Macroeconomic Dynamics, **12** (Supplement 1), 2008, 126–135. Printed in the United States of America.
DOI: 10.1017/S1365100507070058

ROBUST MONETARY POLICY IN THE NEW KEYNESIAN FRAMEWORK

KAI LEITEMO
Norwegian School of Management

ULF SÖDERSTRÖM
Università Bocconi

We study the effects of model uncertainty in a simple New Keynesian model using robust control techniques. Due to the simple model structure, we are able to find closed-form solutions for the robust control problem, analyzing both instrument rules and targeting rules under different timing assumptions. In all cases but one, an increased preference for robustness makes monetary policy respond more aggressively to cost shocks but leaves the response to demand shocks unchanged. As a consequence, inflation is less volatile and output is more volatile than under the nonrobust policy. Under one particular timing assumption, however, increasing the preference for robustness has no effect on the optimal targeting rule (nor on the economy).

Keywords: Knightian Uncertainty, Model Uncertainty, Robust Control, Minmax Policies

1. INTRODUCTION

The New Keynesian approach to macroeconomic modeling has now dominated the monetary policy literature for a decade. It has produced several important insights concerning the conduct of monetary policy, and is commonly used to provide policy prescriptions [see, e.g., Clarida et al. (1999)]. However, although based on the optimizing behavior of private agents, like any model it rests on a set of assumptions that may or may not be good approximations of true economies. Because a complete description of reality cannot be given, policymakers are likely to prefer basing policy on principles that are also valid if the assumptions behind the model differ from reality. That is, policy prescriptions should be robust to reasonable deviations from the benchmark model.

In this paper, we explore how monetary policy in the New Keynesian model should be designed to be robust to small changes in the specification of the model. We assume that the policymaker is endowed with a model that is believed to be the most likely description of reality, but fears that reality deviates from this

Financial support from the Financial Market Fund, a program under the Norwegian Research Council, is gratefully acknowledged. We are also grateful for comments from Paolo Giordani, Juha Kilponen, Tom Sargent, Paul Söderlind, Juha Tarkka, Jouko Vilmunen, two anonymous referees, and the editor, Peter Norman Sørensen. We also thank participants at a Bank of Finland workshop in May 2004 and at the University of Copenhagen Conference on Dynamic Macroeconomic Theory in June 2004. We are particularly grateful to Carl Walsh for many insightful comments. Address correspondence to: Kai Leitemo, Department of Economics, Norwegian School of Management (BI), Nydalsveien 37, 0442 Oslo, Norway; e-mail: kai.leitemo@bi.no.

© 2007 Cambridge University Press 1365-1005/07 $18.00

https://doi.org/10.1017/S1365100507070058 Published online by Cambridge University Press

model in ways that cannot be described by a known probability distribution. The policymaker wants to avoid particularly bad outcomes, and therefore wants policy to be robust against specification errors that could have particularly severe consequences.

This problem has recently been addressed by Hansen and Sargent (2007) using "robust control" techniques. Assuming that the policymaker is unable to formulate a probability distribution over plausible models, the robust policymaker designs policy for the worst possible outcome within a prespecified set of models. We apply robust control techniques developed by Hansen and Sargent (2007) and Giordani and Söderlind (2004) to a simple New Keynesian model of a closed economy. Due to its simple structure, we are able to solve the robust control problem analytically. This gives us policy prescriptions that are more general than those in the previous literature, which has typically used numerical methods.

We analyze the effects of small degrees of robustness on both optimal instrument rules and targeting rules under two different timing assumptions. In the first timing assumption, the central bank chooses its optimal policy rule and a fictitious evil agent chooses the optimal degree of misspecification simultaneously, leading to a Nash equilibrium. Under the second assumption, the central bank chooses policy taking into account the choice of the evil agent, thus acting as a Stackelberg leader.

In all cases but one, an increased preference for robustness makes monetary policy respond more aggressively to cost shocks but leaves the response to demand shocks unchanged. The reason is that the central bank fears cost shocks to have larger impact on inflation, and it therefore counteracts these shocks more vigorously. As a consequence, in the most likely outcome of the model, inflation is less volatile but output is more volatile than under the nonrobust policy.

There is one exception to this rule, however: in the Nash equilibrium, the optimal *targeting rule* is not affected by the central bank's preference for robustness, in contrast to the optimal *instrument rule*. In this case, therefore, if the central bank implements policy through the optimal targeting rule, its preference for robustness has no effect on the behavior of the economy.

We begin in Section 2 by presenting the model and the general features of the robust control problem. Section 3 discusses the optimal robust policy under the two alternative timing assumptions. Section 4 concludes.

2. MODEL

Our economic environment follows the standard New Keynesian model with sticky prices that has been used extensively in the recent literature on monetary policy. The attractiveness of this model is due to the fact that it summarizes the behavior of rational optimizing agents in two equations: a New Keynesian Phillips curve for inflation and a forward-looking IS equation for output. Thus, the benchmark model is given by

$$\pi_t = \beta \mathrm{E}_t \pi_{t+1} + \kappa x_t + \Sigma_\pi \varepsilon_t^\pi, \tag{1}$$

$$x_t = \mathrm{E}_t x_{t+1} - \sigma^{-1} [i_t - \mathrm{E}_t \pi_{t+1}] + \Sigma_x \varepsilon_t^x, \tag{2}$$

https://doi.org/10.1017/S1365100507070058 Published online by Cambridge University Press

where π_t is the rate of inflation (the log change in the price level), x_t is the output gap (the log deviation of output from its natural level), and i_t is the one-period nominal interest rate, controlled by the central bank. The parameters β, κ, σ are all positive with $\beta < 1$, and depend on deep parameters describing preferences and technology. In particular, β is the discount factor of private agents, σ is the elasticity of intertemporal substitution, and κ depends negatively on the degree of price stickiness. Finally, ε_t^{π} and ε_t^{x} are, respectively, a cost shock (e.g., a shock to firms' markup) and a demand shock (e.g., a preference shock or a shock to the natural level of output). Although in the literature these are often assumed to be persistent, we will assume that they are white noise with mean zero and unit variance, as this allows for a closed-form solution of the robust control problem. The parameters Σ_{π} and Σ_x denote the standard deviations of these shocks.

Although the central bank sees the model (1), (2) as the most likely specification, it realizes that the true model may deviate from this benchmark model, although it is unable to specify a probability distribution for these deviations. To model such misspecification fears we follow Hansen and Sargent (2007) and introduce in each equation a second type of disturbance, denoted v_t^{π} and v_t^{x}. Thus, the model with misspecification is given by

$$\pi_t = \beta \mathrm{E}_t \pi_{t+1} + \kappa x_t + \Sigma_{\pi}\left[v_t^{\pi} + \varepsilon_t^{\pi}\right], \tag{3}$$

$$x_t = \mathrm{E}_t x_{t+1} - \sigma^{-1}\left[i_t - \mathrm{E}_t \pi_{t+1}\right] + \Sigma_x\left[v_t^{x} + \varepsilon_t^{x}\right]. \tag{4}$$

3. ROBUST MONETARY POLICY

To be robust against specification errors, the central bank is assumed to follow a minmax strategy and design policy for the worst possible outcome of the model, where a fictitious "evil agent" chooses the amount of misspecification v_t^j to maximize central bank loss. This model will be referred to as the *worst-case model* and is the outcome against which the central bank wants policy to be robust. A more likely outcome of the model, however, is when the central bank sets policy and agents form expectations to reflect misspecification in the worst-case model, but there is no such misspecification in practice (so all v_t^j are zero). We will refer to this model as the *approximating model*.

The central bank minimizes an objective function that is quadratic in deviations of inflation and the output gap from their zero target levels. Depending on its preference for robustness, the central bank allocates a budget η to the evil agent, which is used to create misspecification. Thus the budget constraint for the evil agent is

$$\mathrm{E}_t \sum_{\tau=0}^{\infty} \beta^{\tau}\left[\left(v_{t+\tau}^{\pi}\right)^2 + \left(v_{t+\tau}^{x}\right)^2\right] \leq \eta, \tag{5}$$

https://doi.org/10.1017/S1365100507070058 Published online by Cambridge University Press

where in a standard control problem we would have $\eta = 0$. Following Hansen and Sargent (2007), the robust monetary policy is obtained by solving the problem

$$\min_{\{i_t\}} \max_{\{v_t^j\}} \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\pi_t^2 + \lambda x_t^2\right] \tag{6}$$

subject to the model with misspecification in equations (3), (4) and the evil agent's budget constraint (5). The central bank thus sets the interest rate to minimize the value of its intertemporal loss function, whereas the evil agent sets its controls to maximize the central bank's loss, given the constraints on misspecification.

As a benchmark assumption, we will follow the existing literature and assume that the central bank and the evil agent play a Nash game, so each player's choice is optimal given the other player's choice. This is, however, not the only possible assumption. We will also analyze the case where the central bank is a Stackelberg leader and so makes its policy choice taking into account how the evil agent will choose the specification errors. This will have some important consequences for the effect of robustness on policy and therefore on the economy.

One interpretation of these alternative equilibrium concepts relates to the central bank's ability to make short-term commitments. If the central bank is able to commit to a policy in the short term, that is, within a period in the model, it may want to take into account the worst-case misspecification during this period, leading to a Stackelberg equilibrium. If such within-period commitments are not possible, however, e.g., because the central bank can change its policy decision within the period, the Nash equilibrium would seem more natural. Which equilibrium concept is more reasonable then depends on how long we interpret a time period to be: shorter time periods would make the Nash equilibrium more reasonable and the Stackelberg equilibrium less reasonable, and vice versa. Thus, in an empirical application, it would be more straightforward to choose between the two equilibria than in our purely theoretical framework.

3.1. The Nash Solution

In the Nash game, the Lagrangian is given by

$$\begin{aligned}
&\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{\pi_t^2 + \lambda x_t^2 - \theta\left[\left(v_t^{\pi}\right)^2 + \left(v_t^{x}\right)^2\right]\right. \\
&-\mu_t^{\pi}\left[\pi_t - \beta \mathrm{E}_t \pi_{t+1} - \kappa x_t - \Sigma_{\pi} v_t^{\pi} - \Sigma_{\pi} \varepsilon_t^{\pi}\right] \\
&\left.-\mu_t^{x}\left[x_t - \mathrm{E}_t x_{t+1} + \sigma^{-1}(i_t - \mathrm{E}_t \pi_{t+1}) - \Sigma_x v_t^{x} - \Sigma_x \varepsilon_t^{x}\right]\right\},
\end{aligned} \tag{7}$$

where μ_t^j are Lagrange multipliers on the constraints (3), (4) and θ determines the set of models available to the evil agent against which the policymaker wants to be robust. This robustness parameter is inversely related to the evil agent's budget η:

https://doi.org/10.1017/S1365100507070058 Published online by Cambridge University Press

as the budget shrinks toward zero, the degree of misspecification approaches zero, and θ will approach infinity.

Throughout, we will focus on marginal amounts of model misspecification. For sufficiently large amounts of misspecification, the evil agent will be able to overturn any relationship in the model. We therefore want to consider reasonable degrees of model uncertainty that cannot be easily identified by the policymaker. More specifically, we analyze the effects of small increases in the preference for robustness starting from the nonrobust policy, that small decreases in θ starting from $\theta = \infty$.

We assume that neither the central bank nor the fictitious evil agent has access to any mechanism that allows them to commit to future policies. Consequently, we take expectations as given in the optimization and look for a discretionary equilibrium.[1] From the first-order conditions we can derive the following optimality conditions relating inflation, output, and the degree of misspecification to each other:

$$x_t = -\frac{\kappa}{\lambda}\pi_t \equiv -A_{\mathrm{N}}\pi_t, \tag{8}$$

$$v_t^{\pi} = \frac{\Sigma_{\pi}}{\theta}\pi_t, \tag{9}$$

$$v_t^{x} = 0. \tag{10}$$

These optimality conditions reveal some interesting features of our model.

First, the optimal inflation–output trade-off in equation (8) is not affected by the preference for robustness. In other words, the presence of model misspecification will not alter the central bank's optimal "targeting rule."[2] Second, the central bank only worries about model misspecification in the Phillips curve, as the policymaker is able to counteract any specification errors in the IS equation by an appropriate adjustment of the interest rate (and these interest rate movements do not influence central bank loss independently). Third, the worst-case amount of misspecification in the Phillips curve is increasing in inflation and in the standard deviation of cost shocks, Σ_{π}. This is because the central bank is more vulnerable to increases in inflation (in absolute terms) when inflation is already high.[3] And the larger the variance of cost shocks, the more difficult it is for the central bank to identify misspecification. Therefore the central bank is more on its guard against specification errors.

It is straightforward to show[4] that the optimal interest rate rule for the central bank is given by

$$i_t = c_{\mathrm{N}}\Sigma_{\pi}\varepsilon_t^{\pi} + \sigma\,\Sigma_x\varepsilon_t^{x}, \tag{11}$$

where

$$c_{\mathrm{N}} \equiv \frac{\sigma\kappa}{\lambda\left(1 - \Sigma_{\pi}^2/\theta\right) + \kappa^2} > 0. \tag{12}$$

(We evaluate the signs of coefficients for small degrees of robustness, i.e., when θ is large.) The solution for the approximating model is obtained by using the

https://doi.org/10.1017/S1365100507070058 Published online by Cambridge University Press

optimal robust interest rate rule from equation (11) in the original model (1), (2), yielding

$$\pi_t = a_{\mathrm{N}} \Sigma_\pi \varepsilon_t^\pi, \tag{13}$$

$$x_t = b_{\mathrm{N}} \Sigma_\pi \varepsilon_t^\pi, \tag{14}$$

where

$$a_{\mathrm{N}} \equiv 1 - \frac{\kappa^2}{\lambda\left(1 - \Sigma_\pi^2/\theta\right) + \kappa^2} > 0, \tag{15}$$

$$b_{\mathrm{N}} \equiv -\frac{\kappa}{\lambda\left(1 - \Sigma_\pi^2/\theta\right) + \kappa^2} < 0. \tag{16}$$

Thus, for small degrees of misspecification, the central bank responds to a positive cost shock by tightening policy (as under the nonrobust policy). However, c_{N} is decreasing in θ, so an increased preference for robustness (a smaller θ) leads the central bank to respond more aggressively to cost shocks, thereby increasing interest rate volatility. This is because the central bank fears that cost shocks have a larger impact on inflation. As a consequence, output becomes more volatile under the robust policy (b_{N} decreases in θ in absolute terms), whereas inflation becomes less volatile (a_{N} increases in θ). As monetary policy responds more aggressively to cost shocks when the central bank's preference for robustness increases, the effects of these shocks on inflation are dampened, but at the cost of more output volatility.

3.2. The Stackelberg Solution

Although the Nash timing assumption has been more commonly used in applied work, we now analyze an alternative timing assumption, where the central bank acts as a Stackelberg leader and designs policy taking into account the evil agent's optimal choice of the level of misspecification in equations (9) and (10).[5] The Lagrangian for the central bank's optimal choice of policy is then given by

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \pi_t^2 + \lambda x_t^2 - \mu_t^\pi \left[\pi_t - \beta \mathrm{E}_t \pi_{t+1} - \kappa x_t - \frac{\Sigma_\pi^2}{\theta} \pi_t - \Sigma_\pi \varepsilon_t^\pi \right] \right.$$

$$\left. - \mu_t^x \left[x_t - \mathrm{E}_t x_{t+1} + \sigma^{-1} \left(i_t - \mathrm{E}_t \pi_{t+1} \right) - \Sigma_x \varepsilon_t^x \right] \right\}, \tag{17}$$

and the first-order conditions for the central bank give the optimal trade-off

$$x_t = -\frac{\kappa}{\lambda\left(1 - \Sigma_\pi^2/\theta\right)} \pi_t \equiv -A_S \pi_t. \tag{18}$$

https://doi.org/10.1017/S1365100507070058 Published online by Cambridge University Press

Whereas in the Nash equilibrium the optimal trade-off is independent of the preference for robustness, this is no longer true in the Stackelberg equilibrium, where the central bank foresees the evil agent's choice and adapts its policy accordingly.

The optimal policy rule is now given by

$$i_t = c_S \Sigma_\pi \varepsilon_t^\pi + \sigma \Sigma_x \varepsilon_t^x, \tag{19}$$

where

$$c_S \equiv \frac{\sigma\kappa}{\lambda\left(1 - \Sigma_\pi^2/\theta\right)^2 + \kappa^2} > 0, \tag{20}$$

whereas inflation and output in the approximating model follow

$$\pi_t = a_S \Sigma_\pi \varepsilon_t^\pi, \tag{21}$$

$$x_t = b_S \Sigma_\pi \varepsilon_t^\pi, \tag{22}$$

where

$$a_S \equiv 1 - \frac{\kappa^2}{\lambda\left(1 - \Sigma_\pi^2/\theta\right)^2 + \kappa^2} > 0, \tag{23}$$

$$b_S \equiv -\frac{\kappa}{\lambda\left(1 - \Sigma_\pi^2/\theta\right)^2 + \kappa^2} < 0. \tag{24}$$

In the Stackelberg equilibrium the central bank knows that the worst-case misspecification raises inflation volatility and it guards against these fears by focusing more on reducing inflation volatility, at the cost of increased volatility in the output gap. Thus, the optimal trade-off between inflation and output in equation (18) is steeper ($A_S > A_N$) and monetary policy responds more aggressively to inflationary shocks in the Stackelberg equilibrium ($c_S > c_N$). This implies that inflation in the approximating model is less volatile than in the Nash equilibrium ($a_S < a_N$), while output is more volatile ($|b_S| > |b_N|$).

A stronger preference for robustness makes the central bank focus even more on reducing inflation volatility, giving an even steeper trade-off (A_S is decreasing in θ), and the central bank puts more weight on reducing inflation volatility, again at the cost of more volatility in output. Thus, the interest rate and output become more volatile, while inflation in the approximating model becomes less volatile.[6]

Comparing the two solutions, we see that the weight on output stabilization in the Nash equilibrium, λ, is everywhere multiplied by the term $(1 - \Sigma_\pi^2/\theta)$ in the Stackelberg equilibrium. For sufficiently large θ, this term is positive but smaller than one, so the central bank in the Stackelberg equilibrium behaves as a Nash central bank with a larger weight on stabilizing inflation (a smaller λ). As the preference for robustness increases, this weight increases further, and the difference between the Nash central bank and the Stackelberg central bank becomes greater. However, although the choice of timing assumption matters for the quantitative results—the size of response coefficients and the effects of

https://doi.org/10.1017/S1365100507070058 Published online by Cambridge University Press

increased robustness—the qualitative results under the two assumptions are the same when the central bank implements policy using the optimal instrument rule.

When policy is implemented using the optimal *targeting rule*, this is no longer true. In the Nash equilibrium, the optimal targeting rule given by equation (8) is independent of the preference for robustness, so if policy is implemented using the targeting rule, the central bank's preference for robustness will not affect the behavior of the economy. In the Stackelberg equilibrium this is no longer the case: if policy is implemented using the optimal targeting rule (18) rather than the interest rate rule (19), the approximating model is given by

$$\pi_t = \hat{a}_S \Sigma_\pi \varepsilon_t^\pi, \tag{25}$$

$$x_t = \hat{b}_S \Sigma_\pi \varepsilon_t^\pi, \tag{26}$$

where

$$\hat{a}_S \equiv [1 + \kappa A_S]^{-1} = \frac{\lambda\left(1 - \Sigma_\pi^2/\theta\right)}{\lambda\left(1 - \Sigma_\pi^2/\theta\right) + \kappa^2}, \tag{27}$$

$$\hat{b}_S \equiv -\frac{\kappa}{\lambda\left(1 - \Sigma_\pi^2/\theta\right) + \kappa^2}. \tag{28}$$

Thus, under the Stackelberg targeting rule policy, increasing the preference for robustness makes inflation in the approximating model less volatile and output more volatile, as the central bank implicitly puts more weight on stabilizing inflation rather than output. These results mimic those under the optimal instrument rule under either the Nash or the Stackelberg assumption.

4. FINAL REMARKS

Our analysis shows that a central bank that wants to be robust against particularly bad outcomes will typically respond more aggressively to cost shocks, as the central bank fears that inflationary shocks have larger effects on the economy. As a consequence, inflation is more stable and output more volatile than under the nonrobust policy.

We expect these results to hold as long as two assumptions are fulfilled: the central bank influences inflation through aggregate demand only, with no other influence of the interest rate on inflation; and interest rate fluctuations in themselves do not affect social loss. The first of these assumptions is common in the closed-economy literature. In a companion paper (Leitemo and Söderström, 2005), we extend the analysis to a New Keynesian model of a small open economy, in which policy moves also influence the economy through the exchange rate. We find that there is also a role for specification errors in the IS equation, as the central bank cannot costlessly offset demand shocks without affecting inflation through the exchange rate. Furthermore, we show that robust policy can be either more or less aggressive than the nonrobust policy, depending on the type of shock and the

https://doi.org/10.1017/S1365100507070058 Published online by Cambridge University Press

source of misspecification. Another extension that may change our conclusions is when social loss depends directly on fluctuations in the interest rate, as in Giannoni and Woodford (2005). In that case also, policy moves would be costly, introducing a role for specification errors in the IS equation.

Results similar to those reported here have been obtained before, for instance, by Giannoni (2002) and Giordani and Söderlind (2004). However, these studies rely on numerical methods, and so are limited to particular parameterizations of the model. In contrast, using our analytical approach we are able to show that robustness leads to aggressive policy in any parameterization of our simple version of the New Keynesian model.

NOTES

1. As stressed by Woodford (1999), the optimal policy under commitment is characterized by history-dependence, as the current policy depends on past commitments. This policy thus introduces persistence in the model, which we are unable to handle with our analytical approach. Numerical simulations show that the effects of increased robustness are qualitatively the same under commitment as under discretion, with one exception: whereas an increased preference for robustness makes policy respond more aggressively to cost shocks under discretion, under commitment the initial policy response becomes less aggressive, but the response becomes more persistent.

2. Walsh (2004) obtains a similar result in the New Keynesian model, showing that the optimal implicit instrument rule using robust control methods is equivalent to the robustly optimal instrument rules of Giannoni and Woodford (2003) and thus does not depend on the central bank's preference for robustness.

3. This is reminiscent of the results in Söderström (2002) that optimal monetary policy under multiplicative parameter uncertainty responds more aggressively to shocks when there is uncertainty about the persistence of inflation.

4. See the working paper version, Leitemo and Söderström (2004), for details.

5. We are grateful to Carl Walsh for suggesting this alternative timing assumption.

6. The effects of robustness on inflation volatility in the worst-case model are ambiguous, however. On the one hand, an increase in the preference for robustness makes the central bank reduce inflation volatility more aggressively, but, on the other hand, the evil agent induces more volatility in inflation. In the Nash equilibrium, where the trade-off does not depend on the preference for robustness, the net effect is a reduction in inflation volatility, but in the Stackelberg equilibrium, there is also an effect through the optimal trade-off, and the net effect depends on parameter values.

REFERENCES

Clarida, Richard, Jordi Galí, and Mark Gertler (1999) The science of monetary policy: A New Keynesian perspective. *Journal of Economic Literature* 37 (4), 1661–1707.

Giannoni, Marc P. (2002) Does model uncertainty justify caution? Robust optimal monetary policy in a forward-looking model. *Macroeconomic Dynamics* 6 (1), 111–144.

Giannoni, Marc P. and Michael Woodford (2003) Optimal Interest-Rate Rules: I: General Theory. Working Paper No. 9419, National Bureau of Economic Research.

Giannoni, Marc P. and Michael Woodford (2005) Optimal inflation-targeting rules. In Ben S. Bernanke and Michael Woodford (eds.), *The Inflation-Targeting Debate*, pp. 93–172. Chicago: University of Chicago Press.

Giordani, Paolo and Paul Söderlind (2004) Solution of macromodels with Hansen–Sargent robust policies: Some extensions. *Journal of Economic Dynamics and Control* 28 (12), 2367–2397.

https://doi.org/10.1017/S1365100507070058 Published online by Cambridge University Press

Hansen, Lars Peter and Thomas J. Sargent (2007) *Robustness*. Monograph manuscript, University of Chicago and New York University. Princeton, NJ: Princeton University Press.
Leitemo, Kai and Ulf Söderström (2004) Robust Monetary Policy in the New-Keynesian Framework. Discussion paper 4805, Centre for Economic Policy Research.
Leitemo, Kai and Ulf Söderström (2005) Robust Monetary Policy in a Small Open Economy. Discussion paper 5071, Centre for Economic Policy Research.
Söderström, Ulf (2002) Monetary policy with uncertain parameters. *Scandinavian Journal of Economics* 104 (1), 125–145.
Walsh, Carl E. (2004) Robust optimal instrument rules and robust control: An equivalence result. *Journal of Money, Credit, and Banking* 36 (6), 1105–1113.
Woodford, Michael (1999) Optimal Monetary Policy Inertia. Working paper 7261, National Bureau of Economic Research.

https://doi.org/10.1017/S1365100507070058 Published online by Cambridge University Press