EUROPEAN CENTRAL BANK

WORKING PAPER SERIES

WORKING PAPER NO. 250

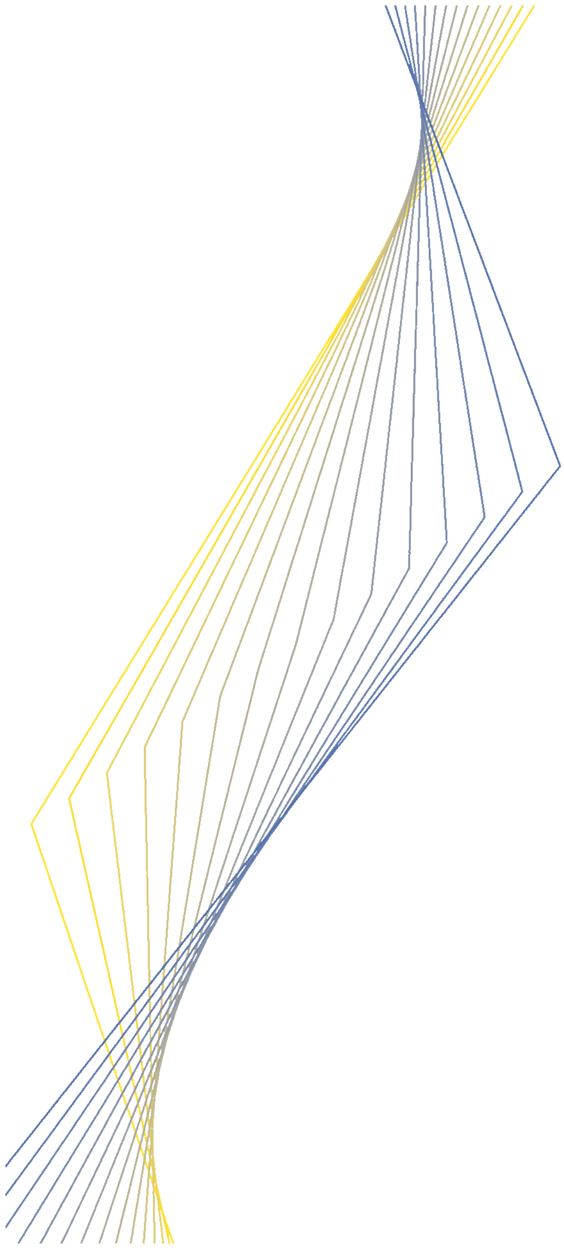
PERSISTENCE, THE TRANSMISSION MECHANISM AND ROBUST MONETARY POLICY

BY IGNAZIO ANGELONI, GÜNTER COENEN AND FRANK SMETS

August 2003

EUROPEAN CENTRAL BANK

WORKING PAPER SERIES



WORKING PAPER NO. 250

PERSISTENCE, THE TRANSMISSION MECHANISM AND ROBUST MONETARY POLICY[1]

BY IGNAZIO ANGELONI[2], GÜNTER COENEN[2] AND FRANK SMETS[2]

August 2003

1 *This paper was prepared for the conference on "Policy Rules: The next steps" organised by J. Chadha and S. Holly at Cambridge University on 19-20 September 2002. We thank Patrick Minford for his insightful discussion. We also appreciate the excellent research assistance of Keith Kuester. The opinions expressed herein are those of the author(s) and do not necessarily represent those of the European Central Bank. This paper can be downloaded without charge from http://www.ecb. int or from the Social Science Research Network electronic library at: http://ssrn.com/abstract_id=457322.*

2 *European Central Bank. Ignazio Angeloni: Ignazio.Angeloni@ecb.int; Günter Coenen: Gunter.Coenen@ecb.int; Frank Smets: Frank.Smets@ecb.int*

Address	**Kaiserstrasse 29**
	D-60311 Frankfurt am Main
	Germany
Postal address	**Postfach 16 03 19**
	D-60066 Frankfurt am Main
	Germany
Telephone	**+49 69 1344 0**
Internet	**http://www.ecb.int**
Fax	**+49 69 1344 6000**
Telex	**411 144 ecb d**

ISSN 1561-0810 (print)
ISSN 1725-2806 (online)

Contents

Abstract

In this paper we first explore the impact of nominal and real persistence on the transmission process of various shocks in an estimated DSGE model of euro area. We then analyse its impact on optimal monetary policy and investigate the performance of various monetary policies when the policy maker is uncertain about the degree of nominal and real persistence.

Key words: persistence; transmission process; monetary policy; euro area

JEL-classification: E4-E5

Non-technical summary

In this paper we analyse the implications of structural inflation and output persistence for the propagation of structural shocks and for optimal monetary policy using the Smets-Wouters (2003) DSGE model of the euro area. The estimated model incorporates various structural persistence mechanisms such as Calvo-type price and wage setting augmented by the assumption that those prices and wages that cannot be freely set are partially linked to past prices, habit formation in consumption and adjustment costs in investment. In order to illustrate the differences between nominal and real persistence, we concentrate on the implications of inflation persistence due to the augmented price setting model and of output persistence due to adjustment costs in investment.

Our analysis proceeds in three steps. We first analyse the implications of nominal and real persistence for the monetary policy transmission mechanism and the propagation of various structural shocks. We then use a standard welfare criterion in inflation, the output gap and changes in the short-term nominal interest rate to analyse the effects of structural persistence on optimal monetary policy. To this end we look at the efficiency frontiers and the optimal monetary policy responses to the various shocks under both optimised simple rules and fully optimal policies under commitment. Finally, given the uncertainty regarding both the conceptual underpinnings and the empirical importance of structural persistence in inflation and output, we examine the robustness of optimal monetary policy in the presence of uncertainty about the model's relevant persistence parameters, looking again at both optimised simple rules and optimal policies under commitment.

The findings of our analysis can be summarised as follows. First, we find that uncertainty about the degree of output persistence presents much smaller problems for monetary policy-makers than uncertainty about the degree of inflation persistence. In particular, we find that optimised simple rules appear to be relatively robust to different degrees of output persistence. By contrast, when there is uncertainty about the degree of inflation persistence, it is better for monetary policy-makers to work on the assumption that the economy is characterised by a relatively high degree of inflation persistence. The reason is that the cost of assuming a higher degree of inflation persistence than the one prevailing in reality is not as high as the cost of making the opposite mistake. Second, while a similar tendency is found for optimised simple rules and optimal commitment policies, we find that the latter are generally more robust than the former, confirming Svensson's (2002) conjecture that targeting rules, i.e. the first-order conditions characterising the optimal commitment policies, are more robust.

1. Introduction

As highlighted by Fuhrer and Moore (1995), Fuhrer (2000) and Chari, Kehoe and McGrattan (2001) amongst others, the popular micro-founded New Keynesian DSGE model with nominal price and wage staggering is not able to match the persistence and cross-correlations of the main macroeconomic time series (and in particular output and inflation) very well. In order to improve the empirical fit, a number of additional features that introduce structural persistence in the basic building blocks (price and wage setting and consumption and investment decisions) of those models have been introduced.[1] These features typically result in the introduction of lagged endogenous variables in the various Euler equations. However, the importance of those backward-looking components has been subject to a heated debate both on its theoretical foundations and on its empirical importance. From a theoretical point of view, it is not always clear what the "micro-foundations" are of the structural persistence in inflation, wage, consumption and investment equations. While references are often made to generalised adjustment costs, the micro-economic evidence of the exact form of these adjustment costs is scant. Alternative explanations refer to rule-of-thumb behaviour, formal or informal indexation and habit formation. However, also here the evidence is not always clear cut.[2] From an empirical perspective there is a debate about the importance of forward-looking behaviour in inflation, wages, consumption and investment. For example, while some authors claim that the inflation process is dominated by backward-looking components (e.g. Fuhrer, 1997), others have found that inflation follows a primarily forward-looking process (e.g. Galí and Gertler, 1999). A review of some of the evidence for the United States can be found in Rudebusch (2002). Similarly, while Cogley and Sargent (2001) have argued that there has been a downward shift in the degree of persistence in the inflation process in the US suggesting that inflation persistence is not necessarily structural, others (see Stock, 2001) have countered that the statistical evidence in favour of such a break is weak.[3]

The degree of structural persistence in the process for inflation and output has potentially important implications for optimal monetary policy. A number of authors have examined the robustness of policy with respect to the degree of inflation persistence. However, also here there does not seem to be a consensus regarding the implications. For example, Amato and Laubach (2002) conclude that the optimal policy rule under commitment in the benchmark forward-looking model performs also quite well in more backward-looking models. This finding is corroborated by Giannoni and Woodford (2002a,b), who show that introducing inflation persistence in the standard New Keynesian model introduces forward-looking elements in the optimal policy rule. However, the weights on these forward-looking elements are quite small. In contrast, Coenen (2002), who focuses on simple instrument rules, finds that it is better for the

---

[1] See, for example, Galí and Gertler (1999), Christiano et al. (2001), Amato and Laubach (2002) and Smets and Wouters (2003).

[2] For example, Amato and Laubach (2002) refer to micro-economic studies of consumption behaviour to argue in favour of rule-of-thumb behaviour in consumption rather than habit formation.

[3] See also the cross-country evidence presented in Benati (2002) and Levin and Piger (2002).

monetary policy maker to assume that the economy is characterised by a relatively high degree of persistence because the costs of making a mistake when the economy in reality is less persistent are not as high as making the reverse mistake.[4]

In this paper, we revisit this issue using the DSGE model estimated for the euro area in Smets and Wouters (2003) looking not only at nominal persistence, but also at real persistence. The model used incorporates various structural persistence mechanisms such as price and wage indexation, habit formation in consumption and adjustment costs in investment. In order to illustrate the differences between nominal and real persistence we concentrate on the implications of inflation persistence due to price indexation on the one hand, and of output persistence due to adjustment costs in investment on the other hand. The main features of the Smets-Wouters model are described in Section 2. We then proceed in three steps. In Section 3, we first analyse the effects of different degrees of persistence on the dynamics of the economy. We investigate the implications of structural nominal and real persistence for the monetary policy transmission mechanism and the transmission of various structural shocks. Next, in Section 4 we use a standard welfare criterion in inflation, the output gap and changes in interest rates, to analyse the effects of structural persistence on optimal monetary policy. This is done by looking at the efficiency frontiers and the optimal response of policy under commitment to the various shocks. Finally, in Section 5 we examine the robustness of policy in the presence of uncertainty about the degree of structural persistence, looking again at both simple policy rules and optimal policy under commitment.

2. The Smets-Wouters euro area (SWEAR) model

In this section we briefly describe the estimated model for the euro area that we will use in the subsequent analysis.[5] The model is an extended version of the standard New-Keynesian DSGE closed-economy model with sticky prices and wages as, for example, analysed in Erceg et al. (2001). Households maximise a utility function with two arguments (goods and leisure) over an infinite life horizon. Consumption appears in the utility function relative to a time-varying external habit variable.[6] Labour is differentiated over households, so that there is some monopoly power over wages which results in an explicit wage equation and allows for the introduction of sticky nominal wages à la Calvo (see Calvo, 1983). Households also rent capital services to firms and decide how much capital to accumulate given certain capital adjustment costs. As the rental price of capital goes up, the capital stock can be used more intensively according to some cost schedule. Firms produce differentiated goods, decide on labour and capital inputs, and set prices, again according to the Calvo model. The Calvo model in both wage and price setting is augmented by the assumption that those prices and wages that can not be freely set are partially indexed to past prices. Prices are therefore set as a function of current and expected marginal

4 Coenen (2002) also analyses the cost of using inflation forecasts based on models with the wrong degree of inflation persistence.

5 A more complete derivation and description can be found in Smets and Wouters (2003).

6 Habit depends on lagged aggregate consumption which is unaffected by any one agent's decisions. Abel (1990) calls this the "catching up with the Joneses" effect.

costs, but are also determined by the past inflation rate. The marginal costs depend on wages and the rental rate of capital. In what follows, we briefly describe the linearised version of the model, emphasising the various persistence parameters that are of interest.[7] Variables dated *t+1* correspond to the expectation of that variable at time *t+1* given information available at time *t*.

The *consumption equation* with external habit formation is given by:

$$(1) \qquad C_t = \frac{h_c}{1+h_c} C_{t-1} + \frac{1}{1+h_c} C_{t+1} - \frac{1-h_c}{(1+h_c)\sigma_c}(R_t - \pi_{t+1}) + \frac{1-h_c}{(1+h_c)\sigma_c}(\varepsilon_t^b - \varepsilon_{t+1}^b)$$

where C_t is consumption, R_t is the nominal short-term interest rate, π_t is inflation and ε_t^b is a temporary, but persistent shock to the consumer's discount rate. σ_c is the inverse of the intertemporal degree of substitution. The parameter h_c captures the degree of external habit formation in consumption and lies between zero and one. When $h_c = 0$, equation (1) reduces to the traditional forward-looking consumption equation. With external habit formation, consumption depends on a weighted average of past and expected future consumption.

The *investment equation* is given by:

$$(2) \qquad I_t = \frac{h_I}{1+\beta h_I} I_{t-1} + \frac{\beta}{1+\beta h_I} I_{t+1} + \frac{\varphi}{1+\beta h_I} Q_t + \frac{\beta \varepsilon_{t+1}^I - \varepsilon_t^I}{1+\beta h_I}$$

where I_t is investment, Q_t is the value of capital and φ is the inverse elasticity of the cost function of changing investment. A negative shock to the adjustment cost function, ε_t^I, (also denoted as a positive investment shock) temporarily increases investment. As discussed in Christiano et al. (2001), modelling the capital adjustment costs as a function of the change in investment rather than its level introduces additional dynamics in the investment equation, which is useful in capturing the hump-shaped response of investment to various shocks including monetary policy shocks. In equation (2), we have generalised this adjustment cost function. If h_I is zero, then the adjustment costs only depend on current investment and the investment process becomes completely forward-looking. If in contrast h_I is one, then the investment process becomes partly backward-looking with a weight on past investment of about one half. β is the households' discount rate.

The corresponding *Q equation* is given by:

$$(3) \qquad Q_t = -(R_t - \pi_{t+1}) + \frac{1-\tau}{1-\tau+\bar{r}^k} Q_{t+1} + \frac{\bar{r}^k}{1-\tau+\bar{r}^k} r_{t+1}^k + \eta_t^Q$$

where $\beta = 1/(1-\tau+\bar{r}^k)$, τ is the rate of depreciation and $\bar{r}^k$ is the steady-state rental rate on capital. The current value of the capital stock depends negatively on the ex-ante real interest rate, and positively on its expected future value and the expected rental rate. The introduction of a shock to the required rate

[7] Table A of the Appendix reports the estimated values of the parameters of the model. See Smets and Wouters (2003).

of return on equity investment, η_t^Q, is meant as a shortcut to capture changes in the cost of capital that may be due to stochastic variations in the external finance premium.[8]

The *capital accumulation equation* is standard:

(4) $$K_t = (1-\tau)K_{t-1} + \tau I_{t-1}$$

With partial indexation, the *inflation equation* becomes a more general specification of the standard New-Keynesian Phillips curve:

(5) $$\pi_t = \frac{\beta}{1+\beta\gamma_p}\pi_{t+1} + \frac{\gamma_p}{1+\beta\gamma_p}\pi_{t-1} + \frac{1}{1+\beta\gamma_p}\frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p}\left[\alpha r_t^k + (1-\alpha)w_t - \varepsilon_t^a + \eta_t^p\right]$$

Inflation depends on past and expected future inflation and the current marginal cost, which itself is a function of the rental rate on capital (r_t^k), the real wage (w_t) and the productivity parameter (ε_t^a). When the degree of inflation persistence is zero ($\gamma_p = 0$), this equation reverts to the standard purely forward-looking Phillips curve. In other words, the parameter γ_p determines how backward looking the inflation process is. The elasticity of inflation with respect to changes in the marginal cost depends mainly on the degree of price stickiness. When all prices are flexible ($\xi_p = 0$) and the price-mark-up shock, η_t^p, is zero, this equation reduces to the normal condition that in a flexible price economy the real marginal cost should equal one.

Similarly, partial indexation of nominal wages to price inflation results in the following linearised real wage equation:

(6) $$\begin{aligned} w_t = {} & \frac{\beta}{1+\beta}w_{t+1} + \frac{1}{1+\beta}w_{t-1} + \frac{\beta}{1+\beta}\pi_{t+1} - \frac{1+\beta\gamma_w}{1+\beta}\pi_t + \frac{\gamma_w}{1+\beta}\pi_{t-1} \\ & - \frac{1}{1+\beta}\frac{(1-\beta\xi_w)(1-\xi_w)}{\left(1+\frac{(1+\lambda_w)\sigma_L}{\lambda_w}\right)\xi_w}\left[w_t - \sigma_L L_t - \frac{\sigma_c}{1-h_c}(C_t - h_c C_{t-1}) - \varepsilon_t^L - \eta_t^w\right] \end{aligned}$$

where L_t is labour. The real wage, w_t, is a function of expected and past real wages and the expected, current and past inflation rate where the relative weight depends on the degree of indexation of the non-optimised wages. When $\gamma_w = 0$, real wages do not depend on the lagged inflation rate. There is a negative effect of the deviation of the actual real wage from the wage that would prevail in a flexible labour market. The size of this effect will be greater, the smaller the degree of wage rigidity (ξ_w), the lower the demand elasticity for labour (λ_w) and the lower the inverse elasticity of labour supply (σ_L) (the flatter the labour supply curve). ε_t^L is a persistent labour supply shock, while η_t^w is a temporary wage mark-up shock.

[8] This is the only shock that is not directly related to the structure of the economy. For alternative interpretations of this equity premium shock and an analysis of optimal monetary policy in the presence of such shocks, see Dupor (2001).

The equalisation of marginal cost implies that, for a given installed capital stock, *labour demand* depends negatively on the real wage (with a unit elasticity) and positively on the rental rate of capital:

(7) $$L_t = -w_t + (1+\psi) r_t^k + K_{t-1}$$

where K_{t-1} is last period's capital stock and ψ is the inverse of the elasticity of the capital utilisation cost function.

The *goods market equilibrium condition* can be written as:

(8) $$Y_t = (1 - \tau k_y - g_y) C_t + \tau k_y I_t + g_y \varepsilon_t^G = \phi \varepsilon_t^a + \phi \alpha K_{t-1} + \phi \alpha \psi r_t^k + \phi(1-\alpha) L_t ,$$

where k_y is the steady state capital-output ratio, g_y the steady-state government spending-output ratio and ϕ is one plus the share of the fixed cost in production. ε_t^G captures a government spending shock.

Finally, the model is closed by adding the following empirical monetary policy reaction function:

(9) $$\begin{aligned} R_t &= \rho R_{t-1} + (1-\rho)\{\overline{\pi}_t + r_\pi(\pi_{t-1} - \overline{\pi}_t) + r_Y(Y_t - Y_t^p)\} + \\ &\quad r_{\Delta\pi}(\pi_t - \pi_{t-1}) + r_{\Delta y}(Y_t - Y_t^p - (Y_{t-1} - Y_{t-1}^p)) + \eta_t^R \end{aligned}$$

The monetary policy-makers gradually respond to deviations of lagged inflation from a time-varying inflation objective ($\overline{\pi}_t$) and to the output gap, defined as the difference between actual and potential output (Y_t^p). Consistent with the DSGE model, potential output is defined as the level of output that would prevail under flexible prices and wages in the absence of the three "cost-push" shocks: η_t^Q, η_t^p and η_t^w. The parameter ρ captures the degree of interest rate smoothing. In addition, there is also a short-run feedback from the current change in inflation and the output gap. Finally, in addition to the persistent time-varying inflation objective, we also assume that there is a temporary interest rate shock (η_t^R), which will also be denoted as a monetary policy shock.

Equations (1) to (9) determine the nine endogenous variables: π_t, w_t, K_{t-1}, Q_t, I_t, C_t, R_t, r_t^k, L_t of our model. The stochastic behaviour of the system of linear rational expectations equations is driven by ten exogenous shock variables: five shocks arising from technology and preferences (ε_t^a, ε_t^I, ε_t^b, ε_t^L, ε_t^G), three "cost-push" shocks (η_t^w, η_t^p and η_t^Q) and two monetary policy shocks ($\overline{\pi}_t$ and η_t^R).[9] The first set of shock variables is assumed to follow independent first-order autoregressive processes, whereas the second set is assumed to be IID independent processes. The estimated autoregressive parameters and standard deviations of these shocks are reported in Table A of the Appendix.

The two parameters that are of particular interest in this paper are γ_p and h_I, capturing the structural persistence in the inflation and in the investment process respectively. Table A of the Appendix reveals that the price indexation parameter is estimated to be around 0.46, implying that the weight on lagged

[9] In addition, we will also use a flexible price and wage version of the DSGE model in order to define a model-consistent output gap. In what follows, the output gap is defined as the difference between the actual level of output under sticky prices and wages and the level of output that would prevail under flexible prices and wages in the absence of distortionary equity-premium, price and wage mark-up shocks.

inflation in the inflation equation is only 0.28. This is quite consistent with the results in Galí, Gertler and Lopez-Salido (2001). Following Smets and Wouters (2003), the parameter that captures the structural persistence in investment is fixed at one, implying a coefficient on lagged investment in equation (2) of about 0.5.

3. Nominal and real persistence and the propagation of shocks

In this section we analyse the implications of changes in inflation and investment persistence for the propagation of various shocks in the estimated euro area model discussed above. Charts 1 and 2 illustrate how the economy responds to a monetary policy shock under various degrees of nominal and real persistence when the monetary authorities follow the estimated policy rule. In each case, the persistence parameter takes three values: a low value of 0.1, a medium value of 0.5 and a high value of 0.9.

A number of observations are worth making. As expected, higher inflation persistence amplifies and prolongs the output and inflation effects of a monetary policy shock. It clearly delays the peak effect of a policy shock on inflation, thereby producing a more pronounced hump-shaped response in inflation. It also implies a larger peak effect of the policy shock on inflation (Chart 1). The effects of higher inflation persistence on the response of the output gap are smaller: while the size of the peak effect on output increases somewhat, the timing of the peak effect does not change very much.[10] Higher inflation persistence also implies a much more persistent real interest rate response.

In contrast, the effects of higher output persistence (as captured by a higher degree of investment persistence) on the response of the output gap and inflation are much less pronounced (Chart 2). Higher investment persistence delays the peak effect of a policy shock on output, but it does not appear to affect the peak effect on inflation. Those peak effects increase somewhat (in absolute value) as the persistence in investment increases, but the size of those effects is much smaller than in the case of higher inflation persistence.

These results are confirmed in Table 1, which reports the maximum size (and its timing in quarters following the shock) of the effect of the various other shocks on inflation and the output gap. Higher inflation persistence increases and delays the maximum response of inflation to the various shocks. As a result, the output gap generally also responds more, but the timing of its peak is not much affected. Consistent with the results for a monetary policy shock, higher output persistence generally delays the maximum response of the output gap to the various shocks, but has little effect on the timing of the peak response in inflation which is governed by the degree of inflation persistence. There is no clear effect on the size of output gap and inflation responses. The relatively limited size effects of higher investment persistence may be due to the fact that the share of investment in total output is relatively small and consumption is not very much affected by shifts in the response of investment.

---

[10] While the shift in the peak effect is common across different ways of introducing inflation persistence (e.g. rule-of-thumb behaviour), the increase in the size of the peak effect is not. For example, Amato and Laubach (2002) show that increased rule of thumb behaviour in their set-up reduces the sensitivity of inflation to marginal cost and therefore tends to reduce the size of the inflation effects.

4. Structural persistence and optimal monetary policy

In order to analyse the effects of structural persistence on optimal monetary policy, we use the following standard quadratic loss function in deviations of inflation from a zero inflation target, the output gap and changes in the nominal interest rate:

(10) $$\ell_t = \lambda_1 \pi_t^2 + (1-\lambda_1)(Y_t - Y_t^p)^2 + \lambda_2 (R_t - R_{t-1})^2$$

While this loss function does not necessarily fully capture the welfare of the representative consumer in the estimated DSGE model, it is likely to be a close approximation for two reasons. First, the output gap concept used in the loss function is consistent with the underlying structure of the model. Potential output is defined as the output level that would prevail under flexible prices and wages in the absence of the distortionary equity premium and price and wage mark-up shocks. As shown by Woodford (2001), in a simple version of the estimated model, optimal policy can be characterised as closing the output gap defined as such. Second, nominal price staggering creates costs of inflation, which can be captured by the term in inflation. While it is true that this term may be modified when there is price and wage indexation and when also nominal wages are rigid, the dominant weight will still be on inflation variability in both cases.[11] Finally, the term in interest rate changes is mainly introduced to avoid extreme and counterfactual interest rate volatility under the optimal policies. Various arguments such as a desire to avoid hitting the lower zero bound or financial stability considerations could be used to justify a concern for interest rate volatility. As a benchmark we will assume equal weights on output gap and inflation variability ($\lambda_1 = 0.5$) and a relatively small weight ($\lambda_2 = 0.1$) on changes in interest rates.[12]

Charts 3 and 4 show how the efficiency frontier shifts when the inflation and investment persistence parameters shift from a low to a high value. In each case we calculate two efficiency frontiers. The first one is derived by optimising the loss function for various relative weights on inflation and the output gap under the assumption that the central bank follows a simple Taylor-type rule with interest rate smoothing. The second one is derived under the assumption that the central bank implements the fully optimal commitment rule that maximises loss function (10). Not surprisingly, the efficiency frontier under the fully optimal commitment rule lies closer to the origin than the one under a simple Taylor rule with interest rate smoothing. The loss associated with constraining the central bank to follow a simple policy rule is, however, generally not very large.

Focusing on how the efficiency frontiers shift as nominal and real persistence increases, two features are worth highlighting. First, not surprisingly given the results in Section 3, the efficiency frontiers shift out most in the case of increasing inflation persistence (Chart 3). The outward shift due to higher investment persistence is very limited (Chart 4). From a macro-economic stabilisation point of view, nominal

---

11 See Amato and Laubach (2002) and Giannoni and Woodford (2002b) for a fully model-consistent welfare analysis of monetary policy in a simple version of the New-Keynesian model with inflation persistence. Amato and Laubach (2002) find that the welfare loss from not modifying the loss function appropriately is quite small.

12 A model-based welfare criterion would also determine the weights on the various terms. Here we follow the general practice in the literature (see, for example, Taylor, 1999).

persistence therefore appears to be much more costly than real persistence. Second, the slope of the efficiency frontier becomes flatter with increasing inflation persistence, while it tends to become steeper with increasing output persistence. The policy implications of a change in the degree of persistence can be most easily seen by looking at the impact of higher persistence on the optimised coefficients in the Taylor rule with interest rate smoothing reported in Table 2. Higher inflation persistence increases the optimised reaction coefficient to inflation from a relatively small number of 0.07 to a more significant number of 0.47, while the coefficient on the output gap falls from 0.51 to 0.33. The intuition for this result is quite straightforward: as the inflation process becomes harder to control it becomes more important for the central bank to respond promptly to increases in inflation. In contrast, the opposite happens when the degree of output persistence increases: the reaction coefficient to inflation falls from 0.23 to 0.18, while the coefficient on the output gap increases from 0.40 to 0.47.

A common feature of all the optimised Taylor rules reported in Table 2 is the substantial degree of interest rate smoothing. In all cases, the coefficient on the lagged interest rate hovers around one, typically being somewhat larger than one. This is in line with Woodford's (2001) finding that optimal policies under commitment usually exhibit (super-) inertial behaviour. It also mirrors Amato and Laubach's (2002) finding that this feature is robust to different degrees of rule-of-thumb behaviour. The robustness of first-difference Taylor-type rules was also noted by Williams (1999), Levin et al. (1999, 2001), Orphanides and Williams (2002) and Coenen (2002), amongst others.

The fully optimal commitment rule is more difficult to interpret as it is a much more complicated function of the underlying state of the economy. In order to get a better sense of the difference between the various policy rules, Charts 5 to 8 plot the optimal nominal and real interest rate response to a selected set of shocks under the policy rule estimated in the Smets-Wouters model (equation (9)), the optimised Taylor rule and the fully optimal commitment rule. The most striking result is that, with the exception of the cost-push shock, the historically estimated interest rate response to the various supply and demand shocks is always much smaller than those under the optimal policies. As a result the output gap and inflation respond much stronger to the various shocks, explaining the overall higher volatility under the estimated rule compared to the optimal policies. The most striking example is given in Chart 6, which depicts the response to a preference shock. While the impact effect on the nominal interest rate is quite similar in all cases, the interest rate response is much more hump-shaped under the optimal policies. This helps in closing the output gap and stabilising inflation. A second common finding is that in general the interest rate response under the optimised Taylor rule is quite close to the response under the fully optimal commitment rule.

By way of example, Charts 9 to 12 compare the optimal policy response under commitment to a productivity shock and to a price mark-up shock under different degrees of inflation persistence (Charts 9 and 11) and investment persistence (Charts 10 and 12). Output persistence does not appear to give rise to large changes in the response of the economy to shocks. The outcome for inflation and the output gap are very similar under different degrees of investment persistence (Chart 10), although the required nominal and real interest rate response is somewhat stronger when the economy is characterised by greater investment persistence. Increased inflation persistence does lead to a more volatile and protracted response of inflation and in the case of the cost-push shock also the output gap. For example, Chart 11 illustrates that higher inflation persistence does lead to a higher output cost of stabilising inflation following a price mark-up shock.

5. Persistence and robust monetary policy

Finally, given the conceptual and empirical uncertainty regarding the structural persistence parameters highlighted in the introduction, in this section we examine robust monetary policy in the face of such uncertainty. Tables 3 and 4 report the main results for the optimised simple rules and the optimal policies under commitment respectively. For both inflation and investment persistence, those tables report the maximum and the mean (absolute and relative) regret or opportunity loss (i.e. the absolute and relative difference in loss compared to the optimal policy[13]) that the central bank would experience if it were to implement optimal policy under the assumption of a given degree of persistence. For each degree of persistence that the policy maker assumes when formulating its policy, the maximum and the mean are calculated over all possible values of the *true* degree of persistence. A robust policy is then the policy that minimises the maximum or mean regret.

There are a number of interesting findings. First, the results confirm the analysis of Coenen (2002) that the policy rules obtained under the assumption of high inflation persistence (and which respond more aggressively to inflation) are more robust than those obtained under low inflation persistence. The cost of assuming that inflation can be controlled quite easily through the expectation channel when in fact inflation is significantly backward looking is quite high. An analysis of the various components of the loss function shows indeed that the main cost is in terms of a higher variance of inflation. This is true both for the simple policy rules and the optimal commitment policies. In contrast to Coenen (2002) who compares two models (featuring Taylor-type contracts (close to $\gamma_p = 0$) versus Fuhrer-Moore-type contracts (close to $\gamma_p = 1$)), our analysis also allows for the intermediate cases. We find that, if the policy maker wants to minimise the maximum regret, he or she should assume a degree of inflation persistence equal to 0.8. Under this policy, the maximum opportunity loss is quite small. It will only be 2.6 percent higher than under the optimal policy, which would assume a much more forward-looking inflation process. In this case, also the mean opportunity loss will only be 1.4 percent.[14] In contrast, implementing policies that assume a highly forward-looking Phillips curve may result in much higher relative losses (15.6 percent) when in reality inflation turns out to be significantly backward looking.

Second, uncertainty about investment persistence does not appear to be problematic from a robustness point of view. None of the rules gives rise to very large losses, which is not very surprising given the findings in Sections 3 and 4.

---

[13] That is, the one the central bank would implement if it knew the true degree of persistence.

[14] As shown in Table 3, the mean opportunity loss could be further reduced to 0.9 percent by assuming that the degree of inflation persistence is somewhat lower at 0.7. However, in this case, the maximum opportunity loss is somewhat higher (3.3 percent).

Finally, the robustness exercise regarding the optimal commitment policies (Table 4) shows that those policies are generally more robust than the simple Taylor-type policy rules, confirming Svensson's (2002) conjecture that targeting rules are more robust. The relative robustness of optimal commitment rules can potentially also explain why Amato and Laubach (2002) and Giannoni and Woodford (2002b) find that optimal policies derived in a simple forward-looking New-Keynesian model also work reasonably well in the more backward-looking versions of that model.

6. Conclusions

In this paper we have analysed the implications of structural inflation and output persistence for the transmission of shocks and for optimal monetary policy in an estimated DSGE model of the euro area. Given the uncertainty regarding both the conceptual underpinnings and the empirical importance of structural persistence in inflation and output, our ultimate focus was to analyse the robustness of various monetary policies in the face of this uncertainty. Our main findings in this regard are as follows. First, we find that uncertainty about the degree of output persistence presents much smaller problems for monetary policy-makers than uncertainty about the degree of inflation persistence. In particular, it is found that optimal monetary policies appear to be less sensitive to different degrees of output persistence. By contrast, when there is uncertainty about the degree of inflation persistence, we find that it is better for policy-makers to work under the assumption that the economy is characterised by a relatively high degree of inflation persistence because the costs of making a mistake when the inflation process in reality is less persistent are not as high as making the reverse mistake. This finding confirms the results in Coenen (2002). Second, while a similar tendency is found for optimised simple rules and optimal commitment policies, we find that the latter are generally more robust than the former. It would be interesting to analyse what feature of these policies makes them more robust. For this it would be necessary to characterise the optimal policy rules under commitment more explicitly, such as proposed by Giannoni and Woodford (2002a,b). We leave this for future research.

References

Abel A.D. (1990), "Asset Prices under Habit Formation and Catching Up with the Joneses", *American Economic Review*, 80, 38-42.

Amato, J. and T. Laubach (2002), "Rule-of-thumb behaviour and monetary policy", forthcoming in *European Economic Review*.

Benati, L. (2002), "Investigating inflation persistence across monetary regimes: Empirical evidence", mimeo.

Calvo, G. (1983), "Staggered prices in a utility maximising framework", *Journal of Monetary Economics*, 12, 383-398.

Chari, V.V., P. Kehoe and E. McGrattan (2000), "Sticky price models of the business cycle: Can the contract multiplier solve the persistence problem", *Econometrica*, 68, 1151-1180.

Christiano, L.J., Eichenbaum, M. and C. Evans (2001), "Nominal rigidities and the dynamic effects of a shock to monetary policy", Federal Reserve Bank of Cleveland, Working Paper No. 01/07.

Coenen, G. (2002), "Inflation persistence and robust monetary policy design", mimeo, European Central Bank.

Cogley, T. and T. Sargent (2001), "Evolving post-world war II inflation dynamics", NBER Macroeconomics Annual, 16.

Dupor, W. (2001), "Nominal price versus asset price stabilisation", mimeo, Wharton School, University of Pennsylvania.

Erceg, C.J., Henderson, D.W. and A.T. Levin (2000), "Optimal monetary policy with staggered wage and price contracts", *Journal of Monetary Economics*, 46, 281-313.

Fuhrer, J. (1997), "The (un)importance of forward-looking behavior in price specifications", *Journal of Money, Credit and Banking*, 29, 338-350.

Fuhrer J. (2000), "Optimal monetary policy in a model with habit formation", *American Economic Review*, 90, 367-390.

Fuhrer, J. and G. Moore (1995), "Inflation persistence", *Quarterly Journal of Economics*, 110, 127-160.

Galí, J. and M. Gertler, (1999), "Inflation dynamics: a structural econometric analysis", *Journal of Monetary Economics*, 44, 195-222.

Galí, J., Gertler, M. and D. Lopez-Salido (2001), "European inflation dynamics*", European Economic Review*, 45, 1121-1150

Giannoni, M. and M. Woodford (2002a), "Optimal interest rate rules: I. General theory", mimeo, Princeton University.

Giannoni, M. and M. Woodford (2002b), "Optimal interest rate rules: II. Applications", mimeo, Princeton University.

Levin, A. and J. Piger (2002), "Is inflation persistence intrinsic in industrial economies?", Working Paper 2002-23, Federal Reserve Bank of St. Louis, October.

Levin, A., V. Wieland and J.C. Williams (1999), "Robustness of simple policy rules under model uncertainty", in Taylor (1999).

Levin, A., V. Wieland and J.C. Williams (2001), "The performance of forecast-based monetary policy rules under model uncertainty", ECB Working Paper No. 68, European Central Bank, July.

Orphanides, A. and J.C. Williams (2002), "Robust monetary policy rules with unknown natural rates", Federal Reserve Bank of San Francisco Working Paper 03-01, December.

Rudebusch, G. (2002), "Assessing nominal income rules for monetary policy with model and data uncertainty", *Economic Journal*, 112, 402-432.

Smets, F. and R. Wouters (2003), "An estimated DSGE model for the euro area", forthcoming in *Journal of European Economic Association*.

Stock, J. (2001), Comment, NBER Macroeconomics Annual, 16.

Svensson, L. (2002), "What is wrong with Taylor rules? Using judgment in monetary policy through targeting rules", forthcoming in *Journal of Economic Literature*.",

Taylor, J.B. (ed.) (1999), *Monetary policy rules*, NBER and University of Chicago Press, Chicago.**Williams, J.C.** (1999), "Simple rules for monetary policy rules", Finance and Economics Discussion Series, Federal Reserve Board, 1999-12.

Woodford M. (2001), *Interest and prices*, manuscript, Princeton University.

Chart 1: The effects of a monetary policy shock under different degrees of inflation persistence

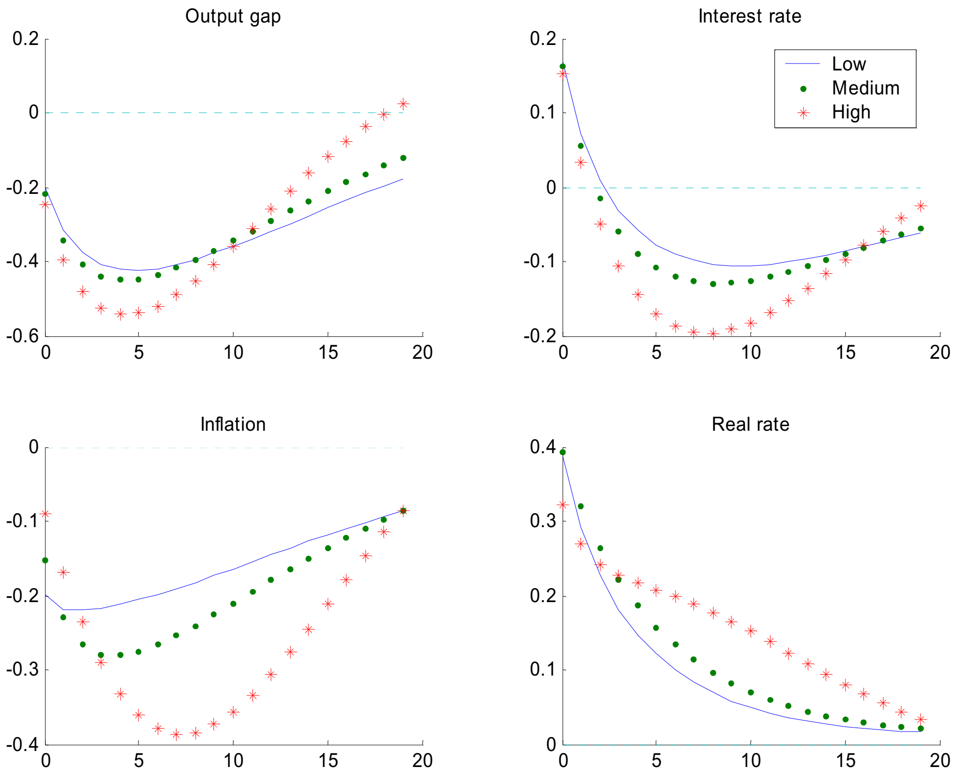


Chart 2: The effects of a monetary policy shock under different degrees of investment persistence

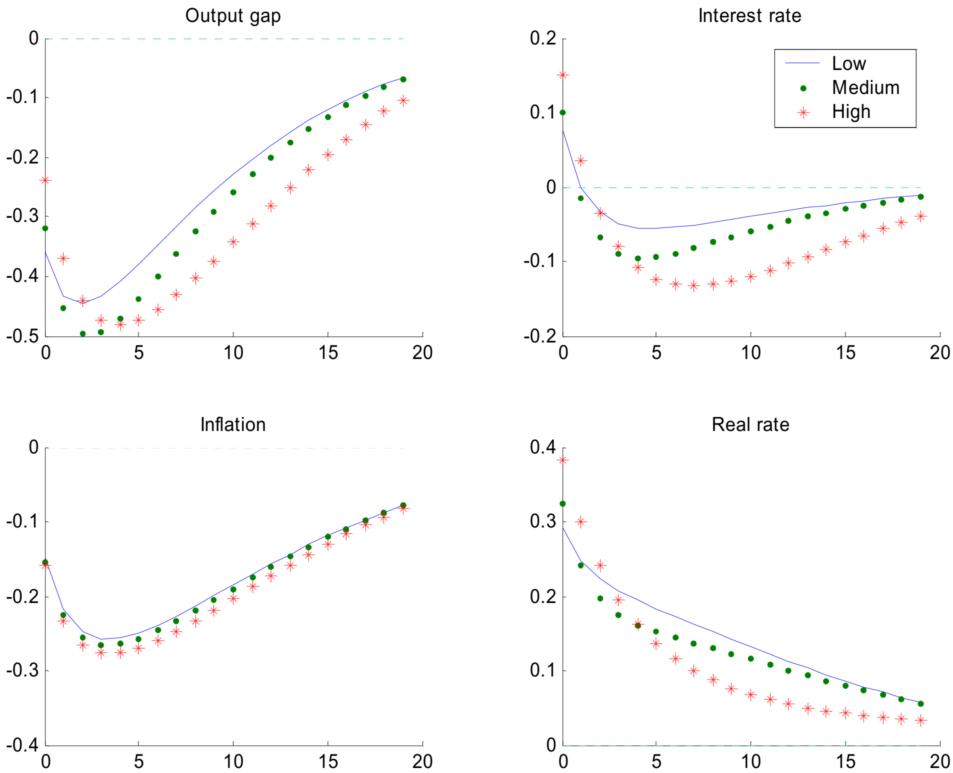


Chart 3: Efficiency frontiers under different degrees of inflation persistence

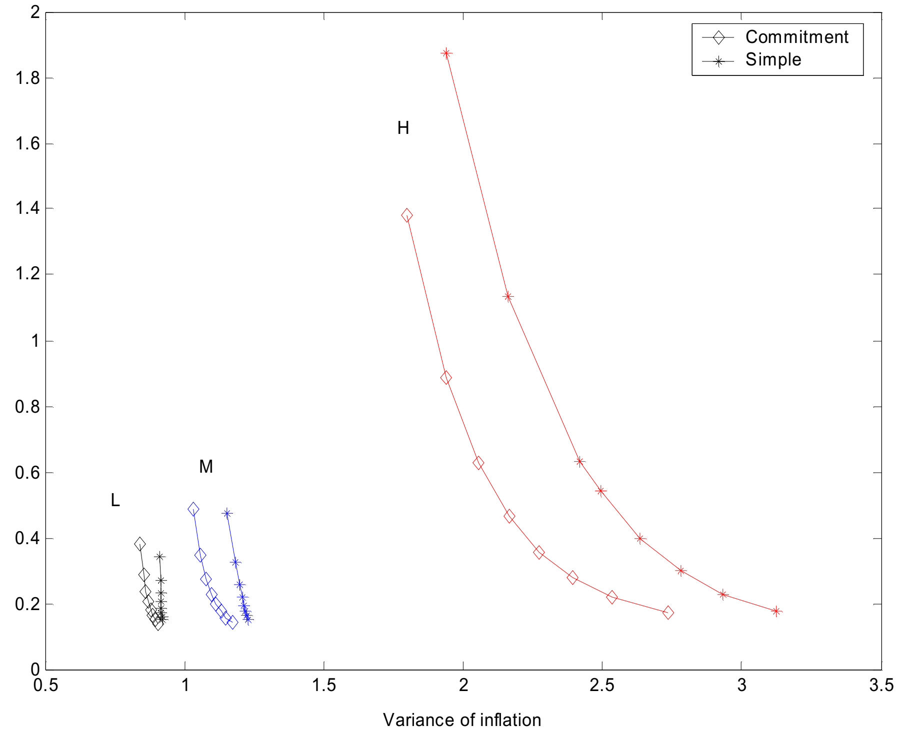
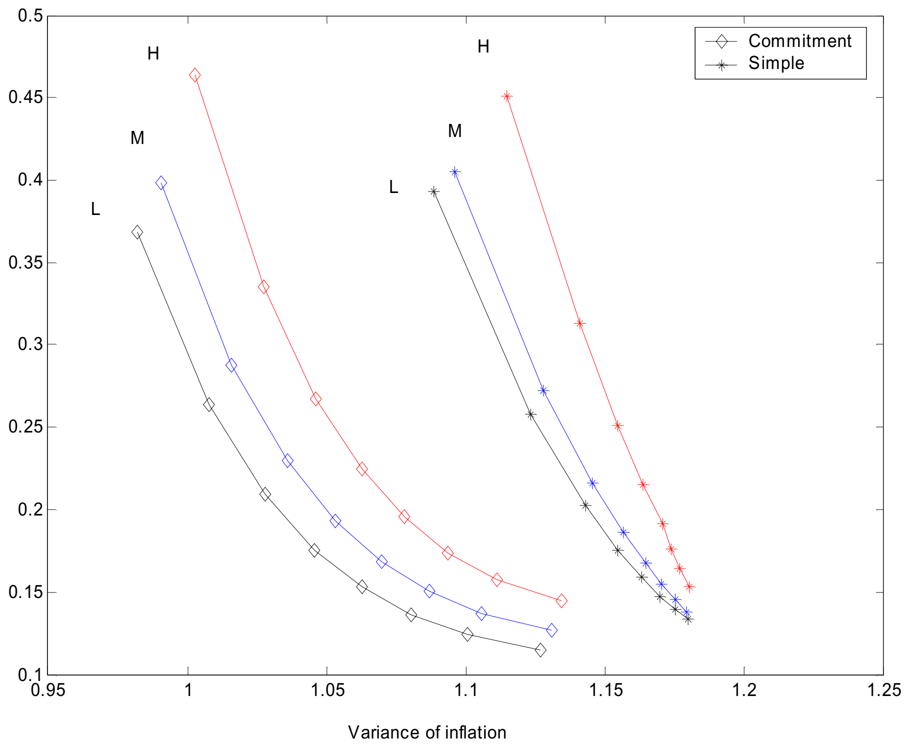


Chart 4: Efficiency frontiers under different degrees of investment persistence



Notes: H: high persistence; M: medium persistence; L: low persistence; x-axis: variability of inflation; y-axis: variability of output gap.

Chart 5: Estimated and optimal monetary policy responses to a productivity shock

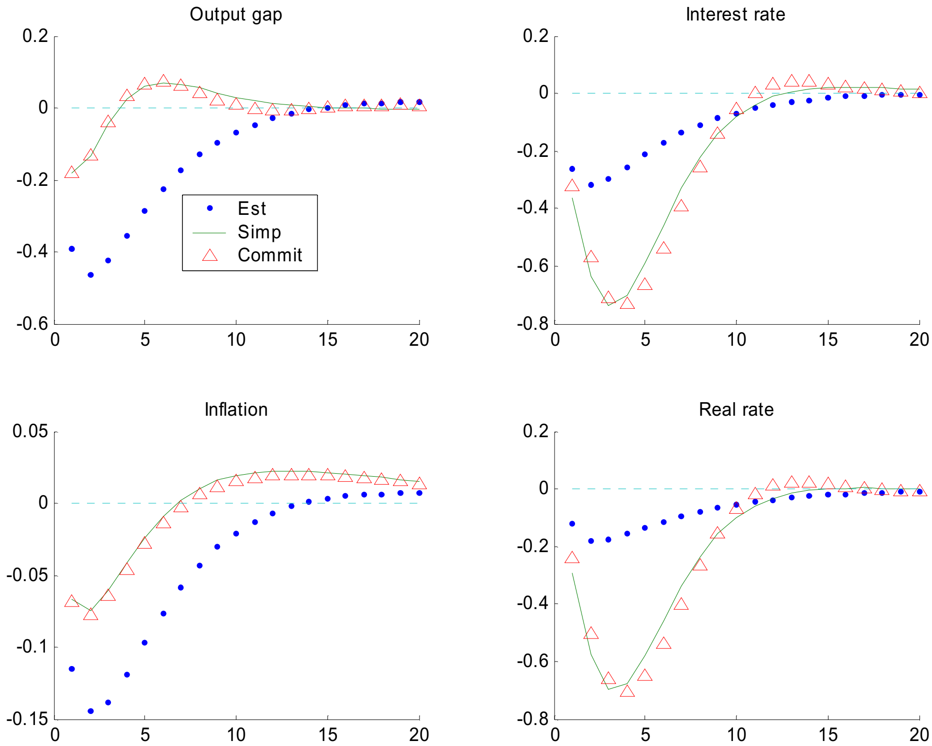


Chart 6: Estimated and optimal monetary policy responses to a preference shock

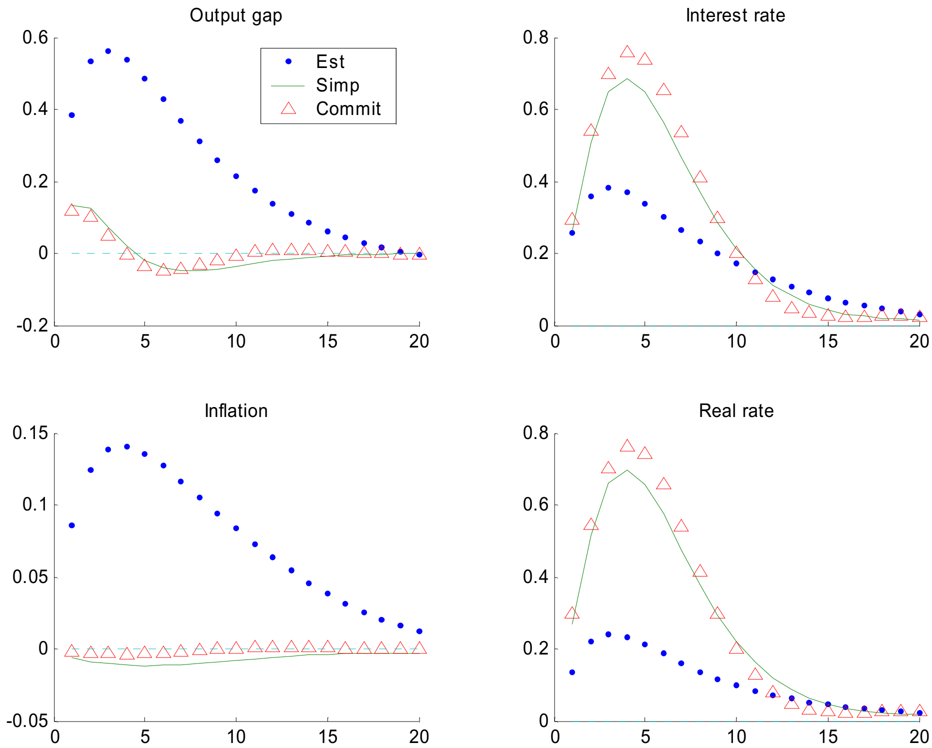


Chart 7: Estimated and optimal monetary policy responses to a price mark-up shock

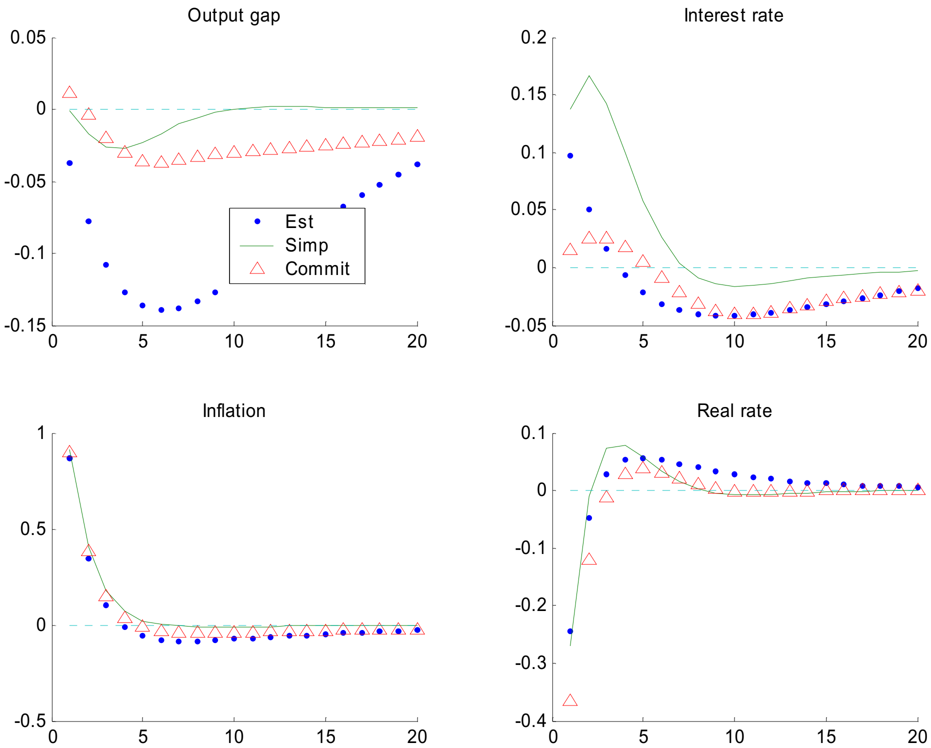


Chart 8: Estimated and optimal monetary policy responses to an equity premium shock

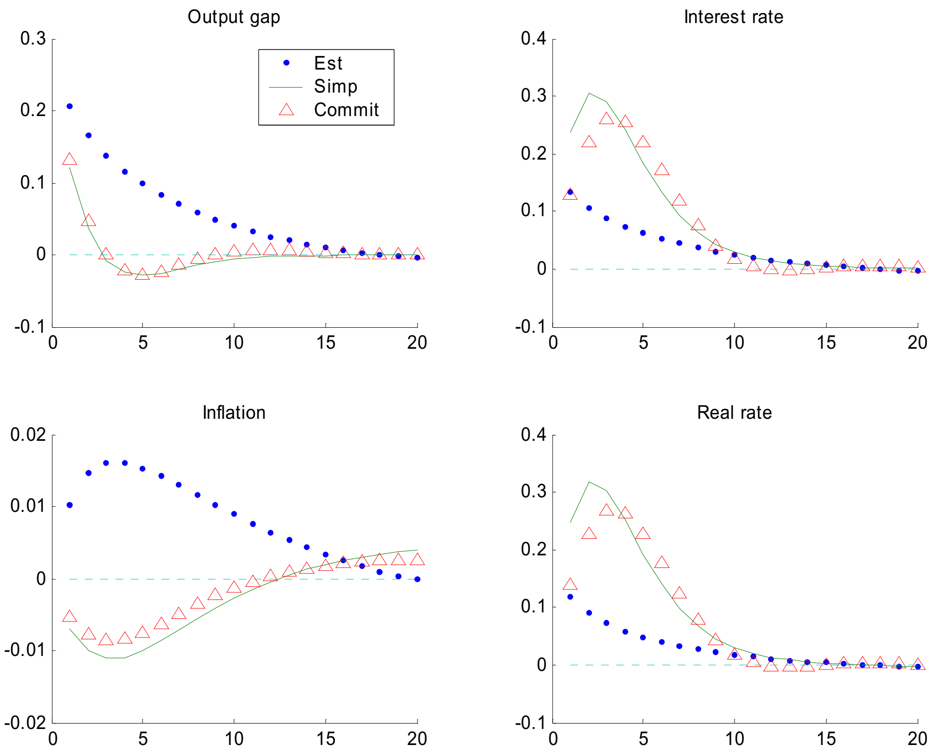


Chart 9: Optimal monetary policy responses to a productivity shock under different degrees of inflation persistence

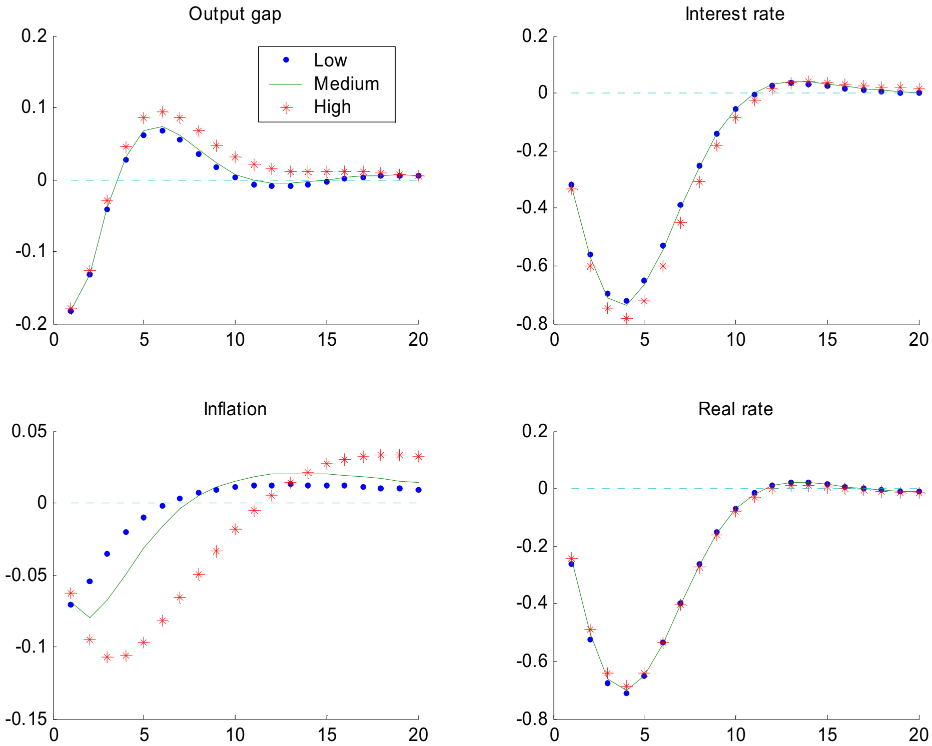


Chart 10: Optimal monetary policy responses to a productivity shock under different degrees of investment persistence

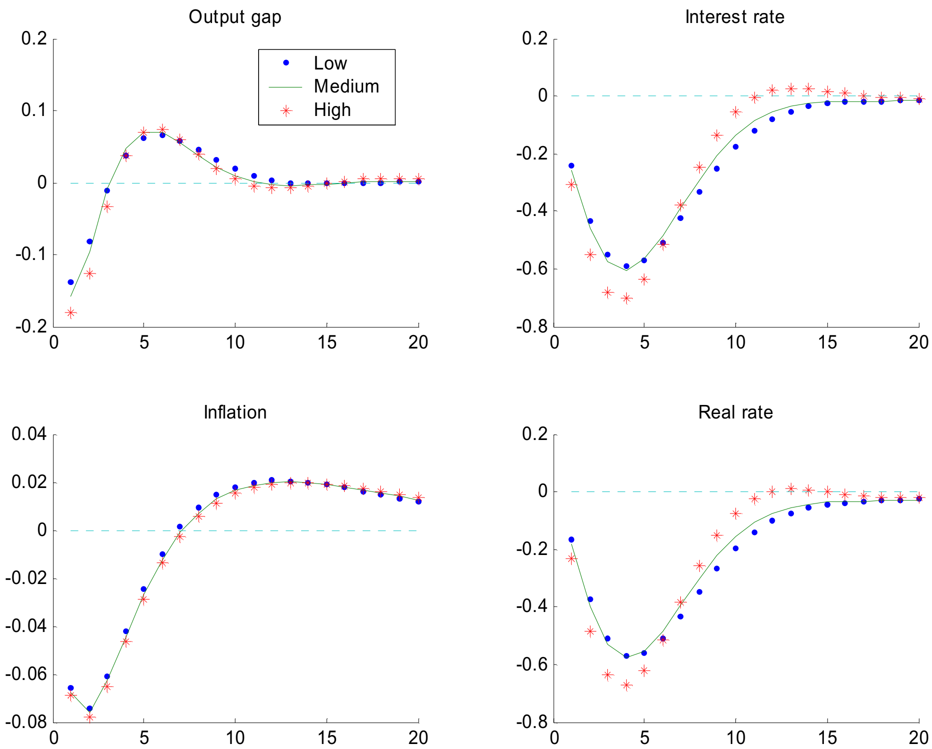


Chart 11: Optimal monetary policy responses under commitment to a price mark-up shock under different degrees of inflation persistence

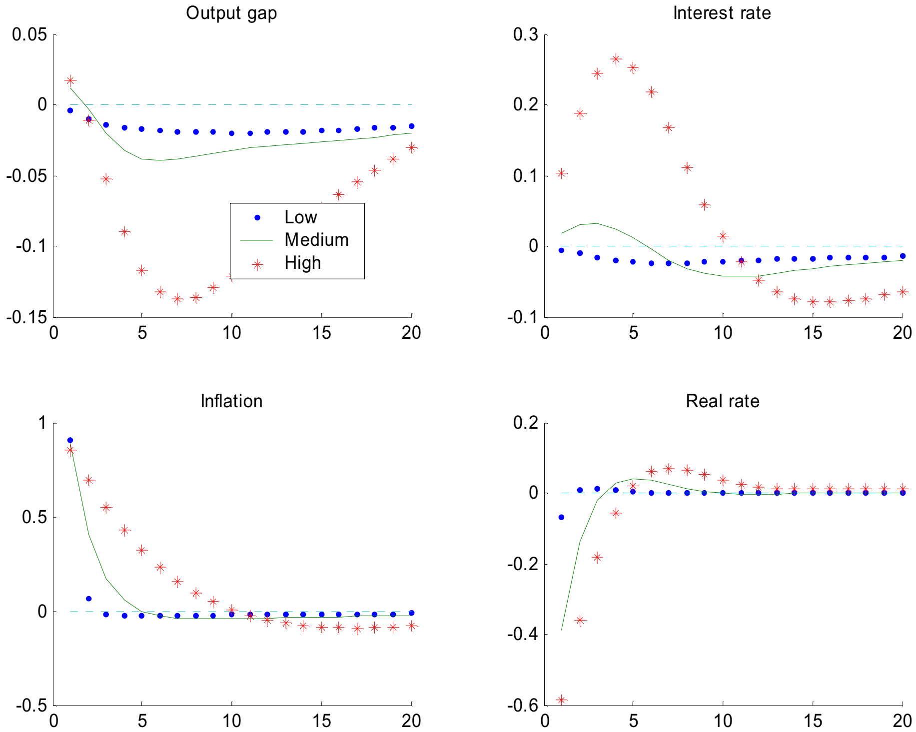
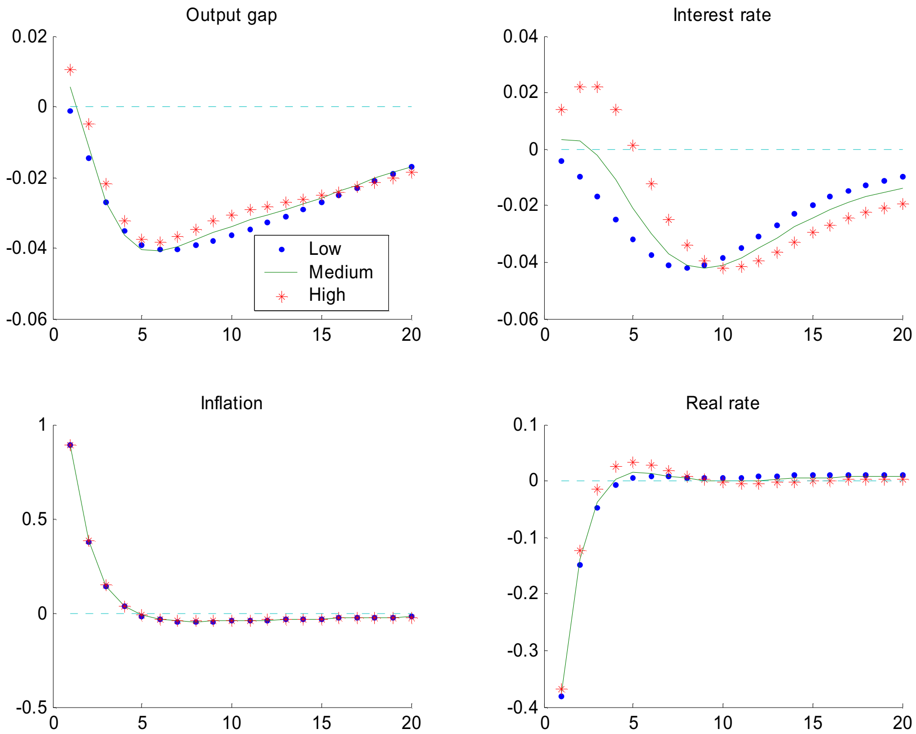


Chart 12: Optimal monetary policy responses under commitment to a price mark-up shock under different degrees of investment persistence



Appendix

Table A: Parameter estimates of the SWEAR model (Smets and Wouters, 2003).

	Prior distribution			Estimated maximum posterior		Posterior distribution MH			
	type	mean	st. error	mode	st.error (Hessian)	5%	median	95%	mean
σ productivity shock	inv gamma	0.4	2 *	0.598	0.113	0.469	0.624	0.874	0.639
σ inflation obj. shock	inv gamma	0.02	2 *	0.017	0.008	0.012	0.025	0.085	0.033
σ cons.pref. shock	inv gamma	0.2	2 *	0.336	0.096	0.237	0.392	0.631	0.407
σ gov.spending shock	inv gamma	0.3	2 *	0.325	0.026	0.292	0.333	0.385	0.335
σ labour supply shock	inv gamma	1.00	2 *	3.520	1.027	2.313	3.674	5.845	3.818
σ investment shock	inv gamma	0.10	2 *	0.085	0.030	0.060	0.105	0.196	0.113
σ interest rate shock	inv gamma	0.10	2 *	0.081	0.023	0.060	0.089	0.125	0.090
σ equity premium shock	inv gamma	0.40	2 *	0.604	0.063	0.514	0.608	0.727	0.613
σ price mark-up shock	inv gamma	0.15	2 *	0.160	0.016	0.140	0.164	0.197	0.165
σ wage mark-up shock	inv gamma	0.25	2 *	0.289	0.027	0.256	0.295	0.346	0.297
ρ productivity shock	beta	0.85	0.10	0.823	0.065	0.697	0.815	0.910	0.811
ρ inflation obj. shock	beta	0.85	0.10	0.924	0.088	0.658	0.865	0.970	0.855
ρ cons.pref. shock	beta	0.85	0.10	0.855	0.035	0.772	0.842	0.894	0.838
ρ gov. spending shock	beta	0.85	0.10	0.949	0.029	0.900	0.945	0.977	0.943
ρ labour supply shock	beta	0.85	0.10	0.889	0.052	0.773	0.891	0.952	0.881
ρ investment shock	beta	0.85	0.10	0.927	0.022	0.864	0.913	0.946	0.910
investment adj cost	Normal	4.00	1.5	6.771	1.026	5.148	6.920	8.898	6.962
σ consumption utility	Normal	1.00	0.375	1.353	0.282	0.959	1.371	1.902	1.391
h consumption habit	beta	0.70	0.10	0.573	0.076	0.464	0.595	0.713	0.592
σ labour utility	Normal	2.00	0.75	2.400	0.589	1.603	2.491	3.481	2.503
fixed cost	Normal	1.45	0.25	1.408	0.166	1.169	1.407	1.693	1.417
calvo employment	beta	0.50	0.15	0.599	0.050	0.513	0.598	0.673	0.597
capital util. adj.cost	Normal	0.20	0.075	0.169	0.075	0.062	0.175	0.289	0.201
calvo wages	beta	0.75	0.05	0.737	0.049	0.662	0.742	0.824	0.742
calvo prices	beta	0.75	0.05	0.908	0.011	0.888	0.905	0.922	0.905
indexation wages	beta	0.75	0.15	0.763	0.188	0.455	0.745	0.930	0.728
indexation prices	beta	0.75	0.15	0.469	0.103	0.309	0.472	0.670	0.477
r inflation	Normal	1.70	0.10	1.684	0.109	1.526	1.688	1.844	1.688
r d(inflation)	Normal	0.30	0.10	0.140	0.053	0.072	0.151	0.237	0.151
r lagged interest rate	beta	0.80	0.10	0.961	0.014	0.932	0.958	0.974	0.956
r output-gap	Normal	0.125	0.05	0.099	0.041	0.037	0.095	0.169	0.098
r d(output-gap)	Normal	0.0625	0.05	0.159	0.027	0.119	0.156	0.201	0.158

* For the Inverted Gamma function the degrees of freedom are indicated.

Note: The model parameters used in this paper correspond to the mode of their posterior distribution (column 4). The SWEAR model is estimated using Bayesian techniques. The first three columns report the assumed prior distributions for each of the parameters. Columns 4 and 5 report the mode and a proximate standard error of the posterior distribution. The last four columns report the 5, 50 and 95 percentiles and the mean of the posterior distribution sampled using the Metropolis-Hastings algorithm. See Smets and Wouters (2003) for further details.

Table 1: Persistence and the transmission of shocks

	Inflation persistence					
	Inflation			Output gap		
	Low	Medium	High	Low	Medium	High
Productivity	-0.12	0.14	-0.17	0.45	0.46	0.48
	1	2	4	2	2	2
Inflation target	0.01	0.02	0.03	0.02	0.02	0.03
	3	5	9	8	7	6
Preference	0.11	0.14	0.19	0.55	0.56	0.59
	2	4	7	3	3	3
Investment	0.03	0.04	0.06	0.09	0.09	0.10
	3	5	8	10	9	8
Government	0.02	0.03	0.04	0.07	0.08	0.09
	2	4	8	3	3	3
Labour supply	-0.10	-0.13	-0.17	-0.53	-0.54	-0.56
	2	4	7	2	2	2
Equity premium	0.01	0.01	0.02	0.20	0.20	0.20
	2	4	7	1	1	1
Price mark-up	0.88	0.86	0.81	-0.08	-0.14	-0.33
	1	1	1	6	6	9
Wage mark-up	0.08	0.09	0.11	-0.03	-0.04	-0.10
	1	2	4	17	15	15
Monetary policy	-0.21	-0.28	-0.38	-0.42	-0.45	-0.54
	3	5	8	6	5	5

	Investment persistence					
	Inflation			Output gap		
	Low	Medium	High	Low	Medium	High
Productivity	-0.15	-0.15	-0.14	-0.43	-0.46	-0.46
	2	2	2	2	2	2
Inflation target	0.02	0.02	0.02	0.02	0.02	0.02
	5	5	5	3	4	6
Preference	0.15	0.15	0.14	0.53	0.56	0.56
	4	4	4	2	3	3
Investment	0.01	0.02	0.04	0.07	0.09	0.10
	4	4	4	2	4	7
Government	0.03	0.03	0.03	0.08	0.08	0.08
	4	4	4	2	2	3
Labour supply	-0.14	-0.14	-0.13	-0.53	-0.55	-0.54
	4	4	4	2	2	2
Equity premium	0.00	0.00	0.01	0.25	0.24	0.22
	2	3	3	1	1	1
Price mark-up	0.86	0.86	0.86	-0.12	-0.14	-0.14
	1	1	1	4	4	6
Wage mark-up	0.08	0.08	0.09	-0.04	-0.04	-0.04
	2	2	2	11	11	14
Monetary policy	-0.25	-0.26	-0.27	-0.44	-0.49	-0.48
	4	4	4	3	3	5

Note: Each entry gives the peak effect (in absolute value) of the various (one standard deviation) shocks on inflation and the output gap. The number below indicates the timing of the peak effect (in quarters following the shock). Low, medium and high persistence refers to a parameter value of respectively 0.1, 0.5 and 0.9.

Table 2: Persistence and optimal Taylor rules with interest rate smoothing

	Inflation persistence								
	γ_p=0.1	γ_p =0.2	γ_p =0.3	γ_p =0.4	γ_p =0.5	γ_p =0.6	γ_p =0.7	γ_p =0.8	γ_p =0.9
Inflation	0.07	0.08	0.11	0.14	0.19	0.25	0.32	0.40	0.47
Output gap	0.51	0.51	0.51	0.50	0.49	0.47	0.44	0.39	0.33
Lagged int. rate	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00
	Investment persistence								
	h_I=0.1	h_I=0.2	h_I=0.3	h_I=0.4	h_I=0.5	h_I=0.6	h_I=0.7	h_I=0.8	h_I=0.9
Inflation	0.23	0.22	0.22	0.22	0.21	0.20	0.20	0.19	0.18
Output gap	0.40	0.41	0.41	0.41	0.41	0.42	0.43	0.45	0.47
Lagged int. rate	1.03	1.03	1.02	1.02	1.02	1.02	1.01	1.01	1.00

Note: The numbers refer to the optimal reaction coefficients to current inflation, the output gap and the lagged interest rate in a Taylor rule with interest rate smoothing.

Table 3 – Persistence and the robustness of simple policy rules

	Inflation persistence								
	γ_p=0.1	γ_p =0.2	γ_p =0.3	γ_p =0.4	γ_p =0.5	γ_p =0.6	γ_p =0.7	γ_p =0.8	γ_p =0.9
Max relative regret	15.6	14.5	13.0	11.1	8.7	6.0	3.3	2.6*	5.3
Max regret	0.24	0.23	0.20	0.17	0.13	0.09	0.05	0.01*	0.03
Mean rel. regret	2.6	2.4	2.1	1.8	1.4	1.0	0.9*	1.4	3.2
Mean regret	0.03	0.03	0.03	0.02	0.02	0.01	0.01*	0.01	0.02

	Investment persistence								
	h_I=0.1	h_I=0.2	h_I=0.3	h_I=0.4	h_I=0.5	h_I=0.6	h_I=0.7	h_I=0.8	h_I=0.9
Max relative regret	0.44	0.41	0.38	0.34	0.28	0.20	0.11*	0.22	0.40
Max regret	0.00	0.00	0.00	0.00	0.00	0.00	0.00*	0.00	0.00
Mean rel. regret	0.09	0.08	0.07	0.06	0.05	0.04*	0.05	0.10	0.22
Mean regret	0.00	0.00	0.00	0.00	0.00	0.00*	0.00	0.00	0.00

Note: The optimised simple rule is a Taylor rule with interest rate smoothing. A "*" refers to the minimum of the maximum (mean) regret.

Table 4 – Persistence and the robustness of optimal commitment policies

	Inflation persistence								
	γ_p=0.1	γ_p =0.2	γ_p =0.3	γ_p =0.4	γ_p =0.5	γ_p =0.6	γ_p =0.7	γ_p =0.8	γ_p =0.9
Max rel. regret	6.6	5.9	5.1	4.2	3.3	2.3	1.3	0.7*	1.0
Max regret	0.09	0.08	0.07	0.06	0.04	0.03	0.01	0.00*	0.00
Mean rel. regret	1.3	1.1	0.9	0.7	0.5	0.4	0.3*	0.4	0.7
Mean regret	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00*	0.00

	Investment persistence								
	h_I=0.1	h_I=0.2	h_I=0.3	h_I=0.4	h_I=0.5	h_I=0.6	h_I=0.7	h_I=0.8	h_I=0.9
Max rel. regret	0.58	0.52	0.44	0.35	0.25	0.15*	0.19	0.28	0.38
Max regret	0.00	0.00	0.00	0.00	0.00	0.00*	0.00	0.00	0.00
Mean rel. regret	0.17	0.14	0.11	0.08	0.06	0.06*	0.07	0.12	0.18
Mean regret	0.00	0.00	0.00	0.00	0.00	0.00*	0.00	0.00	0.00

Note: A "*" refers to the minimum of the maximum (mean) regret.

European Central Bank working paper series

For a complete list of Working Papers published by the ECB, please visit the ECB's website (http://www.ecb.int).

202 "Aggregate loans to the euro area private sector" by A. Calza, M. Manrique and J. Sousa, January 2003.

203 "Myopic loss aversion, disappointment aversion and the equity premium puzzle" by D. Fielding and L. Stracca, January 2003.

204 "Asymmetric dynamics in the correlations of global equity and bond returns" by L. Cappiello, R.F. Engle and K. Sheppard, January 2003.

205 "Real exchange rate in an inter-temporal n-country-model with incomplete markets" by B. Mercereau, January 2003.

206 "Empirical estimates of reaction functions for the euro area" by D. Gerdesmeier and B. Roffia, January 2003.

207 "A comprehensive model on the euro overnight rate" by F. R. Würtz, January 2003.

208 "Do demographic changes affect risk premiums? Evidence from international data" by A. Ang and A. Maddaloni, January 2003.

209 "A framework for collateral risk control determination" by D. Cossin, Z. Huang, D. Aunon-Nerin and F. González, January 2003.

210 "Anticipated Ramsey reforms and the uniform taxation principle: the role of international financial markets" by S. Schmitt-Grohé and M. Uribe, January 2003.

211 "Self-control and savings" by P. Michel and J.P. Vidal, January 2003.

212 "Modelling the implied probability of stock market movements" by E. Glatzer and M. Scheicher, January 2003.

213 "Aggregation and euro area Phillips curves" by S. Fabiani and J. Morgan, February 2003.

214 "On the selection of forecasting models" by A. Inoue and L. Kilian, February 2003.

215 "Budget institutions and fiscal performance in Central and Eastern European countries" by H. Gleich, February 2003.

216 "The admission of accession countries to an enlarged monetary union: a tentative assessment" by M. Ca'Zorzi and R. A. De Santis, February 2003.

217 "The role of product market regulations in the process of structural change" by J. Messina, March 2003.

218 "The zero-interest-rate bound and the role of the exchange rate for monetary policy in Japan" by G. Coenen and V. Wieland, March 2003.

219 "Extra-euro area manufacturing import prices and exchange rate pass-through" by B. Anderton, March 2003.

220 "The allocation of competencies in an international union: a positive analysis" by M. Ruta, April 2003.

221 "Estimating risk premia in money market rates" by A. Durré, S. Evjen and R. Pilegaard, April 2003.

222 "Inflation dynamics and subjective expectations in the United States" by K. Adam and M. Padula, April 2003.

223 "Optimal monetary policy with imperfect common knowledge" by K. Adam, April 2003.

224 "The rise of the yen vis-à-vis the ("synthetic") euro: is it supported by economic fundamentals?" by C. Osbat, R. Rüffer and B. Schnatz, April 2003.

225 "Productivity and the ("synthetic") euro-dollar exchange rate" by C. Osbat, F. Vijselaar and B. Schnatz, April 2003.

226 "The central banker as a risk manager: quantifying and forecasting inflation risks" by L. Kilian and S. Manganelli, April 2003.

227 "Monetary policy in a low pass-through environment" by T. Monacelli, April 2003.

228 "Monetary policy shocks – a nonfundamental look at the data" by M. Klaeffing, May 2003.

229 "How does the ECB target inflation?" by P. Surico, May 2003.

230 "The euro area financial system: structure, integration and policy initiatives" by P. Hartmann, A. Maddaloni and S. Manganelli, May 2003.

231 "Price stability and monetary policy effectiveness when nominal interest rates are bounded at zero" by G. Coenen, A. Orphanides and V. Wieland, May 2003.

232 "Describing the Fed's conduct with Taylor rules: is interest rate smoothing important?" by E. Castelnuovo, May 2003.

233 "The natural real rate of interest in the euro area" by N. Giammarioli and N. Valla, May 2003.

234 "Unemployment, hysteresis and transition" by M. León-Ledesma and P. McAdam, May 2003.

235 "Volatility of interest rates in the euro area: evidence from high frequency data" by N. Cassola and C. Morana, June 2003.

236 “Swiss monetary targeting 1974-1996: the role of internal policy analysis” by G. Rich, June 2003.

237 “Growth expectations, capital flows and international risk sharing” by O. Castrén, M. Miller and R. Stiegert, June 2003.

238 “The impact of monetary union on trade prices” by R. Anderton, R. E. Baldwin and D. Taglioni, June 2003.

239 “Temporary shocks and unavoidable transitions to a high-unemployment regime” by W. J. Denhaan, June 2003.

240 “Monetary policy transmission in the euro area: any changes after EMU?” by I. Angeloni and M. Ehrmann, July 2003.

241 Maintaining price stability under free-floating: a fearless way out of the corner?” by C. Detken and V. Gaspar, July 2003.

242 “Public sector efficiency: an international comparison” by A. Afonso, L. Schuknecht and V. Tanzi, July 2003.

243 “Pass-through of external shocks to euro area inflation” by E. Hahn, July 2003.

244 “How does the ECB allot liquidity in its weekly main refinancing operations? A look at the empirical evidence” by S. Ejerskov, C. Martin Moss and L. Stracca, July 2003.

245 “Money and payments: a modern perspective” by C. Holthausen and C. Monnet, July 2003.

246 “Public finances and long-term growth in Europe – evidence from a panel data analysis” by D. R. de Ávila Torrijos and R. Strauch, July 2003.

247 “Forecasting euro area inflation: does aggregating forecasts by HICP component improve forecast accuracy?” by K. Hubrich, August 2003.

248 “Exchange rates and fundamentals” by C. Engel and K. D. West, August 2003.

249 “Trade advantages and specialisation dynamics in acceding countries” by A. Zaghini, August 2003.

250 “Persistence, the transmission mechanism and robust monetary policy” by I. Angeloni, G. Coenen and F. Smets, August 2003.