EUROPEAN CENTRAL BANK

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EUROSYSTEM INFLATION PERSISTENCE NETWORK

INFLATION PERSISTENCE AND MONETARY POLICY DESIGN

AN OVERVIEW

by Andrew T. Levin
and Richhild Moessner

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In 2005 all ECB publications will feature a motif taken from the €50 banknote.

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The Eurosystem Inflation Persistence Network

This paper reflects research conducted within the Inflation Persistence Network (IPN), a team of Eurosystem economists undertaking joint research on inflation persistence in the euro area and in its member countries. The research of the IPN combines theoretical and empirical analyses using three data sources: individual consumer and producer prices; surveys on firms' price-setting practices; aggregated sectoral, national and area-wide price indices. Patterns, causes and policy implications of inflation persistence are addressed.

Since June 2005 the IPN is chaired by Frank Smets; Stephen Cecchetti (Brandeis University), Jordi Galí (CREI, Universitat Pompeu Fabra) and Andrew Levin (Board of Governors of the Federal Reserve System) act as external consultants and Gonzalo Camba-Méndez as Secretary.

The refereeing process is co-ordinated by a team composed of Günter Coenen (Chairman), Stephen Cecchetti, Silvia Fabiani, Jordi Galí, Andrew Levin, and Gonzalo Camba-Méndez. The paper is released in order to make the results of IPN research generally available, in preliminary form, to encourage comments and suggestions prior to final publication. The views expressed in the paper are the author's own and do not necessarily reflect those of the Eurosystem.

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CONTENTS

Abstract

How monetary policy should be set optimally when the structure of the economy exhibits inflation persistence is an important question for policy makers. This paper provides an overview of the implications of inflation persistence for the design of monetary policy.

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Key words: inflation persistence, optimal monetary policy, uncertainty.

Summary

A research network of economists from national central banks of the euro area and the ECB has been investigating the empirical evidence for inflation persistence, its determinants and implications for monetary policy. This paper provides an overview of the implications of inflation persistence for the design of monetary policy.

Hybrid New-Keynesian models, and an ad hoc objective function for the central bank are commonly used for monetary policy analysis; we therefore provide an overview of inflation persistence and optimal policy in this setting. There are two main kinds of micro-foundations for endogenous inflation persistence, partial backward-looking indexation and rule-of-thumb price-setting, and we provide an overview of optimal policy within these structural models. Using a structural objective function for the central bank based on the representative agent's utility within micro-founded models of inflation persistence can alter the results for optimal monetary policy, compared with using an ad hoc objective function for the central bank, and we therefore also review the case of structural objective functions.

The degree of endogenous inflation persistence is a key parameter for assessing the optimality of monetary policies. Given that there is little consensus about the degree of endogenous inflation persistence in the empirical literature, it is of interest to consider optimal monetary policy when the degree of endogenous inflation persistence is uncertain or misspecified; we therefore also review results for optimal policy in this case. Some additional issues relevant for monetary policy design in the presence of inflation persistence are also considered, including the implications of imperfect knowledge.

1 Introduction

How monetary policy should be set optimally when the structure of the economy exhibits inflation persistence is an important question for policy makers. A research network of economists from national central banks of the euro area and the ECB has been investigating the empirical evidence for inflation persistence, its determinants and implications for monetary policy (see Angeloni et al. (2004) for a summary). This paper provides an overview of the implications of inflation persistence for the design of monetary policy.

New-Keynesian models, and an ad hoc objective function for the central bank penalizing inflation and output gap volatility, are commonly used for monetary policy analysis. Section 2 provides an overview of inflation persistence and optimal policy for a central bank with an ad hoc objective function, following Clarida, Gali and Gertler (1999), and illustrates the results for optimal policy under discretion and commitment within a hybrid New-Keynesian model estimated for the euro area by Smets (2003). The degree of endogenous inflation persistence is a key parameter for assessing the optimality of monetary policies. For example, Levin and Williams (2003a) show that monetary policy rules which are optimal in a forward-looking model can yield bad outcomes in backward-looking models. Given that there is little consensus about the degree of endogenous inflation persistence in the empirical literature, it is of interest to consider optimal monetary policy when the degree of endogenous inflation persistence is uncertain or misspecified. Section 2 therefore also review results for optimal policy when the degree of endogenous inflation persistence is uncertain or misspecified.

There are two main kinds of micro-foundations for endogenous inflation persistence, partial backward-looking indexation and rule-of-thumb price-setting (see Gali and Gertler (1999), Woodford (2003), Steinsson (2003), and Amato and Laubach (2003)). Section 3 gives an overview of optimal policy within these structural models. Using a structural objective function for the central bank based on the representative agent's utility within these micro-founded models of inflation persistence can alter the results for optimal monetary policy, compared with using an ad hoc objective function for the central bank. Optimal policy in structural models with micro-founded loss functions when inflation inertia is uncertain or misspecified is also reviewed in Section 3.

Results for optimal policy in the presence of backward-looking indexation of wages as well as of prices in micro-founded models are reviewed in Section

4, discussing the role of wage-setting and of uncertainty about the degree of indexation (see Levin et al. (2005)). Additional issues relevant for monetary policy design in the presence of inflation persistence are considered in Section 5, including the implications of heterogeneity in inflation persistence between different regions of a currency union, and of imperfect knowledge. Finally, Section 6 provides a summary.

2 New-Keynesian models and ad hoc objective functions

2.1 Optimal policy under discretion

This section provides an overview of the implications of endogenous inflation persistence for optimal monetary policy and the associated inflation dynamics, for a central bank with an ad hoc objective function, within hybrid New-Keynesian models commonly used for monetary policy analysis, drawing heavily on Clarida, Gali and Gertler (1999), where more details can be found. We illustrate results for inflation dynamics under optimal policy within a hybrid New-Keynesian model estimated for the euro area by Smets (2003), with a hybrid New-Keynesian Phillips curve[1]

$$\pi_t = \alpha y_t + \phi \pi_{t-1} + (1-\phi)\beta E_t \pi_{t+1} + e_{ut}, \tag{1}$$

assuming serially uncorrelated shocks e_{ut}. This allows to focus on the implications of endogenous inflation persistence, ϕ, as opposed to inflation persistence arising merely due to a serially correlated external driving process. More details and estimates of the model parameters are given in the appendix.

The central bank is assumed to have an ad hoc quadratic objective function penalizing the volatility of inflation around target, and the volatility of the output gap, with a relative weight, λ^y, assigned to output gap stabilisation,

$$E_0 \sum_{t=0}^{\infty} \beta^t L_t, \tag{2}$$

[1] In comparison with Smets (2003), we introduce a factor of β in front of $E_t\pi_{t+1}$in equation 1, so that the hybrid New-Keynesian Phillips curve reduces to the standard one as endogenous inflation persistence, ϕ, approaches zero.

where

$$L_t = \pi_t^2 + \lambda^y y_t^2. \tag{3}$$

We first discuss the implications of endogenous inflation persistence under optimal discretionary policy, before discussing the gains from commitment. The first-order condition yields the following targeting rule, which is a relationship between inflation and the output gap under optimal policy,

$$\pi_t + \frac{\lambda^y}{\alpha}(1 - \beta\rho_\pi)y_t = 0, \tag{4}$$

and the solution for inflation dynamics in reduced form in this model is given by (see Clarida, Gali and Gertler (1999), Walsh (2003a))

$$\pi_t = \rho_\pi \pi_{t-1} + \frac{\rho_\pi}{\phi} e_{ut}, \tag{5}$$

where the serial correlation of inflation under optimal policy, ρ_π, depends on the parameters λ^y, β, ϕ and α. Under optimal discretionary policy, the form of the IS-curve (see equation 14 in the appendix) does not influence the serial correlation of inflation or the optimal targeting rule.

The serial correlation of inflation under optimal discretionary policy depends on the degree of endogenous inflation persistence, ϕ, and the relative weight on output stabilization, λ^y, as shown in Figure 1.[2] We can see that inflation gradually returns to equilibrium in the presence of endogenous inflation persistence, with ρ_π lying between 0 and 1. In the presence of inflation inertia, optimal policy influences the speed with which inflation converges back to target following inflationary disturbances. We can see from Figure 1 that as the central bank puts relatively more weight on inflation stabilisation, the speed of convergence of inflation under optimal policy increases, for a given degree of endogenous inflation persistence, since the central bank reacts more strongly to inflationary disturbances when inflation volatility is penalized more heavily, as can be see from equations 17 and 18 in the appendix.

Figure 1 also shows that as endogenous inflation persistence increases, for a given weight on inflation stabilisation, the serial correlation of inflation increases, due to the greater degree of backward-lookingness in the New-Keynesian Phillips curve. Under optimal policy for the parameter values

[2] Analytical solutions for the serial correlation of inflation are not available, and we therefore present numerical solutions.

considered in Figure 1, interest rates react more strongly to lagged inflation and cost-push shocks in the presence of endogenous inflation persistence than in its absence. When endogenous inflation persistence is higher, the output-inflation trade-off due to cost-push shocks becomes less favourable. The central bank needs to respond more strongly to inflationary disturbances, since any such disturbances not eliminated today continue in future periods, which might require more output contraction in future (see Clarida, Gali and Gertler (1999)).

As in the case without endogenous inflation persistence, interest rates should perfectly offset demand shocks in the presence of endogenous inflation persistence, since demand shocks do not introduce an output-inflation trade-off.

2.2 Optimal policy under commitment

There are gains from conducting optimal monetary policy under commitment in this hybrid New-Keynesian model (see Clarida, Gali and Gertler (1999)). Under commitment, the targeting rule takes the following form,

$$\pi_t + \frac{\lambda^y}{\alpha}[y_t - (1-\phi)y_{t-1} - \beta\phi E_t y_{t+1}] = 0, \tag{6}$$

For optimal policy under commitment, the targeting rule depends additionally on the lagged and expected future output gap, in contrast to the discretionary targeting rule. Figure 2 shows the implications of optimal policy under commitment for the first-order autocorrelation of inflation.[3] In the absence of intrinsic persistence ($\phi = 0$), optimal policy is essentially price-level targeting, so a positive cost-push shock causes an initial rise of inflation, followed by an extended period of deflation. In this case, inflation exhibits negative serial correlation. In contrast, if inflation exhibits relatively high intrinsic persistence, then the optimal policy brings inflation monotonically back towards zero, and hence inflation exhibits positive serial correlation. As in the discretionary case, we can see from Figure 2 that under commitment the speed of convergence of inflation increases when the central bank assigns a relatively greater weight to inflation stabilisation. Moreover, as under discretion, the form of the IS-curve does not influence the serial correlation of inflation or the optimal targeting rule under commitment.

[3] Since no analytical solutions are possible, we present numerical results.

We can also see by comparing Figures 1 and 2 that as intrinsic inflation persistence approaches 1, the results for the serial correlation of inflation under discretion and commitment approach each other.

2.3 Uncertainty about inflation persistence

The degree of endogenous inflation persistence is a key parameter for assessing the optimality of monetary policies. For example, Levin and Williams (2003a) show that monetary policy rules which are optimal in a forward-looking model can yield very bad outcomes in backward-looking models, and Rudebush (2002) shows that nominal income-targeting performs well when inflation is forward-looking, but not when the degree of inflation inertia is high. Given that there is little consensus about the degree of endogenous inflation persistence in the empirical literature, it is of interest to consider optimal monetary policy when the degree of inflation inertia is uncertain or misspecified.

One approach of dealing with uncertainty is a Bayesian approach, in which the policy maker has a prior distribution of the parameters, and sets policy to minimize expected loss based on this prior distribution. Optimal monetary policy with uncertainty about inflation persistence has been studied in purely backward-looking models by Söderström (2002), who finds that it may be optimal for policy to respond more aggressively to shocks when the degree of inflation persistence is uncertain than when it is certain. This is in contrast to the classic finding by Brainard (1967), who finds for a static model that optimal policy should be more cautious in the presence of uncertainty about the policy multiplier. Similarly, Moessner (2005) finds within the hybrid New-Keynesian model estimated for the euro area by Smets (2003) that it may be optimal for policy to respond more aggressively to shocks in the presence of uncertainty about inflation inertia.[4]

Another approach to investigating the implications of uncertainty is to study the effect of setting policy based on parameter values that are incorrect, but taken as certain in the central bank's optimisation problem. This approach is taken in the following papers. Walsh (2004) considers the New-

[4]Moessner (2005) finds that if the central bank cares about inflation and output gap volatility, then the optimal policy response to cost-push shocks is more aggressive, while the optimal response to demand shocks does not depend on uncertainty about inflation inertia; if the central bank's objective function only penalizes inflation volatility, then the optimal policy response to shocks does not depend on uncertainty about inflation inertia.

Keynesian model with partial indexation of Benigno and Woodford (2004). Studying specific targeting rules within this model, he finds that an ad hoc loss function suggests that policy should be set optimally based on significantly overestimating the degree of inflation inertia. Angeloni, Coenen and Smets (2003), Walsh (2003) and Coenen (2004) also find for an ad hoc loss function that robust monetary policy is set based on a relatively high degree of inflation inertia.

3 Micro-founded models and objective functions

The main motivation for introducing endogenous inflation persistence in macroeconomic models is of an empirical nature. There are two main structural mechanisms, however, through which endogenous inflation persistence may be generated in a micro-founded way, although there is no consensus on the true mechanism lying behind the inflation inertia found empirically. The two structural mechanisms are backward-looking price indexation and rule-of-thumb price-setting. Depending on the structural mechanism giving rise to inflation persistence, an approximation to a social welfare function can be derived, based on the representative household's utility, which may be taken as the central bank's objective function, rather than the ad hoc loss function of equation 3 considered above.

3.1 Backward-looking indexation

One structural mechanism for generating endogenous inflation persistence is partial indexation of prices to a lagged price index (see Woodford (2003)). Each period, only a fraction of firms re-optimise their prices, while the remaining firms index their prices to a fraction, γ, of the lagged inflation rate. Within a micro-founded model, price dispersion decreases social welfare. The mechanism of partial indexation implies that only deviations of inflation from the rate at which prices increase which are not reoptimised, $\gamma\pi_{t-1}$,are undesirable, since only such deviations increase price dispersion. The second-order approximation of the utility-based social welfare function therefore yields a loss function (see Woodford (2003))[5]

$$L_t = (\pi_t - \gamma\pi_{t-1})^2 + \tilde{\lambda}^y \tilde{y}_t^2, \quad (7)$$

where $\tilde{\lambda}_y$ depends on the structural parameters of the model, rather than being exogenous as in the case of an ad hoc loss function. The appearance of $(\pi_t - \gamma\pi_{t-1})^2$ in the structural loss function, rather than of ${\pi_t}^2$ as in the ad hoc loss function considered above, affects optimal monetary policy, and its dependence on endogenous inflation persistence. Within the partial indexation model, the New-Keynesian Phillips curve (NKPC) also depends on the quasi-difference in inflation, $\pi_t - \gamma\pi_{t-1}$,

$$\pi_t - \gamma\pi_{t-1} = \alpha\tilde{y}_t + \beta E_t(\pi_{t+1} - \gamma\pi_t). \quad (8)$$

Since the quasi-difference of inflation enters in both the structural loss function and the NKPC, the value of the social loss is independent of the degree of partial indexation, γ, in contrast to the case of an ad hoc loss function, where the loss increases as inflation inertia increases (see Walsh (2004)).

However, the equilibrium dynamics of inflation in the case of a structural loss function depends on γ. As shown in Woodford (2003), inflation returns to equilibrium following a cost-push shock more slowly under optimal policy when the degree of indexation is higher, both under discretion and commitment, due to the partial indexation to lagged inflation; π_t is persistent, while $\pi_t - \gamma\pi_{t-1}$ is not persistent.[6] For optimal policy under commitment with a structural loss function, it is optimal for policy to generate a period of below-average inflation in response to an inflationary cost-push shock, as long as indexation is only partial ($\gamma < 1$), following a period of above-average inflation, whose length depends on the degree of indexation (see Woodford (2003)). Such an undershooting of inflation is optimal, since it is incorporated into private agents' inflation expectations in the period of the shock, so that actual inflation is lower in the period of the shock. By contrast, no such undershooting of inflation occurs for optimal policy under discretion, since under discretionary policy the central bank is not able to manipulate private-sector expectations. In the case of full indexation ($\gamma = 1$), inflation stays permanently higher following a cost-push shock in the case of discretionary policy. Moreover, the price level increases permanently in the case

[5] The loss function depends on the variability of deviations, $\tilde{y}_t$, of output from the efficient level of output, rather than on deviations from the natural level of output.

[6] See Figures 7.4 and 7.5 in Woodford (2003) for details.

of full indexation for optimal policy under both discretion and commitment (see Woodford (2003)).

Within the model of backward-looking indexation, specific targeting rules[7] for optimal policy from a timeless perspective[8] can be derived, which can illustrate the implications of using a structural loss function compared with an ad hoc loss function (see Walsh (2004)). In the case of a structural loss function, the targeting rule has the form[9]

$$\pi_t - \gamma\pi_{t-1} = -\frac{\tilde{\lambda}^y}{\alpha}(\tilde{y}_t - \tilde{y}_{t-1}). \tag{9}$$

The targeting rule specifies an appropriate near-term inflation rate, which depends on the projected change in the output gap, as well as on the lagged inflation rate for $\gamma > 1$, since the central bank minimises the variability of the quasi-difference in inflation, $(\pi_t - \gamma\pi_{t-1})^2$ (see Woodford (2003)). The targeting rule depends additionally on structural model parameters via $\tilde{\lambda}^y$. By contrast, in the case of an ad hoc loss function, the targeting rule,

$$\pi_t = -\frac{\lambda^y}{\alpha}(\tilde{y}_t - \tilde{y}_{t-1}) + \beta\gamma\frac{\lambda^y}{\alpha}E_t(\tilde{y}_{t+1} - \tilde{y}_t), \tag{10}$$

does not depend on lagged inflation, but is forward-looking instead, depending on the expected future output gap, since current inflation affects future inflation in the presence of inflation inertia, and the central bank penalizes inflation volatility (see Walsh (2004)).[10]

3.2 Uncertainty about the degree of indexation

As shown by Levin and Williams (2003b), using a structural objective function for the central bank can alter the results for optimal monetary policy

[7] Specific targeting rules are relationships between endogenous variables, to which a central bank is assumed to be able to commit (see Svensson and Woodford (2003)). It is assumed that such a targeting rule can be implemented by setting nominal interest rates appropriately, ignoring the issue of how this is achieved.

[8] Optimal policy from a timeless perspective has been defined by Woodford (1999) as a time-invariant policy which a central bank would always wish to have been expected to follow.

[9] Note that this rule is also robustly optimal in the sense of Giannoni and Woodford (2002), in that it does not depend on the properties of shocks hitting the economy.

[10] This assumes that the output gap $\tilde{y}_t$ appears in the standard loss function.

with parameter uncertainty, compared with using an ad hoc objective function, so that it is also of interest to consider structural objective functions with uncertainty about inflation persistence. Using a Bayesian approach, optimal monetary policy under commitment in the presence of parameter uncertainty about the degree of indexation is studied in Kimura and Kurozumi (2003). They study optimal policy using a micro-founded loss function[11] within the model with backward-looking indexation of Giannoni and Woodford (2003). They find that policy should respond more aggressively to shocks to the natural real interest rate when uncertainty about the degree of inflation inertia is higher.

Walsh (2004) considers optimal policy for a micro-founded loss function when the degree of indexation is misspecified, within the New-Keynesian model with partial indexation of Benigno and Woodford (2004). Studying specific targeting rules within this model, he finds that a structural loss function suggests that policy should be set optimally assuming a moderate value of inflation inertia (but one that is still larger than the true value), in contrast to the result found for an ad hoc loss function, which suggested that optimal policy should be set based on significantly overestimating the degree of inflation inertia, as discussed in Section 2.3. This result is due to the fact that inflation inertia is less costly using a structural loss function, which penalizes volatility in the quasi-difference in inflation; by contrast, the loss increases as inflation inertia increases using an ad hoc loss function, which penalizes inflation volatility.

3.3 Rule-of-thumb price-setting

An alternative structural mechanism for generating endogenous inflation persistence is an extension of the Calvo pricing model to include a fraction of backward-looking rule-of-thumb price-setters, as proposed by Gali and Gertler (1999); the remaining firms set prices optimally. Amato and Laubach (2003) and Steinsson (2003) derive a second-order approximation to the micro-founded loss function with rule-of-thumb price-setting. In the model of Amato and Laubach (2003), backward-looking firms follow a rule-of-thumb based on the average price set in the last period and the lagged

[11] Note that Kimura and Kurozumi (2003) include a term penalizing interest rate volatility in the central bank's objective function, motivated by considerations other than the structural mechanism giving rise to inflation persistence, such as a desire of avoiding the zero bound on nominal interest rates.

inflation rate; the expression for the micro-founded loss function takes the following form,

$$L = \pi_t^2 + \hat{\lambda}^y y_t^2 + \hat{\lambda}^{\Delta\pi}(\pi_t - \pi_{t-1})^2, \tag{11}$$

where y_t is the difference between output and the flexible-price level of output, and the relative weights depend on the structural parameters of the model. Steinsson (2003) considers a more general rule-of-thumb, where backward-looking firms also take account of last period's demand condition, in addition to last period's average price and inflation rate. This leads to the presence of two additional terms involving the output gap in the micro-founded loss function, compared with equation 11,

$$L = \pi_t^2 + \hat{\lambda}^y y_t^2 + \hat{\lambda}^{\Delta\pi}(\pi_t - \pi_{t-1})^2 + w^y {y_{t-1}}^2 + w^{\Delta\pi y}(\pi_t - \pi_{t-1})y_{t-1}, \tag{12}$$

with relative weights again depending on the structural model parameters. Similar to Woodford (2003)'s finding of a dependence of the structural loss function on the quasi-difference $(\pi_t - \gamma\pi_{t-1})^2$, the structural loss functions for rule-of-thumb price-setting models depend on variations in changes in inflation, $(\pi_t - \pi_{t-1})^2$, rather than just on inflation volatility, but with a different functional form.

One notable feature of the structural objective function of equation 12 derived within this rule-of-thumb price-setting mechanism is a low weight placed on output stabilisation in the structural objective function (see Steinsson (2003)). Consequently, output is stabilised much less, inflation is lower in the period of the shock, and inflation is less persistent for a structural than for an ad hoc loss function (with $\lambda^y = 0.5$), both under commitment and discretion.

Steinsson (2003) finds that in response to cost-push shocks, inflation returns more slowly to equilibrium for optimal policy with inflation inertia than in its absence, both under discretion and commitment. As in models with partial indexation, it is optimal for policy under commitment with a structural loss function to generate a period of below-average inflation in response to an inflationary cost-push shock, as long as there is some degree of forward-lookingness in the NKPC (see Steinsson (2003)).

3.4 Uncertainty about the fraction of rule-of-thumb price-setters

Optimal monetary policy under commitment in the presence of parameter uncertainty about the fraction of rule-of-thumb price-setters is studied in Kimura and Kurozumi (2003), considering micro-founded loss functions within models based on Amato and Laubach (2003) and of Steinsson (2003). For both models of rule-of-thumb price-setting they find that policy should respond more aggressively to shocks to the natural real interest rate when uncertainty about the fraction of rule-of-thumb price-setters is higher. This finding is in line with their result in the case of uncertainty about the degree of indexation discussed in Section 3.2.

4 Role of wage-setting

4.1 Micro-founded objective functions

Considering a Calvo-type model with nominal rigidities in both price- and wage-setting, as well as with partial backward-looking indexation of prices and wages, Levin et al. (2005) find that a policy rule where changes in the nominal interest rate react to wage inflation performs nearly as well in terms of social welfare as the fully optimal rule under commitment. By contrast, they find that an estimated monetary policy rule which does not target wage inflation performs much worse in terms of social welfare than a policy rule reacting to wage inflation. However, for an ad-hoc objective function, instead of a micro-founded one, Levin et al. (2005) find that the estimated monetary policy rule which does not target wage inflation no longer performs much worse than a policy rule reacting to wage inflation. This result shows that wage dispersion due to nominal wage rigidity is responsible for large social welfare costs. Within their model, the micro-founded loss function can be represented in a form containing the following terms,

$$\hat{\lambda}^{y}(\pi_t - \gamma\pi_{t-1})^2 + \hat{\lambda}^{w}(w_t - w_{t-1} + \pi_t - \gamma_w\pi_{t-1})^2, \tag{13}$$

in addition to more complicated terms due to fluctuations in consumption (see Onatski and Williams (2004)). Here, w_t is the real wage, γ is the degree of price-indexation, and γ_w is the degree of wage-indexation. Variations in wage inflation are costly in terms of social welfare due to the dispersion of labour supply across households. These results are related to Erceg, Henderson and Levin (2000)'s findings within a Calvo-type model with nominal price and wage rigidity, but without partial backward-looking price- or wage-indexation, where the micro-founded objective function can be expressed in terms of the variances of the output gap, price- and wage-inflation. Consequently, there exists a trade-off between stabilisation of the output gap, price- and wage-inflation. Erceg, Henderson and Levin (2000) find that a simple hybrid policy rule targeting wage-inflation in addition to price-inflation performs nearly as well in terms of social welfare as the fully optimal policy under commitment. By contrast, a policy rule targeting price-inflation does not perform well in terms of social welfare, due to excessive variation in nominal wage-inflation and the output gap, since all adjustment in real wages has to occur via changes in nominal wages, which in turn require variation in the output gap.

Levin et al. (2005) also consider a model with nominal rigidities in both price- and wage-setting, as well as with partial backward-looking indexation of prices and wages, using Taylor-contracts instead of Calvo's approach. Using this alternative model of wage-setting, they find that a policy rule where changes in the nominal interest rate react to wage inflation no longer performs better in terms of social welfare than an estimated rule not reacting to wage inflation. This happens since for Taylor-contracts wage dispersion is much smaller than within the Calvo model, so that wage inflation is no longer the dominant component of social welfare. This shows that results for monetary policy design based on structural loss functions can be affected by the type of wage-setting behaviour, ie Taylor contracts versus Calvo wage-setting. One might also expect that optimal monetary policy based on structural loss functions may be affected by the type of pricing behaviour, for example the use of Taylor contracts versus Calvo price-setting.

4.2 Uncertainty about the degree of price- and wage-indexation

Levin et al. (2005) estimate their model using Bayesian techniques. Quantifying the degree of parameter uncertainty via the width of the estimated Bayesian posterior probability distribution for each parameter, they find that sampling uncertainty about parameters describing the degree of price- and wage-indexation imply only modest costs in terms of social welfare. However, considering robustly optimal policy for a wider range of parameter values than implied by the estimation, they find that knowledge of the degree of price-indexation could lead to a large gain in welfare.

5 Other issues

5.1 Heterogeneity in inflation persistence

Within a monetary union such as the euro area, the implications for optimal policy of possible heterogeneity in the degree of inflation inertia among different members of the monetary union is of interest. Benigno and Lopez-Salido (2002) analyse different inflation targeting policies in the presence of heterogeneity in inflation persistence among different regions in the euro area. They employ a micro-founded New-Keynesian model of a currency area, and rank the different inflation targeting policies using the social welfare function based on the representative household's utility. They find that targeting euro-area-wide HICP is not optimal. Instead, it is optimal for the central bank to assign a greater weight to inflation volatility in the region with a greater degree of inflation inertia. In earlier related work, Aoki (2001) found within a two-sector model (a flexible-price and a sticky-price sector), but without inflation inertia, that it is optimal for policy to target the inflation rate in the sticky-price sector, rather than to target aggregate inflation.

5.2 Imperfect information

Imperfect knowledge may also affect optimal policy in models with inflation inertia. Orphanides and Williams (2002) study a model with inflation inertia where economic agents have imperfect knowledge about the dynamic structure of the economy and the relative weight placed on output gap stabilisation in the central bank's objective function. Private agents are assumed to rely on adaptive learning to continually form expectations and update their beliefs about the structure of the economy. With such 'perpetual learning', Orphanides and Williams (2002) show that policy should respond more aggressively to inflation under imperfect knowledge than under perfect knowledge. They also show that inflation persistence may increase if the central bank places a large weight on output gap stabilisation. Moreover, Gaspar, Smets and Vestin (2005) show that with imperfect knowledge and expectation formation on the part of the private sector based on adaptive learning, there is a clear relationship between the monetary policy regime and the probability distribution of a time-varying inflation persistence parameter. They find that a more credible policy with a greater weight assigned to price stability leads to a reduction in inflation persistence. Moreover, they find an asymmetry in the central bank's response to shocks, with the ability of the central bank to influence private sector expectations via the learning mechanism contributing additionally to a more aggressive response to shocks when inflation persistence is higher.

6 Summary

This paper provided an overview of the implications of inflation persistence for the design of monetary policy, since it is an important question how monetary policy should be set optimally when the structure of the economy exhibits inflation persistence. We reviewed results for models with both ad-hoc objective functions, and in micro-founded models with micro-founded objective functions, considering partial backward-looking indexation and rule-of-thumb price-setting as the mechanisms underlying inflation inertia. We also reviewed the implications of uncertainty about inflation persistence for monetary policy design, the role of wage-setting, and the implications of heterogeneity in inflation persistence and of imperfect knowledge.

Appendix

Section 2 illustrates results for inflation dynamics under optimal policy within a hybrid New-Keynesian model for the euro area. The IS-curve of this model is given by

$$y_t = -\sigma(i_t - E_t\pi_{t+1}) + \theta y_{t-1} + (1-\theta)E_t y_{t+1} + e_{gt}. \tag{14}$$

Table 1 presents estimates of the model parameters for the euro area of Smets (2003), where ϕ is the degree of endogenous inflation peristence, θ is the degree of endogenous output peristence, β is the discount factor, α is the slope of the New-Keynesian Phillips curve, and σ is the interest elasticity of demand. The shocks in equations 1 and 14,

$$e_{ut+1} = \rho_u e_{ut} + \eta_{ut+1}, \quad e_{gt+1} = \rho_g e_{gt} + \eta_{gt+1}, \tag{15}$$

are assumed to be serially uncorrelated, i.e. $\rho_u = \rho_g = 0$.

Table 1: Model parameters; Euro-area estimates for 1977-1997 (see Smets 2003).

ϕ	0.48
θ	0.44
σ	0.06
α	0.18

Given a solution for the serial correlation of inflation, the optimal discretionary policy rule in this model can be expressed as (see Clarida, Gali and Gertler (1999))

$$i_t = \gamma_\pi E_t \pi_{t+1} + \frac{\theta}{\sigma} y_{t-1} + \frac{1}{\sigma} e_{gt}, \tag{16}$$

where[12]

$$\gamma_\pi = 1 + \frac{\alpha(1-\rho_\pi(1-\theta))}{\sigma\lambda^y \rho_\pi (1-\beta\rho_\pi)}. \tag{17}$$

The optimal policy rule can be written in terms of the predetermined variables as

$$i_t = (\gamma_\pi \rho_\pi^2)\pi_{t-1} + (\frac{\gamma_\pi \rho_\pi^2}{\phi}) e_{ut} + \frac{\theta}{\sigma} y_{t-1} + \frac{1}{\sigma} e_{gt}. \tag{18}$$

While the serial correlation of inflation does not depend on the parameters of the IS-curve, the optimal discretionary policy rule depends on them.

[12]Note the extra factor of $(1-\theta)$ multiplying the serial correlation of inflation, ρ_π in the numerator of equation 17, compared with equation (6.6) in Clarida, Gali and Gertler (1999).

Figures

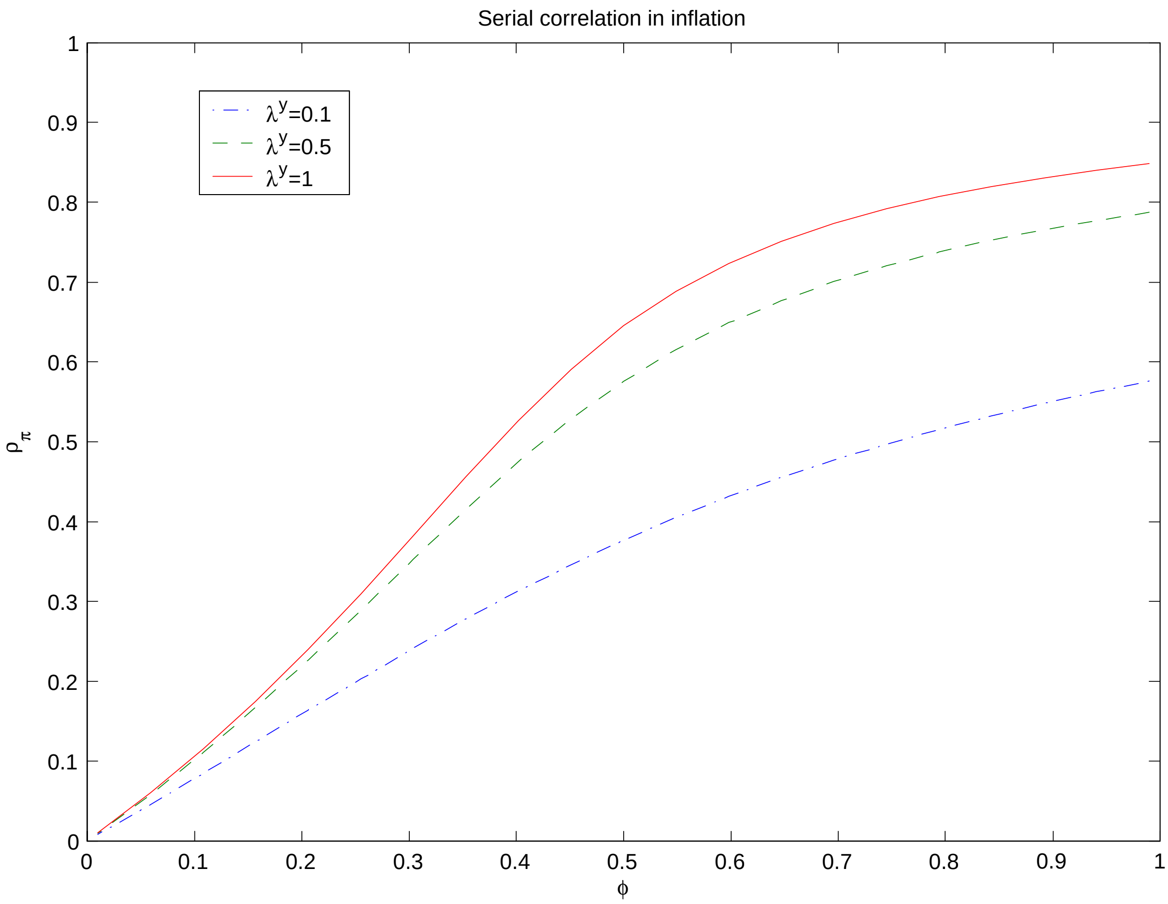

Figure 1: Serial correlation in inflation for optimal discretionary policy, ρ_π, as a function of endogenous inflation persistence, ϕ, and the relative weight on output in the central bank's loss function, λ^y, within an estimated model for the euro area.

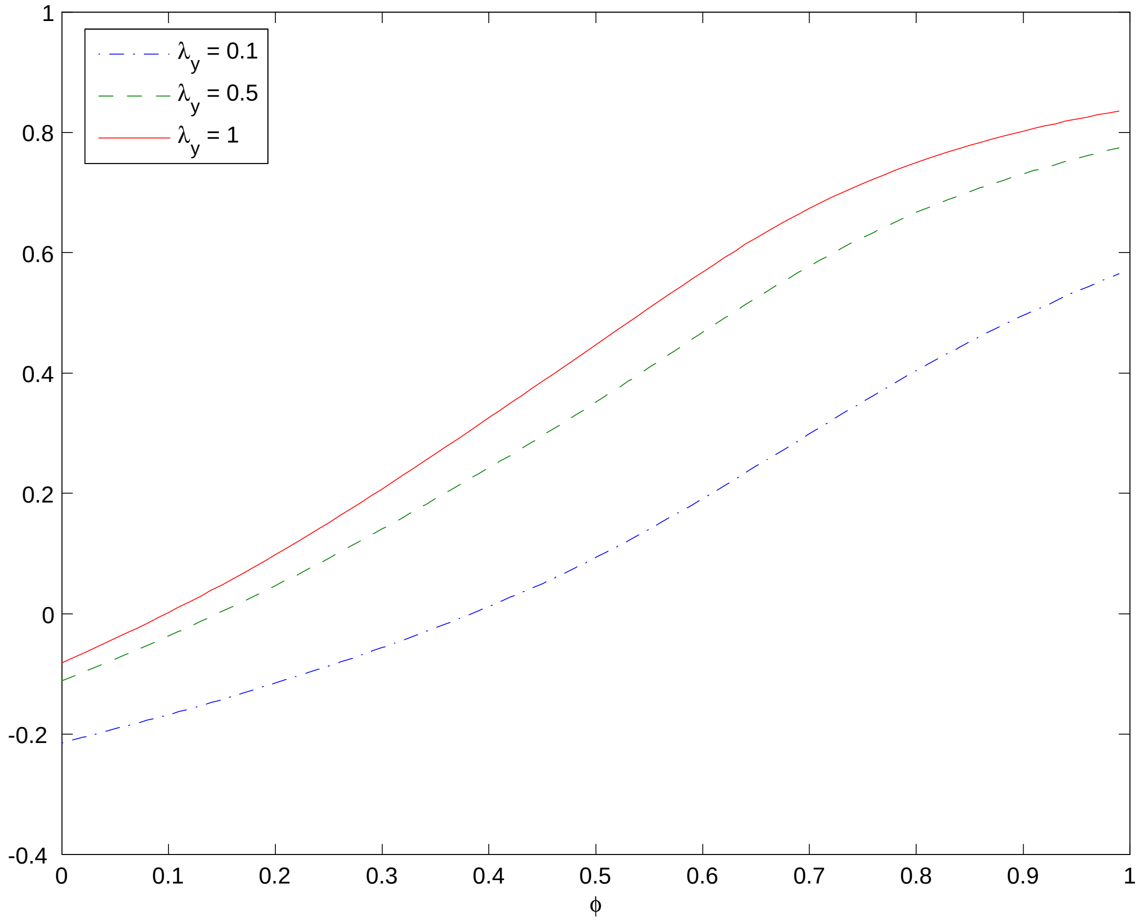

Figure 2: Serial correlation in inflation for optimal policy under commitment, ρ_π, as a function of endogenous inflation persistence, ϕ, and the relative weight on output in the central bank's loss function, λ^y, within an estimated model for the euro area.

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