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ROBUST MONETARY POLICY UNDER UNCERTAINTY ABOUT CENTRAL BANK PREFERENCES

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ABSTRACT

In this paper, we study the impact of central bank opacity on macroeconomic performances in a new Keynesian framework with model uncertainty using robust control techniques. We identify a new source of central bank opacity, which refers to the lack of information about the central bank's preference for robustness in the sense of Hansen and Sargent. We find closed-form solutions for the robust control problem, analysing the impact of the lack of transparency about the central bank's preferences for robustness. We show that an increased transparency about the central bank's preference for robustness makes monetary policy respond less aggressively to cost-push shocks, thus reducing the inflation and output gap variability. As a consequence, inflation and output gap are less volatile than under central bank opacity about its preference for robustness.

Keywords: central bank opacity, min–max policies, model uncertainty, robust control
JEL classification numbers: E52, E58, F41

I. INTRODUCTION

The transparency of central bank decision making and its effects on macroeconomic performances have recently received a growing attention in the literature (Eijffinger *et al.*, 2000; Cukierman, 2001; Geraats,

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2002). This literature considers that the policy makers and the private agents know the 'true model' of the economy. However, recent research (Levin and Williams, 2003; Walsh, 2003; Leitemo and Söderström, 2005) has illustrated a renewed interest in monetary policy decision making by introducing model uncertainty.

Model uncertainty refers to the discrepancy between the real state of the economy and the mathematical model supposed to represent it. As long as mathematically expressed economic models remain an incontrovertible tool for economists, the problem of the mapping between an objective real data-generating process and a subjective artificial model will inevitably exist. In other words, mathematical models cannot be considered to be anything more than approximations to the reality of the economy. Policy decision making based on such models suffers from uncertainty due to the lack of perfect precision in the process of modelling the real world.

The robust control approach, suggested by Hansen and Sargent (2007), is one efficient approach for policy makers confronting uncertainty, especially when the latter is characterized by possible specification errors over which they are unable to specify a probability distribution. This approach provides a set of tools to assist decision makers in dealing with uncertainty, but it also allows private agents to express concerns about model misspecifications when forming expectations. Most of the papers on robust control literature (see among others Giordani and Söderlind, 2004; Hansen and Sargent, 2007; Kilponen and Leitemo, 2008) consider that both the private sector and the central bank share the same preference for robustness and thereby incorporate this information into their decision making. However, as Brock and Durlauf (2004) pointed out, the customary assumption may be unrealistic under certain circumstances. On the one hand, it is plausible that the private sector has less information available than the central bank about its preference for robustness. On the other hand, the central bank may have an intent to manipulate the private sector's belief in the degree of model uncertainty, as the latter generally increases inflation expectations.

In fact, the introduction of model uncertainty into monetary policy design favours activism in terms of stabilizing the policy in response to exogenous shocks. Giannoni (2002) states that, in a set-up with model uncertainty, the interest rate responds more aggressively to shocks with respect to when there is no uncertainty. Similarly, Kilponen (2003) and Leitemo and Söderström (2005) find that inflation and its expected value are higher in the worst case compared with the case without uncertainty. The argument that model uncertainty justifies active responses to shocks can motivate the central bank's choice of opacity about revealing the information regarding its preference for robustness. Intuitively, the private sector's belief in a relatively low preference for robustness may help anchor inflation expectations. In this context, the central bank may have an incentive to be opaque about its choice of the degree of robustness in order to generate surprise inflation and thereby to stabilize inflation with a lower cost of output.

It is therefore of interest to study whether it is beneficial for the central bank to reveal its estimate of the degree of model uncertainty to the public. We thus depart from the conventional assumption and investigate the uncertainty about this robust preference parameter of the central bank because of asymmetric information. In this context, we assume that private agents are aware of the fact that the central bank sets its monetary policy according to its preference for model robustness. However, the central bank does not reveal all information to the private agents and they cannot, therefore, predict its preference for robustness. Thus, the lack of transparency arises from the fact that there is asymmetric information (poor communication) between the central bank and the private agents.

In this paper, we identify two sources of uncertainty: first, uncertainty concerning the central bank's preference about model robustness, and second, model uncertainty that comes from the ignorance of the true model (structure) of the economy. In this respect, by applying the robust control approach (Hansen and Sargent, 2007), we show that an increased degree of transparency about the central bank's preference for robustness makes monetary policy respond more aggressively to cost-push shocks. Thus, we find that a greater transparency in the monetary policy reduces the variability of output gap and inflation expectations. More precisely, the central bank can stabilize better the impact of shocks to private agents' expectations by revealing more information about its preference for robustness. As a consequence, inflation and output gap are less volatile than under central bank opacity about its preference for robustness.

The rest of the paper is organized as follows. Section II presents the model using robust control techniques and uncertainty in the central bank's preferences. Section III gives the optimal robust solutions under a discretionary equilibrium. Section IV analyses the impact of opacity about the preference for robustness on macroeconomic performance. Our conclusions are given in Section V.

II. THE MODEL

Our analysis follows the standard new Keynesian Phillips curve (NKPC) model with sticky prices that has been used extensively in the recent literature on monetary policy.[1] Thus, the benchmark model is given by

$$\pi_t = E_t\pi_{t+1} - ax_t + \varepsilon_t \tag{1}$$

[1] See Clarida *et al.* (1999), and for a more recent analysis, see Vestin (2006).

where π_t is the rate of inflation, x_t is the output gap controlled by the central bank, $E_t\pi_{t+1}$ is the expected inflation rate of the next period based on the information available in period t and ε_t denotes a cost-push shock. We also assume that the shock is persistent, following a first-order autoregressive process

$$\varepsilon_t = \rho\varepsilon_{t-1} + \xi_t \tag{2}$$

with $0 \leq \rho \leq 1$ and ξ_t an independent identically distributed random variable with zero mean and variance σ_ξ^2. To incorporate robust control techniques, according to Hansen and Sargent (2007), we introduce a misspecification term h_t and obtain the robust set-up as follows:

$$\pi_t = E_t\pi_{t+1} - ax_t + \varepsilon_t + h_t \tag{3}$$

where h_t is an additional deterministic disturbance that introduces ambiguity to the model. The two disturbances terms ε_t and h_t have different properties. The term ε_t is assumed to be a random error with prior known stochastic properties, while h_t represents, in the spirit of robust control, a totally ambiguous model misspecification error in the sense that the policy maker is not able to assign any prior probability distribution to h_t. The model with $h_t = 0$ represents the reference model, while the models with $h_t \neq 0$ represent candidate models surrounding the reference model. In this context, as the central bank is assumed to be unable to provide a probability distribution over different deviations from the reference model, it instead designs its monetary policy to be optimal in the worst possible outcome within a neighbourhood of the reference model.

Hence, the central bank's doubts for misspecification may be formalized by assuming that the worst-case specification errors are chosen by a fictitious evil agent subject to a budget constraint specified as

$$E_t \sum_{j=0}^{\infty} \delta^j h_{t+j}^2 \leq \chi^2 \tag{4}$$

where the parameter χ is assumed to be the budget allocated from the central bank to the evil agent in order to create misspecifications.

To introduce this ambiguity into the decision-making problem, the robust monetary policy in the sense of Hansen and Sargent is obtained by solving the following min–max problem:

$$\min_{x_t} \max_{h_t} V_{cb} = E_t \sum_{j=0}^{\infty} \frac{1}{2}\delta^j \left(\phi\pi_{t+j}^2 + x_{t+j}^2 - \theta h_{t+j}^2\right) \tag{5}$$

subject to the misspecified model (3) and the evil agent's budget constraint in Equation (4). The parameter $\phi > 0$ measures the weight policy makers attached to inflation stabilization relative to output stabilization.

To hedge against the loss from the worst-case model, the policy maker sets the output gap to minimize the value of its inter-temporal loss function, while the evil agent sets its controls to maximize the central bank's loss, given the constraint on misspecifications. This is the so-called multiplier problem in the sense of Hansen and Sargent.

Understanding the implications of the new parameter, θ, is a critical point in the application of the robust control approach. The decision makers' distrust of their benchmark model introduces a desire for robustness against the model uncertainty, which is proportional to their estimated degree of model uncertainty. Therefore, θ can be considered as a measurement of the preference for robustness against the model uncertainty (see Walsh, 2003; Leitemo and Söderström, 2005).

While the limit case, $\theta = +\infty$, describes a situation without model uncertainty, smaller values of θ mean an increasing degree of model uncertainty about the reference model, inducing a greater preference for robustness as well as a higher degree of robustness of the distorted model. This, in turn, implies a smaller nuisance from the evil agent's behaviour. However, if the degree of robustness is sufficiently high, θ will eventually vanish. Indeed, there exists a lower bound under which the evil agent has enough degrees of freedom to send the decision maker's loss function to $-\infty$. In this case, it is not necessary to discuss the policy maker's minimizing action. The robustness concept disappears for values of θ to the left of the lower-bound θ, since critical points represent a minimum and not a saddle point. This lower-bound θ is associated with an upper bound of the evil agent's budget constraint χ and, thus, to the largest set of alternative models.[2] In the recent literature on the robust control approach, both private sector and monetary authorities are assumed to share the same preference for robustness and thereby incorporate this information into their decision making. However, it is interesting to introduce the uncertainty about the preferences of the central bank and study the macroeconomic implications of more or less transparency of the central bank. Brock and Durlauf (2004) pointed out that it is plausible that the central bank has more information available than the private sector. In this case, the central bank may also have incentives to manipulate the private sector's belief in the degree of model uncertainty, as the latter generally increases inflation expectations.

The issue of transparency arises when the public's perception about the central bank's degree of model robustness, $\bar{\theta}$, differs from the values of θ that the bank itself actually considers. Equation (6) specifies the stochastic behaviour of the parameter θ as

$$\theta = \bar{\theta} - \mu_t \text{ with } E_t(\mu_{t+1}) = 0 \text{ and } \mathrm{Var}(\mu) = \sigma_\theta^2 \tag{6}$$

[2] For the problem of the evil agent to be concave and well defined, it is necessary that the second-order condition with respect to h should be negative, implying that $\theta > \phi$.

This implies that the public is correct on average, but may be mistaken when making guesses about the central bank's preferences for robustness in individual cases or at certain points in time. The term σ_θ^2 measures the degree of opacity of the central bank. If the variance of the preference shock σ_θ^2 increases (decreases), the central bank becomes less (more) transparent.

III. THE EQUILIBRIUM SOLUTION UNDER DISCRETION

Assuming that neither the central bank nor the evil agent has access to any commitment mechanism, we take expectations as given in the optimization and look for a discretionary equilibrium. From the first-order conditions, we derive the following optimality conditions relating output gap, x_t, inflation, π_t, and the degree of misspecification, h_t, to each other as follows:

$$x_t = -a\phi\pi_t \tag{7}$$

$$h_t = \frac{\phi}{\theta}\pi_t \tag{8}$$

The first optimality condition shows that the preference for robustness does not affect the optimal trade-off between inflation and output in Equation (7). The misspecifications in the NKPC model consist in worsening the deviation of inflation with respect to its target level. If the cost-pushed shocks induce a higher inflation, the misspecifications tend to enhance the inflationary tensions and furthermore contract the output, thus reducing the social welfare.

To find a closed-form solution for the robust control problem, we will look for the worst-case solution for the endogenous variables, π_t and x_t, and the worst possible degree of misspecification or the evil agent's instrument, h_t. Now, using optimality conditions (7) and (8) in the misspecified Phillips curve (3), we obtain

$$\pi_t = \left[\frac{\theta}{(a^2\phi + 1)\theta - \phi}\right](E_t\pi_{t+1} + \varepsilon_t) \tag{9}$$

In order to determine the inflation rate, π_t, we use the technique of undetermined coefficients in which the bubble-free solution is obtained via a minimal-state-variable procedure described by McCallum (1983). Since the relevant state variable in Equation (9) is ε_t, it is apparent that π_t will be of the form

$$\pi_t = \beta_0\varepsilon_t \tag{10}$$

Thus, using Equation (2), we obtain the following expression for the expected value of the future inflation:

$$E_t\pi_{t+1} = E(\beta_0)\rho\varepsilon_t \tag{11}$$

Substituting Equation (11) into Equation (9) yields

$$\pi_t = \frac{\theta}{(a^2\phi + 1)\theta - \phi}[1 + E(\beta_0)\rho]\varepsilon_t \tag{12}$$

Comparing the above equation with Equation (10), we can derive the following expression:

$$\beta_0 = \frac{\theta}{(a^2\phi + 1)\theta - \phi}[1 + E(\beta_0)\rho] \tag{13}$$

To calculate the expected value of the coefficient β_0, we take rational expectations across expression (13) and have

$$E(\beta_0) = E\left[\frac{\theta}{(a^2\phi + 1)\theta - \phi}\right][1 + E(\beta_0)\rho] \tag{14}$$

Then, using a second-order Taylor series expansion in the above equation and replacing the expression $E(\beta_0)$ into Equation (13), we obtain the solution for β_0 as follows:

$$\beta_0 = \left[\frac{\theta}{(a^2\phi + 1)\theta - \phi}\right]\frac{G^3}{G^3 - \rho\left[\bar{\theta}G^2 + \phi(a^2\phi + 1)^2\sigma_\theta^2\right]} \tag{15}$$

where $G = (a^2\phi + 1)\bar{\theta} - \phi$.

The equilibrium solution of the worst-case model is given by

$$\pi_t = \left[\frac{\theta}{(a^2\phi + 1)\theta - \phi}\right]\frac{G^3}{G^3 - \rho\left[\bar{\theta}G^2 + \phi(a^2\phi + 1)^2\sigma_\theta^2\right]}\varepsilon_t \tag{16}$$

$$x_t = -\left[\frac{a\phi\theta}{(a^2\phi + 1)\theta - \phi}\right]\frac{G^3}{G^3 - \rho\left[\bar{\theta}G^2 + \phi(a^2\phi + 1)^2\sigma_\theta^2\right]}\varepsilon_t \tag{17}$$

$$h_t = \left[\frac{\phi}{(a^2\phi + 1)\theta - \phi}\right]\frac{G^3}{G^3 - \rho\left[\bar{\theta}G^2 + \phi(a^2\phi + 1)^2\sigma_\theta^2\right]}\varepsilon_t \tag{18}$$

The above equilibrium solution is the reduced form under the worst possible case of misspecification. This equilibrium solution illustrates the central bank's worst fears of misspecification, which helps us to understand the design of the robust monetary policy. The central bank faces a trade-off between inflation and output stabilization. In the case of a positive cost-push shock $\varepsilon_t > 0$, output will be contracted and inflation will be raised. The misspecification term h_t is considered as an endogenous variable illustrating the worst possible degree of model misspecification. In this context, the evil agent chooses the specification errors to be as damaging as possible, and the optimal policy rule of the central bank and the expectations of the private sector reflect this misspecification.

Assuming rational expectations for the private agents, we derive from Equation (16) the expected future inflation

$$E_t\pi_{t+1} = \left\{ \frac{\bar{\theta}G^2 + \phi(a^2\phi + 1)\sigma_\theta^2}{G^3 - \rho\left[\bar{\theta}G^2 + \phi(a^2\phi + 1)\sigma_\theta^2\right]} \right\} \rho\varepsilon_t \tag{19}$$

When a positive cost-push shock, i.e., $\varepsilon_t > 0$, hits the economy, private agents will anticipate an increase in the inflation rate. In order to ensure $E_t\pi_{t+1} > 0$, we require that $G^3 - \rho\bar{\theta}G^2 - \phi(a^2\phi + 1)\sigma_\theta^2 > 0$. By rearranging the terms, we derive the following inequality:

$$\sigma_\theta^2 < \frac{G^2(G - \rho\bar{\theta})}{(1 + a^2\phi)\phi\rho} \tag{20}$$

To some extent, this inequality allows us to define an upper bound of the degree of the central bank's opacity σ_θ^2.

Then, using Equations (7) and (19), we obtain the expected future output gap as

$$E_t x_{t+1} = -a\phi E_t\pi_{t+1} = -a\phi \left\{ \frac{\bar{\theta}G^2 + \phi(a^2\phi + 1)\sigma_\theta^2}{G^3 - \rho\left[\bar{\theta}G^2 + \phi(a^2\phi + 1)\sigma_\theta^2\right]} \right\} \rho\varepsilon_t \tag{21}$$

The above equilibrium solution of the worst-case model is based on the second-order Taylor approximation in order to obtain the solution for β_0. As a result, the approximate solution of the model is available if and only if the values of the parameter θ are close to its average $\bar{\theta}$. Therefore, this observation reveals the question of the impact of the transparency about the central bank's preference for robustness on the macroeconomic variables. In the following section, we give an answer to the question whether it is beneficial for the monetary authority to disclose its assessment on the parameter θ.

IV. TRANSPARENCY AND MACROECONOMIC PERFORMANCE

The main focus of our next analysis concerns the relationship between the degree of opacity of the central bank's preference for robustness and the macroeconomic variables. Thus, we analyse the effects of uncertainty about the central bank's preference for robustness on the inflation, the output gap and the expected values of future inflation and output gap. At the first stage, we study the impact of greater opacity on inflation expectations' variability. We derive the following proposition.

Proposition 1. Greater central bank opacity about the central bank's preference for robustness (θ) *induces a higher variability of expected future inflation.*

Proof. Differentiating Equation (19) twice with respect to the cost-push shock and then the degree of the central bank's opacity yields

$$\frac{\partial^2 E_t \pi_{t+1}}{\partial \sigma_\theta^2 \partial \varepsilon_t} = \frac{\phi(a^2\phi + 1)\rho G^3}{\left\{G^3 - \rho\left[\bar{\theta} G^2 + \phi(a^2\phi + 1)\sigma_\theta^2\right]\right\}^2} > 0 \qquad (22)$$

■

Note that in the above result a positive sign implies that the expected future inflation becomes more sensitive to that particular cost-push shock (ε_t) when the opacity of the central bank's preference for robustness (σ_θ^2) increases, and vice versa. This analysis reveals that uncertainty about the central bank's preference for robustness (increase of σ_θ^2) increases future inflationary expectations. In the opposite case, if the central bank shares more information about its preference with private agents (i.e., becomes more transparent), the latter tend to reduce their inflationary expectations. Consequently, the robust central bank fears that inflation is more volatile than in the reference model and responds more aggressively to the cost-push shock's effects on expected future inflation, as the worst-case misspecification increases the volatility. In this line, Brock and Durlauf (2004) suggest that model uncertainty has an impact on the way in which expectations are formulated. The intuition behind this result is that model uncertainty leads to an additional cost of information acquisition for the public when forming expectations. Without accurate information about the value of the parameter θ, private agents prefer to act in a precautionary manner by increasing their inflationary expectations against the risk of underestimating the central bank's preference for robustness and thus the inflation rate.

We now analyse the impact of opacity on output gap expectations and derive the following proposition.

Proposition 2. A greater central bank opacity about the preference for robustness θ *induces a higher variability of expected future output gap.*

Proof. Differentiating Equation (21) twice with respect to the cost-push shock and then the degree of the central bank's opacity yields

$$\frac{\partial^2 E_t x_{t+1}}{\partial \sigma_\theta^2 \partial \varepsilon_t} = \frac{-a\phi^2(a^2\phi + 1)\rho G^3}{\left\{G^3 - \rho\left[\bar{\theta} G^2 + \phi(a^2\phi + 1)\sigma_\theta^2\right]\right\}^2} < 0 \qquad (23)$$

■

According to this result, the output gap expectations evolve in the opposite direction of the expected inflation in Proposition 1. In fact, higher inflation expectations induced by a higher level of opacity about the central bank's preference for robustness lead to a larger fall in expected future output gap. Thus, the uncertainty about θ yields a more volatile output gap.

Finally, concerning the impact of the central bank's opacity on current inflation and output gap variability, we can derive the following proposition.

Proposition 3. An increase in the central bank's opacity about the preference for robustness θ leads to a higher variability of inflation and output gap.

Proof. Differentiating Equation (17) twice with respect to the supply shock and then the degree of opacity yields

$$\frac{\partial^2 x_t}{\partial \sigma_\theta^2 \partial \varepsilon_t} = -\left(\frac{a\phi\theta}{(a^2\phi + 1)\theta - \phi}\right)\frac{G^3\phi\rho(a^2\phi + 1)^2}{(G^3 - \rho\theta G^2 - \phi\rho(a^2\phi + 1)^2\sigma_\theta^2)^2} < 0 \tag{24}$$

Similarly, differentiating Equation (16) twice with respect to the cost-pushed shock and then the degree of opacity yields

$$\frac{\partial^2 \pi_t}{\partial \sigma_\theta^2 \partial \varepsilon_t} = \left(\frac{\theta}{(a^2\phi + 1)\theta - \phi}\right)\frac{G^3\phi\rho(a^2\phi + 1)^2}{(G^3 - \rho\theta G^2 - \phi\rho(a^2\phi + 1)^2\sigma_\theta^2)^2} > 0 \tag{25}$$

■

Greater uncertainty induces a higher variation of the current output, as the latter depends positively on expected future output gap. Therefore, current inflation will be stabilized with a larger fall in the output when a positive cost-push shock occurs. As a consequence, the inflation–output trade-off deteriorates. This result is consistent with the literature studying the central bank's transparency in the absence of model uncertainty. The examples include Muscatelli (1998) and Beetsma and Jensen (1998). The general conclusion in this literature is that preference uncertainty distorts stabilization policy, thereby enhancing welfare losses generated by supply shocks. With model misspecifications, uncertainty about the central bank's preference for robustness strengthens the impact of the shock to the economy and is thus welfare reducing.

To illustrate the impact of the uncertainty about the preference for robustness on the macroeconomic equilibrium, we compare the case of limited transparency (meaning that there is a level of opacity about the central bank's preference for robustness, $\sigma_\theta^2 > 0$) with full transparency. The latter, in which there does not exist asymmetric information about the parameter θ, is equivalent to setting $\sigma_\theta^2 = 0$. In this case, the formation of expectations is different with respect to the limited transparency case, since the private sector has perfect information about the preference for robustness. This implies that $E(\beta_0) = \beta_0$ and $E_t\pi_{t+1} = \beta_0\rho\varepsilon_t$. Consequently, the equilibrium solution of the robust set-up under the full transparency regime corresponds to a special case of limited transparency with $\sigma_\theta^2 = 0$. Thus, according to Propositions 1–3, the full transparency case yields the lowest inflation expectations and the lowest variability of output and inflation in comparison with the limited transparency case.

To sum up, we have shown that an increase in the degree of opacity about the central bank's preference for robustness positively affects the variability of inflation and output gap and that of their expected values.

V. CONCLUDING REMARKS

In the literature on central bank transparency, there is an assumption that both policy makers and private agents know the 'true' model of the economy. However, the introduction of model uncertainty into monetary policy design affects the central bank's choice of opacity regarding its preference for robustness.

In this framework, in which the central bank faces uncertainty about its model, we assume that private agents are aware of the fact that the central bank sets its monetary policy according to its preference for model robustness. However, the central bank does not reveal all information to the private agents and they cannot, therefore, predict its preference for robustness. Thus, the lack of transparency arises from the fact that there is asymmetric information between the central bank and the private agents.

The question is whether it is beneficial to the policy maker to reveal the value of the parameter that denotes the model robustness. First, we show that the higher is the variance of the central bank's preference shock σ_θ^2, the higher will be the inflation expectations. Second, future output gap expectations vary more with higher opacity about the central bank's preference for robustness. Finally, the variability of inflation and output gap increases when the central bank reveals less information about its preference for robustness.

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