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Robust control and delegating optimal monetary policy under incomplete exchange rate pass-through*

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Abstract

This study examines the effect of model uncertainty on the performance of delegating optimal monetary policy inertia in a small open economy with imperfect exchange rate pass-through. It addresses the role of nominal income growth targeting with the existence of the law of one price gap under model uncertainty.

JEL codes: E52; E58; F41

Keywords : Optimal monetary policy; Targeting regime; Incomplete exchange rate pass-through; Robust control; small open economy

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1 Introduction

This study examines whether monetary policy objectives with lagged endogenous variables can overcome the stabilization bias caused by discretionary policies in a small open economy with incomplete exchange rate pass-through in the presence of model uncertainty. The stabilization bias arises from inadequate policy responses to structural shocks that generate policy trade-offs under a discretionary policy. The central banker implementing a discretionary policy suffers from stabilization bias even in an open economy because the small open new Keynesian (NK) model is isomorphic to the closed one (Clarida et al., 2001). Thus, the problem of stabilization bias remains an important issue even in an open economy.

Following Bilbiie (2014), Ida and Okano (2021) analytically examined the role of delegating optimal monetary policy inertia to answer the aforementioned problem. Although Ida and Okano (2021) showed the effectiveness of speed limit targeting suggested by Walsh (2003), they did not consider both cases of robust control and imperfect exchange rate pass-through. Ida and Okano (2022) examined the effectiveness of targeting regimes with lagged endogenous variables in a model with complete exchange rate pass-through under robust control. However, they did not consider the case for incomplete pass-through of the exchange rate. Imperfect exchange rate pass-through exacerbates the trade-offs more within policy objectives than in a standard small open economy model.

This study aims to fill such a gap in the existing literature. More concretely, following Monacelli (2005), I consider the role of incomplete exchange rate pass-through in the small open NK model. The exchange rate's incomplete pass-through would complicate more the problem of robust control than in the case of complete pass-through because the law of one price (LOP) no longer holds in the former case. Therefore, we can consider that the stabilization bias will be more severe under the case of incomplete exchange rate pass-through. This paper compares the performance of a commitment policy with several alternative targeting regimes that have different monetary policy objectives from the social loss function. To the best of my knowledge, no study has attempted to investigate this issue.

The main results are summarized as follows. First, the commitment policy can lead to preferable outcomes to all policy regimes with the disappearance of robustness concerns. Second, the policy regimes with a lagged output gap are superior to inflation targeting. Particularly, I emphasize that when robustness considerably matters, nominal income growth targeting

(NIT) outperforms all the regimes considered in this paper.

2 Model description

This paper considers the role of incomplete pass-through of the exchange rate in a small open NK model with robust control. I adopt the small open NK model developed by Monacelli (2005).[1] The log-linearized dynamic system is summarized as follows:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa_y x_t + \kappa_\psi \psi_t + u_t, \tag{1}$$

$$\pi_t^f = \beta E_t \pi_{t+1}^f + \lambda_\psi \psi_t, \tag{2}$$

$$x_t = E_t x_{t+1} - \frac{\omega_s}{\sigma}(i_t - E_t \pi_{t+1}) + \frac{\gamma(\sigma a - \omega_\psi)}{\sigma} E_t \Delta\psi_{t+1}, \tag{3}$$

$$E_t \psi_{t+1} = \psi_t + i_t - i_t^* + E_t \pi_{t+1}^* - E_t \pi_{t+1}^f, \tag{4}$$

$$q_t = \psi_t + (1-\gamma) s_t, \tag{5}$$

$$s_t = \frac{1}{\omega_s}(\sigma x_t - \omega_\psi \psi_t), \tag{6}$$

where π_t is producer currency inflation, x_t is the output gap, i_t is the nominal interest rate, and π_t^f is import inflation. Moreover, ψ_t is the LOP gap, which represents the deviation of law of one price in terms of import prices. Note that ψ_t becomes zero under complete exchange rate pass-through. π_t^* and i_t^* are the foreign inflation and the foreign interest rate, respectively. Meanwhile, q_t, s_t, and u_t denote the real exchange rate, the terms of trade, and the price mark-up (cost-push) shock, respectively. The coefficients of this system are defined as follows:

$$\kappa_y = \frac{(1-\alpha_h)(1-\alpha_h\beta)}{\alpha_h}\left(\varphi + \frac{\sigma}{\omega_s}\right); \ \kappa_\psi = \frac{(1-\alpha_h)(1-\alpha_h\beta)}{\alpha_h}\left(1 - \frac{\omega_\psi}{\omega_s}\right);$$
$$\omega_s = 1 + \gamma(2-\gamma)(\sigma a - 1); \ \omega_\psi = 1 + \gamma(\sigma a - 1); \ \lambda_\psi = \frac{(1-\alpha_f)(1-\alpha_f\beta)}{\alpha_f},$$

where σ is the relative risk aversion for the utility of consumption, φ is the inverse of labor supply elasticity, a is the elasticity of substitution between home and foreign goods. α_h and α_f are Calvo lottery for home-goods firms and import-goods firms, respectively. γ denotes the degree of openness. u_t and ϵ_t denote the demand and supply shocks captured by the standard AR(1) process.

[1]See Monacelli (2005) for a detailed derivation of a small open NK model with incomplete path-through of the exchange rate.

Equation (1) represents the price new Keynesian Phillips curve (NKPC) derived from the presence of nominal price rigidity. Unlike complete exchange rate pass-through, the LOP gap affects price inflation dynamics. Equation (2) is the import-price NKPC derived by the incomplete pass-through of the exchange rate. Equation (3) represents the dynamic aggregate demand curve, which is now affected by the LOP gap that evolves in accordance with Equation (4). Equations (5) and (6) determine the real exchange rate and the terms of trade, respectively.

Next, to consider optimal monetary policy in this model, we must specify the central bank's loss function. Following Monacelli (2005), I use the following standard loss function:

$$\mathcal{L}_t = E_0 \sum_{t=0}^{\infty} \beta^t \Big\{ [(1-\gamma)\pi_t^2 + \gamma(\pi_t^f)^2] + \lambda x_t^2 \Big\}. \tag{7}$$

The loss function (7) is the social true loss function. The parameter λ denotes the stabilization weight on the output gap relative to inflation.

3 Solution methods: Robust control approach

Following Giordani and Söderlind (2004) and Tillmann (2009), I briefly describe the robust control approach in this section.[2] In this approach, the central bank considers the model presented in the previous section as a reference model that suggests the most likely model description of the economic structure. However, the central bank also knows that this structural model faces various distortions associated with the possibility of model misspecification. In this case, the central bank sets the policy instrument r_t to minimize the loss function. However, it is concerned about the existence of model misspecification and attempts to be robust to such misspecification. To examine this robust control problem, previous studies have considered an optimization problem in which the central bank minimizes the value of the loss function, but the evil agent maximizes the loss. In this way, the optimization problem faced by the central bank under model uncertainty is transformed into a min–max problem. In the following analysis, we focus on the worst-case distortion defined as the economy's behavior when the pessimism of the planners is fully warranted.

Under model uncertainty, the central bank faces the following distorted model that incor-

[2]See Giordani and Söderlind (2004) for a detailed explanation of robust control approach in linear-quadratic optimization problem.

porates the distortions associated with possible model misspecification:

$$X_{t+1} = AX_t + Br_t + C(\varepsilon_{t+1} + \nu_{t+1}), \tag{8}$$

where $X_{t+1} = [y_{1t+1} \; E_t y_{2t+1}]'$. y_{1t} and y_{2t} denote vectors of predetermined and forward-looking variables, respectively. r_t denotes the vector of policy instruments. Meanwhile, A and B are coefficient matrices constructed by structural parameters. Distortion ν_{t+1} denotes the worst-case distortions chosen by evil agent, and ε_{t+1} is a vector caused by structural shocks. The additional term $\nu_{t+1} + \varepsilon_{t+1}$ is multiplied by matrix C. Evil agents who maximize the central bank's loss function chose the worst-case distortions, subject to the following budget constraints:

$$E_0 \sum_{t=0}^{\infty} \beta^t \nu_{t+1}^{'} \nu_{t+1} \leq \eta, \tag{9}$$

where η denotes the measure of the central bank's preference for robustness. Accordingly, in our model the central bank implements optimal monetary policy by solving the following optimization problem:

$$\min_{\{i_t\}} \max_{\{\nu_{t+1}\}} E_0 \sum_{t=0}^{\infty} \beta^t \left\{ [(1-\gamma)\pi_t^2 + \gamma(\pi_t^f)^2] + \lambda x_t^2 \right\},$$

subject to Equations (8) and (9). Following Giordani and Söderlind (2004), we can rewrite the mentioned optimization problem as the following equivalent multiplier problem:[3]

$$\min_{\{i_t\}} \max_{\{\nu_{t+1}\}} E_0 \sum_{t=0}^{\infty} \beta^t \left\{ [(1-\gamma)\pi_t^2 + \gamma(\pi_t^f)^2] + \lambda x_t^2 - \theta \nu_{t+1}^{'} \nu_{t+1} \right\},$$

subject to Equation (8). We define θ as $1/\eta$; therefore, $\theta \in (0, \infty)$ means a set of models available to the evil agent.

Let us now consider the optimal delegation problem in the presence of imperfect exchange rate pass-through. As described by Walsh (2003), the alternative targeting regime can be characterized by the policy objectives delegated to the central bank and the stabilization weights for each objective in the loss function. Following Walsh (2003), this study defined the targeting rule as (a) the variables in the central bank's objective function and (b) the stabilization weights for the policy objectives in the loss function chosen to minimize the expected discounted value of the social loss function (7).

[3]See Giordani and Söderlind (2004) for a detailed discussion of this transformation.

The targeting rules in this study are specified in Table 1. Except for the definition of inflation in this paper, Table 1 defines the first three regimes, following Walsh (2003). According to Jensen (2002) and Walsh (2003), the performance of speed limit policy (SLP) and NIT is superior to that of inflation targeting (IT). The fourth regime is suggested by Ida and Okano (2021) in a model with a complete exchange rate pass-through. Then, we consider the policy regime targeting a change in the LOP gap under a discretionary policy. Note again that the stabilization weight λ_i (for $i = IT, SLP, NIT, LOP, REX$) is chosen so that the central bank minimizes the social loss function under each delegated objective function, indicating that λ_i does not generally coincide with λ.

[Table 1 around here]

I numerically solve the optimal delegation problem under robust control using the solution algorithm developed by Giordani and Söderlind (2004).

4 Quantitative results

This section provides the quantitative results of the performance of targeting regimes under robust control in a model with incomplete exchange rate pass-through. The calibrated values in this paper are used in the standard NK model (Table 2). Before reporting the simulation result, I briefly mention the selection of the parameter θ representing the degree of robustness. I assume that the value of θ, which represents the degree of robustness, ranges from 30 to 500 to obtain stable equilibrium. My calibration strategy is based on Tillmann (2009). Thus, this paper considers the values of θ that the detection error probability ranges from 0 to 0.5. Moreover, it assumes that the selected values of θ satisfy the range of detection error probability suggested in previous studies.

[Table 2 around here]

Table 3 reports the welfare losses under several values of robustness parameter θ. The results are summarized as follows. First, the precommitment policy can lead to preferable outcomes to all policy regimes as long as the parameter θ is above 75. Second, the policy regimes with a lagged output gap are superior to IT. Third, the LOP targeting induces the worst welfare losses of all regimes. Finally and importantly, NIT becomes the most effective tool of all policy regimes when $\theta < 75$. In this case, the performance of NIT outperforms that of a precommitment policy. Moreover, it follows from Table 3 that within the parameter range of θ, NIT produces the most stable outcomes for all policy regimes. Ida and Okano (2022) showed that the performance of NIT dominates that of a commitment policy in the case of a smaller value of θ under complete exchange rate pass-through. In contrast to their study, the present study addresses the role of NIT when the central banker worries about model uncertainty in the presence of ψ_t.

[Table 3 around here]

Figure 1 shows that a price mark-up shock induces policy trade-off between PPI inflation and the output gap in a worst-case equilibrium. Also, it causes the trade-off between price and import inflation stabilization. Thus, in contrast to a standard open economy model, an introduction of incomplete exchange rate pass-through causes a worse policy trade-off between inflation and the output gap. More concretely, stabilizing PPI inflation creates a fluctuation in the output gap following the movements in ψ_t.

[Figure 1 around here]

As shown in Figure 1, unlike discretion, a policy target with a lagged output gap imparts policy inertia into the economy. This policy inertia can ease a policy trade-off in the presence of ψ_t. Jensen (2002) and Walsh (2003) suggested that this indicates the gain from adopting delegated optimal monetary policy inertia to overcome the stabilization bias. In particular, I address that NIT containing the stabilization of both PPI inflation and a change in the output can alleviate such a trade-off caused by incomplete exchange rate pass-through. The gain from employing NIT might be justified by the dynamics of the nominal exchange rate. Indeed, Figure 2 illustrates that the exchange rate under NIT retains the stationarity compared with other discretionary policy regimes.

[Figure 2 around here]

5 Concluding remarks

This paper examined the effect of model uncertainty on the performance of delegating optimal monetary policy inertia in a small open economy with imperfect exchange rate pass-through.

It showed the effectiveness of NIT under model uncertainty in the presence of the LOP gap.

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Table 1: Alternative policy regimes

Regime	Loss function
Inflation targeting (IT)	$(1-\gamma)\pi_t^2 + \gamma(\pi_t^f)^2 + \lambda_{IT} x_t^2$
Speed limit policy (SLP)	$(1-\gamma)\pi_t^2 + \gamma(\pi_t^f)^2 + \lambda_{SLP}(x_t - x_{t-1})^2$
Nominal income growth targeting (NIT)	$(1-\gamma)\pi_t^2 + \gamma(\pi_t^f)^2 + \lambda_{NIT}(\pi_t + x_t - x_{t-1})^2$
Real exchange rate targeting (REX)	$(1-\gamma)\pi_t^2 + \gamma(\pi_t^f)^2 + \lambda_{REX}(q_t - q_{t-1})^2$
LOP gap targeting (LOPG)	$(1-\gamma)\pi_t^2 + \gamma(\pi_t^f)^2 + \lambda_{LOP}(\psi_t - \psi_{t-1})^2$

Table 2: Parameterization

	Parameter	Value
β	Discount rate	0.99
σ	Relative risk aversion coefficient for consumption	2.0
φ	Inverse of the elasticity of labor supply	5.0
α_h	Calvo lottery for home goods firms	0.75
α_f	Calvo lottery for import goods firms	0.75
a	Elasticity of substitution between home and foreign goods	1.0
γ	Degree of openness	0.4
λ	Weight on the output gap in the true loss function	0.25
ρ	Persistency of a price mark-up shock	0.4

Table 3: Welfare losses under alternative delegated policy regimes: Worst-case equilibrium

	PC	IT	SLP	NIT	REX	LOPG
$\theta = 500$	89.48	135.97	97.30	92.33	102.03	153.32
$\theta = 400$	89.59	136.18	97.34	92.35	102.06	153.33
$\theta = 300$	89.77	136.44	97.40	92.38	102.12	153.36
$\theta = 200$	90.14	137.06	97.53	92.43	102.25	153.41
$\theta = 100$	91.27	138.87	97.93	92.59	102.62	153.57
$\theta = 75$	92.05	140.09	98.19	92.60	102.87	153.67
$\theta = 50$	93.71	142.60	98.72	92.91	103.37	153.88
$\theta = 40$	95.04	144.49	99.13	93.07	103.74	154.04
$\theta = 30$	97.41	147.70	99.80	93.35	104.38	154.30

(Note) PC: precommitment, IT: inflaiton targeting, SLP: speed limit policy, NIT: nominal income growth targeting, REX: real exchange rate targeting, LOPG: LOP gap targeting. Each loss is multiplied by 100.

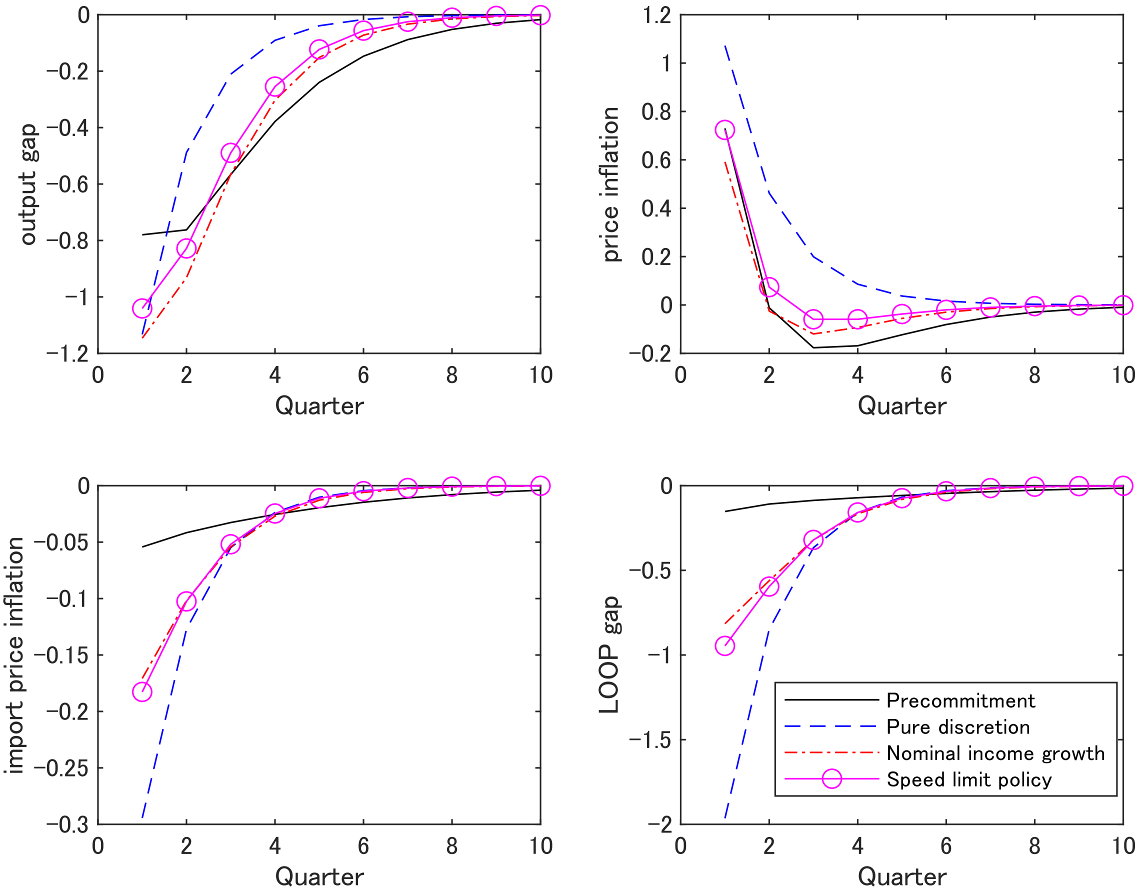

Figure 1: Impulse response to a cost-push shock under worst-case equilibrium

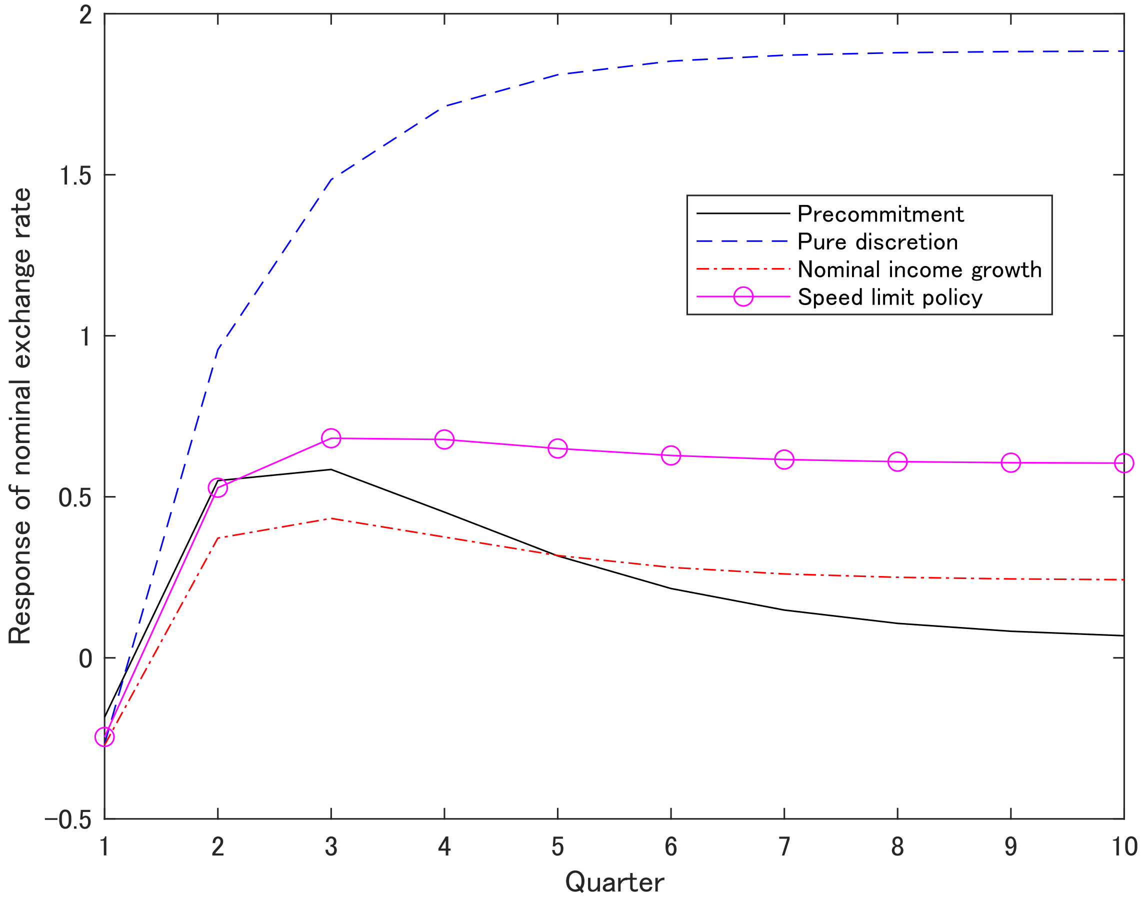

Figure 2: Impulse response of the nominal exchange rate to a cost-push shock under worst-case equilibrium