007) for closed economy models with nominal contracts and frictions in the domestic credit market.

[3]These financial shocks may be interpreted ad shocks to the supply-side of credit in domestic and international credit markets.

to reduce the cost of price and wage dispersion and increase economic activity and welfare. Assets in nominal terms induce private risk generated by the uncertain returns. In particular, nominal debt contracts generate unnecessary redistribution of wealth between borrowers and lenders as a result of unexpected changes in the debt-services. Since entrepreneurs borrow from financial intermediaries to finance part of their capital acquisitions, variations in the price level generate distortions in the allocation of resources and thus affect the economic activity. Therefore, stabilizing the debt-services through the stabilization of the real interest rate would minimize the allocative distortions generated by the debt-deflation channel and improve welfare. Mendicino and Pescatori (2005), show that the monetary authority faces a trade-off between the minimization of the nominal debt distortion and the inefficiency generated by nominal price stickiness. Under a Taylor-type rule, to reduce the volatility of the real interest rate, monetary policy generates an optimal degree of inflation volatility and does not completely eliminate the inefficiency linked to price dispersion.

Our findings show that an optimal price level targeting rule significantly reduces the welfare cost of business cycle fluctuations in terms of steady state consumption when compared to the historical inflation targeting rule. The price level targeting regime dominates in terms of welfare since it delivers lower variability in the real interest rate, which minimizes the distortion generated by the existence of nominal debt, and significantly reduces the cost of price and wage dispersion. Price-level targeting also outperforms the inflation targeting regime in the class of optimal non-inertial rules. Due to history dependence, the optimal price-level targeting rule requires a less aggressive response to the target in order to perform at least as well as the optimal inflation targeting rule in minimizing the inefficiency linked to price stickiness. The resulting reduction in the volatility of the policy rate further minimizes the distortion generated by the presence of debt in nominal terms. Thus, the optimal price-level targeting rule performs generally better in terms of welfare than the optimal inflation targeting rule. However, the introduction of history dependence through interest rate smoothing improves the performance of the inflation targeting rule and substantially reduces the gains of adopting a price level targeting stance.

Some authors have argued that the presence of uncertainty significantly affects the comparison between the two monetary policy regimes. Recently, Aoki and Nikolov (2005) show that in a New-Keynesian model, a price-level targeting rule implies bigger gains in terms of output and inflation volatility in the presence of uncertainty.[4] Our paper contributes to the debate about uncertainty and

[4]Gorodnichenko and Shapiro (2005) document that price-level targeting outperforms inflation-targeting under uncertainty about the potential output. Cateau (2008) using the actual projection model of the Bank of Canada, shows that the

price-level targeting by analyzing the effects of parameter uncertainty in relation to the model's endogenous welfare measure instead of ad-hoc policy functions. We show that welfare exhibits little sensitivity to uncertainty about the model's parameters. The benefits of adopting a price-level targeting regime are more sizeable when uncertainty is related to the persistence and volatility of the shocks. However, compared to the optimal inflation targeting rule, the magnitude of the welfare gains of adopting the optimal price level targeting rule is unchanged and the benefits related to the variability of welfare are not quantitatively important. According to our model, the presence of parameter uncertainty does not significantly increase the welfare gains of adopting a price level targeting regime.

Our findings also highlight the importance of understanding the source of business cycle fluctuations when assessing the benefits of alternative monetary policy regimes. In fact, the gains from price-level targeting are significantly linked to the occurrence of financial shocks, which are among the main sources of business cycle fluctuations in the estimated model considered in this paper.

Layout. The paper proceeds as follows. Section 2 summarizes related literature and highlights the contribution of our paper. Section 3 presents the model. Section 4 discusses the estimation method and the quantitative properties of the model. Section 5 assesses the desirability of alternative monetary policy rules and section 6 conducts sensitivity analysis for parameter uncertainty. Section 7 presents the conclusions of the study.

2. Related Literature

Since Taylor (1979), the output-inflation volatility trade-off criterion has been used to rank alternative policy rules. Several authors compared the effects of loss functions that involve either inflation variability or price-level variability. According to the conventional view in central banking, dating back to Fischer (1994), in the presence of nominal rigidities, a price level targeting regime would increase both inflation and output volatility in the short-run.[5] Thus, there would be a trade-off between

gains of price-level targeting are robust to model uncertainty. In particular, he finds that if the correct model is a robust control version of the projection model, the optimal price-level targeting rule is robust in models that are at a reasonable distance from the reference model. These recent results are in contrast with the conventional view suggesting that when the central bank faces uncertainty about the structure of the economy, a price-level targeting regime could increase the cost of policy mistakes and increase macroeconomic volatility. See Gaspar, Smets and Vestin (2007) for a review of the literature.

[5]See also Lebow, Roberts and Stockton (1992), Fillion and Tetlow (1994), Haldane and Salmon (1995), Laxton, Ricketts and Rose (1994).

long-term price-level variability and short-term volatility of inflation and output gap. Svensson (1999) shows that a trade-off between less low-frequency price-level variability and less high-frequency inflation and employment variability arises from the use of exogenous reaction functions for monetary policy or exogenous inflation and price level processes. These are not necessarily consistent with the objective function of the central bank and the constraints implicitly imposed by the model. Deriving endogenous decision rules, and equilibrium price level and inflation, Svensson documented that under rational expectations and (at least) moderate persistence in employment, a price-level targeting path leads to lower inflation and identical output variability.[6]

Clarida, Gali and Gertler (1999) and Woodford (1999) highlight the fact that in a forward-looking model optimal monetary policy under commitment is characterized by a stationary price level. [7]Vestin (2006) shows that under discretion price-level targeting is also preferred. If the central bank commits to price-level targeting, then rational expectations become automatic stabilizers. Nevertheless, Kryvtsov, Shukayev and Ueberfeldt (2008) showed that under imperfect credibility, the effectiveness of the expectation channel is weakened and the welfare gains of price-level targeting are substantially reduced. [8]

The approach adopted in this paper characterizes monetary policy in terms of interest-rate feedback rules and assumes that the policymaker credibly commits to a policy rule for the entire future. In particular, we assume commitment to a policy rule that determines the nominal interest rate as a function of the lagged nominal interest rate, GDP and either inflation or the price-level. Batini and Yates (2003) investigate the implications of price-level targeting, inflation targeting, and hybrid rules. They document that the performance of the rules in terms of inflation and output volatility depends on several modeling assumptions, including the degree of forward-lookingness in the price-setting behavior of firms. Williams (1999), using the FRB/US large-scale model, shows that price-level targeting rules outperform rules that react to a 1-year inflation rate and perform nearly as well as inflation targeting rules that react to a multi-period inflation rate.

We evaluate the performance of the two regimes in terms of welfare rather than ad-hoc loss functions. Following the same criterion, Giannoni (2000) argues that in a simple forward-looking model,

[6]Duguay (1994) and Coulombe (1998) also document that a price level target path implies expectations to help resisting deflation and profound downturns if the economy falls into a zero-lower-bound situation.

[7]Gaspar, Smets and Vestin (2007) show that under optimal policy under commitment the price level is stationary even in larger-scale models that include several frictions such as the estimated model of the Euro area by Smets and Wouters (2003).

[8]See a more detailed discussion of credibility and price-level targeting in Gaspar, Smets and Vestin (2007).

price-level targeting rules generally perform better than Taylor rules because they result in lower welfare loss and lower variability of inflation and of the nominal interest rate. On the contrary, Ortega and Rebei (2006), using a two sector small open economy model fit to Canadian data, find that the welfare gains of price-level targeting are negligible. Using a more elaborate two-sector model enriched with credit flows, we find that the benefits of price level targeting are mainly linked to the occurrence of financial shocks in the economy.

This paper is also closely related to the literature on optimal monetary policy in an environment with nominal assets. In particular, Mendicino and Pescatori (2005) and Pescatori (2008) highlight the role of inflation and debt-service stabilization for the optimal conduct of monetary policy in models with nominal debt and price stickiness. Meh, Rios-Rull and Terajima (2008) show that in the presence of nominal assets and liabilities with different terms-to-maturity, an unexpected one percent increase in the price level generates consistently higher redistribution and more sizeable effects on aggregate output under inflation targeting than price level targeting. Covas and Zhang (2008) document that, in a model with nominal debt contracts, the output-inflation volatility trade-off criterion suggests that price-level targeting is generally better than an estimated inflation targeting rule for the Canadian economy. We assess the role of monetary policy in reducing the distortions generated by the presence of nominal debt contracts in a full-fledged DSGE model.

The paper is also linked to the growing literature on estimated small open economy models.[9] In particular, we relate our findings to previous estimated small open economy models of the Canadian economy.[10] This paper represents the first attempt to quantify the role of financial shocks in Canada. Christiano *et al.* (2007) provide evidence on the importance of financial shocks for macroeconomic fluctuations in US. Unlike Christiano *et al.* (2007), we do not limit our attention to domestic financial shocks but we also document the role of international financial shocks. One of the novel aspects of this paper is the empirical assessment of international financial spillovers to Canada. According to the IMF country report (2008), financial conditions are by far the largest source of US spillover to Canada. Over the period 1983-2007, Canadian non-financial firms raised on average one-quarter of their funds in the US financial market. This suggests that changes in the US financial conditions can

[9]Among others see Adolfson *et al.* (2007), Bergin (2003), Ghironi (2000), Lubik and Schorfeide (2003, 2005), Lubic and Teo (2005), Rabanal and Tuesta (2005, 2008), Del Negro (2003), Curdia and Finocchiaro (2007), Smets and Wouters (2008), and Lindé *et al.* (2004).

[10]Among others, see Ambler, Dib and Rebei (2004), Justiniano and Preston (2008) for standard one-sector models; Ortega and Nooman (2006) for a two-sector model; Dib (2008) for a multi-sector model; and Christensen, Corrigan, Mendicino and Nishiyama (2008) for a an estimated model with collateralized debt.

have substantial implications for economic conditions in Canada.[11] Thus, we contribute to this later literature by highlighting the role of domestic and international financial shocks in business cycle fluctuations.

3. The Model

In this section we describe the model economy. We consider a small open economy populated by households, producers of final goods for consumption and investment purposes, a continuum of retailers and importers, producers of physical capital, entrepreneurs, a government, and a central bank.

3.1 Households

The economy is populated by a continuum of households indexed by $h \in [0,1]$. Each household h has preferences defined over consumption, C_{ht}, and labour supply, H_{ht}. Preferences are described by

$$E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_{ht}, H_{ht}\right),$$

where E_0 denotes the expectations operator conditional on information available at the period 0, $\beta \in (0,1)$ is a subjective discount factor, and $U(\cdot)$ is a utility function, which is assumed to be strictly concave, strictly increasing in C_{ht} and strictly decreasing in H_{ht}. The single-period utility function is specified as

$$U(\cdot) = \frac{C_{ht}^{1-\gamma}}{1-\gamma} + \frac{\left(1-H_{ht}\right)^{1-\tau}}{1-\tau}. \tag{1}$$

The parameter γ is the inverse of the elasticity of intertemporal substitution of consumption, and τ is the inverse of the Frisch wage elasticity of labour supply. The preference parameters, γ and τ, are strictly positive. Households supply specialized labour services to the tradable and non-tradable sectors, which are indexed by T and N, respectively. Thus, $H_{ht} = \left[\eta_T H_{T,ht}^{\frac{1+\varsigma}{\varsigma}} + \eta_N H_{N,ht}^{\frac{1+\varsigma}{\varsigma}}\right]^{\frac{\varsigma}{1+\varsigma}}$, where $H_{T,ht}$ and $H_{N,ht}$ represent hours worked by the household h in the two sectors.

At time *t*, households receive total factor payment, $W_{T,ht}H_{T,ht} + W_{N,ht}H_{N,ht}$, pay a lump-sum tax, Υ_{ht}, to the government and receive dividend payments from retailers and importers, Ω_{ht}; where $\Omega_{ht} = \Omega_{T,ht} + \Omega_{N,ht} + \Omega_{F,ht}$ is the total profit from retailers in tradable and non-tradable sectors and

[11] See Swiston and Bayoumi (2008) and Klyuev (2008).

importers. Households deposit funds at the domestic financial intermediary, D_{ht}, and trade foreign bonds denominated in foreign currency, B_{ht}^*. The budget constraint of household h is given by:

$$\begin{aligned} P_t C_{ht} + D_{ht} + \frac{e_t B_{ht}^*}{\kappa_t R_t^*} &\leq W_{T,ht} H_{T,ht} + W_{N,ht} H_{N,ht} \\ &+ R_{t-1} D_{ht-1} + e_t B_{ht-1}^* + \Omega_{ht} - \Upsilon_{ht}. \end{aligned} \tag{2}$$

Household h chooses C_{ht}, D_{ht}, and B_{ht}^* to maximize its lifetime utility, subject to the budget constraint. e_t is the nominal exchange rate. The foreign bond return rate, $\kappa_t R_t^*$, depends on the foreign interest rate R_t^* and a country-specific risk premium κ_t, that is assumed to be increasing in the foreign-debt-to-GDP ratio:

$$\kappa_t = \exp\left(-\upsilon \frac{e_t \tilde{B}_t^*}{P_t Y_t}\right), \tag{3}$$

where $\upsilon > 0$ is a parameter determining the foreign-debt-to-GDP ratio, Y_t is total real GDP and $\tilde{B}_t^*$ is the total level of indebtedness of the economy. The introduction of this risk premium ensures that the model has a unique steady state. The uncovered interest rate parity (UIP) condition derived from first order conditions is such that

$$\frac{R_t}{\kappa_t R_t^*} = \frac{e_{t+1}}{e_t}. \tag{4}$$

We define the CPI inflation rate and the real exchange rate, respectively as $\pi_t = P_t/P_{t-1}$ and $S_t = e_t P_t^*/P_t$ where P_t^* is a foreign price index.

As in Erceg, Henderson and Levin (2000), we assume that households are monopolistic suppliers of differentiated labour services. After setting their wages, they inelastically supply the services to a competitive "employment agency" that transforms individual labour hours into sectoral labour inputs using the same proportions that firms would choose:

$$L_{i,t} = \left(\int_0^1 H_{i,ht}^{\frac{\vartheta-1}{\vartheta}} dh\right)^{\frac{\vartheta}{\vartheta-1}}, i = T, N, \tag{5}$$

where $L_{T,t}$ and $L_{N,t}$ denote aggregate labour supplies in the tradable and non-tradable sectors, respectively, and $\vartheta > 1$ is the constant elasticity of substitution among different types of labour. The aggregator takes the wage rate $W_{i,ht}$ for the household h as given and sells the labour input to the production sectors at the unit cost

$$W_{i,t} = \left(\int_0^1 (W_{i,ht})^{1-\vartheta} dh\right)^{\frac{1}{1-\vartheta}}, \tag{6}$$

where $W_{i,t}$ is the nominal wage in the sector i. The demand for each type of labour of household h is given by

$$H_{i,ht} = \left(\frac{W_{i,ht}}{W_{i,t}}\right)^{-\vartheta} L_{i,t}. \tag{7}$$

Households set nominal wages in staggered contracts, where $(1-\varphi_i)$ is the probability of changing the nominal wage for the labour services used in sector $i = \{T, N\}$ at the beginning of each period t. See Calvo (1983). We assume full indexation as in Yun (1996). If household h is not allowed to change its nominal wage, it charges last period's wage multiplied by the average inflation rate, $W_{i,ht+1} = \pi W_{i,ht}$, where $\pi > 1$. Thus, the nominal wage index in the sector i evolves over time according to the following recursive equation:

$$(W_{i,t})^{1-\vartheta} = \varphi_i(\pi W_{i,t-1})^{1-\vartheta} + (1-\varphi_i)(\widetilde{W}_{i,t})^{1-\vartheta}, \tag{8}$$

where $\widetilde{W}_{i,t}$ is the wage of those workers who are allowed to revise their wage at period t in the sector i. Each household sets its optimized nominal wage in the sector i, $\widetilde{W}_{i,ht}$, to maximize the flow of its expected utility,

$$\max_{\widetilde{W}_{i,ht}} E_0 \left[\sum_{l=0}^{\infty} (\beta\varphi_i)^l \left\{U\left(C_{ht+l}, H_{i,ht+l}\right) + \lambda_{t+l}\pi^l \widetilde{W}_{i,ht} H_{i,ht+l}/P_{t+l}\right\}\right],$$

subject to $H_{i,ht+l} = \left(\frac{\pi^l \widetilde{W}_{i,ht}}{W_{i,t+l}}\right)^{-\vartheta} L_{i,t+l}$. The first-order condition derived for $\widetilde{W}_{i,ht}$ is

$$E_0 \left[\sum_{l=0}^{\infty} (\beta\varphi_i)^l \lambda_{t+l} \left(\frac{\pi^l \widetilde{W}_{i,ht}}{W_{i,t+l}}\right)^{-\vartheta} L_{i,t+l} \left\{\zeta_{i,t+l} - \frac{\vartheta-1}{\vartheta}\frac{\widetilde{W}_{i,ht}}{P_t}\frac{\pi^l P_t}{P_{t+l}}\right\}\right] = 0, \tag{9}$$

where $\zeta_{i,t} = -\frac{\partial U/\partial H_{i,ht}}{\partial U/\partial C_{ht}}$ is the marginal rate of substitution between consumption and labour type i. λ_{t+l} denotes the marginal utility of consumption in period $t+l$. Dividing Eq. (9) by P_t and rearranging yields:

$$\widetilde{w}_{i,ht} = \frac{\vartheta}{\vartheta-1}\frac{E_t\sum_{l=0}^{\infty}(\beta\varphi_i)^l \lambda_{t+l}\zeta_{i,t+l} w_{i,t+l}^{\vartheta} L_{i,t+l}\prod_{k=1}^{l}\pi^{-\vartheta l}\pi_{t+k}^{\vartheta}}{E_t\sum_{l=0}^{\infty}(\beta\varphi_i)^l \lambda_{t+l} w_{i,t+l}^{\vartheta} L_{i,t+l}\prod_{k=1}^{l}\pi^{l(1-\vartheta)}\pi_{t+k}^{\vartheta-1}}, \tag{10}$$

where $\widetilde{w}_{i,ht} = \widetilde{W}_{i,ht}/P_t$ is household h's real optimized wage in the sector i, while $w_{i,t} = W_{i,t}/P_t$ is the real wage index in the sector i.

We define the output loss function associated with wage dispersions in sector i by the equation:

$$s_{i,t}^w = \int_0^1 \left(\frac{\tilde{W}_{i,ht}}{W_{i,t}} \right)^{-\vartheta} dh, i = T, N. \tag{11}$$

As in Schmitt-Grohé and Uribe (2006), the loss function can be represented by the the following law of motion:

$$s_{i,t}^w = (1 - \varphi_i) \left(\frac{\tilde{w}_{i,t}}{w_{i,t}} \right)^{-\vartheta} + \varphi_i \left(\frac{\pi_{i,t}^w}{\pi} \right)^{\vartheta} s_{i,t-1}^w, i = T, N \tag{12}$$

where $\tilde{w}_{i,t}$ and $w_{i,t}$ are respectively the real optimized wage and average real wages in sector i, while $\pi_{i,t}^w$ is the wage inflation rate in sector i.[12]

3.2 Firms

Final consumption and investment goods are produced by combining tradable, non-tradable and imported goods. Sectoral output is produced by aggregating different brands through the Dixit-Stiglitz aggregator. Branding firms buy domestic and foreign homogeneous intermediate inputs, differentiate them slightly and then sell the products in a competitive manner. They set prices as in Calvo (1983). We follow Yun (1996) and assume that firms that cannot change their price index it to the average inflation rate. Domestic manufacturing firms produce goods for both domestic use and export. Following Obstfeld and Rogoff (1995), we assume the producers' *currency pricing* behavior in the manufacturing sector. Thus, the *law of one price* holds for exported domestic goods. However, due to the presence of nominal rigidities in the import sector, exchange rate movements are partially passed through to domestic prices. Capital producers use investment goods to produce new capital purchased from entrepreneurs. In particular, we assume that entrepreneurs borrow to finance part of their acquisitions of capital used in the production processes. Entrepreneurs produce intermediate tradable and non-tradable goods using labour services and sector-specific capital.

3.2.1 Consumption and investment goods

There is a representative firm that acts in a perfectly competitive market and uses sectoral output to produce final consumption and investment goods, Z_t^j, with $j = \{C, I\}$, according to the following

[12]Note that under full price indexation the deterministic steady-state value of $s_{i,t}^w$ is 1.

CES technology:

$$Z_t^j = \left[(\omega_T^j)^{\frac{1}{\nu_j}} \left(Y_{T,t}^{d,j} \right)^{\frac{\nu_j - 1}{\nu_j}} + \left(\omega_N^j \right)^{\frac{1}{\nu_j}} \left(Y_{N,t}^j \right)^{\frac{\nu_j - 1}{\nu_j}} + \left(\omega_F^j \right)^{\frac{1}{\nu_j}} \left(Y_{F,t}^j \right)^{\frac{\nu_j - 1}{\nu_j}} \right]^{\frac{\nu_j}{\nu_j - 1}}, \tag{13}$$

where ω_T^j, ω_N^j, and ω_F^j denote the shares of domestically-used tradable, non-tradable, and imported composite sectoral goods, $Y_{N,t}^{d,j}$,$Y_{N,t}^j$, and $Y_{F,t}^j$, respectively, in the final good, where $\omega_T^j + \omega_T^j + \omega_F^j = 1$, and $\nu_j > 0$ is the elasticity of substitution between sectoral goods. Given the prices $P_{T,t}$, $P_{N,t}$, $P_{F,t}$, and P_t, the final good producer chooses $Y_{T,t}^{d,j}$, $Y_{N,t}^j$, and $Y_{F,t}^j$ to maximize its profits:

$$\max_{\{Y_{F,t}^j, Y_{T,t}^{d,j}, Y_{N,t}^j\}} P_t^j Z_t^j - P_{T,t} Y_{T,t}^{d,j} - P_{N,t} Y_{N,t}^j - P_{F,t} Y_{F,t}^j, \tag{14}$$

subject to (13). Profit maximization implies the following demand functions for domestically-used tradable, non-tradable, and imported sectorial goods in consumption and investment production:

$$Y_{T,t}^{d,j} = \omega_T^j \left(\frac{P_{T,t}}{P_t^j} \right)^{-\nu_j} Z_t^j, Y_{N,t}^j = \omega_N^j \left(\frac{P_{N,t}}{P_t^j} \right)^{-\nu_j} Z_t^j, Y_{F,t}^j = \omega_F^j \left(\frac{P_{F,t}}{P_t^j} \right)^{-\nu_j} Z_t^j.$$

Thus, as the relative prices of domestic and imported goods rise, the demand for domestic and imported goods decrease.

The zero-profit condition implies that the final-good price level, which is the consumer-price index (CPI), is linked to tradable, non-tradable, and imported goods prices through:

$$P_t \equiv P_t^C = \left[\omega_T^C P_{T,t}^{1-\nu_C} + \omega_N^C P_{N,t}^{1-\nu_C} + \omega_F^C P_{F,t}^{1-\nu_C} \right]^{1/(1-\nu_C)}. \tag{15}$$

Similarly, the investment-price index is

$$P_{I,t} \equiv P_t^I = \left[\omega_T^I P_{T,t}^{1-\nu_I} + \omega_N^I P_{N,t}^{1-\nu_I} + \omega_F^I P_{F,t}^{1-\nu_I} \right]^{1/(1-\nu_I)}. \tag{16}$$

3.2.2 Brands

There is a continuum of producers of domestic (tradable and non-tradable) and imported brands $z^{\varkappa} \in [0,1]$ in each sector $\varkappa = \{N, T, F\}$. Branding firms buy tradable, non-tradable or foreign homogeneous intermediate inputs, $Y_t^{\varkappa}$, either from domestic entrepreneurs or foreign producers at price $P_t^{\varkappa}$ in a competitive market. The unit costs for tradable and non-tradable inputs equal their marginal cost, $\xi_{i,t}$, with $i = \{N, T\}$. The unit cost for imported intermediate goods is $e_t P_t^*$ for a given nominal exchange rate, e_t, and foreign price level, P_t^*. Using a linear technology, branding firms differentiate the input slightly and transform it into $Y_t(z^\varkappa)$ that they sell at price $P_t(z^\varkappa)$ in a monopolistically competitive manner. Intermediate goods of each brand are imperfect substitutes in the production of the final composite sectorial goods. Each brand is aggregated into a final good for each sector, $Y_{\varkappa,t}$. Specifically, $Y_{\varkappa,t} = \left[\int\limits_o^1 (Y_t(z^\varkappa))^{\frac{\theta_\varkappa - 1}{\theta_\varkappa}} dz^\varkappa\right]^{\frac{\theta_\varkappa}{\theta_\varkappa - 1}}$. This implies that the price for each good, $P_{j,t}$, is given by $P_{\varkappa,t} = \left[\int\limits_o^1 (P_t(z^\varkappa))^{1-\theta_\varkappa} dz^d\right]^{\frac{1}{1-\theta_\varkappa}}$.

At time t, each branding firm $z^\varkappa$ is allowed to revise its price at time with probability $(1-\phi_\varkappa)$. Firms set $\tilde{P}_t(z^\varkappa)$ to maximize the expected present value of their real dividends:

$$\max_{\{P_t(z^\varkappa)\}} E_0 \left[\sum_{l=0}^{\infty} (\beta\phi_\varkappa)^l \lambda_{t+l} \left(\frac{\pi^l P_t(z^\varkappa) - P_{t+l}^\varkappa}{P_{t+l}}\right) Y_{t+l}(z^\varkappa)\right].$$

The demand curve for each good obeys $Y_t(z^\varkappa) = \left(\frac{\pi^l P_t(z^\varkappa)}{P_{\varkappa,t+l}}\right)^{-\theta_\varkappa} Y_{\varkappa,t+l}$. The producer's discount factor is given by $\beta\lambda_{t+l}$, where λ_{t+l} denotes the marginal utility of consumption in period $t+l$. When producer $z^\varkappa$ is allowed to change its price, it chooses $\tilde{P}_t(z^\varkappa)$ so that

$$\tilde{p}_t(z^\varkappa) = \frac{\theta_j}{\theta_j - 1} \frac{E_t \sum_{l=0}^{\infty} (\beta\phi_\varkappa)^l \lambda_{t+l} p_{t+l}^\varkappa p_{\varkappa,t+l}^{\theta_\varkappa} Y_{\varkappa,t+l} \prod_{k=1}^{l} \pi^{-\theta_\varkappa l} \pi_{t+k}^{\theta_\varkappa}}{E_t \sum_{l=0}^{\infty} (\beta\phi_\varkappa)^l \lambda_{t+l} p_{\varkappa,t+l}^{\theta_\varkappa} Y_{\varkappa,t+l} \prod_{k=1}^{l} \pi^{l(1-\theta_\varkappa)} \pi_{t+k}^{\theta_\varkappa - 1}}; \tag{17}$$

where $p_t^\varkappa = P_t^\varkappa / P_t$ is the unit cost in real terms of the input used to produce the brand-good $\varkappa$, $\tilde{p}_t(z^\varkappa) = \tilde{P}_t(z^\varkappa)/P_t$ is the real optimized price for the brand-good $z^\varkappa$, and $p_{\varkappa,t} = P_{\varkappa,t}/P_t$ is the relative price of the final good in sector $\varkappa$. We assume full indexation as in Yun (1996). If the firm cannot re-set the price, it charges last period's price multiplied by the average inflation rate, $P_t(z^\varkappa) = \pi P_{t-1}(z^\varkappa)$. It is possible to show that the price index in sector $\varkappa$ evolves as follows:

$$P_{\varkappa,t} = \left(\phi_\varkappa \left(\pi P_{\varkappa,t-1}\right)^{1-\theta_\varkappa} + (1-\phi_\varkappa)\left(\widetilde{P}_{\varkappa,t}\right)^{1-\theta_\varkappa}\right)^{\frac{\theta_\varkappa}{1-\theta_\varkappa}}. \tag{18}$$

The output loss function associated with price dispersions in sector $\varkappa$ is given by the equation:

$$s_{\varkappa,t}^p = \int_0^1 \left(\frac{\tilde{P}_{\varkappa,t}}{P_{\varkappa,t}}\right)^{-\theta} dz^\varkappa, \varkappa = T, N, F. \tag{19}$$

As in Schmitt-Grohé and Uribe (2006), the losses can be represented by the following law of motion:

$$s^P_{\varkappa,t} = (1-\phi_\varkappa)\left(\frac{\tilde{p}_{\varkappa,t}}{p_{\varkappa,t}}\right)^{-\theta} + \phi_\varkappa\left(\frac{\pi_{\varkappa,t}}{\pi}\right)^{\theta} s^p_{\varkappa,t-1}, i = T, N, F, \tag{20}$$

where $\tilde{p}_{\varkappa,t}$ and $p_{\varkappa,t}$ are the real optimized price and average real price in sector $\varkappa$, respectively, while $\pi_{\varkappa,t}$ is the price inflation rate in sector $\varkappa$.[13]

Retailers in the tradable sector produce goods for domestic use, $Y^d_{T,t}$, and exports, $Y^e_{T,t}$, so that $Y_{T,t} = Y^d_{T,t} + Y^e_{T,t}$. Following Obstfeld and Rogoff (1995), we assume that the producer exhibits *currency pricing* behavior in the branding sector. Under this assumption, the firm $\varkappa = T$ sets the price $\tilde{P}_t(z^\varkappa)$ for both home and foreign markets. Thus, the *law of one price* holds and movements of the exchange rate are completely passed through to export prices.

The aggregate foreign demand function for exports of manufactured goods under the assumption of producer *currency pricing* is

$$Y^e_{T,t} = \varpi\left(\frac{e_t P_{T,t}}{P^*_t}\right)^{-\nu} Y^*_t, \tag{21}$$

where Y^*_t is foreign output. The elasticity of demand for domestic manufactured goods among foreigners is $-\nu$, and $\varpi > 0$ is a parameter determining the fraction of domestic manufactured-goods exports in foreign spending. Since the economy is small, exports represent an insignificant fraction of foreign expenditures and have a negligible weight in the foreign price index.

3.3 Capital producers

At the end of the period *t*, capital producers buy investment goods I_t, at real price $p_{I,t} = P_{I,t}/P_t$ to produce sector-specific capital that can be used by entrepreneurs at time $t+1$. Following Christiano, Eichenbaum and Evans (2005), we assume that capital producers in sector $i = \{T, N\}$ face investment adjustment costs $S(I_{i,t}, I_{i,t-1})$, which is given by

$$S(I_{i,t}, I_{i,t-1}) = \frac{\chi_i}{2}\left(\frac{I_{i,t}}{I_{i,t-1}} - 1\right)^2 I_{i,t}, \tag{22}$$

such that in steady state $S = S' = 0$ and $S'' > 0$, and $\chi_i > 0$ is an investment adjustment cost parameter. Due to the adjustment costs, the capital producers face a dynamic problem

[13] Note that under full price indexation the deterministic steady-state value of $s^p_{\varkappa,t}$ is 1.

$$\max_{I_{i,t},} E_t \sum_{k=0}^{\infty} \beta^t \lambda_{t+k} \Pi^i_{t+k}, \tag{23}$$

where λ_{t+k} is the marginal utility of consumption in period $t+k$. The production of each capital stock yields the following time-t profit function

$$\Pi^i_t = q_{i,t} I_{i,t} \left[\mu_t - S(I_{i,t}, I_{i,t-1})\right] - p_{I,t} I_{i,t}, \tag{24}$$

where $q_{i,t}$ is the capital price (asset prices) in the sector $i = \{T, N\}$, while $p_{I,t}$ is the relative price of investment goods. The aggregate stock of capital evolves as follows:

$$K_{i,t+1} = I_{i,t} \left[\mu_t - S(I_{i,t}, I_{i,t-1})\right] + (1-\delta) K_{i,t}, \tag{25}$$

where μ_t is an investment-efficiency shock that follows an AR(1) process.

3.4 Entrepreneurs

We assume that entrepreneurs manage firms that produce wholesale tradable and non-tradable goods according to the following constant-returns-to-scale technology:

$$Y_{i,t} \leq A_{i,t} \left(K_{i,t}\right)^{\alpha_i} \left(L_{i,t}\right)^{1-\alpha_i}, \tag{26}$$

where $i = \{N, T\}$. To produce output $Y_{i,t}$ in sector i, the entrepreneurs use $K_{i,t}$ units of capital purchased in $t-1$ and $L_{i,t}$ units of labour services and $\alpha_i \in (0,1)$ is the share of capital in the production of the sector i. $A_{i,t}$ is a sector specific shock that evolves exogenously according to an AR(1) process.

As in Bernanke *et al.* (1999), we assume that entrepreneurs borrow to finance part of their investment in capital used in the production processes. At the end of each period t, entrepreneurs in sector i purchase capital $K_{i,t+1}$ to be used in the next period's production. The cost of the purchased capital is $q_{i,t} K_{i,t+1}$. The acquisition of capital is financed partly from their net worth, $X_{i,t}$, and the rest by borrowing from domestic or foreign financial intermediaries. Therefore, the level of entrepreneurial borrowing equals $q_{i,t} K_{i,t+1} - X_{i,t}$.

The entrepreneurs' demand for capital depends on expected marginal returns, and the expected external financing cost at $t+1$, $E_t f_{i,t+1}$. Therefore, the entrepreneurs' capital demand guarantees that

$$E_t f_{i,t+1} = \frac{z_{i,t+1} + (1-\delta) q_{i,t+1}}{q_{i,t}}, \tag{27}$$

where $z_{i,t+1}$ is the marginal productivity of capital at $t+1$, δ is the capital depreciation rate, and $q_{i,t}$ is the real price of capital paid in period t. Intermediaries obtain funds from household deposits and face an opportunity cost of lending equal to either the domestic or the foreign economy's nominal riskless rate of return, R_t, between t and $t+1$. Thus, in equilibrium, the marginal external financing cost is equal to a gross premium of external funds plus the gross real opportunity costs. We follow Bernanke *et al.* (1999) and assume that the external finance premium, $\Psi_i(\cdot)$, depends on the entrepreneur's leverage ratio.[14]

The IMF country report (2008) documents that over the period 1983-2007 Canadian non-financial firms raised on average one-quarter of their funds in the US financial market. Accordingly, we assume that entrepreneurs are allowed to borrow from the international financial market. The model allows for two different sources of external credit finance but does not aim to explain why different types of contracts co-exist. For simplicity, we impose that different sectors of the economy (tradable and non-tradable goods producers) rely on different sources of external financing.

We assume that entrepreneurs in the non-tradable sector borrow only from domestic intermediaries.[15] Thus, the demand for capital in the non-tradable sector should satisfy the following optimality condition[16]:

$$E_t f_{N,t+1} = E_t \left[\frac{R_t}{\pi_{t+1}} \Gamma_t \Psi_N(\cdot) \right], \tag{28}$$

where Γ_t is an AR (1) shock to the external financing cost in the domestic credit market, $E_t\left(R_t/\pi_{t+1}\right)$ is an expected real interest rate, and the external finance premium is

$$\Psi_N(\cdot) = \Psi_N \left(\frac{X_{N,t}}{q_{N,t} K_{N,t+1}} \right), \tag{29}$$

[14]Bernanke *et al.* (1999) assume the existence of an agency problem that makes external finance more expensive than internal funds. The entrepreneur costlessly observes its output, which is subject to a random outcome. In contrast, the financial intermediaries incur an auditing cost to observe the entrepreneurs' output of production. After observing their project outcome, entrepreneurs decide whether to repay their debt or to default. If they default, the financial intermediaries audit the loan and recover the project outcome, less monitoring costs. Bernanke *et al.* (1999) solve a financial contract that maximizes the payoff to the entrepreneur, subject to the required rate of return of lenders. They show that—given the parameter values associated with the cost of monitoring the borrower, the characteristics of the distribution of entrepreneurial returns, and the expected life span of the firms—the optimal contract implies an external finance premium, $\Psi_i(\cdot)$, that depends on the entrepreneur's leverage ratio.

[15]Allowing firms to be able to choose between different sources of external financing would introduce portfolio decisions and require different solution methods.

[16]For more details, see Bernanke *et al.* (1999), who derive an optimal contract between entrepreneurs and financial intermediaries under an asymmetric information problem.

with $\Psi'_N(\cdot) < 0$ and $\Psi_N(1) = 1$. Shocks to the external financing cost can be interpreted as exogenous financial shocks to credit conditions (supply-side of credit in the economy). They represent shocks to the intermediation process the domestic economy.[17]

We assume that entrepreneurs in the tradable sector, T, borrow only from foreign intermediaries that face an opportunity cost of funds equal to R_t^*, the world nominal risk-free return rate between t and $t+1$, adjusted for changes in the real exchange rates. This assumption allows us to model cross-border lending. Thus, tightening international credit conditions would have direct impacts on external financing costs of Canadian firms operating in the tradable sector. Demand for capital in the tradable sector should satisfy the following optimality condition:

$$E_t f_{T,t+1} = E_t \left[\frac{R_t^*}{\pi_{t+1}^*} \frac{S_{t+1}}{S_t} \Gamma_t^* \Psi_T(\cdot) \right], \tag{30}$$

where Γ_t^* is an AR (1) shock to the external financing cost in international credit market that represents shocks to the intermediation process in the international credit market. The external finance premium is given by

$$\Psi_T(\cdot) \equiv \Psi_T \left(\frac{X_{T,t}}{q_{T,t} K_{T,t+1}} \right), \tag{31}$$

with $\Psi'_T(\cdot) < 0$ and $\Psi_T(1) = 1$. Shocks to the external financing cost can be interpreted as exogenous shocks to credit conditions.

In particular, the external finance premium is assumed to have the following functional form

$$\Psi_i(\cdot) = \left(\frac{X_{i,t}}{q_{i,t} K_{i,t+1}} \right)^{-\psi_i}, \tag{32}$$

where $\psi_i \geq 0$ represents the external finance premium elasticity in the sector $i = \{T, N\}$.[18]

Entrepreneurs are risk neutral and have a finite expected horizon. The probability that an entrepreneur will survive until the next period is ζ_i. Therefore, their expected lifetime is $1/(1-\zeta_i)$.

[17] The financial shocks represent exogenous effects and changes in the confidence level of intermediaries with respect to the risks and the health of the economy. They also approximate perceived changes in creditworthiness.

[18] The steady-state leverage ratio is $1 - k_i$, with $k_i = \frac{X_i}{q_i K_i}$. The external finance premia depend on the size of the borrower's equity stake in a project (or, alternatively, the borrower's leverage ratio). As $\frac{X_{i,t}}{q_{i,t} K_{i,t}}$ decreases, the borrower relies on uncollateralized borrowing (higher leverage) to a larger extent to fund the project. Since this increases the incentive to misreport the outcome of the project, the loan becomes riskier and the cost of borrowing rises. When the riskiness of loans increases, the agency costs rise and the lender's expected losses increase. A higher external finance premium paid by successful entrepreneurs offsets these higher losses and ensures that there is no change to the return on deposits for households.

This assumption ensures that entrepreneurial net worth (i.e. firm equity) will never be enough to fully finance net capital acquisitions. Aggregate entrepreneurial net worth in the two sectors evolves according to

$$X_{i,t} = \zeta_i v_{i,t} + (1 - \zeta_i) g_{i,t}, \tag{33}$$

where $v_{i,t}$ denotes the net worth of surviving entrepreneurs (net of borrowing costs) carried over from the previous period, $1 - \zeta_i$ is the share of new entrepreneurs entering the economy, and $g_{i,t}$ is the transfer or "seed money" that newly entering entrepreneurs receive from entrepreneurs who die and depart from the scene.[19] $v_{i,t}$ is given by

$$v_{i,t} = \left[f_{i,t} q_{i,t-1} K_{i,t} - E_{t-1} f_{i,t} (q_{i,t-1} K_{i,t} - X_{i,t-1}) \right], \tag{34}$$

where $f_{i,t}$ is the ex-post real return on capital held at t, and $E_{t-1} f_{i,t}$ is the cost of borrowing (the real interest rate implied by the loan contract signed at time $t-1$). Earnings from operations in this period become next period's net worth. In our formulation, borrowers sign a debt contract that specifies a nominal interest rate.[20] The loan repayment (in real terms) will then depend on the ex-post real interest rate. An unanticipated increase (decrease) in inflation will reduce (increase) the real cost of debt repayment and, therefore, will increase (decrease) entrepreneurial net worth which in turn affects economic activity and welfare.

3.5 Government and monetary policy

To fit the model to Canadian data, we assume that the monetary authority manages the short-term nominal interest rate, R_t, according to the following Taylor-type monetary policy rule:

$$\widehat{R}_t = \varrho_R \widehat{R}_{t-1} + \varrho_\pi (\widehat{\pi}_t - \widehat{\tilde{\pi}}_t) + \varrho_y \widehat{GDP}_t + \varepsilon_{Rt}, \tag{35}$$

where ϱ_R is a smoothing-term parameter, while ϱ_π and ϱ_y are the policy coefficients measuring the central bank's responses to deviations of CPI inflation, π_t, from the inflation target $\tilde{\pi}_t$ and GDP_t, from its steady-state value, respectively. The variables with hat are the log deviations from their steady-state values. We define the model's GDP at constant prices as

$$GDP_t = Z_t + p_I I_t + p_T Y^e_{T,t} - SY_{F,t}$$

[19]The parameter ζ_i will affect the persistence of changes in net worth.

[20]In Bernanke *et al.* (1999), the contract is specified in terms of the real interest rate.

where p_I and p_T are respectively the steady state prices of investment goods and tradable goods in real terms and and S is the real exchange rate in steady state.

The monetary policy rule is subject to an uncorrelated and normally distributed monetary policy shock, ε_{Rt}. For empirical plausibility, the model features positive long-run inflation. Following Adolfson *et al.* (2007), we also allow for deviations of the inflation target from a time varying inflation targeting, $\tilde{\pi}_t$. We refer to the time-varying inflation targeting as an inflation target shock that follows an AR(1) process with mean equal to the average quarterly inflation rate in the sample.[21]

We assume that the government consumes a fraction G of the final consumption good and runs a balanced-budget financed with lump-sum taxes: $P_t G_t = \Upsilon_t$, where G_t follows an AR(1) process.

3.6 Rest of the world

We assume Canada to be a small open economy. Thus, domestic developments do not affect the rest of the world economy. However, the foreign economy's dynamics have an impact on the Canadian economy. For simplicity we assume that the foreign interest rate, foreign output and the world inflation rate are exogenous and follow AR(1) processes.

3.7 Market clearing conditions

In the symmetric equilibrium, all households, intermediate goods-producing firms, and importers make identical decisions. Therefore, $C_{ht} = C_t$, $D_{ht} = D_t$, $B^*_{ht} = B^*_t$, $\widetilde{W}_{i,ht} = \widetilde{W}_{i,t}$, $H_{ht} = H_t, H_{i,ht} = H_{i,t}$, $P_t(z^{\varkappa}) = P_{\varkappa,t}$, $Y_t(z^{\varkappa}) = Y_{\varkappa,t}$, $Y^*_t(z^T) = Y^*_t$, for all $h \in [0,1]$, $z^{\varkappa} \in [0,1]$, $i = \{T, N\}$ and $\varkappa = \{F, T, N\}$. Furthermore, the final goods market, the loan market, and the bond market must clear. The final good is divided between consumption, C_t, and government spending, G_t, so that $Z^C_t = C_t + G_t$. The production of investment goods equals the use of investment in the production of capital goods, $Z^I_t = I_{N,t} + I_{T,t}$. Domestic real output Y_t, is simply the sum of output in both production sectors, so that $Y_t = Y_{N,t} + Y_{T,t}$.

Combining the household's budget constraint, government budget, and single-period profit functions of manufactured and non-tradable goods producing firms, and foreign goods importers yields a current account equation. The current account equation in real terms, under the producer currency

[21] The Bank of Canada adopted an explicit inflation targeting only since the 1991. The time-varying inflation targeting helps to approximate the conduct of monetary policy in the pre-91 period.

pricing (PCP) assumption, is given by

$$\frac{b_t^*}{\kappa_t R_t^*} = \frac{b_{t-1}^*}{\pi_t^*} + \frac{p_{T,t}}{S_t} Y_{T,t}^e - Y_{F,t}, \tag{36}$$

where $b_t^* = B_t^*/P_t^*$ is the stock of real foreign debt in the domestic economy.

3.8 Shock Processes

Apart from ε_{Rt}, a zero-mean i.i.d. shock with variance σ_R, the other structural shocks follow AR(1) processes:

$$\ln(x_t) = (1-\rho_x)\ln(x) + \rho_x \ln(x_{t-1}) + \varepsilon_{x_t}, \quad \varepsilon_{x_t} \overset{iid}{\backsim} N(0, \sigma_{\varepsilon_x}), \;\; 0 < \rho_x < 1\,. \tag{37}$$

where $x_t = \{\mu_t, A_{N,t}, A_{T,t}, \Gamma_t, \Gamma_t^*, G_t, \tilde{\pi}_t, R_t^*, Y_t^*, \pi_t^*\}$, $x > 0$ is a steady-state value of x_t, ρ_x is an autoregressive coefficient vector, and ε_{x_t} is a vector of uncorrelated and normally distributed innovations with zero means and standard deviations σ_{ε_x}.

4. Estimation

4.1 Estimation strategy

We use Bayesian techniques to estimate a vector of structural parameters of the model, Λ, describing price and wage stickiness, investment adjustment cost, risk premium elasticities, the monetary policy rule and the shocks. First, for given parameter values we solve the model by using standard first-order approximation techniques. Then, we use the Kalman filter to compute the likelihood $L(\Gamma_t\,|\Lambda)$ for the given sample of data Γ_t, as in Hamilton (1994). We add some informative priors, $\varphi(\Lambda)$, to downweigh regions of the parameter space that are widely accepted to be uninteresting. Using Bayes's rule, the posterior distribution can be written as the product of the likelihood function of the data given the parameters, $L(\Gamma_t\,|\Lambda)$, and the prior, $\varphi(\Lambda)$:

$$P(\Lambda|\Gamma_t) \ltimes L(\Gamma_t\,|\Lambda)\varphi(\Lambda) \tag{38}$$

We start by estimating the posterior distribution's mode by maximizing the log posterior function. Second, we obtain a random draw of size 150,000 from the posterior distribution using the random-walk Metropolis-Hastings algorithm. The posterior means of the parameters are then used to draw statistical inference on the parameters themselves or functions of the parameters, such as second moments.

4.2 Data, calibration and priors

Data. We estimate the model using eleven series of quarterly Canadian and U.S. data: tradable and non-tradable outputs, consumption, investment, domestic inflation, the domestic nominal interest rate, real exchange rate, foreign inflation, foreign output, and domestic and foreign external financing cost. The desire to have a sample over which the conduct of monetary policy and the statistical properties of inflation have been relatively stable restricts us to use data from 1981:1 to 2007:2.[22]

The series of tradable output, non-tradable output, consumption, and investment are expressed in real per capita terms using the Canadian population aged 15 and over. Tradable good production is measured by output in manufacturing sectors. Non-tradable output is measured by total services.[23] Consumption is measured by personal spending on services and non-durable and semi-durable goods. Investment is measured by private investment. The nominal interest rate is measured by the rate on Canadian three-month treasury bills. Domestic inflation is measured using CPI. The real exchange rate is measured by multiplying the nominal U.S / CAN exchange rate by the ratio of U.S. to Canadian prices. Foreign inflation is measured by changes in the U.S. GDP implicit price deflator. Foreign output is measured by U.S. real GDP per capita. Finally, domestic and foreign external finance costs are measured by Canadian and U.S. business prime lending rates in real terms.

The model implies that all the variables are stationary, fluctuating around constant means. However, the series described above are non-stationary. Thus, before estimation, the series of tradable, non-tradable, consumption, investment, foreign output and real exchange rate are logged and linearly detrended. The series of nominal interest rate, domestic and foreign inflation, domestic and foreign real external finance costs are demeaned.

Calibration. We calibrate some of the model's parameters to capture the salient features of the Canadian economy. In particular, we calibrate the parameters for which the data used in the estimation contain only limited information. Table 1 reports the calibration values. The discount factor, β, is set to 0.99, which implies an annual steady-state real interest rate of 4 percent which matches the average

[22]Sectorial data are available since 1981:1.

[23]Services includes construction, transportation and storage, communications, insurance, finance and real estate, community and personal services and utilities

observed in the estimation sample. The curvature parameter in the utility function, γ, is set to 2, implying an elasticity of intertemporal substitution of 0.5. Following Bouakez *et al.* (2008), we set the labour elasticity of substitution across sectors and the inverse of the elasticity of intertemporal substitution of labour, ς and τ, to unity. We assume that households allocate one third of their time to market activities. As suggested by Macklem *et al.* (2000), the fractions of labour in the non-tradable and tradable sectors are 0.64 and 0.36, respectively. To match these fractions, the values of η_T and η_N equal 7.5 and 4, respectively.

The capital shares in the production of tradable and non-tradable goods, α_T and α_N, are set to 0.35 and 0.3, which are close to the values suggested by Macklem *et al.* (2000). The capital depreciation rate, δ, is assumed to be common to both tradable and non-tradable sectors and set to 0.025, a value commonly used in the literature. The shares of tradable, non-tradable, and imported goods in the production of consumption good, ω_T^C, ω_N^C, and ω_F^C, equal 0.2, 0.58 and 0.22, respectively, to match the average ratios observed in the data for the estimation period. Since the share of imported good in the production of the investment good is higher than that in consumption good production. we set ω_T^I, ω_N^I, and ω_F^I equal to 0.2, 0.4 and 0.4, respectively.

The parameter measuring the degree of monopoly power in the intermediate-goods markets, θ, is set to be equal to 6, which implies a 20 percent markup in the steady-state. The parameter ϑ, which measures the degree of monopoly power in the labour market, is set equal to 8, implying a steady-state wage markup of 14 percent. Based on Dib (2003), both the elasticity of substitution between tradable, non-tradable and imported goods in the production of final consumption goods, ν^C, and the elasticity of demand for domestic manufactured-goods among foreigners, ν, are set equal to 0.8. The elasticity of substitution between tradable, non-tradable and imported goods in the production of final investment goods, ν^I, is set equal to 0.6, implying that imported goods are less substitutable in producing investment than against the consumption good production .

The parameter υ is calibrated to match a foreign-debt-to-GDP of about 10 percent as in the data. Following King and Santor (2008), the parameters determining the steady-state leverage ratios for tradable and non-tradable sectors, k_T and k_N, are set to 0.7 and 0.6, respectively. The steady-state gross domestic and foreign inflation rates, π and π^*, equal 1.0089 and 1.0088, respectively, which are the historical averages over the estimation sample for Canada and the U.S.

Prior Distribution. Bayesian estimation allows us to formally use informative priors on the probability distributions of the model's parameters. The priors are based on earlier macro and micro evidence. Table 2 reports the prior distributions assumed for the estimated parameters. We use Beta distributions for all parameters bounded in the [0,1] range. This applies to the shocks' autoregressive coefficient, whose mean we set to 0.6. The parameters of nominal stickiness are also assumed to follow a beta distribution with mean 0.67, which corresponds to changing prices and wages every 3 quarters on average. Gamma and Inverted Gamma distributions are assumed for parameters that are supposed to be positive. Our priors on the investment adjustment cost and risk-premium elasticity are in line with previous literature.[24] For the standard deviation of the shocks we assume an Inverted Gamma distribution with mean 0.5 percent and standard deviation 2. We follow previous literature also in setting the priors on the monetary policy parameters. The prior assumptions on the monetary policy parameters allow for a range of interest-rate inertia between 0 and 1, and a positive response to inflation. We use a normal distribution for the reaction to output in order to allow for a negative response.

4.3 Estimation Results

Parameter Estimates. Table 2 reports the results for the estimated parameters and shock processes of the model. The estimated monetary policy rule features a positive reaction to the lagged interest rate, a moderate response to inflation, and a positive but small response to output. These findings are in line with previous estimates for the Canadian economy.[25]

The estimates of the elasticities of the external finance premium, ψ_N and ψ_T, are 0.028 and 0.033 at the posterior mean. This implies a higher degree of credit frictions in the international credit market than in the domestic market. The investment adjustment cost parameters, χ_N and χ_T, are estimated at 0.45 and 0.54. Thus, it is slightly more costly to adjust investment in the tradable sector.

The estimated values of the nominal price and wage stickiness parameters, ϕ_T, ϕ_N, ϕ_F, φ_T, and φ_N, indicate sectoral heterogeneity. Therefore, our prior assumption of the same degree of stickiness on average across sectors doesn't hold. Due to the presence of wage stickiness the estimates of the price rigidity parameters are smaller in the tradable and non-tradable sectors than in the import sector.[26]

Technology, government and investment specific shocks appear to be moderately persistent in the model. However, the estimates of the standard deviations of the shocks suggest that these shocks are

[24]See, among others, Christensen and Dib (2008), Elekdagn, Justiniano and Tchakarov (2006), Mendicino and Pescatori(2005), Queijo von Heideken (2007), Smets and Wouters (2007).

[25]See, among others, Ortega and Rebei (2006) and Dib (2008).

[26]Estimates in which the presence of wage stickiness reduces the role of price stickiness can be found, among others, in Christiano, Eichenbaum and Evans (2005) and Dib (2006).

quite volatile. On the other hand, financial shocks exhibit a higher degree of persistence but much lower volatility. The autocorrelation coefficients of the domestic and international financial shocks are both estimated at 0.98, while the estimated standard deviations of these shocks at the posterior means are around 0.16 and 0.13 percent, respectively.

Sources of Business Cycle Fluctuations in Canada. Since Sims (1980) and Kydland and Prescott (1982), understanding the sources of business cycle fluctuations has been a major issue in macroeconomics. According to the conventional view in the real business cycle literature, technology shocks are identified as the main source of macroeconomic fluctuations. In contrast, the SVAR evidence and DSGE models with a richer stochastic structure tend to conclude that other types of disturbances are more relevant in generating business cycles. In particular, investment specific shocks tend to play a bigger role than neutral technology shocks.[27] Table 3 shows the contribution of each shock to the variability of the model's variables. As a result, financial and investment specific shocks appear to be the main sources of macroeconomic fluctuations for the Canadian economy. Financial shocks to the international and domestic markets explain about 35 and 55 percent of the variability in tradable and non-tradable output, respectively. In particular, financial shocks to the domestic market explain 36 percent of investment and 45 percent of the price of investment variability, 32 percent of variation in the real exchange rate, 31 percent of variation in GDP, 25 percent of fluctuations in hours, and 22 percent of the variation in consumption. On the other hand, international financial shocks account for 11 percent of variations in GDP, 12 percent of investment and real exchange rate variability, 8 percent of consumption's fluctuations, and 7 percent of variation in asset prices.[28] Investment-specific shocks explain only 18 percent of variations in investment but account for most of the variations in asset prices and for 40 percent of the variability in the external financing cost. Investment-specific shocks also contribute to 15 percent of fluctuations in hours worked, 9 percent in GDP, and 10 percent in consumption.

Monetary policy shocks and inflation-targeting shocks explain most of the variability in inflation and nominal interest rate. They also contribute to the volatility of the external financing cost in both sectors by about 25 percent. Foreign interest rate shocks account for 66 percent of fluctuations in foreign debt. They also explain about 20 percent of the variations in investment and the real

[27]See Greenwood, Hercowitz and Krusell (2000), Fisher (2006), Canova, Lopez-Salido and Michelacci (2006), and Justiniano, Primiceri and Tanbalotti (2008).

[28]Our results are in line with Christiano, Motto and Rostagno (2007) that document the significant role of financial shocks for business cycle fluctuations in the US. No previous work on the role of financial shocks has been done using Canadian data.

exchange rate, 12 percent of the variation in tradable output, and 17 percent of the variability in the external finance premium in the domestic sector.[29] Technology shocks are among the main sources of variability in production. Shocks to the production of non-tradable goods explain 22 percent of consumption's fluctuations and only 5 percent of the fluctuations in hours worked.

Tables 4.a-4.b report the model's business cycle statistical properties at the posterior mean of the parameters. The model's correlations are closely related to the correlations displayed in the data. In particular, the model accounts for the correlation between the nominal interest rate and inflation as in the data. However, the correlation between tradable and non-tradable production, and between non-tradable production and investment are slightly lower than in the data. The model implies slightly higher correlation between the external financing cost in the domestic and international markets, and the tradable production and the real exchange rate. Overall, the model's fit in terms of correlations is in line with the data. In terms of autocorrelations, the model implies higher inflation persistence than in the data. Nevertheless, the autocorrelations of sectoral production, the real exchange rate and nominal interest rate are close to those in the data.

5. Price-Level Targeting and Welfare

In the following, we analyze optimal monetary policy rules in the estimated model presented in the previous sections. To maximize welfare, optimal monetary policy should reduce the cost of distortions present in the model. Nominal price and wage stickiness implies that a strong anti-inflationary stance could increase economic activity and welfare by reducing the cost of price and wages dispersions.[30] The presence of debt contracts in nominal terms generates uncertainty about the repayment of the debt and thus unexpected redistribution of wealth between borrowers and lenders. Since entrepreneurs borrow from households to finance part of their capital expenditure, variations in the price level, which generates distortions in the allocation of resources, affect economic activity, consumption and hours worked. Stabilizing the debt-services through the stabilization of the real interest rate would minimize the allocative distortions generated by the debt-deflation channel and improve welfare.[31]

[29] As showed by Justiniano and Preston (2006) medium-scale DSGE small open economy models fail in explaining the synchronization of international business cycle fluctuations. According to their findings, foreign shocks usually play little role in domestic business cycle independently of the priors and the structure of the model.

[30] See among others Woodford (1999), Erceg, Henderson and Levin (2000) and Schmitt-Grohé and Uribe (2006).

[31] The distortion generated by nominal debt contracts has been less explored by the literature. See Mendicino and Pescatori (2005) for the implications of nominal debt contracts for optimal monetary policy in a model with collateralized

5.1 Computation and Welfare Measure

We rely on utility-based welfare calculations, assuming that the benevolent monetary authority maximizes the utility of households, subject to the model's equilibrium conditions. We define V_0^* as the individual welfare level associated with the optimal rule

$$V_0^* \equiv E_0 \left[\sum_{t=0}^{\infty} \beta^t U(C_t^*, H_t^*) \right] ,$$

where C_t^* and H_t^* denote the contingent plans of consumption and labour, respectively, under the optimal policy regime.

Since the rules considered in the paper do not have any first-order effect, the deterministic steady state of the model is the same across the two regimes. Nevertheless, different policy regimes are associated with different stochastic steady states. So, in order not to neglect welfare effects occurring during the transition from one steady state to another, we evaluate welfare conditional on the initial state being the non stochastic steady state.[32]

We limit our attention to simple, optimal, operational interest rate rules that determine the interest rate as a function of the lagged interest rate, GDP and either CPI inflation or the price level. In particular, we consider the welfare performance of optimized rules such as the inflation targeting rule as in (33) and the following price-level targeting rule:

$$\widehat{R}_t = \varrho_R \widehat{R}_{t-1} + \varrho_P (\widehat{P}_t - \widehat{\widetilde{P}}_t) + \varrho_y \widehat{GDP}_t + \varepsilon_{Rt}, \tag{39}$$

where $P_t = \pi_t P_{t-1}$ and $\widetilde{P}_t = \widetilde{\pi}_t \widetilde{P}_{t-1}$ respectively are the level and its target.

We evaluate optimal monetary policy rules by implementing second-order approximation techniques. As shown by previous literature, first-order approximation methods are not locally accurate to evaluate the performance of different policies in terms of welfare.[33]

household debt.

[32] See, among others, Schmitt-Grohé and Uribe (2006).

[33] For instance, Kim and Kim (2003) show that a welfare comparison based on the linear approximation of the policy functions of a simple two-country economy, may yield the odd result of welfare being greater under autarky than under a condition of full risk sharing.

5.2 Optimal Simple Interest-Rate Rules

5.2.1 Price Level Targeting

In what follows, we investigate the optimal design of price-level targeting rules as in (39) and assess the welfare gains compared against the historical rule. Table 5 reports the main findings. We rank the rules according to the implied welfare cost of business cycle fluctuations in terms of steady state consumption. We consider two constrained optimal interest rate rules. The first is a non-smoothing rule. We search over the policy parameters ϱ_P and ϱ_y keeping ϱ_R to zero.[34] The smoothing rule allows for interest-rate inertia by setting ϱ_R equal to its estimated value – i.e. 0.8138. We compare the optimized simple rules to three *ad hoc* rules and the estimated rule. The optimized constrained rules feature an aggressive reaction to the price level and a positive response to deviations of output from the steady state. The welfare gains of allowing for interest rate smoothing are not significant. Our results suggest that responding to output does not deliver significant welfare gains. Instead, a stronger reaction to variation in the price level reduces welfare. With respect to the estimated rule, the optimal price-level targeting rule delivers significant welfare gains in terms of steady state consumption. Using 2006 figures for personal consumption expenditure per person in Canada, the welfare cost of business cycle fluctuations would be \$245 and \$162 per year respectively under the estimated inflation targeting rule and optimal price level targeting rule. So, under the estimated interest rate smoothing, the cost per capita of adopting the estimated inflation targeting rule instead of the optimal price-level targeting rule is about \$83 per year.

To understand the sources of welfare gains by adopting the price-level targeting regime we need to analyze the effectiveness of the optimal rule in minimizing the distortions featured by the model. Price and wage dispersions are costly distortions. The resource costs induced by the inefficient price and wage dispersions featured by Calvo's mechanism in the tradable, non-tradable and import prices, and wages in the tradable and non-tradable sector are summarized respectively by $s^p_{T,t}$, $s^p_{N,t}$, $s^p_{F,t}$ $s^w_{T,t}$, and $s^w_{N,t}$. See Table 6.a for the stochastic mean of these costs under the optimal and estimated rule. The optimal price-level targeting rule, reducing the volatility of inflation, lowers the cost of price and wage dispersions in all the sectors. Table 6.b. shows that an optimal response to the price-level also stabilizes the economy. In fact, the optimal price-level targeting rule delivers lower variability of the inflation rate as well as the real and nominal interest rate. In the table, R^r represents the real interest rate. In the presence of nominal debt, agents face uncertainty regarding the repayment of the

[34] We search over a [0,20] range for both ϱ_P and ϱ_y.

debt. Thus the stabilization of the real interest rate reduces the risk embedded in the nominal contract and increases welfare. Through the stabilization of the returns on nominal assets and liabilities, the optimal price-level targeting rule reduces the volatility of hours worked and thus, output and delivers higher long-run consumption and output.

The optimal price-level targeting rule performs better than the estimated rule in terms of social welfare since it delivers lower variability of the real interest rate which helps reduce the nominal debt distortions and significantly reduces the cost of price and wage dispersions.

5.2.2 Inflation Targeting vs Price-Level Targeting Rules

In order to assess the benefits of price-level targeting, we compare the performance of the optimal price level targeting rule with the optimal inflation targeting rule.[35] As reported in Table 7, the inflation coefficient of the optimized non-inertial inflation targeting rule takes the largest possible value in the grid. Removing the upper bound on the inflation response parameter would imply a much larger response to inflation but would yield negligible improvements in terms of welfare. Introducing interest-rate smoothing improves welfare. The smoothing rule features an aggressive reaction to inflation and little response to output deviations from their steady-state values. However, a strict anti-inflationary stance is not welfare-improving. Compared to the estimated rule, the optimal smoothing inflation targeting rule generates welfare gains in terms of steady state consumption that can be summarized in about $72 per person per year.

According to previous literature, price-level targeting rules perform generally better than optimal Taylor rules due to the introduction of history dependence in monetary policy. History dependence is such that the expectations of future deflation (inflation) immediately depress (spur) inflation when the shock hits the economy. Thus, introducing history dependence in a forward-looking model stabilizes expectations and delivers lower macroeconomic variability and higher welfare. In order to test the desirability of history dependence for monetary policy introduced by the price-level targeting regime, we first compare the optimal non-inertial rules. See Table 8.a. Price level targeting performs better than the inflation-targeting rule by about 7.4 percent in terms of welfare, which is about $17.5 per person per year.

Interest-rate smoothing is an alternative source of history dependency. Thus, adding a response to the lagged interest rate would help the inflation targeting rule approximate a non-smoothing price-level targeting rule. We investigate the benefits of price-level targeting under the estimated interest-

[35]The maximization adopt a [0,20] range for all the optimized parameters.

rate smoothing behavior. As displayed in Table 8.b, allowing for interest-rate smoothing improves the performance of the inflation targeting rule but affects only marginally the performance of the price-level targeting rule.[36]

Tables 9.a and 9.b show that price-level targeting slightly reduces the cost of price and wage dispersions and implies lower variability of the nominal and real interest rate along with hours worked and output. The intuition for why price-level targeting performs better than inflation targeting is as follows. As emphasized previously, a nearly constant real interest rate would reduce the private risk generated by the nature of the debt contract. Under an inflation targeting rule, the minimization of variations in the real interest rate would require a unit response of the policy interest rate to inflation. However, this would lead to higher volatility of inflation and fail in minimizing the distortions generated by the presence of price rigidities. Therefore, there arises a trade-off between the nominal debt distortion and the inefficiency generated by nominal price stickiness.[37] Under the optimal inflation-targeting rule, it is not possible to further reduce the uncertainty in the return of the nominal assets without increasing the cost of price dispersion. Compared to the optimal inflation targeting rule, a price-level targeting rule can reduce the volatility of the real interest rate without increasing the volatility of inflation. Due to the expectation channel triggered by price-level targeting, to generate the same volatility of inflation it requires a lower response to the target in the price-level targeting rule than in the inflation-targeting rule. See column three and four of Table 9.b. As a result, the optimal price-level targeting rule results in a less volatile nominal interest rate that further lowers the volatility of the real interest rate. Thus, the optimal price-level targeting rule performs at least as well as the optimal inflation targeting rule in terms of the inefficiency linked to price stickiness, but it is more successful in minimizing the distortions generated by the presence of debt in nominal terms.

5.2.3 Financial Shocks and Monetary Policy

In the previous section we show that the optimal price level targeting rule outperforms the optimal inflation targeting rule mainly due to its ability to minimize the distortion generated by the presence

[36] In this paper, we limit our attention to simple and implementable interest-rate rules and consider only responses to the lagged interest rate that are less than unity. The maximization over the lagged interest rate leads to optimal super-inertial rules, i.e. a response to the lagged interest rate larger than unity. The optimal inflation targeting rule would require a much more aggressive interest rate smoothing than the optimal price-level targeting rule. However for both rules the optimal response to the lagged interest rate is greater than unity. See, among others, Rotemberg and Woodford (1997), Woodford (2003) and Giannoni (2000) for the optimality of super-inertial rules .

[37] See Mendicino and Pescatori (2005) for further discussion of the trade-off.

of nominal debt in the credit market. Financial shocks, affecting the cost of external finance, are an important source of fluctuations in the borrowing ability of firms and thus, in the redistribution of resources between borrowers and lenders. In the following section, we analyze the role of these shocks for the optimal design of monetary policy.

In Section 4.3, we documented the prominent role of financial shocks for macroeconomic fluctuations. The two shocks explain around 30 percent of consumption variations. According to Table 10, the impact of financial shocks is also relevant for welfare.

Table 11.a compares the performance of the optimal inflation targeting with the optimal price-level targeting rule under three cases: all the shocks (benchmark case), no financial shocks and only financial shocks. Table 11.b reports the implications of the two alternative regimes when financial shocks are the only source of business cycle fluctuations. Significantly lower volatility of inflation is displayed under price level targeting. In the absence of financial shocks, the gains from price-level targeting are significantly reduced. The gains from price-level targeting in the benchmark model economy are mainly linked to the occurrence of financial shocks. In fact, financial shocks account for 40 percent of the gains from adopting the optimal price level targeting rule compared against the optimal inflation targeting rule.

6. Uncertainty and Monetary Policy

Some authors have argued that the gains from a price-level targeting regime are particularly relevant under uncertainty. For completeness, we now study the effects of individual parameter uncertainty in our model. In particular, Aoki and Nikolov (2005) and Gorodnichenko and Shapiro (2005) documented the gains of price-level targeting in the presence of uncertainty in New Keynesian models.[38]

Parameters' Uncertainty. In contrast to previous papers, we do not analyze the effects of uncertainty in relation to an ad-hoc policy function. Instead, we base our analysis on the model's endogenous welfare measure. Following the approach proposed by Justiniano and Preston (2008), we assume that the policymaker adopts either the estimated rule or the optimal price-level or inflation targeting rule and assess the welfare changes implied by variations of single parameters over the 95 percent probability interval of the posterior distribution. We assume that the monetary authority faces uncertainty about a specific parameter but knows with certainty the other parameters. Thus, we investigate how getting a particular parameter wrong affects the comparison between price-level targeting

[38] See also Cateau (2008) for an application to the projection model used by the Bank of Canada.

and inflation targeting. Table 12 reports the welfare implications of uncertainty about the degree of price and wage stickiness, investment adjustment costs, and financial frictions in the different sectors. Welfare exhibits little sensitivity to the parameters considered. Relatively larger variations are implied by uncertainty in the Calvo price parameter in imported goods. Higher Calvo parameter means lower probability of changing prices and thus higher costs of price dispersion. Welfare is invariant to the investment adjustment cost. Also, uncertainty about the elasticity of the risk premium doesn't have large impact on welfare.

Shocks and Monetary Policy. In what follows, we document the role of the stationarity of the price level for welfare in the presence of uncertainty related to the shocks hitting the economy. Price-level targeting performs significantly better than the estimated rule since it implies higher welfare level and lower variability in the presence of uncertainty about the persistence and standard deviation of the shocks. See Table 13.a. In particular, the variability of welfare under the optimal price-level targeting is 0.9 percent while under the estimated rule is 1.27 percent. The largest difference observed in the presence of uncertainty is about the volatility of the shocks.

In comparison with the optimal inflation targeting rule, price level targeting delivers welfare gains of around 6 and 7 percent when the shocks are, respectively, less or more persistent than expected. The difference in the variability in welfare is not quantitatively important. (See Table 13.b.) The same result holds when we allow for uncertainty about the variance of the shocks or both the persistence and variance of the shocks. The gains of price-level targeting with shock uncertainty are around 6 percent in terms of welfare but only 0.06 percent in terms of welfare variability. Thus, under uncertainty, the magnitude of the welfare gains delivered by targeting the price level rather than inflation level is unchanged and the benefits related to the variability of welfare are not quantitatively important.

7. Concluding Remarks

The desirability of adopting a price level targeting regime has become a relevant topic among central bankers. In particular, the Bank of Canada is seriously assessing the desirability of a price-level path targeting in view of the renewal of its agreement on the monetary policy framework with the Government of Canada in 2011.

In this paper we assess the benefits of price level targeting rules in an estimated model of the Canadian economy. Compared to the estimated rule, an optimal price level targeting regime reduces the welfare cost of business cycle fluctuations in terms of steady state consumption. Price-level targeting performs better than the estimated rule since it delivers lower variability of the real interest rate and significantly reduces the cost of price and wage dispersions. In the presence of uncertainty the benefits of adopting a price-level targeting regime are summarized by a lower variability in welfare. In particular, stabilizing price level is important for welfare when shocks are both more persistent and volatile than expected.

We also find some welfare gains from adopting an optimal price-level targeting instead of an optimal inflation targeting rule. The gains are mainly related to the ability of the optimal price level targeting rule to minimize the uncertainty generated by nominal debt contracts in the credit market. The occurrence of financial shocks significantly contributes to quantify the welfare gains of price level targeting.

We also document that the presence of parameters' uncertainty does not significantly affect the performance of the two rules. In fact, the benefits related to the decrease in the variability of welfare under price level targeting, are not quantitatively important.

Investigating the effects of low uncertainty in the price level for financial planning, and in particular, in the presence of long-term debt contracts is beyond the scope of this paper. Modeling long-term contracts in macroeconomics is a major challenge and requires separate consideration. The analysis of the conduct of monetary policy in the presence of long-term debt contract is thus, left to future research.

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Table 1: **Calibration of the Parameters**

Param.	Definition	Values
β	discount factor	0.99
γ	inverse of intertemporal substitution of consumption	2
ς	labour elasticity of substitution across sectors	1
τ	inverse of Frisch elasticity of labour supply	1
ν^C	elasticity of substitution between sectors in consumption	0.8
ν^I	elasticity of substitution between sectors in investment	0.6
ν	elasticity of demand for domestic manufactured goods	0.8
θ	intermediate good elasticity of substitution	6
ϑ	labour elasticity of substitution	8
α_T	capital share in tradable goods production	0.35
α_N	capital share in non-tradable goods production	0.30
δ_T	capital depreciation rate in tradable sector	0.025
δ_N	capital depreciation rate in non-tradable sector	0.025
ω_T^C	share of tradable good in consumption	0.20
ω_N^C	share of non-tradable good in consumption	0.58
ω_F^C	share of imported good in consumption	0.22
ω_T^I	share of tradable good in investment	0.20
ω_N^I	share of non-tradable good in investment	0.40
ω_F^I	share of imported good in investment	0.40
υ	parameter of country-specific risk premium	0.03
k_T	steady-state ratio of net worth to capital in tradable sector	0.7
k_N	steady-state ratio of net worth to capital in non-tradable sector	0.6
ζ_T	survival probability in tradable sector	0.985
ζ_N	survival probability in tradable sector	0.987
H_T	fraction of labour in tradable sector	0.12
H_N	fraction of labour in non-tradable sector	0.21
π	gross steady-state domestic inflation rate	1.0089
π^*	gross steady-state foreign inflation rate	1.0088

Table 2.a: **Estimation Results**

Coef.	Description	Prior			Posterior		
		Density	Mean	Std.	Mean	[5 ,	95]
χ_T	Investment adjustment cost parameter, tradable sector	G	4.00	1.00	0.54	0.45	0.65
χ_N	Investment adjustment cost parameter, non-tradable sector	G	4.00	1.00	0.450	0.448	0.453
ψ_T	Risk premium elasticity, tradable sector	G	0.07	0.025	0.033	0.023	0.042
ψ_N	Risk premium elasticity, non-tradable sector	G	0.07	0.025	0.028	0.019	0.037
ϕ_T	Calvo price parameter, tradable sector	B	0.67	0.05	0.66	0.59	0.74
ϕ_N	Calvo price parameter, non-tradable sector	B	0.67	0.05	0.49	0.42	0.55
ϕ_F	Calvo price parameter, import sector	B	0.67	0.05	0.72	0.65	0.79
φ_T	Calvo wage parameter, tradable sector	B	0.67	0.05	0.63	0.55	0.72
φ_N	Calvo wage parameter, non-tradable sector	B	0.67	0.05	0.56	0.48	0.65
ϱ_R	Taylor rule smoothing	B	0.60	0.20	0.81	0.71	0.92
ϱ_π	Taylor rule inflation	G	0.50	0.30	0.47	0.36	0.58
ϱ_y	Taylor rule output	N	0.125	0.10	0.028	0.008	0.046

Table 2.a: **Estimation Results (Continued)**

		Prior			Posterior		
Coef.	Description	Density	Mean	Std	Mean	[5 ,	95]
ρ_{AT}	Technology, tradable sector	B	0.60	0.20	0.95	0.92	0.98
ρ_{AN}	Technology, non-tradable sector	B	0.60	0.20	0.92	0.88	0.97
ρ_G	Government spending	B	0.60	0.20	0.91	0.88	0.94
ρ_μ	Investment-specific	B	0.60	0.20	0.90	0.88	0.93
ρ_{Γ^*}	Financial, international credit market	B	0.60	0.20	0.98	0.97	0.99
ρ_Γ	Financial, domestic credit market	B	0.60	0.20	0.98	0.97	0.99
σ_{AT}	Technology, tradable sector	I	0.50	2.00	1.23	1.05	1.39
σ_{AN}	Technology, non-tradable sector	I	0.50	2.00	0.92	0.71	1.13
σ_G	Government spending	I	0.50	2.00	3.49	2.84	4.12
σ_R	Monetary policy	I	0.50	2.00	0.30	0.25	0.35
σ_μ	Investment-specific	I	0.50	2.00	1.68	1.42	1.92
σ_{Γ^*}	Financial, international credit market	I	0.50	2.00	0.13	0.11	0.16
σ_Γ	Financial, domestic credit market	I	0.50	2.00	0.16	0.13	0.19
$\sigma_{\tilde{\pi}}$	Inflation target	I	0.50	2.00	0.16	0.10	0.22
	Log likelihood at mean				-2511.33		

Table 2.b: **Estimation Results (Foreign Shocks' Block)**

		Prior			Posterior		
Coef.	Description	Density	Mean	Std	Mean	[5 ,	95]
ρ_{R^*}	Foreign interest rate	B	0.80	0.10	0.97	0.94	0.99
ρ_{π^*}	Foreign inflation	B	0.80	0.10	0.83	0.74	0.93
ρ_{y^*}	Foreign output	B	0.80	0.10	0.93	0.90	0.97
σ_{R^*}	Foreign interest rate	I	0.50	1.00	0.18	0.16	0.20
σ_{π^*}	Foreign inflation	I	0.50	1.00	0.66	0.59	0.74
σ_{Y^*}	Foreign output	I	0.50	1.00	0.25	0.22	0.28
	Log likelihood at mean			-1371.15			

Table 3.a: **Variance Decompositions**

	$A_{T,t}$	$A_{N,t}$	$\varepsilon_{R,t}$	R_t^*	π_t^*	Y_t^*	μ_t	Γ_t^*	Γ_t	G_t	$\tilde{\pi}_t$
$Y_{T,t}$	28.9	0.7	0.2	12.2	1.0	0.1	5.4	34.6	5.9	1.8	9.1
	[25.5, 35.3]	[0.5, 0.9]	[0.2, 0.2]	[10.9, 13.2]	[1.0, 1.2]	[0.1, 0.1]	[4.5, 6.0]	[26.2, 39.5]	[5.4, 6.6]	[1.4, 2.0]	[7.2, 11.7]
$Y_{N,t}$	0.0	28.3	2.2	3.0	0.3	0.1	4.3	1.4	54.9	4.7	0.8
	[0.0,0.0]	[24.6, 32.8]	[1.9, 2.5]	[2.7, 3.4]	[0.3, 0.4]	[0.1, 0.1]	[3.9, 5.1]	[1.2, 1.7]	[51.5, 58.5]	[4.1, 5.2]	[0.6,0.9]
C_t	3.6	21.9	0.8	2.6	0.03	4.6	10.4	8.6	22.0	25.1	0.4
	[3.0, 4.6]	[15.8, 31.9]	[1.5, 0.4]	[1.2, 6.4]	[0.02, 0.3]	[4.3, 7.3]	[16.9, 4.6]	[11.1, 6.4]	[21.0, 15.7]	[23.1, 22.2]	[2.1,0.2]
I_t	0.4	5.2	2.8	21.0	2.5	0.40	18.1	12.6	35.7	0.8	0.5
	[0.3, 0.4]	[4.2, 5.9]	[2.6, 3.0]	[20.5, 21.7]	[2.3, 2.6]	[0.3, 0.5]	[16.8, 19.6]	[10.6, 14.7]	[33.2, 38.8]	[0.8, 0.9]	[0.4, 0.6]
R_t	0.4	3.5	4.8	0.6	0.1	0.1	3.4	0.7	2.4	0.9	83.3
	[0.3, 0.5]	[3.2, 3.7]	[4.3, 5.2]	[0.5, 0.6]	[0.1, 0.1]	[0.1, 0.1]	[2.8, 3.9]	[0.5, 0.8]	[2.1, 2.5]	[0.9, 1.0]	[81.8, 84.8]
S_t	4.2	8.5	3.4	20.1	3.1	7.5	3.5	12.6	31.9	1.5	3.7
	[3.8, 4.9]	[7.4, 9.5]	[3.1, 3.6]	[18.9, 21.3]	[2.9, 3.4]	[7.0, 7.9]	[3.2, 3.9]	[8.9, 15.6]	[29.7, 33.8]	[1.3, 1.7]	[3.1, 4.3]
π_t	0.2	3.3	12.3	0.3	0.1	0.0	0.5	0.3	0.8	0.3	82.0
	[0.2, 0.3]	[2.7, 3.8]	[9.5, 14.2]	[0.3, 0.3]	[0.0, 0.1]	[0.0, 0.0]	[0.4, 0.6]	[0.2, 0.3]	[0.7, 0.9]	[0.2, 0.3]	[79.9, 85.5]
$f_{T,t}$	0.3	9.2	19.2	2.0	0.4	0.2	40.0	24.3	0.6	0.7	3.1
	[0.2, 0.3]	[7.4, 10.4]	[17.8, 20.4]	[1.8, 2.3]	[0.4, 0.5]	[0.2, 0.3]	[37.2, 43.8]	[22.3, 25.4]	[0.5, 0.6]	[0.6, 0.7]	[2.9, 3.3]
$f_{N,t}$	0.0	6.4	21.9	0.2	0.1	0.1	41.8	0.20	21.4	0.5	7.2
	[0.0, 0.0]	[5.4, 7.1]	[20.2, 23.3]	[0.2, 0.3]	[0.1, 0.1]	[0.1, 0.1]	[40.7, 43.6]	[0.2, 0.2]	[20.2, 22.9]	[0.5, 0.6]	[6.8, 7.6]

Table 3.b. **Variance Decompositions**

	$A_{T,t}$	$A_{N,t}$	$\varepsilon_{R,t}$	R^*_t	π^*_t	Y^*_t	μ_t	Γ^*_t	Γ_t	G_t	$\tilde{\pi}_t$
Y_t	1.9	20.9	1.8	12.1	1.3	3.4	10.1	3.3	35.2	8.7	1.3
	[2.5, 1.9]	[15.9, 25.0]	[2.2, 1.4]	[10.5, 12.5]	[0.5, 3.9]	[2.6, 5.6]	[19.8, 3.8]	[4.2, 2.8]	[29.1, 33.9]	[8.6, 8.3]	[4.2, 0.9]
GDP_t	13.3	14.2	2.7	8.1	0.8	0.1	9.3	11.0	31.0	7.3	2.5
	[12.1, 17.9]	[9.8, 15.8]	[3.1, 2.0]	[6.7, 8.8]	[0.3, 2.0]	[0.1, 0.2]	[18.2, 3.4]	[11.3, 11.2]	[25.2, 29.1]	[6.7, 7.6]	[6.7, 2.0]
$q_{T,t}$	0.2	4.2	2.5	0.9	0.1	1.0	76.6	7.6	5.1	0.5	1.4
	[0.2, 0.3]	[3.7, 4.5]	[3.5, 2.0]	[0.7, 1.7]	[0.1, 0.3]	[0.9, 1.9]	[71.2, 73.8]	[9.8, 7.7]	[4.6, 6.2]	[0.5, 0.5]	[4.9, 1.1]
$q_{N,t}$	0.2	2.7	2.3	1.2	0.1	0.8	78.9	0.4	11.5	0.4	1.3
	[0.2, 0.2]	[2.4, 3.1]	[3.1, 2.0]	[1.0, 2.1]	[0.05, 0.4]	[0.6, 1.8]	[73.8, 77.1]	[0.5, 0.7]	[13.4, 11.2]	[0.4, 0.5]	[4.5, 1.1]
$p_{I,t}$	1.2	13.4	1.8	15.7	1.3	8.6	3.9	4.3	44.8	2.9	2.2
	[1.3, 1.4]	[10.5, 14.4]	[2.6, 1.0]	[14.6, 16.7]	[0.6, 3.3]	[7.2, 12.9]	[9.0, 1.3]	[4.5, 5.2]	[39.2, 39.6]	[3.3, 2.8]	[7.4, 1.4]
H_t	3.2	4.9	6.1	1.9	0.4	1.2	14.6	9.4	25.2	28.7	4.4
	[2.4, 4.0]	[2.8, 10.8]	[5.9, 5.5]	[1.7, 3.2]	[0.2, 0.8]	[0.8, 2.4]	[23.5, 7.3]	[9.8, 9.1]	[21.5, 20.9]	[21.7, 32.0]	[9.9, 4.2]
b^*_t	0.6	0.8	1.0	65.9	1.2	3.1	6.2	4.9	13.1	2.5	0.9
	[1.2, 0.1]	[0.7, 0.3]	[1.4, 0.4]	[44.2, 87.5]	[0.3, 3.5]	[4.1, 0.9]	[16.4, 1.0]	[8.3, 1.3]	[17.7, 3.7]	[2.9, 1.0]	[2.8, 0.3]
$\Psi_{T,t}$	1.5	1.0	0.2	17.5	0.2	1.2	7.4	70.0	0.9	0.04	0.2
	[2.7, 0.04]	[1.1, 0.04]	[0.3, 0.01]	[12.6, 3.4]	[0.4, 0.1]	[2.1, 0.05]	[16.7, 0.2]	[61.5, 96.1]	[1.6, 0.03]	[0.1, 0.00]	[1.0, 0.01]
$\Psi_{T,t}$	0.1	0.4	1.1	0.1	0.01	0.1	5.6	0.8	89.3	1.2	1.2
	[0.3, 0.0]	[1.6, 0.01]	[6.6, 0.01]	[0.2, 0.0]	[0.01, 0.0]	[0.5, 0.0]	[9.0, 0.1]	[4.8, 0.01]	[54.4, 99.8]	[5.6, 0.02]	[16.9, 0.01]

Table 4.a **Correlations**

	Data	Model
$Y_{N,t}, Y_{T,t}$	0.46	0.31
$Y_{N,t}, I_t$	0.79	0.64
$Y_{T,t}, I_t$	0.64	0.37
$Y_{T,t}, S_t$	0.47	0.56
f_T, f_N	0.65	0.75
R_t, π_t	0.72	0.73

Table 4.b **Autocorrelations**

	Data	Model
$Y_{T,t}$	0.95	0.98
$Y_{N,t}$	0.98	0.97
π_t	0.64	0.88
R_t	0.97	0.97
S_t	0.98	0.95

Table 5: **Optimal Price-Level Targeting Rule**

$\widehat{R}_t = \varrho_R \widehat{R}_{t-1} + \varrho_P(\widehat{P}_t - \widehat{\widetilde{P}}_t) + \varrho_y \widehat{GDP}_t + \varepsilon_{Rt}$		Welfare	Welfare costs
Optimal, ϱ_R=0	ϱ_P=5, ϱ_y=3	-2.2804	0.702
Optimal, ϱ_R=0.8138	ϱ_P=2.5, ϱ_y=1.5	-2.2803	0.700
Ad hoc, ϱ_R=0.8138	ϱ_P=2.5, ϱ_y=0	-2.2803	0.701
	ϱ_P=3, ϱ_y=1.5	-2.2804	0.708
	ϱ_P=20, ϱ_y=0.5	-2.2815	0.781
Estimated	ϱ_R=0.8138, ϱ_π=0.472, ϱ_y=0.028	-2.2858	1.058

Welfare cost in terms of consumption as percentage of the steady state consumption level

Table 6.a: **Cost of Price and Wage Dispersions** ϱ_R=0.8138

	Optimal	Estimated
$\mu(s_T^p)$	1.0019	1.0034
$\mu(s_N^P)$	1.0005	1.0010
$\mu(s_F^p)$	1.0026	1.0056
$\mu(s_T^w)$	1.0016	1.0035
$\mu(s_N^w)$	1.0009	1.0020

For any variable, x, $\mu(x)$ represents the stochastic mean

Table 6.b: **Price-Level Targeting**

	Optimal	Estimated
$\sigma(C)$	1.73	1.73
$\mu(C)$	0.6612	0.6595
$\sigma(H)$	1.3	1.6
$\mu(H)$	0.5353	0.5361
$\sigma(R^r)$	0.49	0.57
$\mu(R^r)$	1.0091	1.0091
$\sigma(\pi)$	0.80	1.26
$\mu(\pi)$	1.0089	1.0091
$\sigma(Y)$	2.83	3.04
$\mu(Y)$	1.0853	1.0833
$\sigma(R)$	0.86	1.16
$\mu(R)$	1.0181	1.0183
Smoothing coefficient: ϱ_R=0.8138		

Stochastic means ($\mu(x)$), and standard deviations ($\sigma(x)$) as percentage.

Table 7. **Optimal Inflation-Targeting Rule**

$\widehat{R}_t = \varrho_R \widehat{R}_{t-1} + \varrho_\pi \widehat{\pi}_t + \varrho_y \widehat{GDP}_t + \varepsilon_{Rt}$		Welfare	Welfare costs
Optimal, ϱ_R=0	ϱ_π=20, ϱ_y=1.5	-2.2814	0.776
Optimal, ϱ_R=0.8138	ϱ_π=6.5, ϱ_y=0.5	-2.2810	0.749
Ad-hoc, ϱ_R=0.8138	ϱ_π=6.5, ϱ_y=0	-2.2814	0.772
ϱ_R=0	ϱ_π=6.5, ϱ_y =0.5	-2.2819	0.804
	Inflation Stabilization	-2.2820	0.811
Estimated	ϱ_R=0.8138, ϱ_π=0.472 , ϱ_y=0.028	-2.2858	1.058

Welfare cost in terms of consumption as percentage of the steady state consumption level

Table 8.a: **Price-Level Targeting vs. Inflation Targeting**

	IT	PT
Optimal ϱ_R=0	ϱ_π=20, ϱ_y=1.5	ϱ_P=5, ϱ_y=3
Welfare level	-2.2815	-2.2804
Welfare cost	0.776	0.702
PT vs IT: 0.074 $\simeq$ 17.5$		

Welfare cost in terms of the steady state consumption as percentage.

Table 8.b: **Price-Level Targeting vs. Inflation Targeting**

	IT	PT
Optimal ϱ_R=0.8138	ϱ_π=6.5, ϱ_y=0.5	ϱ_P=2.5, ϱ_y=1.5
Welfare level	-2.2810	-2.2803
Welfare cost	0.749	0.700
PT vs IT: 0.049 $\simeq$ 11.4$		

Welfare cost in terms of the steady state consumption as percentage.

Table 9.a: **Cost of Price Dispersion: IT vs PT**

	$\varrho_R = 0$		$\varrho_R = 0.8138$		
	IT	PT	IT	PT	Est. IT
	ϱ_π=20, ϱ_y=1.5	ϱ_P=5, ϱ_y=3	ϱ_π=6.5, ϱ_y=0.5	ϱ_P=2.5, ϱ_y=1.5	ϱ_π=0.472, ϱ_y=0.028
$\mu(s_T^p)$	1.0018	1.0019	1.0019	1.0019	1.0034
$\mu(s_N^p)$	1.0004	1.0005	1.0004	1.0005	1.0010
$\mu(s_F^p)$	1.0028	1.0026	1.0029	1.0026	1.0056
$\mu(s_T^w)$	1.0018	1.0016	1.0017	1.0016	1.0035
$\mu(s_N^w)$	1.0009	1.0009	1.0009	1.0009	1.0020

$\mu(x)$ are Stochastic means, while $\sigma(x)$ are standard deviations as percentage.

Table 9.b. **Level Effect and Stabilization Effect: IT vs PT**

	$\varrho_R = 0$		$\varrho_R = 0.8138$		
	IT	PT	IT	PT	Est. IT
	ϱ_π=20, ϱ_y=1.5	ϱ_P=5, ϱ_y=3	ϱ_π=6.5, ϱ_y=0.5	ϱ_P=2.5, ϱ_y=1.5	ϱ_π=0.472, ϱ_y=0.028
$\sigma(C)$	1.74	1.73	1.73	1.73	1.73
$\mu(C)$	0.6610	0.6612	0.6610	0.6612	0.6595
$\sigma(H)$	1.4	1.3	1.4	1.3	1.6
$\mu(H)$	0.5355	0.5353	0.5355	0.5353	0.5361
$\sigma(R^r)$	0.74	0.53	0.60	0.49	0.57
$\mu(R^r)$	1.0091	1.0091	1.0091	1.0091	1.0091
$\sigma(\pi)$	0.77	0.80	0.79	0.80	1.26
$\mu(\pi)$	1.0090	1.0089	1.0090	1.0089	1.0091
$\sigma(Y)$	3.09	2.83	3.05	2.83	3.04
$\mu(Y)$	1.0850	1.0852	1.0851	1.0853	1.0833
$\sigma(R)$	1.04	0.89	0.95	0.86	1.16
$\mu(R)$	1.0181	1.0181	1.0181	1.0181	1.0183
$\sigma(S)$	3.76	3.50	3.71	3.49	3.77
$\mu(S)$	0.4952	0.4951	0.4954	0.4950	0.4944
$\sigma(P)$	–	1.91	–	1.93	–
$\mu(P)$	–	1.0002	–	1.0002	–

$\mu(x)$ are Stochastic means, while $\sigma(x)$ are standard deviations as percentage.

Table 10: **Welfare and Shocks: Estimated Rule**

$A_{T,t}$	$A_{N,t}$	$\varepsilon_{R,t}$	$\tilde{\pi}_t$	μ_t	G_t	$\Gamma_{T,t}$	$\Gamma_{N,t}$	R_t^*	π_t^*	Y_t^*
2.71	12.82	0.59	0.38	10.02	21.70	5.71	29.58	8.04	0.04	8.41

Table 11.a: **PT vs IT and Financial Shocks**

	Welfare cost % of C All shocks	Welfare cost % of C No fin. shocks	Welfare cost %C Only fin. shocks
IT	0.749	0.516	0.233
PT	0.700	0.486	0.214
PT vs IT	$\simeq 11.4\$$	$\simeq 7\$$	$\simeq 4.4\$$

Welfare cost in terms of steady state consumption as percentage

Table 11.b: **Stabilization Effect PT vs IT: Financial Shocks**

	$\sigma(C)$	$\sigma(H)$	$\sigma(R^r)$	$\sigma(\pi)$	$\sigma(R)$	$\sigma(Y)$	$\mu(C)$	$\mu(H)$
IT	0.96	0.89	0.25	0.18	0.17	1.87	0.6627	0.5340
PT	0.96	0.81	0.24	0.13	0.26	1.81	0.6628	0.5340

$\mu(x)$ are Stochastic means, while $\sigma(x)$ are standard deviations as percentage.

Table 12: **Uncertainty of Parameters**

	PT	IT	Est. IT rule
φ_T	0.064	0.072	0.072
φ_N	0.023	0.024	0.090
χ_T	0.0005	0.0005	0.002
χ_N	0.0003	0.00007	0.00008
ϕ_{T}	0.037	0.041	0.066
ϕ_N	0.016	0.008	0.044
ϕ_F	0.107	0.129	0.246
ψ_T	0.011	0.014	0.029
ψ_N	0.034	0.042	0.086
$\varrho_R = 0.8138$			

Percentage change in welfare due to variation in the parameter in the 5 and 95 probability interval.

Table 13.a: **Uncertainty and Welfare**: Shocks' Persistence and Standard Deviations

	5%	Welfare cost	Mean	Welfare cost	95%	Welfare. cost	Sd.(vf)
IT	-2.2747	0.332	-2.2810	0.749	-2.2966	1.75	0.96%
PT	-2.2744	0.312	-2.2803	0.700	-2.2948	1.64	0.90%
$Est.$	-2.2767	0.464	-2.2858	1.058	-2.3057	2.33	1.27%

Welfare level at the mean and 5 and 95 posterior probability, welfare cost in terms of consumption as percentage of the steady state consumption level; in brackets the welfare gains under the optimal price-level targeting w.r.t. the optimal inflation targeting; Sd(vf) represent the variability of welfare under uncertainty.

Table 13.b: **Uncertainty and Welfare**: Shocks' Persistence

	5%	Welfare cost	Mean	Welfare cost	95%	Welfare cost	Sd(vf)
IT	-2.2783	0.568	-2.2810	0.749	-2.2879	1.19	0.42%
PT	-2.2777	0.529	-2.2803	0.700	-2.2867	1.12	0.39%
$Est.$	-2.2830	0.876	-2.2858	1.058	-2.2929	1.52	0.43%

Welfare level at the mean and 5 and 95 posterior probability, welfare cost in terms of consumption as percentage of the steady state consumption level; in brackets the welfare gains under the optimal price-level targeting w.r.t. the optimal inflation targeting; Sd(vf) represent the variability of welfare under uncertainty.

Table 13.c: **Uncertainty and Welfare**: Shocks' Standard Deviations

	5%	Welfare cost	Mean	Welfare cost	95%	Welfare cost	Sd(vf)
IT	-2.2766	0.457	-2.2810	0.749	-2.2871	1.143	0.46%
PT	-2.2762	0.431	-2.2803	0.700	-2.2859	1.065	0.42%
$Est.$	-2.2787	0.595	-2.2858	1.058	-2.2958	1.703	0.75%

Welfare level at the mean and 5 and 95 posterior probability, welfare cost in terms of consumption as percentage of the steady state consumption level; in brackets the welfare gains under the optimal price-level targeting w.r.t. the optimal inflation targeting; Sd(vf) represent the variability of welfare under uncertainty.