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WORKING PAPER

Robust Monetary Policy in a Model with Financial Distress

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Robust Monetary Policy in a Model with Financial Distress*

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Abstract:

We characterise optimal discretionary monetary policy responses to cost-push shocks and to financial distress in the presence of model uncertainty. Under robust control, the central bank reacts more aggressively to both types of shocks, and less to the lagged policy rate, than if the true model is known. We document how the objective to stabilise the policy instrument conflicts with the concern for robustness to model misspecification: the higher the weight on interest rate stabilisation in the loss function, the more the robust policy deviates from the optimal policy under rational expectations. Financial distress is akin to a contractionary demand shock and does not induce a policy trade-off; thus model uncertainty does not constrain monetary policy in the face of financial shocks.

Keywords: optimal monetary policy, discretion, model uncertainty, interest rate stabilisation, robust control

JEL-Classification: E44, E58, E32

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1 Introduction

We characterise optimal monetary policy responses to cost-push shocks and to financial distress in the presence of model uncertainty. In particular, we examine the interaction between the policy maker's concern for robustness and his desire to avoid excessive volatility in interest rates. We do so by including a penalty on interest rate changes in the central bank's loss function, in addition to inflation and output gap volatility. There is no commitment device for future policy; the central bank sets the policy rate in a discretionary fashion.

The analysis is based on Goodfriend and McCallum's (2007) New Keynesian model with banking, where households need bank loans to make consumption purchases. Loan production uses labour and collateral as inputs. Financial distress is modelled as a negative shock to collateral.

We adopt the robust control approach of Hansen and Sargent (2008). The true data generating process, unknown to the agents, lies in the neighbourhood of a so-called reference model. Facing Knightian uncertainty, the policy maker is unable to formulate a probability distribution over plausible models. A robust policy is one that performs well in the worst possible outcome of a pre-specified set of models.

The paper aims to fill two gaps in the literature. First, robust monetary policy has not previously been applied to financial shocks. Second, the two policy objectives interest rate stability and robustness have not been analysed jointly in existing research.

Our results can be summarised as follows. First, taking model uncertainty into account, the robust instrument rule implies stronger responses. The policy maker is more aggressive to both cost-push shocks and financial shocks. The more aggressive response is mirrored by a smaller degree of interest rate smoothing in the instrument rule. Second, the concern for instrument stability conflicts with the concern for robustness: the higher the weight on interest rate smoothing, the more the robust policy deviates from the optimal policy under rational expectations. Third, financial distress is akin to a demand shock in that it does not generate a policy trade-off. Consequently, the impulse responses to a financial shock in the worst possible outcome do not differ much from those under rational expectations. Thus, model uncertainty plays a minor role for policy in the face of financial distress.

The remainder of the paper is organised as follows. Section 2 presents the New Keynesian model augmented with a banking sector. In Section 3, we analyse optimal robust monetary policy under discretion. As an extension, we consider in Section 4 an alternative policy objective including the external finance premium. Section 5 concludes.

2 Model

Our analysis is based on the two-sector model of Goodfriend and McCallum (2007) to which we refer for a complete exposition. To keep the analysis simple, the model is specified in terms of an optimising problem for a representative household, which not only consumes a bundle of differentiated goods, supplies labour, and saves, but also produces the differentiated goods. In addition, the household operates a competitive bank. Bank loans are needed in order to purchase goods and are produced using monitoring effort (i.e. labour) and collateral as inputs. Collateral consists of government bonds and capital.

The representative household has a time endowment of unity, supplies labour to firms n_t^s and to the bank m_t^s, and consumes a Dixit-Stiglitz consumption bundle c_t^A. It maximises lifetime utility

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\phi \log\left(c_t^A\right) + \left(1-\phi\right) \log\left(1 - n_t^s - m_t^s\right) \right], \tag{1}$$

where β is the subjective discount factor and ϕ denotes the weight on consumption in the utility function, subject to two constraints. The first is a budget constraint

$$\begin{aligned} & c_t^A + tax_t + \frac{B_{t+1}}{P_t^A\left(1+R_t^B\right)} + \frac{H_t}{P_t^A} + q_t K_{t+1} \\ & = w_t\left(n_t^s + m_t^s\right) + \frac{B_t}{P_t^A} + \frac{H_{t-1}}{P_t^A} + q_t\left(1-\delta\right)K_t \, , \end{aligned} \tag{2}$$

where tax_t represents lump-sum taxes, P_t^A is the price of one unit of the consumption bundle, B_{t+1} are government bonds that are purchased in t at price $1/[P_t^A(1+R_t^B)]$ and pay a return of one currency unit in $t+1$, H_t denotes money holdings and K_{t+1} is capital purchased at price q_t. Capital depreciates at rate δ. The household receives wage income $w_t\left(n_t^s+m_t^s\right)$.

The second constraint is a transaction constraint according to which consumption spending must be paid for with bank deposits D_t,

$$c_t^A=\frac{VD_t}{P_t^A}, \tag{3}$$

where V denotes velocity.

Firms use capital K_t and labour n_t to produce a differentiated good c_t subject to a Cobb-Douglas production function

$$c_t=K_t^{\eta}\, n_t^{1-\eta} \tag{4}$$

and a demand function

$$c_t=\left(\frac{P_t}{P_t^A}\right)^{-\sigma} c_t^A, \tag{5}$$

where P_t is the price of the differentiated good and σ denotes the elasticity of substitution between these goods.

The bank's balance sheet consists of high-powered money H_t plus loans L_t on the asset side and household deposits D_t on the liability side

$$H_t+L_t=D_t. \tag{6}$$

Let rr denote the (constant) ratio of high-powered money to deposits. Loan production is constrained by the following technology

$$\frac{L_t}{P_t^A}=\mathcal{F}\left(b_{t+1}+A_t k q_t K_{t+1}\right)^{\alpha} m_t^{1-\alpha} \qquad 0<\alpha<1, \tag{7}$$

where $\mathcal{F}$ denotes banking productivity and k determines the relative efficiency of capital as collateral. Factor inputs are labour m_t and collateral $b_{t+1} + A_t k q_t K_{t+1}$, where $b_{t+1} = \frac{B_{t+1}}{P_t^A \left(1 + R_t^B\right)}$. The variable A_t captures financial distress or a shock to the value of capital as collateral in loan production.

The bank obtains funds from the central bank (or equivalently, from the interbank market) at rate R_t^{IB}, which makes R_t^{IB} the policy interest rate. In addition, we may introduce a one-period default-free security with return R_t^T, which does not provide any collateral. This uncollateralised loan rate represents a pure intertemporal rate. Finally, the external finance premium EFP_t is the real marginal cost of loan production. It is approximated as the spread between the uncollateralised loan rate and the interbank rate

$$EFP_t = R_t^T - R_t^{IB}. \tag{8}$$

The steady state is characterised by zero inflation and a constant aggregate capital stock.[1] Real variables grow at rate γ. We linearise the model around this deterministic steady state. Under a Calvo (1983) price adjustment mechanism, we obtain a New Keynesian Phillips curve

$$\Delta p_t = \beta E_t \Delta p_{t+1} + \kappa\, mc_t + u_t, \tag{9}$$

where $\kappa > 0$, u_t is a cost-push shock, $p_t = \log P_t = \log P_t^A$ such that Δp_t denotes inflation, and mc_t is the real marginal cost of goods production (in deviations from steady state). The calibration of the model parameters follows Goodfriend and McCallum (2007) and is summarised in Table 1.

[1] Note, Goodfriend and McCallum (2007) impose constant aggregate capital in equilibrium. See Casares and Poutineau (2011) for a version of the model with variable capital accumulation and capital adjustment costs.

Table 1: Calibration

α	β	γ	δ	η	κ	ϕ	σ	b	$\mathcal{F}$	k	rr	V
0.65	0.99	0.005	0.025	0.36	0.05	0.4	11	0.56	9	0.2	0.005	0.31

We specify the cost-push shock u_t and the collateral shock $a_t = \log(A_t)$ as exogenous first-order autoregressive processes with persistence 0.6. The innovations of both processes are mutually uncorrelated standard normal random variables.

3 Robust Monetary Policy

We extend Goodfriend and McCallum (2007) by deriving the optimal monetary policy under model uncertainty. More specifically, the central bank sets the policy rate in a discretionary manner; it re-optimises every period, taking private agents' expectations as given (see Söderlind, 1999, for a formal exposition). We derive the optimal implicit instrument rule numerically as in Söderlind (1999) and Giordani and Söderlind (2004).

In the following, we assume a loss function of the form

$$\Lambda_t = E_t \sum_{i=0}^{\infty} \beta^i \left[\left(\Delta p_{t+i} \right)^2 + \lambda_{mc} \left(mc_{t+i} \right)^2 + \lambda_{\Delta i} \left(\Delta R_{t+i}^{IB} \right)^2 \right], \tag{10}$$

such that the central bank seeks to minimise changes in its instrument, as well as the volatilities of inflation and the output gap (i.e. marginal costs). Since the model's core is identical to the canonical New Keynesian model, we follow Woodford (2003, p. 400) and set $\lambda_{mc} = \kappa/\sigma$. We vary the weight on interest rate stabilisation in the range $\lambda_{\Delta i} \in [0.1, 1.0]$.

Central banks tend to smooth interest rates (Goodfriend, 1991). There are several reasons why instrument stability is desirable and may therefore be an objective of monetary policy. In the context of the zero lower bound on nominal interest rates, some studies have found that inertial policy rules perform close to the optimal commitment policy (where policy makers can directly influence agents' expectations), see Williams (2009). When the economy is at, or close to, the zero lower bound and monetary policy exhibits inertia, agents expect that the interest rate will be low for a long time, which creates inflation expectations and helps to get out of the liquidity trap. Furthermore, excessive volatility in interest rates may have detrimental effects on welfare by lowering potential output. This is because the cost of capital increases as a result of a higher term premium stemming from agents having observed a large variance in the past (Tinsley, 1999).

3.1 Robust Control

Up to now we have assumed that agents know the true model with certainty. Uncertainty has been introduced merely by implementing additive errors. Therefore, certainty equivalence holds, i.e. the actions of the agents depend solely on their expectations of future variables but not on the uncertainty surrounding those expectations.[2] Below, we relax the assumption of certainty equivalence and allow for general uncertainty surrounding the reference model along the lines of Hansen and Sargent (2008).[3] Following the robust control approach, we augment the reference model with a vector of misspecification terms η_{t+1},

$$A_0 \begin{bmatrix} x_{1,t+1} \\ E_t\, x_{2,t+1} \end{bmatrix} = A_1 \begin{bmatrix} x_{1,t} \\ x_{2,t} \end{bmatrix} + B\, R_t^{IB} + C\left(\varepsilon_{t+1} + \eta_{t+1}\right), \tag{11}$$

where A_0, A_1 and B are matrices of model parameters, C is a vector that scales the impact of the vector of error terms ε_{t+1}, $x_{1,t}$ is the vector of predetermined variables with $x_{1,0}$ given and $x_{2,t}$ is a vector of jump variables. The degree of misspecification is bounded as

$$E_0 \sum_{t=0}^{\infty} \beta^t\, \eta'_{t+1}\, \eta_{t+1} \le \eta_0, \tag{12}$$

where η_0 reflects the size of the potential misspecification.

The policy maker minimises the loss function (10) subject to the distorted model (11) and the constraint (12). Hansen and Sargent (2008) and Giordani and Söderlind (2004) show that this problem can be formulated as

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[2] If error terms enter differently, certainty equivalence no longer holds (Walsh, 2010a).

[3] This exposition follows Kilponen and Leitemo (2008).

$$\min_{R_t^{IB}} \max_{\eta_t} E_0 \sum_{t=0}^{\infty} \beta^t \left(\Lambda_t - \theta \, \eta'_{t+1} \, \eta_{t+1} \right) \tag{13}$$

subject to (11). The parameter $\theta > 0$ summarises the central bank's dislike of model misspecification.

The *worst case equilibrium* is described by substituting the solution in (11) and then solving for the reduced form in the usual way. The *approximating equilibrium* is obtained by assuming that there are no misspecification errors, but retaining the robust policy and expectation formation under the worst case model. This gives the equilibrium dynamics under robust decision making by the central bank and the private sector. In the *rational expectations (RE) equilibrium*, no misspecification is allowed, such that $\lim_{\eta_0 \to 0} \theta = \infty$.

In order to calibrate the parameter θ, we adopt the concept of a detection error probability. The detection error probability is the probability of making the wrong choice between the approximating model and the worst case model. Smaller values of θ allow for greater specification error, which make it easier for the econometrician to statistically distinguish between the two possible equilibria. Hence, a smaller θ reduces the detection error probability. We choose a preference for robustness that corresponds to a detection error probability of 25 percent.

3.2 Optimal and Robust Implicit Instrument Rules

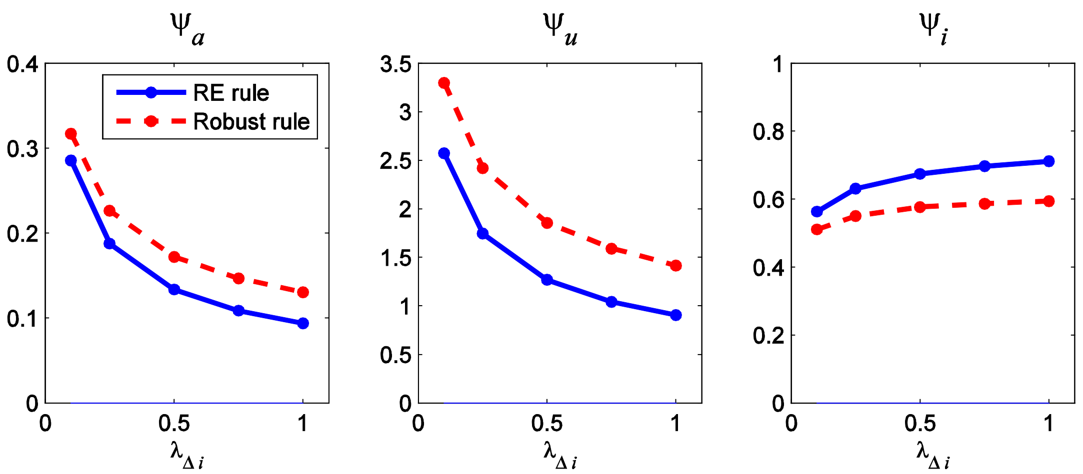
We first derive the optimal monetary policy when certainty equivalence holds, for different weights on the interest rate stabilisation objective. Then, we analyse how the policy maker's concern for robustness alters the optimal response.

The optimal implicit instrument rule summarises the response of the policy maker under discretion. Formally, the policy rate depends on the predetermined variables x_1 of the model

$$R_t^{IB} = \psi_a \, a_t + \psi_u \, u_t + \psi_i \, R_{t-1}^{IB}. \tag{14}$$

The solid line in Figure 1 shows the coefficients of the instrument rule in the rational expectations (RE) equilibrium for different weights on interest rate smoothing in the loss function. A larger weight $\lambda_{\Delta i}$ raises the coefficient on the lagged policy rate ψ_i in the rule while reducing the responses to the two shocks. The more the central bank dislikes volatility in the policy instrument, the more persistent becomes the optimal interest rate path and the less aggressive the response to the shocks.

Figure 1: Parameters of optimal implicit instrument rules



We now investigate how a concern for robustness alters the optimal responses of the RE equilibrium. The robust instrument rule, shown by the dashed line in Figure 1, responds more aggressively to both shocks for any given weight on interest rate stabilisation in the loss function; the coefficients of the robust rule are always higher than their RE equivalents. The opposite is true for the lagged policy rate: the coefficients ψ_i are consistently smaller than in the RE equilibrium. Thus, as a first result, we note that optimal discretionary monetary policy responds more aggressively to cost-push shocks and to financial shocks when model uncertainty is taken into account. While some studies find, as we do, that robustness leads to more aggressive policies (e.g., Giannoni, 2002), this is not a general result but depends on the model and on the loss function (Hansen and Sargent, 2008; Leitemo and Söderström, 2008).[4]

The second result shown in Figure 1 is that the policy maker trades off the concern for instrument stability against robustness to model misspecification. The higher is the

[4] Barlevy (2009) shows by means of simple examples that neither a more cautious nor a more aggressive policy response is a general feature of robust control. For another example in which robust optimal responses to certain shocks are less aggressive, see Tillmann (2009).

weight on interest rate smoothing, the more the robust response deviates from its RE counterpart. Also this second result does not reflect a universal outcome of the robust control approach. For example, Gerke and Hammermann (2011) analyse a model with a cost channel and interest rate smoothing, where the robust responses to a demand shock and a cost-push shock are both less aggressive than the optimal responses in the RE equilibrium. If one increases the weight on interest rate smoothing (not shown in that paper), the deviation from the rational expectations equilibrium *declines* for demand shocks but *increases* for cost-push shocks. Thus, the interaction of robustness and interest rate smoothing does depend on the model.

The key idea behind the robust control approach is that the policy maker insures himself against model uncertainty. Hence, an insurance premium is an intuitive way to present the effects of uncertainty. In Table 2, we calculate an insurance premium as the difference between the loss of the approximating equilibrium and the loss of the RE equilibrium over the difference between the worst case equilibrium and the RE equilibrium (similarly to Kuester and Wieland, 2010, p. 885). The premium measures how much the policy maker is willing to pay, in percent of the "damage" caused in the worst case, to insure against model misspecification. The table shows that, for higher weights on interest rate smoothing, it becomes more costly to insure against model misspecification.

Table 2: Comparison of losses and insurance premium

$\lambda_{\Delta i}$	RE equilibrium	Worst case equilibrium	Approximating equilibrium	Insurance premium in percent
0.10	3.83	5.75	4.92	57.05
0.25	4.64	7.56	6.41	60.59
0.50	5.35	9.18	7.71	61.72
0.75	5.78	10.37	8.62	61.83
1.00	6.09	11.17	9.24	61.85

Note: Differences due to rounding errors.

3.3 Effect of Robustness on Volatility

Table 3 reports the percentage differences between the variances in the approximating equilibrium and those in the RE equilibrium. We observe, first, that all three variables are more volatile when the policy maker takes model uncertainty into account. In contrast, in a New Keynesian model, one typically finds that a preference for robustness dampens the volatility of one of the target variables, notably inflation (e.g. Leitemo and Söderström, 2008). Second, the variances of inflation and the policy rate increase more under robust control, the higher is the weight on interest rate smoothing in the loss function. The opposite is true for marginal costs. Greater interest rate smoothing thus implies greater output (marginal cost) stabilisation at the cost of higher inflation volatility. A less forceful response to the cost-push shock due to a stronger concern for interest rate smoothing implies that inflation is stabilised less and, because of the monetary policy trade-off, the volatility in marginal costs is therefore lower.[5]

Table 3: Effect of robust control on volatilities

$\lambda_{\Delta i}$	Inflation	Marginal costs	Policy rate
0.10	17.33	44.56	40.86
0.25	25.19	32.95	48.51
0.50	29.93	20.95	52.12
0.75	33.16	14.09	55.77
1.00	34.82	9.37	57.67

Note: Percentage difference in variance in approximating equilibrium relative to RE equilibrium.

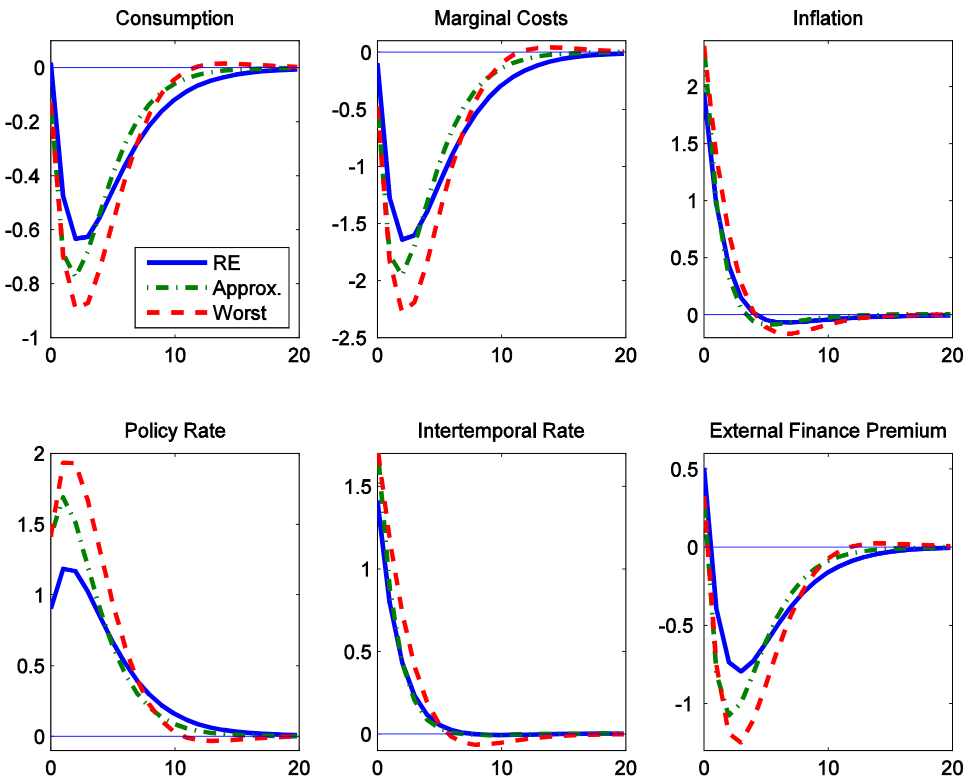
3.4 Impulse Responses: Does Model Uncertainty Matter?

Figures 2 and 3 exhibit the impulse responses to a cost-push shock u_t and to a financial shock a_t for a high weight on interest rate smoothing in the loss function, $\lambda_{\Delta i} = 1.$ The solid lines show the responses in the RE equilibrium under optimal discretion. The dashed lines and the dashed-dotted lines depict, respectively, the impulse responses in

5 Additional results on model uncertainty surrounding only the Phillips curve and only loan production confirm this conclusion and are available upon request.

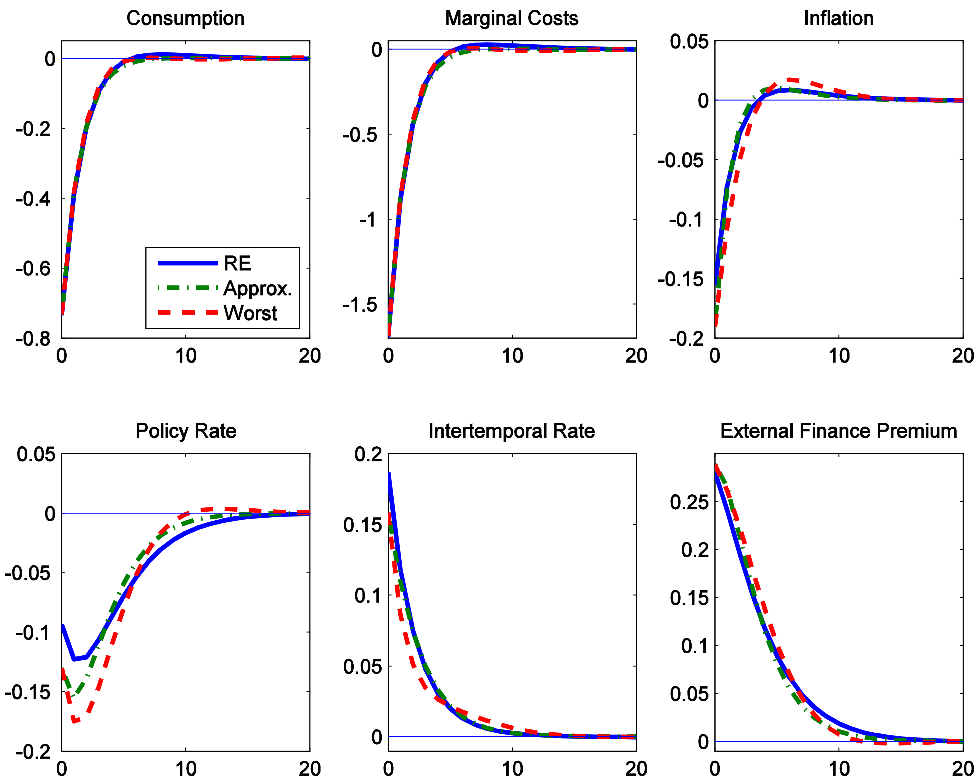
the worst case and approximating equilibrium. Figure 2 shows the policy trade-off induced by a cost-push shock. Inflation increases, while consumption and marginal costs fall below their steady state levels. The central bank reacts by increasing its policy instrument R_t^{IB}. Due to interest rate smoothing, the policy rate R_t^{IB} is more persistent than the intertemporal rate R_t^T. This leads to a decline of the external finance premium, which moves procyclically with consumption and marginal costs. The impulse responses in the worst case equilibrium and the approximating equilibrium deviate considerably from the RE equilibrium, with most variables reacting more strongly under robust control. Overall, both the RE responses and the robust responses to the cost-push shock are similar to those of the canonical New Keynesian model (see Giordani and Söderlind, 2004).

Figure 2: Impulse responses to cost-push shock



As shown in Figure 3, a shock to collateral a_t that makes capital less efficient in producing loans ("financial distress") does not lead to a policy trade-off between inflation and real marginal costs. The financial shock acts like an aggregate demand shock that can easily be stabilised by monetary policy.[6] However, the interest rate smoothing objective induces a mild trade-off in the loss function, which hinders the optimal monetary policy under discretion to fully stabilise inflation and the output gap. Following the financial shock, the household does not provide enough additional collateral to compensate for the fall in *k*, leading to a lower collateral values and thereby to a decline in consumption. The central bank cuts its policy rate R_t^{IB}, whereas the intertemporal benchmark rate R_t^T increases. These interest rate changes lead to a rise in the external finance premium, which moves countercyclically.

Figure 3: Impulse responses to financial shock



Taking model uncertainty into account, the policy rate decreases by more than in the RE case and accordingly, the robust policy response is more aggressive in both the worst case and the approximating equilibrium.

To sum up our third result, due to the absence of a significant policy trade-off, the impulse responses to financial distress in the worst case and the approximating

[6] See also the VAR evidence based on US data by Walsh (2010b).

equilibrium deviate only slightly from the RE equilibrium. Thus, potential model misspecification does not constrain optimal policy in the case of financial distress.

4 Extension: Stabilising the External Finance Premium

As an additional exercise, we consider a loss function including the external financial premium (EFP) instead of the change in the policy rate,

$$\Lambda_t = E_t \sum_{i=0}^{\infty} \beta^i \left[\left(\Delta p_{t+i} \right)^2 + \lambda_{mc} \left(mc_{t+i} \right)^2 + \ \lambda_{EFP} \left(EFP_{t+i} \right)^2 \right]. \tag{15}$$

We again analyse weights in the range $\lambda_{EFP} = [0.1, 1]$ and find that the robust control approach reaches its limit rather quickly when including the EFP in the loss function.

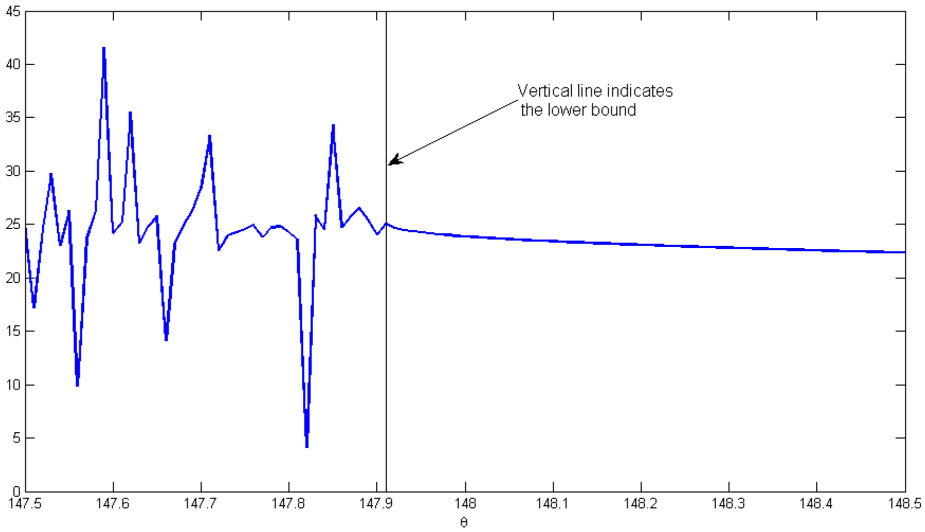
Recall, the rational expectations (RE) equilibrium corresponds to a large θ. Starting from the RE equilibrium and lowering θ (increasing the degree of misspecification), we reach a value $\underline{\theta}$ beyond which it is impossible for the policy maker to attain a robust decision rule. Hansen and Sargent (2008, p. 3 and p. 32) call this lower bound $\underline{\theta}$ the "breakdown point". The breakdown point is best illustrated for the worst case loss (see Figure 4).

In the case of a small weight on the EFP in the loss function, $\lambda_{EFP} = 0.1$, this lower bound is $\underline{\theta} = 147.91$ (see vertical line) with a corresponding detection error probability of 33.6 percent. For larger degrees of misspecification, i.e. $\theta < 147.91$, the worst case loss becomes unstable and the robust control approach breaks down.

For larger weights on the EFP in the loss function, $\lambda_{EFP} > 0.1$, it is possible to attain a robust policy only for an even higher θ (i.e. a smaller degree of misspecification) and, accordingly, a detection error probability that is much larger than 25 percent (our benchmark). However, such high detection error probabilities are at odds with the values suggested in the literature (Hansen and Sargent, 2008, p. 219 and Giordani and Söderlind, 2004, p. 2376).

A smaller weight on the EFP in the loss function, $\lambda_{EFP} < 0.1$, would imply the virtual absence of a meaningful policy trade-off.

Figure 4: Worst case losses for small weight on EFP stabilisation



Note: The horizontal axis shows the degree of misspecification θ: a higher degree of misspecification implies a smaller value of θ. On the vertical axis, we plot the corresponding worst case loss, for a weight on the external finance premium in the loss function given by $\lambda_{EFP} = 0.1$. Increasing the desire for robustness beyond the breakdown point $\underline{\theta}$ (indicated by the vertical line) implies that the loss becomes unstable and it is therefore not possible to attain a robust policy.

5 Conclusion

This paper analyses optimal discretionary monetary policy under model uncertainty when the economy is hit by cost-push shocks and financial distress. Of particular interest is the interaction between a policy maker's interest rate smoothing objective and his concern for robustness to model misspecification. The first objective is captured by a penalty on interest rate changes in the central bank's loss function. To take into account model uncertainty, we follow the robust control approach, where the policy maker chooses a policy that performs well in the worst possible outcome. We compute the optimal implicit instrument rule under discretion.

First, we find that the robust rule responds more aggressively to both cost-push shocks and financial shocks than the optimal policy under certainty equivalence. The increased aggressiveness is supported by a decline in the coefficient of the lagged policy rate. Second, the deviation of the robust policy from the rational expectations equilibrium widens for higher weights on interest rate smoothing in the central bank's objective function. Thus, the policy maker's desire to insure against model uncertainty conflicts with his concern for instrument stability. Third, financial distress is akin to a contractionary demand shock and as such does not induce a policy trade-off. As a consequence, the optimal dynamics following a financial shock are largely unaffected by the presence of model uncertainty.

References

Barlevy, Gadi (2009), Policymaking under Uncertainty: Gradualism and Robustness. *Economic Perspectives*, 33 (2), 38-55.

Calvo, Guillermo A. (1983), Staggered Prices in a Utility-Maximizing Framework. *Journal of Monetary Economics* 12 (3), 383-398.

Casares, Miguel and Jean-Christophe Poutineau (2011), Short-Run and Long-Run Effects of Banking in a New Keynesian Model, *B.E. Journal of Macroeconomics (Contributions)* 11 (1), Article 16.

Gerke, Rafael and Felix Hammermann (2011), Robust monetary policy in a New Keynesian model with interest rate pass-through, Deutsche Bundesbank Discussion Paper, Series 1, 02/2011.

Giannoni, Marc P. (2002), Does Model Uncertainty Justify Caution? Robust Optimal Monetary Policy in a Forward-looking Model, *Macroeconomic Dynamics* 6 (1), 111-144.

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.

Goodfriend, Marvin (1991), Interest Rates and the Conduct of Monetary Policy. *Carnegie-Rochester Conference Series on Public Policy* 34, 7-30.

Goodfriend, Marvin and Bennett T. McCallum (2007), Banking and Interest Rates in Monetary Policy Analysis: A Quantitative Exploration, *Journal of Monetary Economics* 54 (5), 1480-1507.

Hansen, Lars Peter and Thomas J. Sargent (2008), *Robustness*, Princeton University Press, Princeton, NJ.

Kilponen, Juha and Kai Leitemo (2008), Model Uncertainty and Delegation: A Case for Friedman's *k*-Percent Money Growth Rule?, *Journal of Money, Credit and Banking* 40 (2-3), 547-556.

Kuester, Keith and Volker Wieland (2010), Insurance Policies for Monetary Policy in the Euro Area, *Journal of the European Economic Association* 8 (4), 872-912.

Leitemo, Kai and Ulf Söderström (2008), Robust Monetary Policy in a Small Open Economy, *Journal of Economic Dynamics and Control* 32 (10), 3218-3252.

Söderlind, Paul (1999), Solution and Estimation of RE Macromodels with Optimal Policy, *European Economic Review* 43 (4-6), 813-823.

Tillmann, Peter (2009), Robust Monetary Policy with Cost Channel, *Economica* 76, 486-504.

Tinsley, Peter A. (1999), Short Rate Expectations, Term Premiums, and Central Bank Use of Derivates to Reduce Policy Uncertainty, Finance and Economics Discussion Series 1999-14, Board of Governors of the Federal Reserve System, Washington, DC.

Walsh, Carl E. (2010a), *Monetary Theory and Policy,* third edition, MIT Press, Cambridge, MA.

Walsh, Carl E. (2010b), Implementing Monetary Policy, prepared for the Bank of Korea International Conference, May 31-June 1.

Williams, John C. (2009), Heeding Daedalus: Optimal Inflation and the Zero Lower Bound. Brookings Papers on Economic Activity 40 (2), 1-49.

Woodford, Michael (2003), *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton University Press, Princeton, NJ.