Alternative Targeting Regimes, Transmission Lags, and the Exchange Rate Channel

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Abstract:

Using a closed-economy model, Jensen (2002) and Walsh (2003) have, respectively, shown that a policy regime that optimally targets nominal income growth (NIT) or the change in the output gap (SLT) outperforms a regime that targets inflation, because NIT and SLT induce more inertia in the actions of the central bank, effectively replicating the outcome obtained under precommitment. We obtain a very different result when the analysis is extended to open-economy models. Flexible CPI-inflation targeting outperforms both SLT and NIT and is the most robust targeting regime. The gains from targeting CPI inflation are particularly large when the model features transmission lags and/or departures from the uncovered interest parity condition. We also find that the stabilization bias inherent in discretionary policy is smaller in an open-economy setting.

JEL classification: E52, E58
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Rarely does society solve a time-inconsistency problem by rigid precommitment . . . . Enlightened discretion is the rule. Blinder (1998, 49)

1 Introduction

The inflation bias, forcefully described by Kydland and Prescott (1977) and subsequently by Barro and Gordon (1983), is based on the notion that the policy-maker targets a level of employment above the natural level. This bias inherent in discretionary policy-making is a well-known dynamic inconsistency of monetary policy and has been thoroughly analyzed in the literature. In recent work, however, this inefficiency has received little attention because it is generally assumed that the policy-maker targets a zero output gap. Nevertheless, even in the absence of an over-ambitious output target and an inflation bias, discretionary policy in models with forward-looking agents remains inefficient, since it leads to a stabilization bias.[1] Recent papers on optimal monetary policy have focused on this bias. They have shown that there are gains from commitment and that they can be large.[2]

A stabilization bias arises in forward-looking models under discretion because of a lack of history dependence in the policy actions of the central bank, and this bias usually manifests itself through greater inflation variability and lower output variability. On the other hand, as Clarida, Gali, and Gertler (1999) and Woodford (1999) show in models in which expectations are important for determining inflation, optimal monetary policy under commitment exhibits a considerable degree of inertia. The reason for this is intuitive; with forward-looking agents, expected inflation and the expected policy response become more important. Hence, a more gradual response to shocks allows the central bank to appropriately affect private sector expectations. This, in turn, improves the performance of monetary policy and the inflation output-gap trade-offs the central bank faces.

The problem with optimal commitment is that it is time-inconsistent, since the central bank has an incentive to renege on its promises and deviate from the optimal plan promised

[1] Under discretion, the central bank reoptimizes every period and optimizes once and for all under precommitment.

[2] See Dennis and Söderström (2002), who quantify the welfare differential between discretion and commitment using various calibrated and estimated closed-economy models.

in the first period once the inflation shocks have passed.[3] Thus, if commitment is not feasible and the central bank has to operate under discretion, it may be beneficial to design proper institutional features that can shape its incentives appropriately, and thereby delegate monetary policy to a central bank that can effectively implement and conduct better discretionary monetary policy.

Jensen (2002) and Walsh (2003) have recently used closed-economy models to show that the delegation of monetary policy to a central bank that targets, respectively, the growth of nominal income or the change in the output gap (speed limit targeting) can improve welfare and reduce the policy imperfections inherent in discretionary policy-making.[4] They also show that regimes that target the change in the output gap and nominal income growth are superior to a regime that targets inflation—the overriding objective of monetary policy in many countries—because they help minimize the volatility of inflation and the output gap.[5]

The main purpose of this paper is to examine whether the size of the stabilization bias—the difference between precommitment and discretion—is different, and whether a regime that targets the change in the output gap (speed limit targeting) or nominal income targeting regime outperforms a regime that targets CPI inflation when the analysis is extended to a series of small open-economy models. To examine the above issues, we compare the performance of various targeting regimes using several open-economy models.

The conclusions reached in this paper are very different from those of Jensen (2002) and Walsh (2003). One of the conclusions is that the stabilization bias inherent in discretionary policy-making is smaller in all our open-economy models. Another conclusion is that a conservative central bank (a central bank that assigns more weight to inflation than society) that optimally targets CPI inflation performs very well and is robust to different model and parameter specifications. The gains from targeting CPI inflation relative to nominal income growth and speed limit targeting are especially important when explicit lags in the transmission mechanism and/or departures from the uncovered interest parity (UIP) condition are

[3] According to Woodford (1999), optimization from a timeless perspective would eliminate this initial period problem. He argues that the central bank should adopt a pattern of behaviour "to which it would have wished to commit itself to at a date far in the past."

[4] Jensen's (2002) definition of targeting the nominal income growth involves stabilizing nominal income growth and the output gap.

[5] Others have proposed appointing a conservative central bank (Clarida, Gali, and Gertler 1999), interest rate smoothing (Woodford 1999), price-level targeting (Vestin 2000), and money-growth targeting (Söderström 2001) as a way of improving the outcome under pure discretion.

allowed in the model.[6]

In closed-economy models, nominal income growth targeting and speed limit targeting are superior to inflation targeting because they introduce more inertia in the policy actions of the central bank, effectively replicating the optimal response under commitment. Under a regime that targets nominal income growth, the central bank implicitly introduces lagged output as an endogenous state variable, whereas it is the lagged output gap that introduces inertia into the policy response of the central bank that targets the change in the output gap. Therefore, policy under these two targeting regimes is not only a function of the contemporaneous state variables—it also depends on the lagged state variables.

In contrast, policy under inflation targeting in a closed economy lacks history dependence and is not inertial. Consider a positive cost-push shock that leads to an increase in inflation and a fall in output. To curb the rise in inflation, the central bank has to increase rates, even if this exacerbates the initial fall in output. A central bank that targets inflation in a flexible manner will not have an incentive to let the contractionary policy persist once the cost-push shock has hit and inflation has returned to target, because the period of deflation is costly in terms of social welfare. Instead, it will switch to an expansionary policy to close the output gap. With this in mind, agents will not revise their expectations accordingly and this results in a less favourable trade-off between inflation variability and output variability.

On the other hand, under speed limit targeting, once inflation starts moving back to its target following a contractionary policy, there is less incentive for the central bank to switch to an expansionary policy, because its goal is to stabilize the change in the output gap and not the level itself. Since the central bank implements a tight monetary policy longer, thereby acting more in accordance with policy under commitment, this in turn affects private sector expectations in a favourable manner, improving the trade-off between inflation variability and output variability.[7]

In an open-economy framework, however, a central bank concerned with maximizing welfare has to take into account the important role the exchange rate plays in stabilizing the economy. Changes in the real exchange rate affect aggregate demand by altering the relative price between domestic and foreign goods; they affect inflation directly through their effects on the domestic currency price of imported goods, and indirectly through their effects on

[6] In an open-economy model, the output gap has a smaller effect on inflation. As a result, speed limit targeting becomes less attractive.

[7] Under NIT, the central bank also allows a contraction to persist longer because nominal income growth remains above its equilibrium value for some time.

imported intermediate inputs.

Since the real exchange rate plays a stabilizing role in the face of demand, inflation, and foreign shocks, the policy-maker has to do less to neutralize those shocks. For example, consider a demand shock that increases inflation and output. By raising interest rates to eliminate the shock, the central bank also causes an appreciation of the exchange rate. This, in turn, helps to push output and CPI inflation back to equilibrium. Because the exchange rate does part of the stabilizing job, the central bank has to do less to neutralize shocks in an open economy. As a result, the policy response of a central bank will typically be more inertial in an open-economy model than in a closed-economy model. This suggests that the stabilization bias is likely to be less important in an open-economy framework.

On the other hand, as an asset price, the exchange rate is forward looking and thus will bring some extra forward-looking dimension to the standard model. Consequently, this will tend to increase the gains from precommitment, in turn increasing the stabilization bias. Therefore, a priori, the net effect on the stabilization bias in an open-economy framework is ambiguous and will depend on these opposite forces.

In the baseline open-economy model studied in this paper, we find that the stabilization bias is smaller than in a standard closed-economy framework, which indicates that the exchange rate, despite being forward looking, contributes additional inertia to the system. Thus, a central bank that acts under discretion will come close to the precommitment outcome. Moreover, we find that a policy regime that implicitly relies on the (lagged) exchange rate can introduce enough inertia into the central bank's policy response to make it act more in accordance with the precommitment outcome. This may explain why a regime that targets CPI inflation (with a conservative central bank), which explicitly introduces the lagged value of the exchange rate in the central bank's objective function, performs very well and is able to replicate the precommitment outcome, whereas a regime that targets the change in the output gap and nominal income growth performs poorly.

Our results are even stronger when explicit lags in the transmission mechanism and/or departures from the UIP condition are introduced into the baseline model.[8] One of the benefits of precommitment is that it helps policy-makers to efficiently offset shocks once they occur. When monetary policy operates with a lag, however, it is more difficult for policy-makers to offset or mitigate the impact of shocks, which reduces the benefits of precommitment.

[8] Dennis and Söderström (2002) also find that the stabilization bias is reduced when transmission lags are introduced into one of their closed-economy models.

Our results also show that a conservative central bank that targets CPI inflation performs very well in a model where exchange rate expectations are assumed to be partially and not completely forward looking. This result is intuitive, because backward-looking expectations reduce the benefits of commitment while making the economy more inertial, thus decreasing the size of the stabilization bias.

This paper is organized as follows. Section 2 describes the baseline open-economy model and compares the stabilization bias in a forward-looking closed- and open-economy framework. Section 3 describes the different targeting regimes considered in this paper and presents our measure of welfare. Section 4 describes the parameters chosen for the baseline model. Section 5 reports our simulation results. Section 6 presents two alternative open-economy models and compares the performance of the different targeting regimes. Section 7 describes several sensitivity tests performed on our baseline parameter values. Section 8 offers some conclusions.

2 A Stylized Small Open-Economy Model

The baseline model used in this paper is largely an extension of the closed-economy models used by Jensen (2002) and Walsh (2003). It is very similar to the models found in Batini and Haldane (1999), Svensson (2000), and Leitemo and Söderström (2002). The baseline model assumes no transmission lags and completely forward-looking exchange rate expectations. For any variables, x, $x_{t+\iota|t}$ denotes expectations of $x_{t+\iota}$ conditional on the information available at time t. All variables (except the nominal interest rate) are log deviations from their long-run averages; foreign variables are denoted by the superscript f, and all parameters are assumed to be positive.

The model has an aggregate supply function that takes the following form:

$$\pi_t = (1-\phi_\pi)\pi_{t-1} + \phi_\pi \beta \pi_{t+1|t} + \phi_X x_t + \phi_Q q_t + v_t. \tag{1}$$

The parameter $0 \leq \phi_\pi \leq 1$ denotes the degree of forward-looking behaviour in price-setting, π_t domestic inflation, x_t the output gap, q_t the real exchange rate, and the term v_t a cost-push shock, which is assumed to follow a stationary univariate autoregressive process with variance σ_ε^2. The cost-push shock, v_t, captures any factors affecting inflation that alter the relationship between real marginal cost and the output gap. Apart from the standard output-gap effect, the open-economy Phillips curve also features a direct real exchange rate channel.

In its purely forward-looking form, and ignoring the real exchange rate, this equation can be derived from a model with staggered price-setting, as in the discrete-time variant of the model proposed by Calvo (1983). In this model, a fraction of goods prices remain unchanged each period, whereas new prices are chosen for the other fraction of goods.[9] Inflation inertia in the standard Calvo model can be introduced by assuming that the fraction of producers that do not set their prices optimally are allowed to index their prices to the most recent inflation measure. A number of authors, including Christiano, Eichenbaum, and Evans (2001) and Smets and Wouters (2003), have argued that partial or full indexation of the price level of this kind results in a more realistic specification of the inflation process and improves the empirical fit of their model.

The aggregate demand equation for domestically produced goods expressed in terms of the output gap is as follows[10]:

$$x_t = (1-\alpha_x)x_{t-1} + \alpha_x x_{t+1|t} - \alpha_r[i_t - \pi_{t+1|t}] + \alpha_q q_t + \alpha_f y_t^f + u_t, \tag{2}$$

where $0 \leq \alpha_x \leq 1$ denotes the degree of forward-looking behaviour in output, i_t the nominal interest rate, y_t^f foreign output, and u_t a demand disturbance that is assumed to follow an autoregressive process with variance σ_d^2. The output gap in the model depends negatively on the expected real interest rate and positively on the real exchange rate. Here, the output gap is defined as the deviation of actual output from its flexible-price value. In its closed-economy version, when $\alpha_x = 1$, this equation essentially collapses to an intertemporal IS function that is derived from the representative household's Euler equation linking consumption at time t and *t+1*. This equation is featured predominantly in the work of Kerr and King (1996), Clarida, Gali, and Gertler (1999), McCallum and Nelson (1999b), Woodford (1999), Walsh (1999a, 2003), and a host of other papers. As in the aggregate supply relation, this equation is augmented with a backward-looking element in the form of lagged output. A simple theoretical interpretation of such a specification, in terms of optimizing behaviour, is to assume that private consumption exhibits habit persistence, as in Christiano, Eichenbaum, and Evans (2001) and Smets and Wouters (2003):

[9]For simplicity, the probability that any given price is adjusted in any given period is assumed to be independent of the length of time since the price was set.

[10]This IS equation is a simplified version of the function described in McCallum and Nelson (1999b) and Lam (2002), which is derived from first principles. In those papers, output depends on the expected change in the real exchange rate and not on the level of the exchange rate itself.

$$i_t - i_t^f = s_{t+1|t} - s_t + \varphi_t. \tag{3}$$

Equation (3) imposes interest parity on the part of risk-neutral asset holders. This equation implies that, if domestic interest rates exceed foreign interest rates, the exchange rate is expected to depreciate. The shock term φ represents a foreign-exchange risk premium that follows a stationary univariate AR(1) process (equation (12)). In the baseline model, departures from the UIP condition are not allowed for and it is assumed that exchange rate expectations are completely forward looking, an assumption that will be subsequently relaxed:

$$q_t = s_t + p_t^f - p_t. \tag{4}$$

Equation (4) defines the real exchange rate in terms of domestic prices; s_t denotes the nominal exchange rate. Note that, since there are no non-traded goods, the real exchange rate is the terms of trade:

$$\pi_t^c = (1-\omega)\pi_t + \omega\pi_t^{im} = \pi_t + \omega(q_t - q_{t-1}). \tag{5}$$

Equation (5) defines total CPI inflation as a weighted average of domestic inflation and the domestic currency inflation of imported foreign goods (ω is the share of imported goods in the CPI). The model assumes that the pass-through of import costs to domestic prices is perfect[11]:

$$i_t^f = f_\pi^f \pi_t^f + f_y^f y_t^f, \tag{6}$$

$$\pi_{t+1}^f = \gamma_\pi^f \pi_t^f + \varepsilon_{t+1}^f, \tag{7}$$

$$y_{t+1}^f = \gamma_y^f y_t^f + \eta_{t+1}^f. \tag{8}$$

We assume that the foreign interest rate (equation (6)) follows a Taylor-type rule where the coefficients are constant and positive. Furthermore, foreign inflation (equation (7)) and foreign output (equation (8)) are modelled as stationary univariate AR(1) processes:

$$y_{t+1}^n = \gamma_y^n y_t^n + \eta_{t+1}^n. \tag{9}$$

Potential output is modelled as an exogenous AR(1) process where $0 \leq \gamma_t^n \leq 1$ and η_{t+1}^n is a serially uncorrelated zero-mean shock to the natural level of output. Finally, equations (10), (11),

[11]Imperfect pass-through would likely introduce more inertia into the system, reducing further the stabilization bias.

and (12), respectively, describe a demand, cost-push, and risk-premium shock:

$$u_{t+1} = \gamma_u u_t + \eta_{t+1}^d, \tag{10}$$

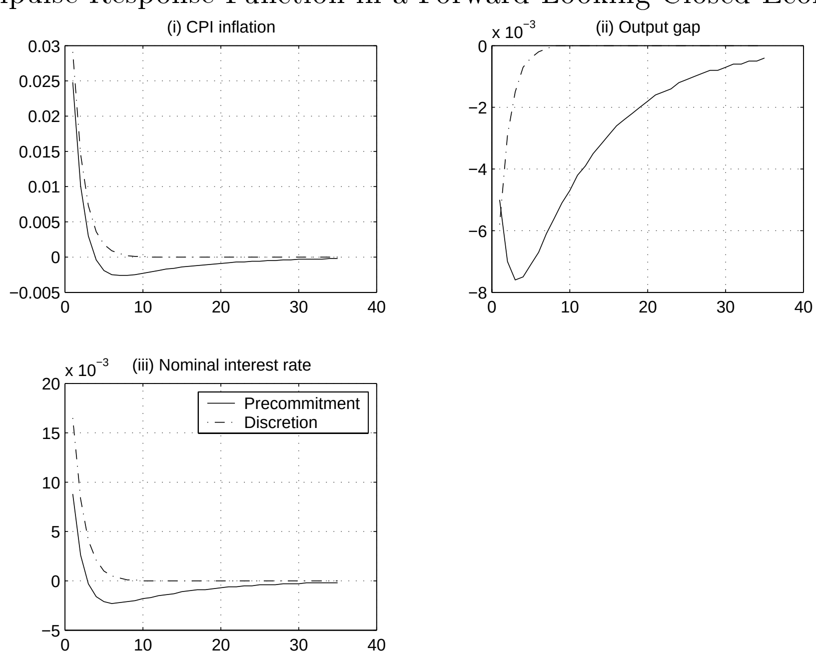
$$v_{t+1} = \gamma_v v_t + \varepsilon_{t+1}, \tag{11}$$

$$\varphi_{t+1} = \gamma_\varphi \varphi_t + \eta_{t+1}^\varphi. \tag{12}$$

2.1 The stabilization bias in a closed- and open-economy framework

As stated in the introduction, we find that the stabilization bias is smaller in an open-economy than in a closed-economy framework. This is because, despite being forward looking, the exchange rate makes the response of the central bank under discretion more inertial, thus acting more in accordance with the outcome under precommitment. In this section, we compare the dynamic response of the economy with a one-unit cost-push shock under precommitment and discretion for both a closed-economy and a small open-economy model. For simplicity, we assume that both models are completely forward looking.

Figure 1: Impulse-Response Function in a Forward-Looking Closed-Economy Model



In a closed-economy framework, a unit cost-push shock leads to an increase in inflation and to a negative output gap under both discretion and precommitment (see Figure 1). To dampen the inflationary pressures, the central bank creates a negative output gap by raising interest rates. Under precommitment, the central bank promises to let the period of inflation be followed by a period of deflation by creating a more persistent output gap. Consequently, the response of the central bank is very inertial (see Woodford 2003). By promising to let the period of above-target inflation be followed by a period of below-target inflation, the central bank can favourably affect the expectations of private agents and hence current inflation. This results in a more favourable inflation–output-gap trade-off.

On the other hand, under discretion, the central bank has no incentive to let the contraction persist once inflation is back at its target, since the period of deflation is costly in terms of welfare. The central bank therefore brings inflation and the output gap back to target, resulting in a larger policy response from the central bank. It is clear from both figures that precommitment entails a lower volatility for inflation and interest rate change, but a higher volatility for the output gap. Consequently, the loss function is higher under discretion than under precommitment in both closed- and open-economy models.

Figure 2: Impulse-Response Function in a Small-Open Economy Model

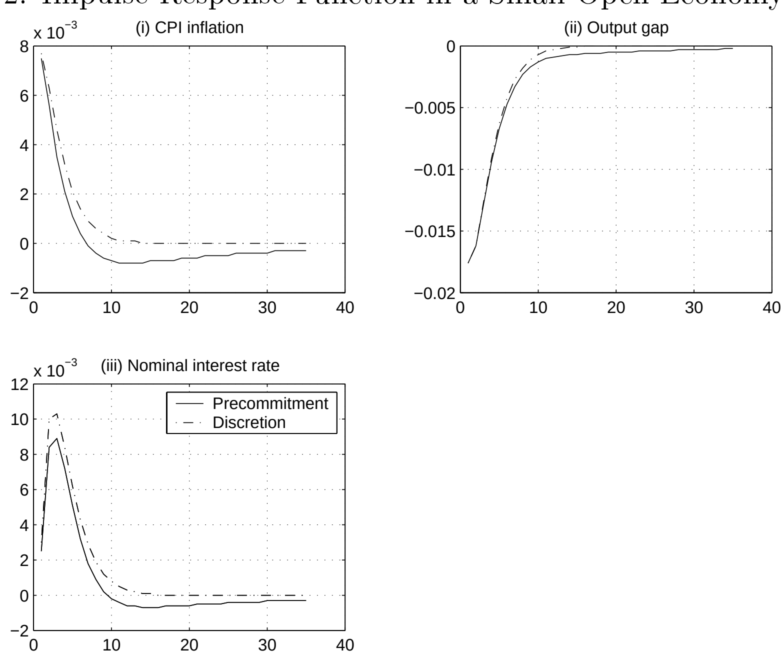


Figure 2 shows the dynamic response of the economy from a unit cost-push shock in an open-economy framework under precommitment and discretion. One striking feature is that the dynamics of the model are very similar under precommitment and discretion, especially for the output gap. In response to the unit cost-push shock, the central bank raises interest rates slightly more under discretion than under precommitment. Although the response of the central bank under precommitment is more inertial— as in the closed-economy model—the interest rate differential between precommitment and discretion is smaller in the open-economy model than in the closed-economy model. Consistent with these smaller differences in impulse-response functions, we find that the difference between precommitment and discretion—the stabilization bias—is smaller in an open-economy framework than in a closed-economy model. Our numerical results confirm that the gains from precommitment are effectively smaller in an open-economy framework (see Table 3).

3 Alternative Targeting Regimes

In this paper, in addition to precommitment and discretion, five other targeting regimes are evaluated: flexible CPI-inflation (Clarida, Gali, and Gertler 1999; Svensson 2000), flexible domestic inflation targeting (Svensson 2000), speed limit targeting (Walsh 2003) and two forms of nominal income growth targeting. The first form of nominal income growth targeting has the central bank targeting nominal income growth and the output gap as in Jensen (2002). The second form of nominal income growth targeting has the central bank targeting inflation and nominal income growth as in McCallum and Nelson (1999a).

In each case, it is assumed that the actual conduct of monetary policy is delegated to an independent central bank that operates under discretion. Although the central bank can choose to have a loss function that is different from society both in terms of the variables included and the relative weights on the different variables, it is constrained in its objective.

Table 1 lists the single-period loss functions for each targeting regime. As in Jensen (2002) and Walsh (2003), we focus on optimal targeting regimes, thereby eliminating any arbitrariness in the choice of the weight the central bank assigns to its targeting variable. For each, and independent of the targeting regime, a grid search is performed to find the optimal value the central bank assigns to its objective function ($\widehat{\lambda}$ in Table 1). The same procedure is followed for all of the targeting regimes, each time finding the optimal weight the central bank assigns to its targeting variable.

Table 1: Alternative Targeting Regimes

Targeting regimes		Loss function*
Precommitment	COM	$\lambda_x^s x_t^2 + \pi_t^{c^2}$
Pure discretion	PD	$\lambda_x^s x_t^2 + \pi_t^{c^2}$
CPI inflation	CPI	$\widehat{\lambda}_x x_t^2 + \pi_t^{c^2}$
Domestic inflation	DIT	$\widehat{\lambda}_x x_t^2 + \pi_t^2$
Output-gap growth	SLT	$\widehat{\lambda}_{slt}(x_t - x_{t-1})^2 + \pi_t^{c^2}$
Nominal income growth 1	NIT1	$\widehat{\lambda}_{nit1}(\pi_t + \Delta y_t)^2 + \pi_t^{c^2}$
Nominal income growth 2	NIT2	$\widehat{\lambda}_{nit2}(\pi_t + \Delta y_t)^2 + \lambda_x^s x_t^2$

*The increment for $\widehat{\lambda}$ is set at 0.05. A finer grid does not alter the results.

3.1 Social welfare function

All the policy regimes considered in this paper are evaluated according to a social welfare function. We assume that social welfare can be represented by the following function:

$$L_t^s = E_t \sum_{t=1}^{\infty} \beta^{t-1} \left[\lambda_x^s x_t^2 + \pi_t^{c^2} \right], \tag{13}$$

where L_t^s is society's loss function, β the representative agent's discount factor, x_t the output gap, π_t^c the deviations of CPI inflation from its target (assumed to be zero), and λ_x^s denotes society's preference for output stabilization relative to inflation stabilization.[12] The social loss function includes the variance of the output gap and inflation for a simple reason. Inflation is costly because it generates price dispersion between firms that can adjust prices and those that cannot, thereby inducing socially inefficient substitution between goods produced by the different producers. On the other hand, output gaps are costly because they denote deviations of output from its efficient or optimal level.

We are aware that, since our model features backward- and forward-looking expectations and the source of rigidity is domestic and not CPI inflation, equation (13) may not represent society's welfare function appropriately. As Woodford (2003) shows, in case the model features backward- and forward-looking expectations, the utility-based function should be modified to include lagged inflation and lagged output. Moreover, as Smets and Wouters (2003) show, if

[12]This quadratic loss function is standard in the literature and is an important element of "the science of monetary policy." Woodford (2003) shows that this social welfare function can be derived as a second-order Taylor approximation of the utility of a representative agent in a forward-looking closed-economy model.

the only rigidity in the economy lies in domestic inflation, the latter should enter the welfare function and not CPI inflation. Since our models do not have explicit micro-foundations and therefore a utility-based welfare function cannot be derived, and since most central banks and private sector surveys tend to focus on CPI inflation instead of domestic inflation, we use equation (13) as a general formulation of social welfare.[13]

To evaluate the welfare differential between precommitment and the different targeting regimes, we use two alternative measures, as in Dennis and Söderström (2002). The first measure is the percentage deviation of the optimal targeting regimes from the outcome under precommitment. It is calculated as:

$$L^{diff} = 100[\frac{L_{TR}}{L_C} - 1], \tag{14}$$

where L_R and L_C are, respectively, the loss function value under the optimal targeting regime and precommitment.

As this measure does not have a direct economic interpretation, we follow Jensen (2002) and Dennis and Söderström (2002), and also calculate the permanent deviation of inflation from target (the inflation equivalent) when the central bank moves from precommitment to an optimal discretionary regime. This measure is calculated as:

$$\pi^{diff} = \sqrt{(L_{TR} - L_C)}. \tag{15}$$

This measure has a more direct economic interpretation, because it indicates how inflation is affected if the central bank chooses to renege on its promises.

3.2 Optimal policy

The optimal policy rule obtained under precommitment and the various discretionary regimes is calculated using the numerical solutions described by Söderlind (1999). To derive the central bank's optimal policy and the associated societal welfare loss, the baseline model is written in state-space form:

$$\begin{bmatrix} x_{1t+1} \\ x_{2t+1|t} \end{bmatrix} = A \begin{bmatrix} x_{1t} \\ x_{2t} \end{bmatrix} + Bi_t + \begin{bmatrix} \zeta_{t+1} \\ 0 \end{bmatrix}, \tag{16}$$

where x_{1t} is a vector of backward-looking variables, x_{2t} is a vector of forward-looking variables, with $x_{1t} = [u_t, v_t, \varphi_t, y_t^n, y_{t-1}^n, \pi_t^f, y_t^f, q_{t-1}, i_{t-1}, x_{t-1}, \pi_{t-1}]$, $x_{2t} = [\pi_t, q_t, x_t]$, and ζ is a vector of

[13] We have performed sensitivity tests by including domestic or lagged inflation in the social welfare function. However, these changes did not affect our results qualitatively.

disturbances. The matrices A and B contain the coefficients of the model. The central bank has the following loss function:

$$L = z_t' W z_t, \tag{17}$$

where z_t is a vector of goal variables and W is a matrix of preference parameters with $z_t = [\pi_t^c, \pi_t, x_t, \Delta x_t, \pi_t^c + \Delta y_t]$, and the matrix W depends on the targeting regime the central bank chooses. The decision problem for the central bank involves minimizing equation (17) subject to (16).

4 Model Parameters

Since numerical simulations are used to evaluate the different targeting regimes, representative values are chosen for the various parameters of the model. They are mostly illustrative. Selected to be a priori reasonable, the values are very similar to those in McCallum and Nelson (1999a), Svensson (2000), Jensen (2002), Leitemo and Söderström (2002), and Walsh (2003). Table 2 lists the baseline parameters. Many sensitivity tests are performed on the baseline parameter values (Table 6).

Table 2: Baseline Parameter Values

Inflation	Output gap	Foreign	Stochastic shocks
$\phi_\pi = 0.5$	$\alpha_x = 0.5$	$f_\pi^f = 1.5$	$\gamma_u = 0.3, \gamma_y^n = 0.97, \gamma_v = 0$
$\phi_x = 0.05$	$\alpha_r = 0.15$	$f_y^f = 0.5$	$\gamma_\varphi = 0.5, \gamma_\pi^f = \gamma_y^f = 0.8$
$\phi_q = 0.025$	$\alpha_q = 0.05$		$\sigma_d = \sigma_\varepsilon = 0.015, \sigma_{y^n} = 0.005$
$\omega = 0.3$	$\alpha_{y^f} = 0.05$		$\sigma_\pi^f = \sigma_y^f = \sigma_\varphi = 0.015$

With respect to the aggregate supply function, the parameter that governs the degree of persistence in prices, ϕ_π, is set at 0.5. Since this parameter is subject to much controversy, we provide a range of sensitivity tests and experience with more forward- and backward-looking versions of the aggregate supply (the results are shown in Tables A1 and A2 in Appendix A). The elasticities with respect to the output gap, ϕ_x, and the real exchange rate, ϕ_q, are set, respectively, at 0.05 and 0.025. The share of imported goods in the CPI, ω, is set at 0.3. In the aggregate demand equation, α_x is set at 0.5, α_r at 0.15, and $\alpha_q = 0.05$, reflecting the three-to-one ratio used in many monetary condition indices. The parameter on foreign output, α_{y^f}, is set at 0.005. The persistence parameters for the demand, cost-push, and supply shock are set, respectively, at 0.3, 0, and 0.97, while their variances are fixed at $\sigma_d = 0.015$, $\sigma_\varepsilon = 0.015$, and $\sigma_{y^f} = 0.005$.

The coefficients on the foreign Taylor rule are assigned values of 1.5 for inflation and 0.5 for output; the variances of foreign shocks are set to 0.015 in the baseline case. Foreign inflation and output are assumed to be persistent and the autoregressive coefficient is fixed at 0.8. The persistence of the risk premium shock is set at 0.5. The weight on the output gap in the social loss function, λ_x, is set to 0.25, so that the deviations of inflation from its target level are penalized four times as heavily as output deviations.

5 Simulation Results

Table 3 shows the results for the different targeting regimes when the baseline model and parameter values are used. For illustrative purposes and comparison, the results from a closed-economy model—calibrated using our baseline parameter values—are also provided.[14]

Table 3: Results from Baseline Model and Parameters

Targeting regimes	Closed economy			Open economy		
	Loss	L^{diff}	π^{diff}	Loss	L^{diff}	π^{diff}
COM	9.94	-	-	10.32	-	-
PD	13.16	35.05	1.86	11.90	15.34	1.26
CPI	11.74	18.16	1.34	11.01	6.70	0.83
DIT	-	-	-	16.69	61.78	2.52
SLT	9.97	0.30	0.17	10.92	5.84	0.78
NIT1	11.98	20.69	1.43	11.71	13.55	1.18
NIT2	10.00	0.61	0.25	11.86	15.01	1.24

The results of the simulation show that the stabilization bias—the difference between precommitment and pure discretion—in a closed-economy setting is fairly large. The loss function under discretion is around 35 per cent higher than under precommitment. Moreover, the inefficiency of a purely discretionary policy amounts to a permanent deviation of inflation from target of around 1.86 percentage points. Table 3 also shows that the speed limit targeting (SLT) of Walsh (2003) and Jensen's nominal income growth targeting (NIT2) perform well in the closed-economy model. The gains of moving from SLT or NIT2 to precommitment are very small (less than 1 per cent in both cases).

[14]The results for our baseline closed-economy model are similar to those of Walsh (2003).

These two targeting regimes perform well in a closed-economy setting because they introduce inertia into the policy actions of the central bank, effectively replicating the outcome under precommitment. On the other hand, a regime that targets CPI inflation performs poorly. Targeting CPI inflation results in a loss function that is 18 per cent higher and in a permanent deviation of inflation from target of 1.34 percentage points. In a closed-economy framework, targeting CPI inflation is not history-dependent (there is no lagged endogenous variable in the central bank's objective function). Consequently, the inflation–output-gap trade-off under a regime that targets CPI inflation is less favourable, resulting in a bigger stabilization bias.

Turning to the open-economy model, our numerical simulations confirm that the stabilization bias inherent in discretionary policy-making is smaller in our baseline framework. The percentage gain of moving from discretion to precommitment is around 15.3, about half the size of the stabilization bias in the closed-economy model. Moreover, the permanent deviation of inflation from target is also smaller in the open-economy framework, by around 0.60 percentage points.

We have already explained why the stabilization bias is smaller in an open-economy model. In an open-economy framework, movements in the exchange rate help insulate the economy from shocks because the exchange rate acts as a shock absorber. As a result, the response of the central bank is more inertial, thus acting more in accordance with the precommitment outcome. The difference between the optimal response of the central bank in a closed- and open-economy model is clearly illustrated in Figures 1 and 2.

Our results for the open-economy model reveal that Walsh's SLT performs well and is the most efficient targeting regime. Contrary to the closed-economy framework, however, a regime that targets CPI inflation in a flexible manner (with a conservative central bank) also performs very well. Using the loss-function values from Table 3, we find that the percentage gains of moving from a regime that targets CPI inflation in a flexible manner (with an optimal value of λ of 0.15) to a regime that targets the change in the output gap is less than 1 per cent. Moreover, moving from CPI inflation to SLT results in a permanent decrease of only 0.3 percentage points in inflation, compared with 1.3 percentage points in the closed-economy model.

The same intuition that was used to explain why the stabilization bias is smaller in an open economy can be applied to account for the smaller difference between CPI inflation targeting and SLT.[15] A regime that targets CPI inflation takes into account the direct and indirect effects of the exchange rate on the economy and introduces the lagged value of the real exchange rate in the objective function of the central bank, making its optimal reaction history-dependent and inertial. By introducing inertia into its policy actions, this allows the central bank to appropriately affect private sector expectations. This, in turn, improves the performance of monetary policy and the inflation–output-gap trade-off, because current inflation depends on expected future inflation.

Table 3 also shows that regimes that target domestic inflation or nominal income growth do not perform well in our baseline open-economy model. Jensen's nominal income growth targeting—which performs well in a closed-economy model—has a higher loss function than either SLT or CPI inflation. Both forms of nominal income growth and domestic inflation targeting perform poorly in our baseline open-economy model, because these targeting regimes lead to more volatility in the real exchange rate and hence to a more volatile inflation and output gap.

Table 4: Standard Deviation and Optimal λ–Baseline Model

Targeting regime	s.d(ygap)	s.d(CPI)	s.d(Δq)	optimal λ
Precommitment	5.04	1.98	4.62	-
Discretion	4.36	2.67	5.11	-
CPI inflation	5.30	1.99	4.68	0.15
Domestic inflation	4.41	3.43	9.76	0.10
Output-gap growth	5.29	1.98	5.45	0.60
Nominal income growth 1	5.63	1.96	5.53	1.00
Nominal income growth 2	4.40	2.65	6.64	1.85

Table 4 shows the standard deviation of the change in the real exchange rate, CPI inflation, the output gap, and the optimal λ the central bank assigns to its target variable.[16] It is clear from Table 4 that CPI inflation targeting entails considerable real exchange rate smoothing, whereas both forms of nominal income growth targeting regime introduce more volatility in the real exchange rate and hence CPI inflation.

[15] The only difference between CPI inflation targeting and a purely discretionary regime is that, in the former, the central bank optimizes over λ and not under discretion.

[16] The standard deviations are multiplied by 100.

6 Model Uncertainty

6.1 Model with transmission lags

In practice, the central bank, when designing optimal policy, has to face numerous uncertainties. Among the most important of these are model and parameter uncertainty. In this section, we introduce two simple forms of model uncertainty and analyze how the different targeting regimes fare when these modifications are brought to the baseline model.

The first modification to the baseline model introduces a lag in the transmission mechanism, to account for the fact that monetary policy works with long and variable lags. The second modification allows for the possibility of backward-looking exchange rate expectations, and therefore allows for departures from the UIP condition.[17] Both modifications have implications for the stabilization bias and for the choice of the optimal targeting regime.

Explicit transmission lags make it more difficult for policy-makers to offset shocks, thus reducing the benefits of precommitment.[18] Similarly, departures from the UIP condition make the whole system more inertial, thus again reducing the benefits of precommitment.

When explicit transmission lags are introduced in the baseline model, the following changes to equation (2) are required. Equation (18) assumes that there is a delayed effect of monetary policy on aggregate demand and, indirectly through the aggregate supply, on domestic inflation:

$$x_t = (1-\alpha_x)x_{t-1} + \alpha_x x_{t+1|t} - \alpha_r[i_{t-1} - \pi_t] + \alpha_q q_t + \alpha_f y_t^f + u_t. \tag{18}$$

[17] For more details regarding model uncertainty and for a more complex treatment, see Lam and Pelgrin (2003), who introduce uncertainty, in the form of imperfect and asymmetric information, in the model of Walsh (2003).

[18] In an earlier version of this paper, Svensson's (2000) framework was used to model transmission lags. The results are essentially the same and are available from the author upon request.

6.2 Model with partially forward-looking exchange rate expectations

The second modification to the baseline model allows for deviations from the UIP condition. Following Leitemo and Söderström (2002), the interest parity condition is modelled as:

$$i_t - i_t^f = s^*_{t+1,t} - s_t + \varphi_t, \tag{19}$$

$$s^*_{t+1,t} = \vartheta s_{t+1|t} + (1-\vartheta) s^A_{t+1,t}, \tag{20}$$

$$s^A_{t+1,t} = (1-\gamma) s_t + \gamma s^A_{t,t-1}. \tag{21}$$

Exchange rate expectations as shown in equation (19) are a combination of rational and adaptive expectations. The parameter ϑ measures the degree of forward-lookingness or rationality. If ϑ is one, exchange rate expectations are purely forward looking and equation (19) collapses to the UIP condition of equation (3). On the other hand, if $0 \leq \vartheta \leq 1$, deviations from the UIP condition are allowed. Under adaptive expectations, it is assumed that the exchange rate is a weighted average of previously observed exchange rates. The parameter γ in equation (21) measures the rate at which agents update their expectations. When departures from the UIP condition are allowed for, ϑ and γ are set to 0.5. No sensitivity tests are performed on these parameter values.

The results for the different targeting regimes when the model features transmission lags and/or departures from the UIP condition are shown in Table 5.

Table 5: Results from Alternative Models and Baseline Parameters

Regimes	Transmission lags			Departures from UIP			Both		
	Loss	L^{diff}	π^{diff}	Loss	L^{diff}	π^{diff}	Loss	L^{diff}	π^{diff}
COM	5.55	-	-	8.84	-	-	2.80	-	-
PD	6.25	12.70	0.84	8.91	0.78	0.26	2.94	5.02	0.37
CPI	5.92	6.69	0.61	8.91	0.78	0.26	2.87	2.52	0.27
DIT	7.18	29.42	1.28	15.97	80.70	2.67	3.84	37.16	1.02
SLT	10.33	86.13	2.19	11.59	31.08	1.66	4.25	51.68	1.20
NIT1	7.74	39.52	1.48	13.15	48.76	2.08	4.51	60.92	1.31
NIT2	18.20	228.01	3.56	11.43	29.29	1.61	5.80	107.06	1.73

Our numerical results from Table 5 confirm that, compared with the baseline open-economy model, the stabilization bias is smaller when the model allows for either transmission lags and/or departures from the UIP condition.[19] Introducing a lag in the transmission mechanism decreases the stabilization bias by around 3 per cent, whereas allowing for departures from the UIP condition has a larger impact on the percentage gain from precommitment, as well as on the inflation equivalent. Compared with the baseline open-economy model, the percentage gain decreases by around 15 per cent, whereas the inflation equivalent falls by 0.40 percentage points.

The reason for the decrease in the stabilization bias in these two models is intuitive. One of the main benefits of precommitment is that it allows policy-makers to influence agents' expectations in a favourable manner. Hence, through credible announcements, policy-makers are able to offset shocks efficiently. However, when monetary policy operates with a lag, or when the model allows for departures from the UIP condition, it is more difficult for policy-makers to offset the impact of shocks and to affect agents' expectations as the expectations channel becomes less important. As a result, reneging on commitments becomes less important.

The above result also implies that, when the model features either transmission lags and/or departures from the UIP condition, an optimal targeting regime that is similar to the pure discretion outcome—in this case, CPI inflation targeting with a conservative central bank—can effectively replicate the precommitment outcome.

We find that CPI inflation targeting (with a conservative central bank) performs very well and is the best targeting regime.[20] More importantly, CPI inflation is very robust to model uncertainty and clearly outperforms both Walsh's speed limit targeting and Jensen's nominal income growth targeting (NIT2). For example, when the model features transmission lags, the gain of moving from speed limit targeting to CPI inflation targeting is around 80 per cent, while the inflation equivalent falls by around 1.60 percentage points. Similarly, moving from NIT2 to CPI inflation targeting entails significant gains in both models.

The results from Table 5 also reveal that SLT and, in particular, NIT2 are not robust to model uncertainty. The loss function under both targeting regimes, especially under NIT2, shoots up when transmission lags are introduced or when departures from the UIP condition are introduced. Our findings are clearly very different from those obtained in closed-economy models (see Jensen 2002 and Walsh 2003). CPI inflation targeting is the most robust targeting

[19]Dennis and Söderström (2002) obtain a similar result when they use Rudebusch's model, which also features transmission lags.

[20]Leitemo, Røisland, and Torvik (2002), using a backward-looking IS and Phillips curve but forward-looking behaviour for the exchange rate, also find that optimal policy under discretion consists of delegating policy to a conservative central bank.

regime and is superior to both Walsh's speed limit targeting and Jensen's nominal income growth targeting (NIT2).

7 Parameter Uncertainty

To test the robustness of our results, several sensitivity tests are performed on the baseline parameters by changing one structural parameter of the model at a time. Table 6 lists the alternative parameters; the results are shown in Appendix A.

Table 6: Values of Alternative Parameters

Parameter	Baseline value	Alternative values
ϕ_π	$\alpha_\pi = 0.5$	$\alpha_\pi = [0.01, 0.1, 0.2, 0.3, ..., 0.9, 0.99]$
σ_{y^n}	$\sigma_{y^n} = 0.005$	$\sigma_{y^n} = 0.015$
γ_v	$\gamma_v = 0$	$\gamma_v = 0.5$
λ_x^s	$\lambda_x^s = 0.25$	$\lambda_x^s = [0.1, 0.5, 0.75, 1]$

The first sensitivity test allows for various degrees of forward-lookingness of the aggregate supply function. Overall, our results, using these alternative values, are very similar to the baseline case. We find that a conservative central bank that targets CPI inflation continues to perform well even in models that feature a very forward-looking aggregate supply. This result differs from the findings of Jensen (2002) and Walsh (2003). They argue that, in a closed-economy setting, the gains of moving from CPI inflation targeting to SLT or NIT2 increase as the model becomes more forward looking. Unlike Jensen (2002) and Walsh (2003), we do not find that such a result holds in our open-economy models.

The gains from targeting CPI inflation are again especially large when the model features transmission lags and the possibility of backward-looking expectations. Moreover, regimes that target domestic inflation and nominal income growth (NIT1 and NIT2) continue to perform poorly when transmission lags and departures from the UIP condition are present. In particular, we find that, when the model is predominantly backward looking, NIT1 leads to a very high social loss function (relative to precommitment). This result is similar to Ball (1999), who argues that nominal income targeting (NIT1) can be disastrous and can result in non-stationary output and inflation. As in McCallum and Nelson (1999a), however, we find that this disastrous outcome holds only under certain conditions, notably when the aggregate supply is very backward looking.[21]

The second sensitivity test involves increasing the variance of the shock to potential output to around 6 per cent in annual terms. In this case also, the results are not different from the baseline case (see Table A3). A regime that targets CPI inflation continues to perform well and remains the best targeting regime when the model features transmission lags and/or backward-looking exchange rate expectations. Moreover, we find that it is optimal for a central bank that targets CPI inflation to assign more weight to inflation in its objective function; in other words, to become more conservative. For example, when the variance of the potential output shock is increased, the optimal weight the central bank assigns to output volatility falls to 0.1 from 0.15.

If some persistence in the cost-push shock is allowed, a regime that targets CPI inflation again performs very well (see Table A3). Furthermore, when the degree of persistence of the cost-push shock is increased to 0.5, our results show—as in Clarida, Gali, and Gertler (1999)—that it is optimal to appoint a more conservative central bank, one that assigns more weight to inflation in its objective function. For example, results from the baseline open-economy model show that the optimal weight on output when the central bank is targeting CPI inflation falls from 0.15 (baseline values) to 0.1.

The final sensitivity test consists of varying the relative weight that society assigns to the stabilization of the output gap in its objective function. The results—shown in Table A3—are again not very different from the baseline scenario. In general, CPI inflation targeting continues to perform well and is robust to this parameter uncertainty. Moreover, we find that, as society cares more about output, it becomes optimal to appoint a more liberal central bank; i.e., one that cares more about output. Overall, our results—which show that the stabilization bias is smaller in an open-economy setting and that a regime that targets CPI inflation performs well—are very robust to both model and parameter uncertainty.

[21] Since the importance of precommitment depends on the degree of forward-lookingness, one would think that the gains from commitment would increase monotonically as the economy becomes more forward looking. Surprisingly, this is not generally the case. The stabilization bias does not increase monotonically as the economy becomes more forward looking (Tables A1 and A2 in Appendix A). See Steinsson (forthcoming) for a similar result in a closed-economy setting, and Dennis and Söderström (2002) for an intuition.

8 Concluding Remarks

Several recent papers have shown that gains can be made by delegating monetary policy to a central bank allowed to have a loss function that is different from society both in terms of the variables included and the weight on the variables itself. In two recent papers, Jensen (2002) and Walsh (2003), using closed-economy New Keynesian models, have shown that a policy that optimally targets nominal income growth or the change in the output gap can perform better than a regime that targets CPI inflation. The intuition behind their result is simple. SLT and NIT2 induce some history dependence in the policy actions of the central bank, effectively replicating the outcome under precommitment. Using several open-economy models, however, this paper has shown that a central bank that optimally targets CPI inflation (with a conservative central bank) can deliver a better outcome than Jensen's nominal income growth targeting and Walsh's output-gap growth targeting. The gains from appointing a conservative central bank are particularly important when transmission lags and/or departures from the UIP condition are allowed in the model. The results of this paper are very robust and hold for various parameter and model specifications.

Since the results are sensitive to model uncertainty, one interesting avenue for future research (among many) would be to compare the performance of optimal targeting regimes and optimal policy rules in open-economy models that feature other types of uncertainty—particularly imperfect information and measurement errors regarding key variables. Another avenue for future research is to conduct the same exercise from the timeless perspective advocated by Woodford (2003).

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Appendix A: Sensitivity Test Results

Table A1: Results with $\alpha_\pi = [0.01, ..., 0.99]$

α_π	Disc		DIT		CPI		SLT		NIT1		NIT2	
	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}
0.01	0.52	0.34	25.23	2.36	0.40	0.30	27.24	2.46	83.94	4.31	12.87	1.69
0.1	0.28	0.24	26.17	2.36	0.28	0.24	22.60	2.19	70.18	3.87	14.08	1.73
0.2	0.75	0.38	29.03	2.39	0.20	0.20	16.93	1.83	52.86	3.23	15.68	1.76
0.3	2.67	0.67	34.95	2.46	0.42	0.27	10.81	1.37	33.92	2.42	16.71	1.70
0.4	8.72	1.09	48.57	2.58	2.47	0.58	7.05	0.98	19.77	1.65	16.88	1.52
0.5	15.34	1.26	61.78	2.52	6.70	0.83	5.84	0.78	13.55	1.18	15.01	1.24
0.6	15.83	1.12	66.91	2.31	9.88	0.87	7.13	0.75	14.64	1.08	15.98	1.13
0.7	10.56	0.84	61.74	2.02	8.53	0.75	8.44	0.75	14.24	0.97	17.44	1.07
0.8	14.65	0.89	65.71	1.88	13.82	0.86	19.13	1.01	24.79	1.15	28.85	1.24
0.9	5.27	0.52	55.18	1.69	5.09	0.51	14.49	0.87	19.15	1.00	23.32	1.10
0.99	3.78	0.43	57.86	1.68	3.78	0.43	16.56	0.90	1.98	0.98	24.87	1.10

Baseline Model

α_π	Disc		DIT		CPI		SLT		NIT1		NIT2	
	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}
0.01	7.69	1.34	12.49	1.71	1.29	0.55	16.98	2.00	3.41	0.89	169.54	6.31
0.1	9.07	1.33	15.14	1.72	1.66	0.57	19.52	1.95	4.61	0.95	173.32	5.81
0.2	11.37	1.32	19.46	1.72	2.28	0.59	22.69	1.86	6.83	1.02	186.10	5.33
0.3	14.82	1.29	23.42	1.63	2.54	0.54	32.23	1.91	11.33	1.13	207.70	4.84
0.4	18.67	1.22	28.10	1.49	4.08	0.57	58.01	2.14	20.79	1.28	234.31	4.31
0.5	12.70	0.84	29.42	1.28	6.69	0.61	86.13	2.19	39.52	1.48	228.01	3.56
0.6	10.68	0.68	26.22	1.06	5.72	0.49	109.04	2.16	69.03	1.66	85.44	1.91
0.7	5.53	0.45	24.48	0.94	4.31	0.40	122.80	2.11	79.28	1.70	65.90	1.55
0.8	3.49	0.34	25.49	0.91	3.04	0.32	131.87	2.08	83.91	1.66	69.12	1.50
0.9	2.01	0.25	39.13	1.09	1.87	0.24	136.80	2.04	81.73	1.58	74.57	1.51
0.99	1.33	0.20	60.79	1.33	1.33	0.20	141.59	2.03	77.95	1.50	80.93	1.53

Model with Transmission Lags

Table A2: Results with $\alpha_\pi = [0.01, ..., 0.99]$

α_π	Disc		DIT		CPI		SLT		NIT1		NIT2	
	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}
0.01	9.00	1.13	54.41	2.78	3.68	0.72	65.27	3.04	168.527	4.89	22.44	1.78
0.1	7.44	1.01	55.05	2.76	3.64	0.71	58.99	2.86	144.471	4.47	24.21	1.83
0.2	5.57	0.85	58.22	2.76	3.57	0.68	51.46	2.60	114.641	3.88	26.95	1.88
0.3	3.57	0.66	63.66	2.77	2.99	0.60	43.49	2.29	87.74	3.26	28.48	1.82
0.4	1.77	0.43	73.77	2.77	1.77	0.43	35.57	1.92	60.15	2.50	31.20	1.80
0.5	0.78	0.26	80.70	2.67	0.78	0.26	31.08	1.66	48.76	2.08	29.29	1.61
0.6	0.94	0.27	80.97	2.49	0.85	0.25	31.11	1.54	46.60	1.89	27.89	1.46
0.7	1.36	0.30	77.97	2.30	1.36	0.30	34.11	1.52	48.91	1.82	28.57	1.39
0.8	1.51	0.31	73.46	2.13	1.51	0.31	38.16	1.54	52.83	1.81	30.31	1.37
0.9	1.50	0.29	70.60	2.01	1.50	0.29	42.29	1.56	56.95	1.81	32.31	1.36
0.99	1.46	0.28	64.56	1.87	1.46	0.28	46.15	1.58	60.76	1.81	34.20	1.36

Model with Backward-Looking Exchange Rate Expectations

α_π	Disc		DIT		CPI		SLT		NIT1		NIT2	
	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}
0.01	1.26	0.18	57.53	1.22	1.26	0.18	67.75	1.32	71.44	1.36	107.56	1.67
0.1	1.25	0.18	54.53	1.20	1.25	0.18	63.46	1.30	67.84	1.34	108.53	1.69
0.2	1.22	0.18	50.65	1.17	1.22	0.18	58.52	1.26	63.73	1.31	109.89	1.72
0.3	1.70	0.22	46.72	1.14	1.64	0.21	54.24	1.22	60.53	1.29	111.89	1.76
0.4	3.30	0.30	42.82	1.09	2.10	0.24	51.69	1.20	59.55	1.29	113.26	1.78
0.5	5.02	0.37	37.16	1.02	2.53	0.27	51.68	1.20	60.92	1.31	107.06	1.73
0.6	5.32	0.38	34.09	0.96	2.71	0.27	56.70	1.24	66.67	1.35	93.77	1.60
0.7	4.24	0.33	33.47	0.93	2.93	0.28	64.88	1.30	74.72	1.39	84.21	1.48
0.8	3.08	0.28	35.36	0.93	2.52	0.25	73.77	1.35	82.62	1.43	80.55	1.41
0.9	2.34	0.24	39.41	0.97	2.27	0.23	82.44	1.40	89.52	1.46	80.61	1.38
0.99	1.74	0.20	43.66	1.00	1.74	0.20	89.28	1.44	94.30	1.48	81.65	1.37

Model with Both

Table A3: Results with different values for λ_x^s, σ_{y^n} and γ_v

test	$\lambda_x^s = 0.1$		$\lambda_x^s = 1$		$\sigma_{y^n} = 0.015$		$\gamma_v = 0.5$	
	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}
Disc	8.41	0.68	31.49	2.56	14.89	1.26	34.18	3.93
DIT	143.27	2.80	24.23	2.25	61.91	2.57	64.92	5.42
CPI	4.38	0.49	13.11	1.65	6.60	0.84	7.87	1.88
SLT	5.66	0.42	23.07	1.47	11.31	0.82	46.98	1.35
NIT1	5.82	0.58	32.38	3.39	12.43	1.34	49.63	2.11
NIT2	8.61	1.77	21.79	0.95	12.60	1.41	11.31	1.76

Baseline Model

Regimes	$\lambda_x^s = 0.1$		$\lambda_x^s = 1$		$\sigma_{y^n} = 0.015$		$\gamma_v = 0.5$	
	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}
Disc	10.24	0.61	39.13	2.00	16.08	1.01	56.39	2.58
DIT	67.41	1.55	13.74	1.19	28.32	1.34	87.76	3.22
CPI	4.39	0.40	10.66	1.05	6.21	0.63	9.00	1.03
SLT	45.83	1.28	239.00	4.95	79.83	2.25	62.89	2.73
NIT1	76.47	1.65	44.87	2.15	210.65	3.66	41.79	2.22
NIT2	391.26	3.74	103.10	3.25	305.15	4.40	250.72	5.44

Model with Transmission Lags

Regimes	$\lambda_x^s = 0.1$		$\lambda_x^s = 1$		$\sigma_{y^n} = 0.015$		$\gamma_v = 0.5$	
	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}
Disc	0.57	0.17	0.78	0.35	0.78	0.27	7.14	1.41
DIT	182.55	2.99	32.64	2.28	83.09	2.76	76.34	4.63
CPI	0.57	0.17	0.71	0.33	0.78	0.27	5.93	1.29
SLT	15.98	0.89	57.42	3.02	31.74	1.70	30.27	2.92
NIT1	45.57	1.49	188.61	5.47	51.48	2.17	58.44	4.05
NIT2	189.89	3.05	21.57	1.85	31.28	1.69	24.37	2.61

Model with Backward-Looking Exchange Rate Expectations

Regimes	$\lambda_x^s = 0.1$		$\lambda_x^s = 1$		$\sigma_{y^n} = 0.015$		$\gamma_v = 0.5$	
	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}	L^{diff}	π^{diff}
Disc	2.84	0.21	3.63	0.47	4.27	0.39	11.73	0.88
DIT	74.18	1.08	15.46	0.98	34.12	1.10	87.61	2.39
CPI	2.84	0.21	2.42	0.39	2.55	0.30	2.13	0.37
SLT	28.54	0.67	114.63	2.66	55.72	1.41	35.90	1.53
NIT1	29.94	0.69	150.16	3.05	62.31	1.49	56.72	1.93
NIT2	186.25	1.71	41.72	1.61	93.83	1.83	65.99	2.08

Model with Both