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New Evidence on Inflation Persistence and Price Stickiness in the Euro Area: Implications for Macro Modelling

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New Evidence on Inflation Persistence and Price Stickiness in the Euro Area:

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Abstract

This paper evaluates new evidence on price setting practices and inflation persistence in the euro area with respect to its implications for macro modelling. It argues that several of the most commonly used assumptions in micro-founded macro models are seriously challenged by the new findings.

JEL classification: E31, E52

1.   Introduction

Inflation persistence and price level stickiness are central issues in conducting monetary policy. Most central banks today accept the notion that monetary policy should be conducted with the aim of stabilising inflation at low levels. Knowing the degree to which the inflation process is "persistent" (that is, the extent to which inflation tends to approach slowly, rather than instantly, its equilibrium level after shocks) gives the central bank vital information on how (how much, how fast, how long) its policy instrument should be adjusted to achieve the desired target. Moreover, the nature of inflation dynamics, as well as the effectiveness of monetary policy, depends to a large extent on the characteristics and patterns of price setting and the associated nominal rigidities. For these reasons, a large body of empirical research over the recent decades has tried to shed light on the question of how much inertia there actually is in price determination and on the dynamics of inflation more generally.

Recognising the importance of these issues, the European Central Bank (ECB) and the National Central Banks (NCBs) comprising the Eurosystem have embarked on a comprehensive research effort (the Inflation Persistence Network – IPN), which investigated both the characteristics of inflation persistence and the patterns and determinants of price setting in the euro area and its member countries.[1] There were at least two main reasons why the Eurosystem should undertake a fresh effort in this field. First, the creation of a new central bank introduced a discontinuity in monetary policy that would potentially change the expectations formation process and the mechanics of price determination. A careful examination of the data in the initial phase of the new regime could help detect the nature and the direction of these changes. Second, the NCBs and the national statistical institutes possess a wealth of disaggregated statistical information on prices, which was mostly unexploited. The Eurosystem, with the ECB at its center, could more easily gather these data and use them in a coordinated way to answer questions of relevance for the conduct of monetary policy. The IPN has thus availed itself of an unprecedented data set, covering a large amount of information at the macro-economic, sectoral and micro level. This information includes the price records underlying the construction of both consumer and producer price indices and one-time surveys on price-setting behaviour of individual firms.

The objective of this paper is to discuss the implications of the new evidence produced by the IPN for macro-economic modelling. The ultimate objective is to use the knowledge about price-setting behaviour at the micro level to improve currently used structural models of inflation, which can then in turn be used to derive policy implications and policy advice. An overview of the main findings of the IPN are presented in the two companion papers. Altissimo et al. (2005) discusses the macro evidence on the degree of inflation persistence, whereas Álvarez et al. (2005) reviews the micro evidence on price setting practices.

This new evidence has important consequences for model-building. Several of the most commonly used assumptions in micro-founded macro models are seriously challenged by the new findings. To put

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[1]   Preliminary findings were presented at a conference hosted by the ECB in December 2004 (see http://www.ecb.int/events/conferences/html/inflationpersistence.en.html). A large number of papers produced within the IPN have been released in the ECB Working Paper Series.

the new evidence into context, this paper starts from a standard stylised model of inflation dynamics and illustrates the main sources of inflation persistence in Section 2. Section 3 then highlights how the new research results can inform and improve model-building. Finally, the last Section concludes.

2. Sources of inflation persistence in a small, stylised model of inflation dynamics

In order to illustrate the potential sources of inflation persistence, in this section we lay out a simple popular model of inflation dynamics. The main building block of this model consists of a structural inflation equation

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t\{\pi_{t+1}\} - \lambda \hat{\mu}_t + \xi_t \tag{1}$$

which relates the evolution of inflation $\pi_t = \Delta p_t$ to its past values π_{t-1}, as well as to the gap between newly optimised prices and the average level of prices. That gap depends, in turn, on (i) the expected path of future inflation $E_t(\pi_{t+1})$ (since firms optimising prices today will seek to offset some of the erosion on their relative price caused by inflation in the period of time until they re-optimise prices again), and (ii) the deviation $\hat{\mu}_t = \mu_t - \overline{\mu}_t$ of the economy's average price mark-up from its frictionless or desired level, so that, on average over the anticipated life of the newly set price, the markup is roughly equal to the optimal one. The coefficient λ gives the sensitivity of inflation to the mark-up gap and is inversely related to the degree of price stickiness. Finally, ξ_t denotes an exogenous shock to desired mark-ups.[2]

Equation (1) can be derived from a micro-founded model of ex-ante identical, monopolistically competitive firms that face a constant probability of being allowed to change their price. As shown in Galí and Gertler (1999), the lagged inflation dependence can be the result of some backward-looking rule-of-thumb behaviour by a fraction of those firms.

Obviously, the mark-up gap will be linked to a measure of economic activity. For simplicity, we postulate the following relationship:

$$x_t = -\alpha \hat{\mu}_t + v_t \tag{2}$$

where $x_t = y_t - y_t^*$ denotes the gap between output and its natural level.[3] v_t can be thought of as an index of the variations in the size of frictions other than price mark-ups (e.g., wage mark-ups, distortionary taxes, etc). Combining (1) and (2) yields an equation often referred to as the hybrid New Keynesian Phillips curve

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t\{\pi_{t+1}\} + \kappa x_t + u_t \tag{3}$$

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[2]   See, e.g., Galí and Gertler (1999) or Smets and Wouters (2003).

[3]   The latter, denoted here by y_t^*, is defined as the equilibrium level of output in the absence of any nominal frictions. For simplicity, we assume that the output gap is expressed in deviations from its mean or steady state level.

with $u_t = \alpha^{-1} v_t + \xi_t$ a *cost-push shock*, which is assumed to follow an AR(1) process with coefficient ρ_u and $\kappa = \lambda / \alpha$.[4]

In such a model, broadly speaking four sources of inflation persistence can be distinguished, corresponding to each of the right-hand-side terms in (1): (i) persistence in the mark-up gap, which will mirror, ceteris paribus, persistent fluctuations in the output gap ("extrinsic persistence"), (ii) dependence on past inflation due to some backward-lookingness in the price-setting mechanism ("intrinsic persistence"), (iii) persistence due to the formation of inflation expectations ("expectations-based persistence") and (iv) persistence in the stochastic error term ("error term persistence"). In the remainder of this section, we will separately discuss those determinants. Nevertheless, it should be emphasized that these sources of persistence may be difficult to distinguish, in theory as well as empirically, since they interact in general equilibrium, and their relative importance will also depend on the monetary policy regime and the policy reaction function.

2.1   Extrinsic Persistence

In the presence of nominal rigidities in price setting[5], a key source of inflation and its variation over time lies in the extent to which average price mark-ups in the economy deviate from their desired levels, now or in the future, for only in that case firms adjusting prices today will want to choose a price different from the average price. The larger is the mark-up gap (current and anticipated) and the greater the fraction of firms adjusting prices at any given time, the larger will be the change in the aggregate price level. In that case the persistence in the average mark-up gap will contribute to determine the persistence of inflation.

But the mark-up gap is an endogenous variable itself, so we need to understand the factors behind its persistence. Consider, for illustrative purposes, a particular case of the model with no lagged inflation dependence or intrinsic persistence ($\gamma_b = 0$). For simplicity we also set $\pi_t^* = 0$ for all t. Then, under rational expectations, equilibrium inflation satisfies $\pi_t = \Lambda_r d_t + \Lambda_u u_t$ where $d_t = r_t^* - z_t$ denotes the interest rate gap and is a measure of the strength of demand, $\Lambda_r \equiv \sigma\kappa / \left(1 + \sigma\kappa\phi - \rho_r \lambda_f\right)$ and

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[4]   To close the model, we relate the output gap linearly to the contemporaneous ex-ante real interest rate, abstracting from more complicated dynamics: $x_t = -\sigma(i_t - E_t\{\pi_{t+1}\} - r_t^*)$, where r_t^* is the natural real rate, defined here as the equilibrium real rate in the absence of any frictions. Finally, interest rates are set by the central bank according to the rule $i_t = E_t\pi_{t+1} + \phi(\pi_t - \pi_t^*) + z_t$, where π_t^* is the inflation target and z_t is an intercept term representing variations in the real interest rate beyond those warranted by deviations of inflation from target. We assume that the "intercept" of the interest rule evolves over time according to the following partial adjustment model: $z_t = r_t^* + \rho_r(z_{t-1} - r_{t-1}^*) - \zeta_r \varepsilon_t^r$. Notice that ρ_r represents the persistence of exogenous variations in the interest rate (un-backed by a corresponding change in the natural rate), as well as the persistence of deviations of the interest rate from the natural rate in response to exogenous variations in the latter. Since they are observationally equivalent in our framework, in what follows we refer to those shocks as *demand shocks*, independently of their source.

[5]   With flexible prices and model-consistent expectations, inflation simply reflects the rate of money growth relative to real potential output growth and equilibrium changes in velocity. Firms would always be able to keep their mark-up at their desired level, so that the mark-up gap would be zero.

$\Lambda_u \equiv 1/\left(1 + \sigma\kappa\phi - \rho_u\lambda_f\right)$. Accordingly, inflation inherits the persistence of both the cost-push and demand shocks.[6]

2.2 Intrinsic Persistence

As shown above, under a purely forward-looking model of inflation ($\gamma_b = 0$), a higher average price duration will reduce the sensitivity of inflation to changes in current and future marginal costs and, in equilibrium, to both demand and cost shocks. But it cannot explain why lagged inflation may enter the inflation equation as an independent factor. Various authors have introduced additional frictions related to indexation or rule-of-thumb behaviour (e.g. Smets and Wouters, 2003 and Galí and Gertler, 1999) to rationalise a lagged inflation term in the hybrid New-Keynesian Phillips curve above. Let us assume for simplicity the absence of any extrinsic persistence. In terms of our simple model this is accomplished by setting $\rho_u = \rho_r = 0$. Once again we assume a zero inflation target and rational expectations.

Under those assumptions equilibrium inflation is now given by $\pi_t = \rho_\pi \pi_{t-1} + b_u \varepsilon_t^u + b_r \varepsilon_t^r$, where $\rho_\pi = \left(1 + \kappa\sigma\phi - \sqrt{(1 + \kappa\sigma\phi)^2 - 4\gamma_b\gamma_f}\right)/2\gamma_f$.

Inflation persistence not only depends on the persistence of the shocks (which is absent in our example), but also exhibits what is often called *intrinsic inflation persistence*. The higher the coefficient γ_b, the higher the degree of intrinsic inflation persistence. For instance, in the model of Galí and Gertler (1999) in which a fraction of firms set prices in a backward-looking fashion, an increase in that fraction raises γ_b and lowers γ_f, thus unambiguously raising inflation persistence. Similarly, in the Smets and Wouters (2003) model with partial backward-looking indexation, the coefficient γ_b will depend on the degree of indexation. Importantly, in the latter model, an increase in the degree of price stickiness (reflected in a lower κ) will also increase the degree of inflation persistence as long as both γ_b and γ_f are strictly positive.

2.3 Expectations-based persistence

Most theories of inflation dynamics accord a significant role to inflation expectations in the determination of inflation. As shown in the discussion above, under the assumption of rational expectations, inflation expectations by themselves will not contribute to the persistence of the inflation process. However, relatively small deviations from the assumption of perfect information can change this result dramatically. Here it suffices to recall two examples.

First, imperfect information about which shocks (e.g. temporary versus permanent) are affecting the economy may lead to more persistent and gradual responses of inflation to shocks. For example, Erceg and Levin (2003) show how learning about the central bank's inflation target can explain the gradual

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[6] Notice that under the assumption that there is no intrinsic persistence (as maintained in the above example), the degree of price stickiness does not affect the persistence of inflation, but only its volatility (through its influence on κ, which is inversely related to price stickiness). However, in more general set-ups, the degree of nominal price stickiness will affect the degree of reduced-form inflation persistence as, for example, discussed in Wolman (1999).

disinflation process during the Volcker era in an otherwise purely forward looking model. Similarly, when private agents have imperfect information about whether a given disturbance to inflation is due to a temporary or permanent supply shock, inflation expectations may adjust only gradually following a purely temporary shock making the inflation response more persistent (e.g. Ehrmann and Smets, 2002).

Second, when private agents use relatively simple recursive learning algorithms to form inflation expectations in the presence of model uncertainty, Orphanides and Williams (2005) show that activist central banks that care a lot about stabilising the output gap may slow down the learning process of agents trying to forecast inflation and may thereby increase the persistence of the inflation process. In this case, the monetary policy regime will affect the formation of inflation expectations and may affect inflation persistence through this channel. Generally speaking, a credible policy regime focused on price stability will reduce the persistence of inflation. For example, Gaspar, Smets and Vestin (2005) find a clear mapping between the monetary policy regime and the distribution of a persistence parameter in the perceived law of motion for inflation.

3. Implications of the new euro area evidence for structural models

The new research results presented in the companion papers (Altissimo et al. 2005; Álvarez et al. 2005) have important bearings on micro-founded macro models of inflation. In this section, we highlight how this evidence sheds light on the underlying assumptions of such models. In particular, section 3.1 considers the extent to which standard macro models are consistent with the macro evidence on inflation persistence. Section 3.2 then compares those models in terms of their ability to match the key features of the micro evidence.

3.1 Consistency with the macro evidence

The standard micro-founded macro models of inflation determination (Calvo, 1983, Taylor, 1999 or Rotemberg, 1982) have often been criticised for not being able to deliver enough aggregate inflation persistence (See, e.g., Fuhrer and Moore, 1995 and Mankiw, 2001). These deficiencies can be addressed by ad hoc adjustments to those models such as the inclusion of automatic indexation of some fraction of the prices (Christiano et al, 2005) or simple rule-of-thumb behaviour by a fraction of price setters (Galí and Gertler, 1999).

However, the bulk of the evidence reported in Altissimo et al. (2005) points to a moderate degree of reduced-form inflation persistence, once occasional shifts in the mean of inflation, which are most likely the result of shifts in the monetary policy regime, are accounted for. Within a stable monetary policy regime, the null of a unit root in inflation is generally rejected. While the estimates of the degree of persistence vary considerably, most shocks to inflation do not appear to have very persistent effects. This finding also seems to be born out by structural estimates of the degree of intrinsic inflation persistence. There is generally a significant role for backward-lookingness, and thus for intrinsic inflation persistence. However, in line with the reduced-form evidence, also structural models find that the degree of intrinsic persistence drops when estimated over more recent samples or over stable monetary policy regimes. For example, for the US Galí and Gertler (1999) find that the weight on the backward-looking component

becomes insignificant when the post-Volcker sample period is considered. Similarly, Coenen and Wieland (2005) and Coenen and Levin (2004) find that a standard Taylor contracting model fits German inflation data, which are characterised by a relatively stable monetary policy regime, quite well. Finally, in the context of a larger DSGE model with many real and nominal frictions, de Walque, Smets and Wouters (2004) find that an inflation model without indexation or a backward-looking component fits the euro area and US data better than one with indexation, when allowing for a time-varying inflation target.

As discussed in Section 2, an important additional channel through which monetary policy can affect the properties of inflation dynamics is by steering the inflation expectations of economic agents. A direct test of the importance of inflation expectations for the dynamics of inflation can be conducted in the framework of a New Keynesian Phillips curve. Whereas most studies assume rational expectations, some model the inflation process through direct measures of inflation forecasts obtained, e.g., from the Survey of Professional Forecasters for the US and from the OECD for the euro area (Adam and Padula 2003; Paloviita 2004; Roberts 1995, 1997). These studies find that the role for explicit backward-looking inflation behaviour (and thus inflation persistence) is significantly reduced, if one allows for bounded rationality in expectations. Consistent with this overall picture, Paloviita (2004) finds that inflation has become more forward-looking in the recent years, and that it has been more forward-looking in the low-inflation countries of the euro area prior to the inception of EMU.

Overall, this evidence suggests that standard micro-founded models can explain the moderate inflation persistence observed in stable monetary policy regimes. In other words, in stable monetary policy regimes the bulk of the observed inflation persistence is due to the persistence in its proximate determinants such as the real margin cost. However, as for example discussed in Coenen and Levin (2004), the macro evidence can not distinguish between the various micro-foundations. In other words, many of the standard micro-founded macro models of inflation are observationally equivalent (Trabandt, 2004). As suggested by the Lucas critique, those micro foundations do, however, matter for policy analysis. In the next section, we therefore use the micro evidence in a first attempt to try to distinguish between the various theories and suggest where the development of new theories may be appropriate.

3.2   Consistency with the micro evidence

In this section, we confront the micro-foundations of some of the most common micro-founded macro models of inflation with some of the stylised facts in European price setting as reported in Álvarez et al. (2005). However, before doing so, it is worth recognizing that any model is necessarily only a rough approximation of the true behaviour of aggregate inflation, such that as a literal description of the micro behaviour, none of those models will pass the test.

3.2.1   Lumpy versus continuous price adjustments

One clear and consistent finding across micro data sets is that in panels of price quotes a large majority of firms typically keep their nominal prices unchanged for some time. This finding is inconsistent with theories of price setting that imply that firms typically change their prices continuously and in small amounts. In particular, this finding provides evidence against the theories of non-convex

price adjustment costs (Rotemberg, 1982), the Calvo models with indexation either to steady-state inflation or past inflation (Yun, 1996 and Christiano et al, 2005) and the sticky information model of Mankiw and Reis (2002). In particular in an environment with positive aggregate inflation, each of those models implies that firms change their prices all the time. They can therefore not explain the large critical mass at zero that distributions of price changes show.

3.2.2   State- versus time-dependent price setting

The surveys conducted by the IPN show that many firms work on the basis of time-dependent reviews that can be amended by state-dependent responses if deemed necessary, e.g. in response to idiosyncratic or large aggregate shocks. In that case, one would expect a bunching of price adjustments when such aggregate shocks occur. As a matter of fact, the micro evidence reported in Álvarez et al. (2005) shows that the frequency of price changes in the CPI price records depends, e.g., on the variability of sectoral inflation and changes in VAT. These findings provide evidence in favour of a state-dependent model such as that of Dotsey, King and Wolman (1999). However, whether it is important to include such features of state dependence will largely be an empirical question and will also depend on the questions one wants to answer.

3.2.3   Time-dependent pricing models: Calvo versus Taylor

As the survey evidence has clearly uncovered that many firms review prices also on a time-dependent basis, the question arises whether this behaviour is better modelled by Calvo or Taylor assumptions, as they imply very different individual price trajectories and levels of synchronisation of price changes across price-setters. In the basic Taylor-contracting model, the length of time in between price changes of an individual firm is constant and there is possibly a relatively high degree of synchronisation of price changes. In contrast, the length of price spells is random in the Calvo set-up, and hence varies over time for the individual price trajectories.

The micro evidence regarding these features is somewhat mixed. The micro price records based on the CPI suggest that the synchronisation of price changes across price setters does not seem to be large at the product level, even within the same country. A closer look at selected individual price records also suggests that the time between price changes varies considerably. However, in all cases, hazard functions of price spells are also characterised by local modes at durations of 12 and 24 months indicating that a fraction of firms may be applying yearly pricing rules, at least some of the time. Overall, it appears, however, that the micro data are more consistent with the Calvo model than the Taylor model. This may not be so surprising when one considers that when Taylor (1980) presented his overlapping contract model he had mostly the labour market in mind.

3.2.4   Sectoral heterogeneity, declining hazard rates and Calvo-mixture models

A robust finding across the various micro studies is that the unconditional hazard functions of price changes are decreasing in the duration of price spells. This contradicts the predictions of the various Calvo and Taylor contracting models that the hazard rates should be constant, or the prediction of state-dependent models that hazard rates should be increasing (approach one as the duration of the price spell

increases). However, Álvarez, Burriel and Hernando (2005) show that a mixture of pure Calvo (1983) price-setting models with different probabilities of price adjustment, corresponding to flexible, intermediate and sticky price setters, may provide a good and relatively parsimonious approximation of the declining hazard functions. This is due to a composition effect: as time elapses the share of less flexible firms decreases thereby reducing the average frequency of price adjustment. Similarly, a number of micro studies show that the hazard functions do become flatter or become moderately increasing when one controls for heterogeneity (Aucremanne and Dhyne 2005, Dias, Robalo Marques and Santos Silva 2005). Accordingly, a Calvo-mixture model can account for a number of the micro stylised facts: (i) the largely random nature of price adjustments; (ii) the common finding of declining unconditional hazard rates; and (iii), importantly, the robust finding that the frequency of price changes differs in a systematic way across sectors. In addition, explicitly accounting for a certain degree of heterogeneity in price setting may help in explaining the degree of persistence at the macro level.

Of course, the Calvo model still relies on the fact that ex-ante all firms within the same monopolistic sector are identical. It can, therefore, not account for the large price adjustments (both positive and negative) that are observed at the micro level within any given sector. These large positive and negative price changes suggest the presence of large idiosyncratic shocks (see Golosov and Lucas, 2003). Large idiosyncratic shocks can also explain why firms appear to change their prices randomly. However, for the behaviour of the aggregate, positive and negative idiosyncratic shocks might wash out, such that only the response to aggregate shocks is observed (Danziger 1999; Gertler and Leahy 2005). Under such conditions, the Calvo model may indeed be a good approximation of the macro dynamics of inflation.

3.2.5 Rule of thumb behaviour and sticky information

One advantage of the rule-of-thumb Calvo model proposed by Galí and Gertler (1999) is that it is consistent with the observation that prices only change infrequently. At the same time, it delivers an observationally equivalent reduced-form inflation equation as the Calvo model with indexation to past inflation. Similarly, Trabandt (2004) shows that this model has very similar implications as the sticky-information model of Mankiw and Reis (2002). What is the evidence on rule-of-thumb behaviour?

At this point, the evidence is rather mixed. First, continuous automatic indexation of prices or analogous rule-of-thumb behaviour would imply that price changes would cluster around average or past inflation. Instead, the average change (whether positive or negative) is typically much larger. Second, the survey evidence suggests that firms do not perceive the costs of collecting and processing information as one of the main reasons for price stickiness. On the other hand, as discussed in Álvarez et al (2005), those surveys that inquired about the degree of forward-lookingness of firms price-setting, did find some evidence of rule-of-thumb behaviour such as indexation to past inflation.

3.2.6 The role of customer markets, coordination failures and fair pricing

There is quite a bit of evidence that customer markets play an important role in price setting. For example, the frequency of price changes in large supermarkets is much higher than in corner shops where customer relationships are probably firmer. Similarly, explicit and implicit contracts are perceived as the most important reason for price stickiness in the producer sector, where long-term relationships are

relatively important. Another finding from the survey papers is that coordination failures are an important factor behind price rigidities. This may explain why in those samples time dependence may be relatively more important than in the retail sector

Finally, the evidence on asymmetries in the way prices increase or decrease in response to changes in costs and demand suggest that theories based on fair pricing as developed by Rotemberg (2004) may be important. Overall, most micro-founded macro models of inflation have used the model of monopolistic competition of Dixit and Stiglitz as the model of the underlying market structure. The various pieces of evidence presented above suggest that more complicated market structures may well be important. One question for macro modellers is how to take these considerations into account, while at the same time retaining tractability at the macro level.

4.   Conclusions

Drawing monetary policy implications from the wealth of micro evidence on the features of price setting in the euro area summarised in Álvarez et al (2005) requires structural macro models that are consistent with that evidence. At this stage, much more work needs to be done to build such models. Several of the most commonly used assumptions in micro-founded macro models have been seriously challenged by the new findings. At the same time, however, it is important to keep the models analytically tractable, while ensuring realistic simulation and forecasting properties. We have argued that a version of the basic Calvo model (possibly extended to allow for sectors with different degrees of price stickiness) may not be a bad approximation. An important question for future research will be to see which micro features are important to capture and which ones are not for the macro-economic and policy analysis.

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