Inflation persistence: alternative interpretations and policy implications*

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Abstract

In this paper I consider the implications of two alternative interpretations of the observed persistence in inflation, that correspond to two alternative specifications of the New Keynesian Phillips curve. The first allows for some degree of intrinsic persistence, in the form of a term in lagged inflation in the *NKPC*. The second is a purely forward-looking model, where expectations farther into the future matter, and where coefficients are time varying. This specification attributes most of the observed persistence to the persistence of the underlying inflation trend, which is a consequence of monetary policy, rather than a structural feature of the economy. With a simple quantitative exercise I illustrate the consequences of implementing monetary policy assuming a degree of persistence different from what is in the economy. The results suggest that the costs of implementing stabilization policy overestimating the degree of intrinsic persistence are potentially higher than the costs of ignoring an existing persistence; the result is more clear cut in the case in which the policymaker minimizes a welfare-based loss function.

PRELIMINARY DRAFT

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1 Introduction

Inflation persistence is defined as the time that it takes for a shock to inflation to dissipate. For central banks, whose task is to stabilize inflation at low levels, it is extremely important to understand the nature of this process. Univariate analyses, based on the size of the highest autoregressive root, or multivariate analyses based on impulse response functions, show that inflation is a highly persistent process, but less agreement exists on whether inflation persistence is an inherent characteristic of the economy, or instead depends on the specific historical sample considered. And if the degree of persistence is sample-specific, on what are the factors that determine changes in the degree of persistence over time.

Recent work by Cogley and Sargent (2006) and Stock and Watson (2005) favour the view that there has been a substantial variation in U.S. inflation persistence over time, associated with changes in the monetary policy regime, while Pivetta and Reis (2006) do not find statistically significant evidence to support this claim. Benati (2006) analyzes the evolution of inflation persistence across countries and across historical monetary regimes and observes that the degree of persistence of inflation appears to have varied a lot, and to have been lower in periods where there was a clearly defined nominal anchor.

To understand the source of persistence, we typically need structural models. Many modern macro models for policy analysis incorporate a process for inflation dynamics derived from a discrete-time version of the Calvo price setting model. In its baseline formulation, this is a purely forward-looking model, where inflation depends on real marginal costs and expected future inflation. To accommodate the observed persistence in inflation data, two main variants of the model have been proposed in the literature. They both require some ad hoc assumptions about the price-setting process in order to generate a dependence of inflation on some past values of inflation. The first variant was introduced by Gali and Gertler (1999) with a simple modification of the Calvo model. They assumed that a proportion of the firms randomly assigned to change their price would follow a rule of thumb, and set prices as a weighted average of the optimal prices set in the previous period plus an adjustment for expected inflation, based on lagged inflation. An alternative modification, obtained assuming that the firms not assigned to optimize would index their price to aggregate inflation of the previous period, was later introduced by Christiano et al (2005), and modified to allow for only partial indexation.[1]

[1] For single equation estimates of the Calvo model with indexation see, among others, Eichenbaum and Fisher (forthcoming), and Sbordone (2005).

The reduced form of these two variants of the Calvo model is similar, in that both generate a backward-looking component in the equation. In the first case the weight on this component depends on the proportion of rule-of-thumb firms, and in the second it depends upon the indexation coefficient.[2] Of the two, indexation is a less appealing modeling strategy because it implies that prices are revised at every point in time, which contradicts empirical evidence that some prices are fixed for a certain amount of time (the very reason why models with nominal rigidities were developed!). Single equation estimates of these augmented models find a small, but statistically significant coefficient on past inflation and find that the introduction of a lag in inflation helps fitting the data better than purely forward-looking models. The coefficient on past inflation is typically estimated to be about .2-.3, depending on other specifications of the model.[3]

In two recent papers with Tim Cogley (Cogley -Sbordone (2005, 2006) I instead estimate a new Keynesian Phillips curve (*NKPC)* taking into account the existence of a slow-moving inflation trend. We derive a variant empirical version of the Calvo model by log-linearizing the model around a time-varying inflation trend, and obtain a *NKPC* with a more forward-looking dynamics than the baseline Calvo model. Expectations of inflation gap further in the future matter, and the coefficients of the *NKPC* depend upon inflation trend: the sensitivity of inflation to marginal cost decreases for higher levels of trend inflation, while the weight on future expectations increases. Our estimates of this specification of the *NKPC* favor a purely forward-looking model for the inflation gap, which we define as deviations of inflation from trend. The absence of a significant intrinsic persistence in the inflation gap implies that the persistence of overall inflation is driven by the persistence of its underlying trend - which is a consequence of monetary policy, rather than a structural feature of the economy.

We were not the first to estimate a long-run moving trend in inflation. Our analysis in fact explores the implication for structural analysis of the results of Cogley and Sargent (2005) on reduced form analysis: they first applied models with time varying coefficients to explore changes over time in the persistence and volatility of inflation, unemployment, and interest rates.

At the same time, a number of small-scale general equilibrium models for policy analysis model inflation as evolving around a long-run trend, which is identified with the inflation objective of the policymaker. These models, unlike ours, assume the existence of intrinsic

[2] In the specifications that assume a unit indexation coefficient the equation is estimated in the rate of growth of inflation, rather than in levels.

[3] See Gali and Gertler (1999),Gali, Gertler and Lopez-Salido (2000, 2005), Sbordone (2005, 2006).

inflation persistence by introducing both indexation to past inflation and also a partial indexation to trend inflation, and obtain an empirical form of *NKPC* of the standard type, where inflation depends upon a lag of inflation, the expected future value of inflation, and current marginal costs (e.g. Smets and Wouters 2003, 2005, Ireland 2005). Because of the assumed indexation, the coefficients of the *NKPC* in these models do not depend upon the level of trend inflation, as in our model. The indexation parameter to past inflation estimated in these models vary, and can be as high as .5 in the Smets and Wouters model.[4]

The absence of intrinsic persistence, and the attribution of inflation persistence to persistent movements in trend inflation squares with several other results in the literature. Altissimo et al. (2006) summarize research done within the Eurosystem Inflation Persistence Network. They find that, for aggregate data, although inflation persistence is very high for samples spanning different decades, it falls dramatically once one allows for time variation in the mean level of inflation. They further find that the timing of the breaks in mean inflation correspond to observed breaks in the monetary policy regime.

In light of this evidence, and considering that policymakers most often base policy decisions on models that postulate a substantial degree of inflation persistence, in this paper I investigate the policy implications of assuming alternative structural interpretations of observed inflation persistence. In particular I ask the following question: are there costs in accommodating inflation when inflation persistence is not intrinsic? Is there the risk that a wrong policy response may translate temporary shocks to inflation into more persistent fluctuations?[5]

To address these issues I focus on two alternative specification of the inflation dynamics, which correspond to the two alternative interpretations of inflation persistence discussed: one is the rule-of-thumb model introduced by Gali and Gertler (1999) and the other is the model with varying trend inflation estimated by Cogley and Sbordone (2006).

In a first exercise I incorporate the inflation dynamics of the Cogley-Sbordone model in a very stylized model of the economy, and ask whether it is possible to infer spuriously some degree of intrinsic persistence in the data. Specifically, I ask whether one would detect a statistically significant coefficient on lagged inflation when estimating the *NKPC* on data

[4] There are other lines of research that show reasons for spurious estimate of a backward-looking component. For example, Milani (2005) estimates a model with shifting inflation trends and reports parameters on backward-looking terms close to zero. Kozicki and Tinsley (2002) find that shifts in the long-run inflation anchor of agents expectations explain most, but not all of the historical inflation persistence in U.S. and Canada.

[5] This is the interpretation that Ireland (2006) gives to his results.

generated from an economy without intrinsic persistence.

Then I consider the two alternative models to conduct a quantitative evaluation of optimal monetary policy. In particular, I consider what are the implications of implementing optimal stabilization policy under assumptions about the persistence of inflation that differ from what the true model implies.

The rest of the paper is organized as follows. In the next section I discuss the characteristics of the two alternative models of inflation persistence, discussing in more detail the model with trend inflation, as it is less known in the literature. Then in section 3 I discuss whether it is possible to make wrong inference on intrinsic persistence from data generated in an economy characterized by a *NKPC* with these characteristics. In section 4 I present an analysis of the optimal response of the economy to cost-push shocks: I first consider the case of optimization based on an ad hoc loss function, and then the case of a welfare-based optimal policy. Section 5 concludes.

2 Inflation persistence: alternative interpretations

In the *NKPC* derived from the standard discrete-time version of the Calvo model with random interval between price changes, inflation depends upon current marginal costs s_t and expected future inflation:

$$\pi_t = \zeta \ s_t + \beta E_t \pi_{t+1} \tag{1}$$

The coefficient on the marginal cost is a non linear combination of structural parameters that may vary depending on the specific market structure assumed. At the minimum, it includes the probability of price changes, which I will denote throughout this paper by α, and the discount factor β: $\zeta = (1-\alpha)(1-\alpha\beta)/\alpha$. In models with some form of strategic complementarity the coefficient may also depend upon the elasticity of substitution among differentiated goods, and the elasticity of marginal cost to firms' output, parameters that I denote respectively by θ and ω. For example $\zeta = (1-\alpha)(1-\alpha\beta)/\alpha(1+\theta\omega)$.[6] This richer specification decouples the degree of nominal rigidity from estimates of the coefficient of marginal cost.

The variant of the Calvo model introduced by Gali and Gertler (1999) implies that the

[6] The *NKPC* model estimated by Cogley-Sbordone (2005, 2006) includes this form of strategic complementarities. For an analysis of other specifications of strategic complementarities, and their implications for monetary policy, see Levin, Lopez-Salido and Yun (2006).

model includes a lagged inflation term, to become

$$\pi_t = \widetilde{\zeta}\ s_t + \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1} + u_t. \tag{2}$$

The lagged inflation term appears because they assume that a fraction χ of rule-of-thumb firms set prices as a weighted average of the optimal prices set in the previous period plus an adjustment for expected inflation, which is based on lagged inflation. Gali and Gertler (1999) do not allow for strategic complementarities: when the fraction $\chi \to 0$, the equation is again (1). The coefficients of the forward and backward-looking terms depend upon the fraction χ as well, and their sum is approximately equal to 1 (it is exactly 1 for $\beta = 1$), making the equation similar to other hybrid Phillips curve formulations in the literature (e.g. Fuhrer and Moore 1995). Models with partial indexation to past inflation can also be written in the form of eq. (2), where the coefficient of past inflation depends upon the degree of indexation, and again the coefficients of the forward and backward-looking terms sum to one when $\beta = 1$.

The *NKPC* in either the form of eq. (1) or eq. (2) is derived as a log-linear approximation to the exact non-linear inflation dynamics described by the Calvo model, where the log-linearization is taken around a steady state with zero inflation: this is a conventional approximation useful for normative studies, since inflation should be close to zero under an optimal policy rule. But in the historical periods covered by the empirical analyses - typically some subsample of the post-WWII period, inflation is often substantially above zero. This raises a question as to how accurate the log-linear approximation used in this empirical work may be. Moreover, because the degree to which inflation exceeds zero has been subject to fairly persistent fluctuations, the approximation error may substantially affect the estimated degree of intrinsic persistence.

To address this problem, the variant of the Calvo model estimated in Cogley and Sbordone (2006) takes the following form:[7]

$$\widehat{\pi}_t = \widetilde{\varrho}_t \widehat{\pi}_{t-1} + \zeta_t\ \widehat{s}_t + b_{1t} E_t \widehat{\pi}_{t+1} + b_{2t} \sum_{j=2}^{\infty} \varphi_{1t}^{j-1} \widehat{\pi}_{t+j} + u_t. \tag{3}$$

Unlike the previous equations, this specification is derived by log-linearizing the non-linear equilibrium conditions of the Calvo model around a steady state with a time-varying trend

[7] This form of the model is correct under the assumption of log-utility. Otherwise it includes some further terms in future expected values of output growth and the discount factor. We considered the restricted form (4) because of evidence that the coefficient of the extra terms were empirically insignificant.

inflation. The hat variables are log-deviation of inflation from trend: $\widehat{\pi}_t = \ln(\pi_t/\overline{\pi}_t)$, and marginal cost from trend: $\widehat{s}_t = \ln(s_t/\overline{s}_t)$, where $\overline{\pi}_t$ and $\overline{s}_t$ indicate trend variables.[8] The coefficients are indexed by t because they depend upon inflation trend $\overline{\pi}_t$, as does the value of $\overline{s}_t$; and they also depend upon the primitives of the Calvo model, the probability of changing prices and the elasticity of demand, which are the parameters that we estimate. Our estimation procedure is based on the moment conditions derived by enforcing the restrictions that the model places on a reduced form *VAR* of inflation and unit labor costs (this variable proxies the unobservable marginal cost in the model, as in most variants of empirical *NKPCs*). This reduced form *VAR* is a model with time varying coefficients and stochastic volatility, which we estimate jointly with the parameters of the Calvo model. We then use the estimated *VAR* model to compute the implied inflation trend.

The coefficient on lagged inflation $\widetilde{\varrho}_t$ depends on the indexation parameter to past inflation, a feature that we include to allow for possible intrinsic persistence: its value is zero when the indexation parameter is zero. Our preferred specification, in fact, excludes lagged inflation, since we find that the indexation parameter is very small, and that a model without indexation is statistically preferred. We have then

$$\widehat{\pi}_t = \zeta_t \, \widehat{s}_t + b_{1t} E_t \widehat{\pi}_{t+1} + b_{2t} \sum_{j=2}^{\infty} \varphi_{1t}^{j-1} \widehat{\pi}_{t+j} + u_t. \tag{4}$$

We conjecture that the contrast between our result and those that find, in the same data, a statistically significant role for the lag of inflation arises because lagged inflation may proxy for omitted terms in the *NKPC*, that is, for the additional forward-looking terms that appear in our more precise approximation to the model when the inflation trend is non-zero.

We conclude that inflation deviations from trend do not show intrinsic persistence, and that the persistence of overall inflation is driven by the persistence of its underlying trend. Rather than a structural feature of the economy, inflation persistence appears to be a consequence of the way monetary policy has been conducted.

It is worth to report at this point two results from Cogley-Sbordone (2006). Figure 1 graphs the estimated inflation trend, actual inflation and average inflation for the period 1960-2003, both expressed at annual rates. As the figure shows, the trend is a quite persistent process, hovering around an average of 1.6 percent annually over the period 1960-2003, but rising to slightly above 7 percent in the late ‘70s.The figure suggests that the properties of

[8] For more details on the derivation of this equation, and the estimation procedure, see Cogley-Sbordone (2006).

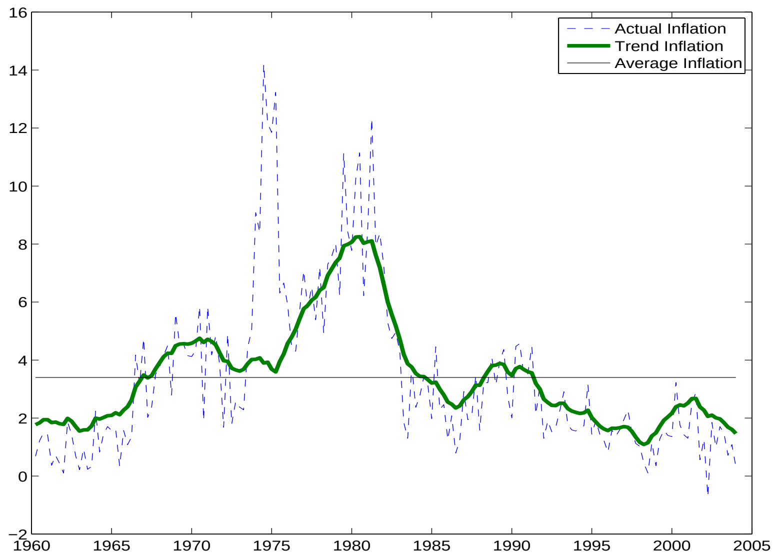

Figure 1: Inflation, trend inflation and average inflation

the inflation gap depend to a large extent upon its measurement. A gap defined as deviation from a constant mean has a great deal more persistence than a gap measured as deviation from the trend. This is also shown in table 1 (again taken from Cogley and Sbordone 2006), which reports the serial correlation of two measures of inflation gap. The first assumes a constant trend equal to the sample average of inflation over the period, while the second, labeled trend-based inflation gap, is computed as deviation of inflation from the trend that we estimate, as described, by imposing the restrictions of the forward-looking model (4).

Table 1: Autocorrelation of the Inflation Gap

	1960-2003	1960-1983	1984-2003
Mean-based inflation gap	0.835	0.819	0.618
Trend-based inflation gap	0.632	0.664	-0.038

The table clearly suggests that the inflation gap measured as deviation from trend has substantially less persistence than the gap measured as deviation from the mean. The difference is particularly striking over the second subsample, when the trend-based gap is close to white noise. Both the figure and the table illustrate how the need for introducing backward-looking component in structural models of inflation dynamics may derive from an inadequate measure of the inflation gap that leads to overemphasize the persistence that such models are asked to explain.

3 Can intrinsic persistence be spurious?

The question I ask at this point is whether the persistence detected in estimated *NKPC* models may be spurious, arising from the fact that the empirical model is constructed to explain inflation deviations from an assumed zero steady state. If, in the sample considered, the economy is characterized by a drifting inflation trend, the appropriate specification of inflation dynamics should be as in eq. (4) instead. To evaluate whether estimating an equation of the kind (2) on data from an economy where inflation dynamics is of the kind in (4) would detect intrinsic inflation persistence, I construct a sample economy, where the NKPC has the form (4), and the underlying inflation trend has the properties of the one estimated in Cogley-Sbordone (2006). I complete the economy with a very simple specification of the demand side and of the policy rule of a kind common in the literature, and with a number of shocks that may generate temporary departures of inflation from trend. I then ask whether in this economy, with a standard econometric technique, we would make a correct assessment of the degree of intrinsic inflation persistence.

For simulating the sample economy, it is convenient to use a recursive representation for eq. (4). This is obtained by defining an auxiliary variable $\widehat{D}_t$ that represents the further forward-looking terms in the equation.[9] The model economy is then composed of the following equations:

$$\begin{aligned}
\widehat{\pi}_t &= \zeta_t \ \widehat{s}_t + \phi_t E_t \widehat{\pi}_{t+1} + \gamma_t \widehat{D}_t \\
\widehat{D}_t &= g_{1t} E_t \widehat{\pi}_{t+1} + g_{2t} E_t \widehat{D}_{t+1} \\
\widehat{s}_t &= \widetilde{\omega} \widehat{Y}_t + \mu_t \\
\widehat{Y}_t &= E_t \widehat{Y}_{t+1} - \sigma \left(i_t - E_t \pi_{t+1} - r_t^n \right) \\
i_t &= i_{t-1} + \phi_\pi \widehat{\pi}_t + \phi_x \left(\widehat{Y}_t - \widehat{Y}_{t-1} \right)
\end{aligned} \tag{5}$$

The first two represent the *NKPC* with trend inflation discussed before. Note that when trend inflation is zero, the coefficient of $\widehat{D}_t$ is zero, and the coefficients ζ_t and ϕ_t become time invariant, reducing the equation to the standard formulation (1). The third describes the

[9] A derivation of the recursive representation is in the appendix of Cogley-Sbordone (2006). A similar derivation, for the case of a constant trend inflation, is in Ascari - Ropele (2006).

relation between marginal cost and output, and the fourth has the form of an intertemporal *IS* equation describing the evolution of output. A process for the interest rate closes the model. This process can be thought as a version of the model used by Gali (2003). The interest rate process is in fact just a way of rewriting a money demand equilibrium, where money supply follows a unit root process. The coefficient of inflation is the inverse of the interest rate (semi) elasticity, and the one on output is the ratio of the output and the interest elasticities of money demand.[10] Hat variables denote again deviations from steady state. The steady state of this economy is characterized by slowly evolving trend inflation and trend labor share (the proxy for the theoretical marginal cost): $\widehat{\pi}_t = \ln \pi_t - \ln \overline{\pi}_t$, and $\widehat{s}_t = \ln s_t - \ln \overline{s}_t$. The values for trends $\overline{\pi}_t$ and $\overline{s}_t$ are those of the estimated series in Cogley-Sbordone (2006), as are the values calibrated for underlying parameters of the Phillips curve, the probability of changing price, set at its posterior mean $\alpha = .55$, and the elasticity of demand $\theta = 12.3$. The coefficients of the *NKPC* are nonlinear function of these, and of other calibrated parameters, and of the inflation trend, and computed accordingly.[11] The dynamics of the economy is driven by shocks to the marginal cost, μ_t, and natural rate shocks r_t^n. Both disturbances are assumed to follow autoregressive processes, with serial correlation respectively of $\varrho_r = .8$ and $\varrho_\mu = .2$.[12] The other parameters are calibrated to values used elsewhere in the literature: $\sigma = 6.25$, the value estimated in Rotemberg-Woodford (1997)[13], $\phi_\pi = \phi_Y = .03$, on the assumption of an income elasticity of 1, and an interest semi-elasticity of 28.

I use this economy to create *100* samples of length equal to the actual series of the inflation used in Cogley-Sbordone. Initial values are chosen to represent the economy at the beginning of the sample, which is 1960:Q1, and the economy is simulated forward for 176 periods, the length of the period for which inflation trend was estimated. The coefficients of the *NKPC* depend upon $\overline{\pi}_t$, and vary with it. I take as initial value for the trend $\overline{\pi}_0 = \overline{\pi}_{60:q1}$ the estimated value of trend inflation for the first period.

Collecting all the parameters in a vector ψ, we have that at any time t, given $\psi_t = (\psi, \overline{\pi}_t)$ there is a unique solution to the dynamic system that describes the evolution of $\widehat{\pi}_t, i_t$

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[10] The choice of this form of interest rate process is suggested by the fact that it assures a determinate equilibrium for all the values of trend inflation considered in the model. The problem of indeterminacy in the case of a standard Taylor rule for high values of trend inflation is discussed by Ascari (2004).

[11] Their expressions are $\zeta_t = \frac{1-\alpha\beta\overline{\pi}_t^\theta}{1+\theta\omega}\frac{1-\alpha\overline{\pi}_t^{\theta-1}}{\alpha\overline{\pi}_t^{\theta-1}}$, $\phi_t = \beta\overline{\pi}_t^{1+\theta\omega}$, $\gamma_t = \frac{1}{1+\theta\omega}\frac{1-\alpha\overline{\pi}_t^{\theta-1}}{\alpha\overline{\pi}_t^{\theta-1}}\left(\overline{\pi}_t^{1+\theta\omega} - 1\right)$, $g_{2t} = \alpha\beta\overline{\pi}_t^{\theta-1}$ and $g_{1t} = (\theta-1)g_{2t}$. $\overline{\pi}_t$ is the gross inflation rate. See Cogley-Sbordone (2006) for further details.

[12] I assume that the natural rate follows a process $r_t^n = (1-\varrho_r)r + \varrho_r r_{t-1}^n + \varepsilon_{r,t}$ and calibrate the mean r to the average value of the real interest rate in the sample.

[13] This is reported in table 5.1 of Woodford (2003) p.341.

and $\widehat{Y}_t$, as function of state variables and shocks. From this solution I compute the one step forward value for the endogenous variables as the next realization, and repeat the same steps for the number of desired observations.

I therefore obtain simulated series for inflation, marginal cost, output and interest rate. On the series generated in this way I then run reduced form estimates of the type introduced by Gali and Gertler (1999) and since then successfully estimated for various countries in different time periods. Specifically I estimate on the mean inflation gap a hybrid model of the form (2) allowing for a disturbance u_t :

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t \pi_{t+1} + \zeta s_t + u_t.$$

Denoting by Z_{t-1} a set of variables dated $t-1$ and earlier, the assumption of rational expectations and the assumption that the error term u_t is an i.i.d. process imply the following orthogonality condition

$$E_{t-1}\left\{\left(\pi_t - \gamma_b \pi_{t-1} + \gamma_f \pi_{t+1} + \zeta mc_t\right) Z_{t-1}\right\} = 0.$$

I exploit this condition for estimation, using a parsimonious set of instruments, which include two lags of real marginal cost, output gap, interest rate and inflation. As Gali et al. (2005), I consider both an unconstrained estimate, and one where the coefficients of future and past inflation are constrained to sum to 1.[14] The table reports two sets of results, one relative to the whole sample created, the other to a shorter sample 1960:Q1 to 1997:Q4, as in the original work of Gali and Gertler (1999). For each coefficient, I report the 16 and 84 percentiles of the estimated values.

Estimate of a hybrid standard *NKPC*				
	ζ	γ_b	γ_f	$J_{p-value}$
Full sample				
unrestricted	[.023,.046]	[.148,.201]	[.602,.739]	[.876,.010]
$\gamma_b + \gamma_f = 1$	[.011,.014]	-	[.798,.907]	[.218,.011]
1960:1-1997:4				
unrestricted	[.022,.044]	[.136,.202]	[.618,.756]	[.750,.062]
$\gamma_b + \gamma_f = 1$	[.009,.013]	-	[.795,.893]	[.234,.010]

From the results in the table, we would not reject the hypothesis that there exists a statistically significant source of intrinsic persistence in inflation dynamics. The intuition

[14] This is imposed by estimating the model as $\pi_t - \pi_{t-1} = \gamma_f \left(\pi_{t+1} - \pi_{t-1}\right) + \zeta mc_t$.

for the spurious result is that past inflation is correlated with the omitted future inflation terms, creating upward bias in the coefficient of past inflation. This correlation is itself due to the serial correlation existing in the generated series.

4 Policy implications: optimal response to cost-push shocks

I now turn to consider the implications for monetary policy of the two structural interpretations of inflation persistence discussed in section 2. One is the hybrid *NKPC*, and the other is the model that takes account of the dependence of *NKPC* coefficients on inflation trend, which now is identified with the inflation objective in the policy loss function.

I conduct a quantitative exercise to evaluate the optimal stabilization policy in response to small cost-push shocks. I consider first the case of an ad hoc quadratic loss function, and then the case of a welfare-based loss function, and evaluate the optimal response to cost push shocks in the case in which the policymaker believes, alternatively, in one of the two different models. (The same ad hoc loss function is assumed in both cases, but the welfare-based loss function is different for each model.) Given the optimal response, and assuming a certain form of the policy rule, I evaluate the equilibrium outcome in terms of the path of inflation, output and interest rate. The objective is specifically to discuss the role played by different assumptions about inflation persistence as represented by the two different forms of the *NKPC*. I construct two model economies that differ only for the supply side assumptions. The rest of the economy is, in both cases, described by an intertemporal IS equation and a simple Taylor rule, where the interest rate responds to the output gap, and to deviations of inflation from target. In addition, the intercept of the Taylor rule is a function of the cost-push shocks, in a way that will be explained below.

To evaluate the cost of implementing monetary policy using a wrong model of the economy I then evaluate how the equilibrium path of output, inflation and interest rate is affected when the true model of the economy is indeed different from the model used by the policymaker. In this case the equilibrium path of output and inflation will be different from the optimal path, and I can compare the cost, in terms of cumulative discounted loss, of using a 'wrong' model for policy, specifically of over or underestimating the degree of intrinsic persistence.

I calibrate the *NKPC* curves in the two models to the parameter values estimated in the single equation models discussed: the Cogley and Sbordone (2006) model for the forward-looking model with trend inflation, and the Gali, Gertler and Lopez-Salido (2005) model for the rule-of-thumb model.

This analysis builds on existing analyses in the literature. Optimal monetary policy in the presence of inflation inertia has been analyzed quite thoroughly by Steinsson (2003) on a generalization of the rule-of-thumb model developed by Gali and Gertler (1999). He analyzes the optimal response of output and inflation to a cost push shock under different assumptions about the policymaker's loss function, whether ad hoc or welfare-based, and under different assumptions about the degree of commitment. He considers the case of i.i.d. cost push shocks, which he derives as a combination of shocks to the elasticity of demand and shocks to the tax code.[15]

In this analysis I uses the specification of Gali and Gertler (1999), and consider both the case of i.i.d. shocks and the case of mildly serially correlated shocks.

For the case of the purely forward-looking model with non-zero inflation, optimal monetary policy has been analyzed by Ascari-Ropele (2006). They find that in response to cost-push shocks in the case of zero trend inflation, there is an aggressive deflation, and a persistent adjustment of the output gap, engineered through an increase in the interest rate; the higher is the level of trend inflation, the smaller the response of the output gap and of the interest rate that is optimal.

The key factors that shape the response to a cost push shock in the calibrated models are the parameters of the loss function, namely the relative weight on the output gap, the persistence of the shock, and the degree of intrinsic inertia: without inertia, the response of inflation to i.i.d. shocks has its maximum at impact, and may be followed by a short period of deflation, and output also has maximum decline at impact. The slope of the Phillips curve matters as well: higher sensitivity of inflation to marginal cost, for a given proportionality of the latter to output gap, reduces the 'optimal' response of output consistent with the inflation response.

[15] Among his results are that in the case of a traditional loss function an increase in the backward-looking component of the *NKPC* implies that the optimal response of inflation is lower in the period of the shock and more persistent, and that increasing the backward-looking component reduces the impact response of the output gap, and makes it less persistent.

4.1 Ad hoc loss function

The first economy I consider is described by the following three equations:

$$\pi_t = \gamma_b \pi_{t-1} + \gamma_f E_t \pi_{t+1} + \kappa x_t + u_t \tag{6}$$

$$x_t = E_t x_{t+1} - \sigma(i_t - E_t \pi_{t+1}) \tag{7}$$

$$i_t = \bar{i}_t + \phi_\pi (\pi_t - \overline{\pi}_t) + \phi_x x_t, \tag{8}$$

The first describes inflation dynamics by a rule-of-thumb *NKPC* model, where x_t is a measure of the output gap, and u_t is a cost-push shock; in this baseline specification I assume that u_t is an i.i.d. process, but then consider also the case of a small serial correlation: $u_t = \varrho_u u_{t-1} + \varepsilon_t$, where ε_t is white noise, and $\varrho_u = .2$. The second equation is an intertemporal *IS* equation, and the third is the policy rule. $\overline{\pi}_t$ is the long run target of the policymaker, and the intercept of the Taylor rule, $\bar{i}_t = \bar{i}(u_t, u_{t-1}, u_{t-2}, ...)$, embeds the policy rule: $\bar{i}_t$ is the response to cost-push shocks that would allow one to implement the optimal path of inflation and output gap in response to the shock u_t, according to the model used by the central bank, This function is constructed to assure that, if the policymaker has the true model of the economy, the equilibrium paths of output gap and inflation are exactly those that are optimal under the postulated loss function.[16]

The policymaker minimizes the following discounted loss function

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

where the instantaneous loss is specified as

$$L_t = \frac{1}{2} \left((\pi_t - \overline{\pi}_t)^2 + \lambda x_t^2 \right),$$

subject to the constraint that the aggregate supply function is satisfied at each t.[17] The optimal paths of inflation and output gap that solve this problem allow to recover, through eq. (7), the interest rate path consistent with them, and then determine the intercept $\bar{i}_t$. Forming the Lagrangean

$$\mathcal{L} = E_0 \sum_{t=0}^{\infty} \beta^t \left(L_t + \varphi_t \left(\gamma_f \pi_{t+1} - \pi_t + \kappa x_t + \gamma_b \pi_{t-1} + u_t \right) \right),$$

[16] Denoting with the superscript o the response in the optimal equilibrium according to the central bank's model, $\bar{i}_t = i_t^o - \phi_\pi(\pi_t^o - \overline{\pi}_t) - \phi_x x_t$, where i_t^o is the interest rate derived from the *IS* equation under the optimal path.

[17] The *IS* constraint is supposed not to bind, so it can be ignored in this step of the calculation of optimal policy.

the first order conditions of this problem form a system of difference equations that can be solved for the paths of π_t and x_t. I then solve for the equilibrium paths of output gap, inflation, and interest rate by solving the system of equations (6)-(8).

To calibrate the *NKPC* parameters I chose values among those estimated by Gali, Gertler and Lopez-Salido (2005). First, I impose that the weights on the forward and backward-looking components sum to 1: $\gamma_f + \gamma_b = 1$, and then consider as baseline value for the forward-looking parameter the value $\gamma_f = .65$. As an alternative, I also consider the case of a higher value $\gamma_f = .89$, which corresponds to only a small degree of intrinsic persistence. Note that this equation does not appear in the exact same form as that estimated by Gali, Gertler and Lopez-Salido. The driving variable in their model is the labor share, which proxies for the theoretical marginal cost of labor. I augment the equation by assuming a proportionality between marginal cost and output gap (here both variables are in deviation from their steady state values, in a steady state with zero inflation), as in the model used to construct the sample economy of the previous section. I set again the proportionality factor equal to .63, so that the slope of the curve is the product of such a factor times the estimated parameter of the marginal cost in Gali, Gertler and Lopez-Salido, which I set equal to .013. This gives a value for the coefficient of the output gap, $\kappa = .0082$. The other parameters are calibrated as follows: $\sigma = 6.25$, and the parameters of the Taylor rule are standard: $\phi_\pi = 1.5$, $\phi_x = .125$. The weight on output in the loss function is chosen to be $\lambda = .0625$. This corresponds to a widely used weight in the literature, and corresponds to an equal weight on the two objectives (here I use quarterly rates of inflation).

For the other economy, I maintain the same specification of the *IS* curve and the Taylor rule, and the same calibration of the relative parameters, but assume that the *NKPC* takes the form of a curve with trend inflation as in the model estimated by Cogley-Sbordone discussed above. The model is represented in recursive form by the following two equations

$$
\begin{aligned}
\widehat{\pi}_t &= \widetilde{\kappa}_t \, \widehat{x}_t + \phi_t E_t \widehat{\pi}_{t+1} + \gamma_t \widehat{D}_t + u_t \\
\widehat{D}_t &= g_{1t} E_t \widehat{\pi}_{t+1} + g_{2t} E_t \widehat{D}_{t+1}
\end{aligned} \tag{9}
$$

Note that, as in the case of the previous model, this model was estimated by Cogley-Sbordone with the marginal cost as the driving variable, so I use again a proportionality factor of .63 to obtain a value for the parameter $\widetilde{\kappa}_t$. The tilde is used to denote that the estimated slope in this model is different (higher) than the one calibrated in the previous model according to the estimates of Gali, Gertler and Lopez-Salido (2005). As discussed before, Cogley-Sbordone do not directly estimate the time-varying coefficients of the *NKPC* (9), but rather the underlying parameters of the model, namely the probability of changing prices and the demand elasticity, together with the implied trend inflation. Here I calibrate the underlying parameters to the posterior median reported in the paper, and consider, together with a level of zero trend inflation, two other levels corresponding to a somewhat higher level of target inflation, 2.6% annual rate, and a lower level of 1% (from figure 1, this range covers the average trend inflation estimated in the past 20 years). The values of the coefficients in (9) depend upon these values: for the low inflation case, $\widetilde{\kappa} = .033$, $\phi = 1.15$, $\gamma = .0019$, $g_1 = 6.33$ and $g_2 = 0.56$; for the high inflation case, $\widetilde{\kappa} = .027$, $\phi = 1.03$, $\gamma = .0046$, $g_1 = 6.62$ and $g_2 = 0.58$. As discussed before, the weight on the output gap decreases with the trend inflation level, while that on forward-looking terms is enhanced.

4.1.1 Results

Table 2 contains a first result of this quantitative exercise. Each cell of the table corresponds to a combination of a policy model and a 'true' model of the supply side. In the cells I report the value of the discounted loss function for that particular combination, where I approximate the infinite sum by the first 64 terms. Since the parameters for each policy are calibrated, as discussed, to the empirical estimates of Gali-Gertler and Cogley-Sbordone, the initials GG and CS identify the models and their parameters. I consider two degrees of intrinsic persistence (a low degree, corresponding to a coefficient on the backward-looking component $\gamma_b = .11$ ($\gamma_f = .89$) and a high degree, corresponding to a coefficient of .35 ($\gamma_f = .65$), and two levels of target inflation, respectively of annual rates of 1% and 2.6%. The first table reports the results for the case of i.i.d. cost push shocks, and the second considers the case of a mild persistence in the cost push shocks, represented by an autoregressive coefficient of .2.

Table 2 - Cumulative Loss Function, i.i.d. shocks

	True model			
Policy model	GG, $\gamma_f = .89$	GG, $\gamma_f = .65$	CS, $\overline{\pi} = 1.0$	CS, $\overline{\pi} = 2.6$
GG, $\gamma_f = .89$	1.221		1.020	1.456
GG, $\gamma_f = .65$		2.862	2.04	2.537
CS, $\overline{\pi} = 1.0$	1.460	4.155	.843	
CS, $\overline{\pi} = 2.6$	1.499	4.222		.790

Consider first the case of i.i.d. shocks. One way to read the numbers is to ask what is the increase in the cumulative discounted loss when stabilization policy is conducted with the wrong model versus the loss incurred under a correct policy model. For this computation, the increase in cost by conducting policy on the basis of a model with intrinsic persistence when the true model is a purely forward-looking one we should compare the numbers in the upper right 4x4 quadrant of the table with the numbers on the bottom right quadrant. To compute instead the cost of ignoring true intrinsic persistence we should compare the numbers on the bottom left quadrant with those above them.

Specifically, conducting policy under the assumption of a moderate degree of persistence when there is none generates an increase in loss of about 21% (from .843 to 1.02) relative to the loss that would occur without the mistake. The cost is much higher - the loss is about one and a half time bigger (from .843 to 2.04) if the assumed degree of persistence is higher. Both costs are proportionally much higher in the case of a higher inflation target: for the case of an inflation target of 2.6%, the loss increases respectively by 84% (from .79 to 1.46) and about four times as much (from .79 to 2.54).

For the mistake of ignoring intrinsic inflation persistence, the cost depends upon the degree of the intrinsic persistence in the true model, while it is not particularly sensitive to the value of the inflation target. For a low degree of intrinsic persistence the loss increases from 1.22 to 1.46, or about 19%; for a high degree of persistence the cost increases by 45% (from 2.86 to 4.155). The bottom line appears to be that it is less costly to ignore intrinsic persistence than to assume it, if that is not the right model of the economy. However, I should note that if the metric is absolute loss instead of relative gain, then the table shows that this is highest for the case in which there is indeed some degree of intrinsic persistence that is ignored by the policymaker.

The story is not much different for the case of serially correlated shocks, as the numbers in table 3 show. In absolute value, the cumulative loss is higher for all the cases considered, but the relative size is the same.

Table 3 - Cumulative Loss Function, persistent shocks ($\varrho_u = .2$)

	True model			
Policy model	GG, $\gamma_f = .89$	GG, $\gamma_f = .65$	CS, $\overline{\pi} = 1.0$	CS, $\overline{\pi} = 2.6$
GG, $\gamma_f = .89$	2.038		1.653	2.780
GG, $\gamma_f = .65$		5.476	3.695	4.942
CS, $\overline{\pi} = 1.0$	2.537	7.981	1.279	
CS, $\overline{\pi} = 2.6$	2.617	8.108		1.186

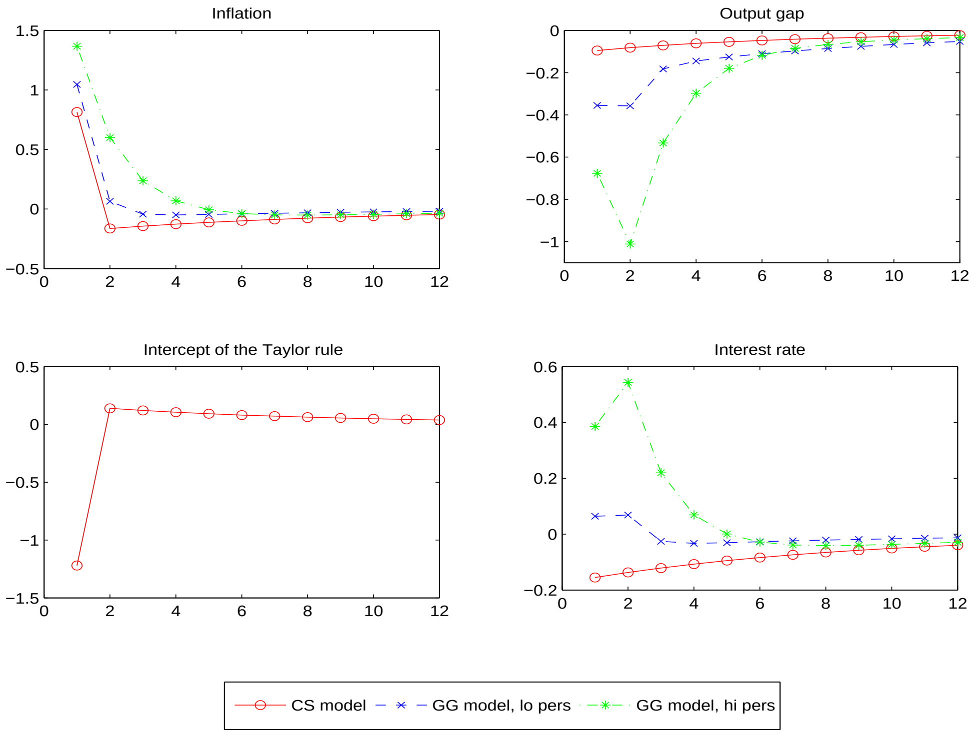

Figure 2: CS optimal policy, iid shocks (ad hoc loss function)

Figures 2 and 3 present a more interesting cut at these results: here I look at the equilibrium path of inflation, output and interest rate that occur in response to a cost-push shock in three different models, when the policymaker implements a stabilization policy that is optimal from the point of view of the model that he/she uses. In each figure the top two panels show the equilibrium path of output and inflation.

The panel on the lower left (intercept of the Taylor rule) is the policy response to the shock, $\bar{i}_t$, and the last panel is the equilibrium interest rate i_t. All responses represent deviations of the variables from the initial steady state; in the case in which the policy model is the true model of the economy, the equilibrium responses of output and inflation are also the responses that minimize the policymaker's loss function.

Figure 2 considers the case of a policymaker implementing an optimal stabilization policy[18] under the assumption that the correct model of the economy is a purely forward-looking model, which incorporates a 2% inflation target. The red lines with circles show the optimal policy (the panel on the lower left) and the equilibrium path of inflation, output and interest rate when the policy model is indeed the true model of the economy.

As the shock occurs, inflation increases, then declines sharply in the second period, falling below target, and recovers slowly in the following quarters. The optimal response of output to the shock is a moderate decline at impact, and a monotonic return to steady state. This response is engineered by the policymaker via a downward shift in the intercept of the Taylor rule at impact followed by an increase above the steady state level in the second period. As output converges gradually to steady state from below, the Taylor rule intercept declines to steady state from above and inflation returns to target. In equilibrium, the interest rate declines at impact, and monotonically increases back to zero in the following quarters.

Although not shown in the figure, the higher the target level of inflation, the smaller is the impact effect of the shock on inflation, and the more pronounced is the second period deflation; higher target inflation also implies a greater reduction in the equilibrium interest rate, and a smaller contraction in output.

The same policy, however, delivers quite different outcomes under the alternative models. In the figure I plot the results obtained under the two parametrizations of the GG model considered previously, one with low intrinsic persistence (setting the backward-looking term in the GG model $\gamma_b = .11$), as a blue dotted line, and the other with higher intrinsic persistence ($\gamma_b = .35$), the green line with asterisks. If the degree of persistence in the true model is relatively low, the equilibrium path of inflation is not too different from the optimal path under the rule considered. The response of inflation to the shock is slightly higher at impact, and then falls temporarily below target. The negative response of output is, however, larger and more persistent, mirrored by the path of the equilibrium interest rate, which remains above steady state for two quarters. These patterns are much more pronounced in the case in which the true degree of persistence in the economy is higher. In particular, equilibrium output sharply falls in the first period and reaches its trough in the second period, while the interest rate has a corresponding peak in the second period before returning monotonically to zero. As the figures show, an optimal, completely forward-looking policy has a larger cost in terms of lost output the higher is the actual inflation persistence.

[18] I assume a shock of 1% at annual rate, so that the responses should be interpreted in terms of percentage variations.

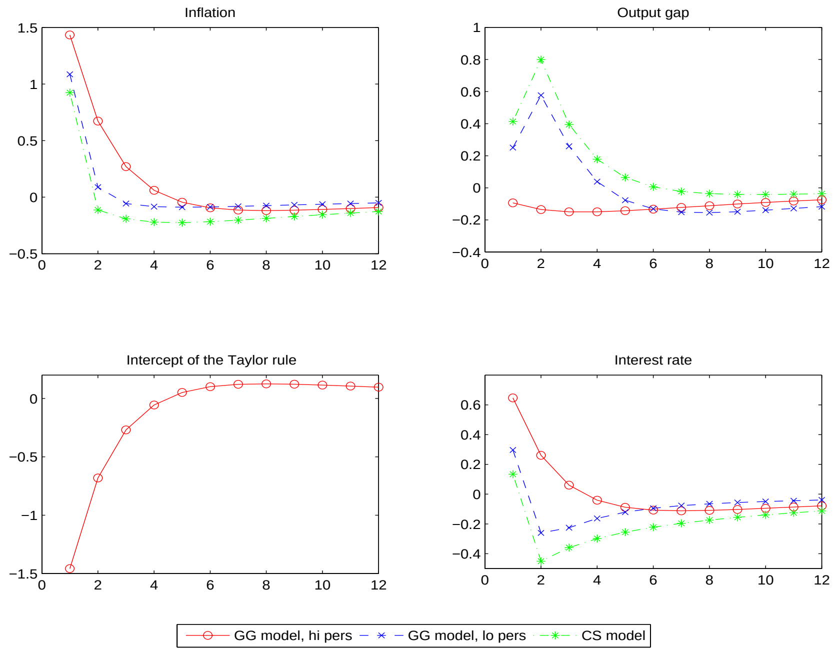

Figure 3: GG optimal policy, iid shocks (ad hoc loss function)

Figure 3 is constructed in similar way to figure 2, and shows the reverse situation. It assumes that policy is implemented on the basis of a model with a relatively high degree of intrinsic persistence (the backward-looking term in the GG model has a coefficient $\gamma_b = .35$). The optimal policy in this case is again shown in the lower left panel, and the red lines with circles in the other panels trace the effects of this policy when the true model of the economy has in fact a relatively high degree of intrinsic persistence. The other lines show the effects of this stabilization policy for the other two models considered in the previous figure.

The optimal response to a cost-push shock in this case is to let inflation remain above target for about four quarters, while the policymaker maintains the intercept of the Taylor rule below steady state for the length of that period. Output declines only mildly below steady state. In equilibrium, the interest rate raises at impact, and then decline slowly. As the degree of assumed persistence increases, the return of inflation to target takes longer time. During that period policy remains accommodative, and output and the Taylor rule intercept approach steady state more and more gradually. The equilibrium interest rate rises above steady state and remains above steady state for few quarters. The equilibrium outcome of

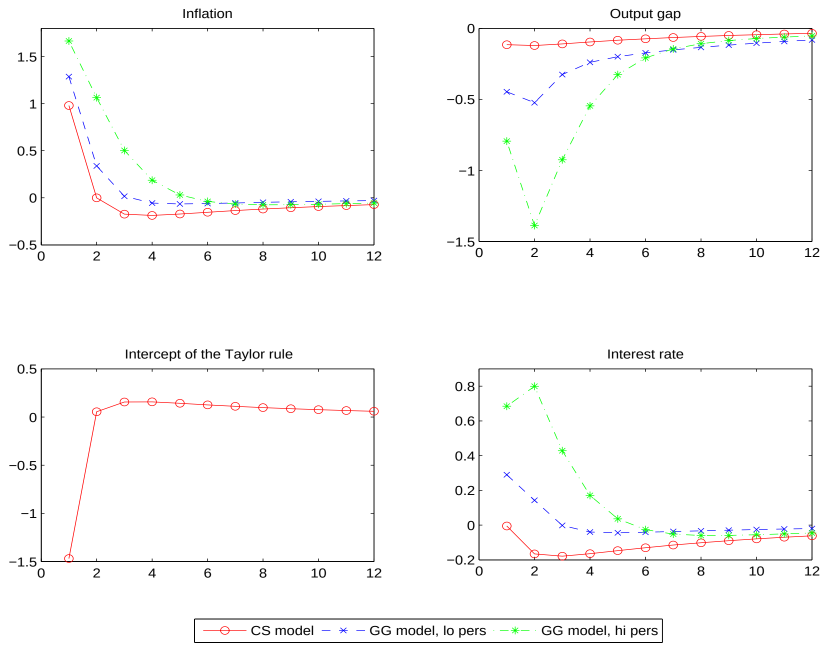

Figure 4: CS optimal policy, serially correlated shocks

such a policy, if the true model of the economy is purely forward-looking, implies a wide departure of output from the optimal path. Indeed, as we saw in the previous figure, when the model is forward-looking the optimal output response to the shock is a mild decline at impact and convergence to steady state from below. Here the accommodative policy determines, in equilibrium, a jump of output above steady state and of interest rate below steady state that peak in the second quarter.

Figures 4 and 5 are like the previous two figures, but allow the cost-push shocks to be mildly serially correlated. I calibrate the autoregressive coefficient $\varrho_u = .2$, a value often estimated for this composite shock process. The effect of serial correlation in the shock is to smooth the policy response to the shock in the case of both policies. For example, in the case of a policy implemented in a forward-looking model inflation declines below target only in the third period , and it takes longer time to decline to target in a policy model with high persistence.

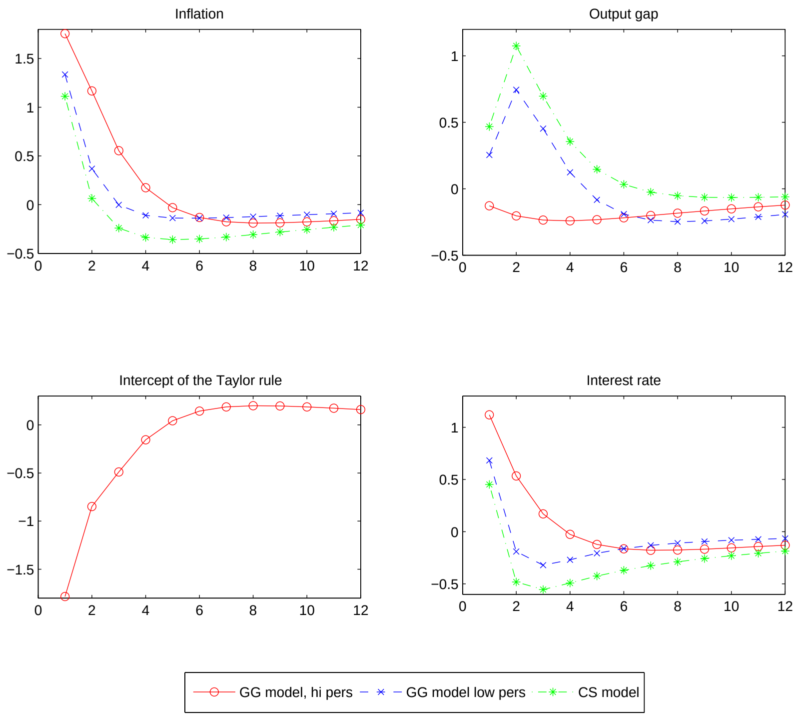

Figure 5: GG optimal policy, serially correlated shocks

4.2 Welfare-based loss function

In this section I consider how the previous analysis carries over to the case of a policy that would maximize welfare according to the micro-foundations of each of the models. While in the previous exercise I assumed a desired level of inflation target, in this case I do not have such a choice, as the optimal target inflation rate will follow from the welfare analysis. Since the optimal rate of inflation is in this case zero, as shown in Benigno and Woodford (2005), it makes sense to consider an approximation of the inflation dynamics around a steady state with zero inflation. The approximation to the welfare function in the case of a model without any intrinsic persistence is therefore the one that applies for the case of the standard purely forward-looking model, since the model here doesn't feature any distortion other than nominal price rigidity. Based on the result in Benigno-Woodford (2005) a welfare-based loss function for the baseline Calvo model has the same quadratic form of the ad hoc loss function considered before, but its weight depends on the model parameters, specifically: $\lambda = \kappa/\theta$. According to the parametrization of Cogley-Sbordone (2006) and setting trend inflation equal to zero, this gives $\lambda = 0.0024$.

For the case of a rule-of-thumb *NKPC*, Steinsson (2003) has derived a welfare-based loss function for a model where the supply side is a slight generalization of the original rule-of-thumb model of Gali and Gertler (1999), and is otherwise similar to the one considered here. Based on his derivation, the approximate welfare function for exactly the model of Gali and Gertler (1999) is proportional to the following loss function

$$L_t = \pi_t^2 + \lambda_1 x_t^2 + \lambda_2 \Delta\pi_t^2,$$

where the coefficients are respectively

$$\begin{aligned}
\lambda_1 &= \frac{(1-\alpha)(1-\alpha\beta)\left(\sigma - \widetilde{\omega}^{-1}\right)}{\alpha\sigma\theta\left(\widetilde{\omega}^{-1} + \theta\right)}, \\
\lambda_2 &= \frac{\chi}{\alpha(1-\chi)}.
\end{aligned}$$

Here the symbol χ indicates, as before, the proportion of firms that use a rule of thumb when resetting prices, and the other symbols as well have the interpretation given them previously.

The value of χ can be backed out from the value calibrated for γ_f given that the two parameters satisfy the following relationship

$$\gamma_f = \frac{\alpha}{\alpha + \chi(1 - \alpha(1-\beta))}$$

For the case of low persistence, $\gamma_f = .89$ implies $\chi = .0684$, while for the higher persistence case the value of γ_f implies $\chi = .2978$. To get round numbers, I set $\chi_L = .07$, and $\chi_H = .3$, and compute the weights of the loss function on the basis of these values.

4.2.1 Results

The table reports the values of the cumulative discounted loss when optimal policy is chosen in each case by minimizing the welfare-based loss functions described above.

Table 4 - Cumulative Loss Function , i.i.d. shocks

	True model		
Policy model	GG, $\gamma_f = .89$	GG, $\gamma_f = .65$	CS, $\overline{\pi} = 0$
GG, $\gamma_f = .89$	1.048		1.086
GG, $\gamma_f = .65$		2.138	2.244
CS, $\overline{\pi} = 0$	1.208	2.257	.474

Since in this case I consider an optimal inflation target of zero, I report the CS case only for that value. As expected, the values in the table are lower than the corresponding values of table 2. But the ranking of the relative losses discussed for the case of the ad hoc loss function holds here as well. Implementing monetary policy under the wrong assumption that there is some degree of intrinsic inflation persistence in the economy increases the welfare loss from almost one and half times to about four times (from .474 to 1.086 or 2.244) depending on the degree of persistence assumed in the policy. Following a policy model that ignores existing persistence instead increases the welfare loss by only 5%.

As in the case of the ad hoc loss function, the next two figures analyze the effects of optimal policy under different models. Figure 6 shows the effect of optimal policy implemented under the purely forward-looking model. Comparing this figure with figure 2, one sees quite clearly what is the effect of changing the relative weights in the loss function. Recall that the 'ad hoc' loss function has the same form (to a second order approximation), for this model, of the welfare-based loss function, but the weight λ is much smaller. The result is that, under an optimal policy, output should decline much more at impact, while the interest rate, in equilibrium, must raise, and monotonically approach steady state from above. Interestingly, if such a policy were implemented in an economy characterized by some degree of intrinsic persistence, the equilibrium interest rate would be higher, avoiding the deflation and increasing slightly the output loss; the degree by which the equilibrium paths of the variables differ in the three cases is not too high.

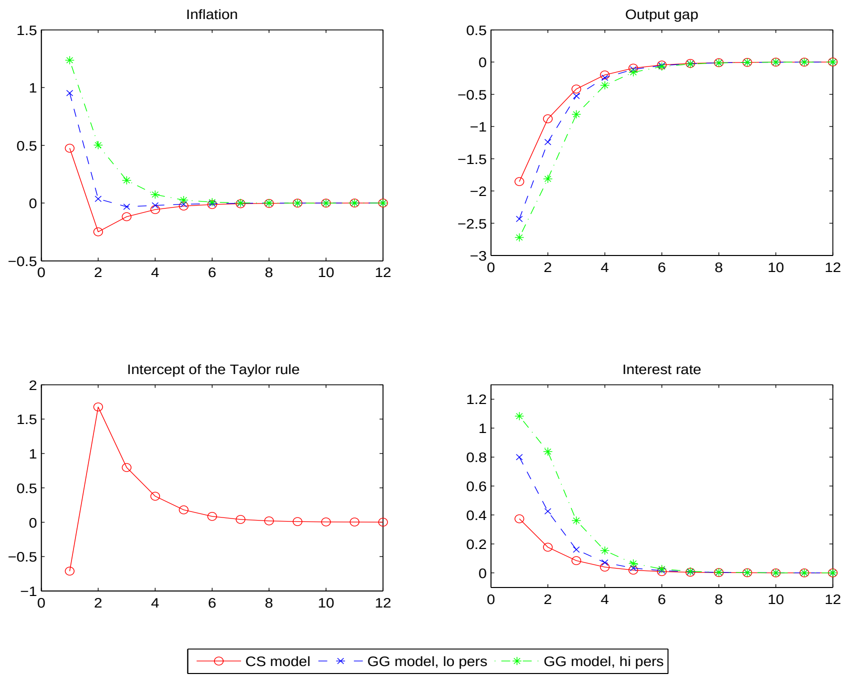

Figure 6: CS welfare-based optimal policy, iid shocks

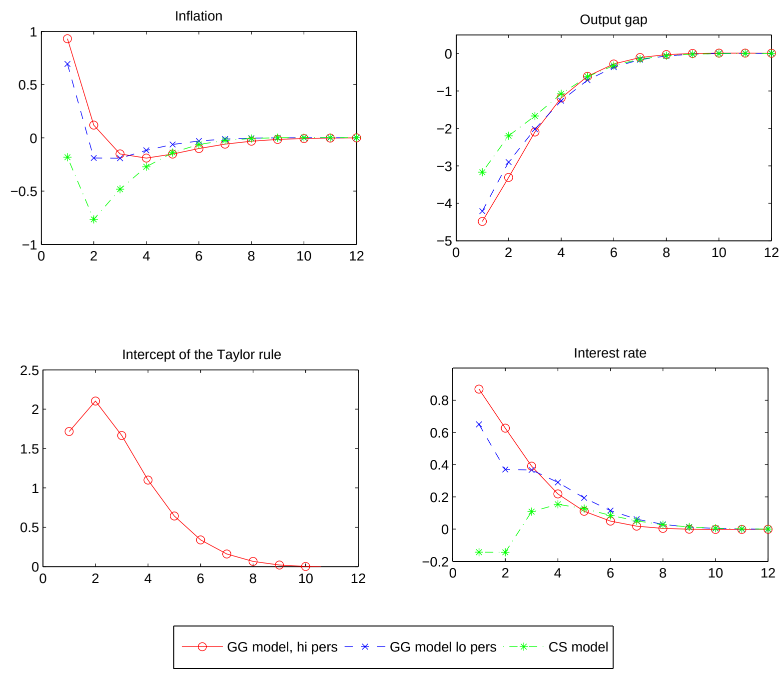

Figure 7: GG welfare-based policy, iid shocks

Finally, figure 7 illustrates the implementation of a welfare-based optimal policy in response to an i.i.d cost-push shock, when policymakers assume a model with high intrinsic inflation persistence. Here the optimal policy requires further tightening after the shock - the intuition is that this should prevent inflation to become ingrained in the economy. The tightening brings a mild deflation, and a noticeable contraction in output. Such a policy, if intrinsic persistence were absent, would generate instead a quite strong deflation accompanied by a period of below steady state interest rates (green line in the graphs). In the case of a welfare-based optimal policy it is much clearer which risk of model misspecification is more dangerous.

5 Conclusions

In this paper I focus on two alternative interpretations of the observed persistence in inflation, that correspond to two alternative specifications of the New Keynesian Phillips curve. The first allows for some degree of intrinsic persistence, in the form of a term in lagged inflation in the *NKPC*. The second is a purely forward-looking model, where expectations farther into the future matter, and where coefficients are time varying. This specification attributes most of the observed persistence to the persistence of the underlying inflation trend, which is a consequence of monetary policy, not a structural feature of the economy.

I first discuss the importance of defining properly the inflation gap in empirical specifications of inflation dynamics, because the persistence of alternative measures of the gap is quite different, and present a simple example of misleading econometric inference.

I then analyze the consequences of implementing monetary policy assuming a degree of persistence different from what is in the economy. I consider two very stylized economic models differing for the specification of the inflation dynamics, and illustrate the equilibrium outcomes for the cases in which the policymakers misinterpret the degree of intrinsic persistence.

The results suggest that the costs of implementing stabilization policy overestimating the degree of intrinsic persistence are potentially higher than the costs of ignoring an existing persistence; the result is more clear cut in the case in which the policymaker's loss function is welfare-based.

References

[1] Altissimo, F.. Bilke, L., Levin, A., Matha, T., Mojon, B., 2006. Sectoral and Aggregate Inflation Dynamics in the Euro Area, *Journal of the European Economic Association*, 4 (2-3), 585–593.

[2] Angeloni, I., Aucremanne, L., Ehrmann, M., Gali, J., Levin, A., Smets F., 2006. New Evidence on Inflation Persistence and Price Stickiness in the Euro Area: Implications for Macro Modelling. *Journal of the European Economic Association*, 4 (2-3), 562-574.

[3] Ascari, G., 2004. Staggered prices and trend inflation: some nuisances. *Review of Economic Dynamics* 7, 642-667.

[4] Ascari, G., Ropele, T., 2006. Optimal monetary policy under low trend inflation, unpublished.

[5] Benati, L., 2006. Investigating Inflation Persistence Across Monetary Regimes,unpublished.

[6] Benigno, P., Woodford, M. 2006. Inflation Stabilization And Welfare: The Case Of A Distorted Steady State. Journal of the European Economic Association December 2005, Vol. 3, No. 6: 1185-1236.

[7] Cogley, T., Sargent, T., 2005. Drifts and Volatilities: Monetary Policies and Outcomes in the Post WWII U.S. *Review of Economic Dynamics*, 262-302.

[8] Cogley, T., Sargent, T., 2006. Inflation-gap Persistence in the U.S., unpublished.

[9] Cogley, T., Sbordone A., 2006. Trend inflation and inflation persistence in the new Keynesian Phillips curve, unpublished.

[10] Cogley, T., Sbordone A., 2005. A search for a structural Phillips curve. Federal Reserve Bank of New York Staff Reports No. 203.

[11] Eichenbaum, M., Fisher, J., 2005. Evaluating the Calvo model of sticky prices. *Journal of Monetary Economics,* forthcoming.

[12] Erceg, C., Levin, A., 2003. Imperfect credibility and inflation persistence. *Journal of Monetary Economics* 50 (4), 915-944.

[13] Fuhrer, J.C., Moore, G.R., 1995. Inflation Persistence. *Quarterly Journal of Economic*s 440, 127-159.

[14] Gali, J., 2003. New perspectives on monetary policy, inflation and the business cycle. In Dewatripont, M., Hansen L.P., Turnovsky, S.J. (eds.) *Advances in Economics and Econometrics. Theory and Applications*, Eighth World Congress, vol. III, Cambridge University Press, 151-197.

[15] Gali, J., Gertler, M., 1999. Inflation dynamics: a structural econometric approach. *Journal of Monetary Economics* 44 (2), 195-222.

[16] Gali, J., Gertler, M., Lopez-Salido, D., 2001. European inflation dynamics. *European Economic Review* 45 (7), 1237-1270.

[17] Gali, J., Gertler, M., Lopez-Salido, D., 2005. Robustness of the estimates of the hybrid new Keynesian Phillips curve. *Journal of Monetary Economics* 52 (6), 1107-1118.

[18] Ireland, P. 2005. Changes in the Federal Reserve's Inflation Target: Causes and Consequences, unpublished.

[19] Levin, A., Lopez-Salido, D, Yun, T., 2006. Strategic Complementarities and Optimal Monetary Policy, unpublished.

[20] Levin, A., Moessner, R.,2005. Inflation persistence and monetary policy design: An overview. ECB working paper n. 539.

[21] Sbordone, A., 2005. Do expected future marginal cost drive inflation dynamics? *Journal of Monetary Economics* 52 (6), 1183-1197.

[22] Smets, F., Wouters, R., 2003. An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area. *Journal of the European Economic Association*, 1 (3), 1123-1175.

[23] Smets, F., Wouters, R., 2005, Comparing shocks and frictions in US and euro area business cycles. *Journal of Applied Econometrics*, 20 (2), 161-183.

[24] Steinsson, J., 2003. Optimal monetary policy in an economy with inflation persistence, *Journal of Monetary Economics* 50 (7), 1425-1456.

[25] Woodford, M. 2003. *Interest and Prices. Foundations of a Theory of Monetary Policy.* Princeton University Press.