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MONETARY POLICY RULES UNDER HETEROGENEOUS INFLATION EXPECTATIONS

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Working Paper

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ABSTRACT

This paper evaluates the role of inflation-forecast heterogeneity in US monetary policy making. The deviation between private and central bank inflation forecasts is identified as a factor increasing inflation persistence and thus calling for a policy reaction. An optimal policy rule is derived by the minimization under discretion of a standard central bank loss function subject to a Phillips curve, modified to include the forecast deviation, and a forward-looking aggregate demand equation. This rule, which itself includes the forecast deviation as an additional argument, is estimated for the period 1974-1998, covering the Chairmanships of Arthur Burns, Paul Volcker and Alan Greenspan, by using real-time forecasts of inflation and the output gap obtained from the FOMC's Greenbook and the Survey of Professional Forecasters. The estimated rule remains remarkably stable over the whole sample period, challenging the conventional view of a structural break following Volcker's appointment as Chairman of the Fed. Finally, the substantial decline in the significance of the interest-rate smoothing term in the rule indicates that monetary policy inertia may, to a large extent, be an artifact of serially correlated inflation-forecast errors that feed into policy decisions in real time.

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1. Introduction

It is widely recognized that central banks face substantial uncertainty regarding the impact of monetary policy decisions on the economy in general and on price developments in particular. This uncertainty is enhanced by the presence of long and often variable time lags in the transmission of monetary impulses to prices and has prompted the design of forward-looking monetary policy strategies. In the context of these strategies, the monetary authorities look at a wide range of economic and financial indicators in order to form a broadly-based assessment of the expected path of the relevant target variables (i.e. inflation and output).

Within this range of indicators, private sector inflation expectations, as reflected in survey data or in financial-market prices are a key piece of information because they can signal future inflationary risks or at least provide some indications about how economic agents gauge these risks (Bernanke, 2004). The usefulness of the information conveyed by private expectations for the conduct of monetary policy critically depends on the degree of uncertainty characterizing monetary policy decision-making. Under the assumption of rational expectations and perfect information about the economy, agents' expectations (i.e. the private sector's and the central bank's) as reflected in their respective forecasts should be identical. In this case, the central bank has only to look at its internal forecasts when making policy decisions. Nevertheless, experience suggests that private inflation expectations often become unmoored from central bank forecasts, and thus, they may represent a distinct source of information for policymakers. Information asymmetries about the nature of the shocks hitting the economy or about the model of the economy, the monetary transmission mechanism and the policy targets appear to be the main source of inflation-forecast heterogeneity.

Private inflation forecasts provide not only a useful information variable in monetary policy analysis but also a potential intermediate target for the conduct of monetary policy. In particular, the achievement of a closer alignment of private forecasts with those of the central bank can, under certain conditions, prove a key component of an effective forward-looking monetary policy strategy. Thus, if agents in the private sector feel sure that inflation will remain well-controlled, they will be more restrained in their

wage-setting and pricing behavior, making it easier for the Federal Reserve to pursue its inflation target. Moreover, by reducing the risk that inflation will come loose from its moorings, the central bank has more short-term flexibility to react to disturbances that affect output and employment (Bernanke, 2004). Changes in monetary policy strategy, so as to take into account private expectations, as well as the effective communication of policy decisions and their rationale to the public, appear to be the main mechanisms for achieving better alignment between private and central bank forecasts.

In general discussions about monetary policy, the question is often asked whether the central bank should focus on observable economic fundamentals and its internal procedures to forecast the future path of policy targets or pay some attention to "reliable outside forecasts" reflecting private expectations (Hall, 1984; Evans and Honkapohja, 2003a). Nevertheless, in the theoretical and empirical literature on monetary policy implementation and transmission, the issue of inflation-forecast heterogeneity has not been properly addressed, with the exception of the literature on optimal filtering of inflation expectations (see among others, Lippi and Neri, 2003).

In the present paper, the role of inflation-forecast heterogeneity in the conduct of monetary policy is analyzed. Specifically, an historical account of the Fed's monetary policy making during the past thirty years is provided and the importance in the Fed's reaction function of the deviation between the Fed's and private inflation forecasts is evaluated. This deviation is identified as a major determinant behind the inflation persistence observed as it leads to a slowdown in the pace at which supply shocks (represented by the error term of a standard New Keynesian Phillips curve) die out. Thus, the Phillips curve is modified by including an additional term which corresponds to the autoregressive behavior of the forecast deviation and enables the decomposition of the autoregressive component of the supply shock into a part related to the forecast deviation and a remaining part reflecting structural supply factors.

An optimal monetary policy rule is obtained by the minimization under discretion of a standard central bank loss function subject to the constraints provided by the modified Phillips curve, including the forecast deviation, and a standard forward-looking aggregate demand equation. The policy rule itself includes the forecast deviation as an

additional argument. According to this modified rule, when the private sector inflation forecast is higher than the central bank forecast, the monetary authorities will react by increasing the interest rate and vice versa. Hence, this deviation, by increasing inflation persistence, leads to monetary policy adjustments additional to those justified by developments in the official forecasts of the relevant target variables. Indeed, the monetary policy reaction to the forecast deviation appears to have been an important factor underlying the successful disinflation of the 1980s in the US as well as the persistence of inflationary pressures during the 1970s.

The rule is estimated on a sample covering the period 1974-1998 corresponding to the Arthur Burns, Paul Volcker and Alan Greenspan Chairmanships on the basis of real-time inflation forecasts obtained from the FOMC's Greenbook and the Survey of Professional Forecasters, with the latter being used as a proxy of private inflation expectations. The results demonstrate that a simple policy rule in which the federal funds rate reacts to the inflation-forecast deviation performs very satisfactorily in describing the behavior of the FOMC as well as in accounting for the anti-inflationary record of the Fed since the early 1980s. In particular, the FOMC appears to have tightened whenever the private inflation forecast was higher than the Fed's forecast, and to have eased when it was lower.

A novel explanation is put forth for the pre-1980 high-inflation period which is attributed not to activist policies aiming at output gap stabilization, as is usually argued, but to the policy reaction in a period in which private inflation forecasts were lower than the respective central bank forecasts. Similarly, the success of Volcker's disinflation can be attributed to the reaction to this deviation in a period when private inflation forecasts were significantly higher than central bank forecasts. Finally, following Rotemberg and Woodford (1998) among others, we introduce an interest-rate smoothing term into the policy rule and investigate its interaction with the forecast-deviation term. We find that including the forecast-deviation term significantly reduces the role of monetary policy inertia characterizing standard rule specifications.

The rest of the paper is structured as follows. Section 2 outlines the theoretical framework under which heterogeneity between private sector and central bank inflation

forecasts can be considered as relevant for describing actual monetary policy decision-making. Section 3 derives our preferred policy rule specification. Section 4 provides estimates of the policy rule specification outlined in the previous section and compares them with conventional rule specifications and, finally, Section 5 concludes.

2. Private inflation expectations and monetary policy

2.1 Inflation-forecast heterogeneity and monetary policy making

In actual policy making, central banks regularly monitor and analyze information regarding inflation expectations, as reflected in surveys or in financial-market prices (Brissimis and Magginas, 2005). Moreover, "forecasts of inflation are at the center of policy deliberations at inflation-targeting central banks and have arguably been equally important for policy decisions in non-inflation-targeting central banks such as the Federal Reserve and the European Central Bank" (Orphanides and Williams, 2005). A recent example of such views is the following comment by the Federal Reserve's Chairman Alan Greenspan who said in May 2001: "We have often pointed before to the essential role that low inflation expectations play in containing price pressures and promoting growth. Any evident tendency in financial markets or in household and business attitudes for such expectations to trend higher would need to factor importantly into our policy decisions" (Greenspan, 2001).

Central bank leverage on the economy depends to a large extent on inflation expectations. Given that the Fed directly controls only one very short-term interest rate, the federal funds rate, its ability to affect longer-term yields and asset prices is conditional on private sector expectations about future monetary policy and, thus, on the path of the main policy target variables.

Nevertheless, experience suggests that private expectations often become disconnected from official forecasts, especially at the outset of significant supply-side shocks. In such cases, even guidance from a transparent central bank cannot ensure the alignment of private expectations with the official central bank forecasts. The problem is even more serious in the case of central banks, such as the Fed, that publish their

forecasts on which monetary policy decisions are based only after a considerable delay. Episodes when expectations appeared to have become unmoored from the policymakers' objectives can be easily identified in the monetary history of the United States. The hikes in private inflation expectations during the first and second oil crises as well as during the first years of the Volcker Chairmanship provide examples of serious delinking of central bank forecasts from private expectations. This fact is reflected in the words of Chairman Volcker who noted in December 1980: "With all its built-in momentum and self-sustaining expectations, [the inflationary process] has come to have a life of its own". Fears of inflation or deflation, whether entirely justified from the policymakers' perspective or not, seemed to have influenced actual decision-making and economic behavior at times, presenting real complications for policy decisions (Orphanides and Williams, 2005).

The ability of the central bank to steer private inflation expectations toward its internal forecasts and policy targets appears to be a key component of a successful monetary policy strategy. The adoption of a more anti-inflationary policy stance, compared to what would have been dictated by internal forecasts only, may be a prerequisite for bringing private forecasts closer to central bank forecasts. This alignment is achieved mainly through expectational effects about the future path of the monetary policy instrument. The cost of this alignment, in terms of output and policy instrument volatility, appears to be negatively related to the degree of monetary authorities' credibility. For this reason, modern central banks are becoming increasingly transparent about their objectives and their policy strategy, conveying more information to the private sector with a view to increasing their credibility and accountability as well as the private sector's understanding of the major factors underlying monetary policy decisions. It is of significant interest to assess whether the monetary authorities take into account forecast deviations in their decision-making process, adjusting their policy strategy in relation to the size of these deviations.

2.2 Rational expectations and forecast heterogeneity

Even though in actual policy making central banks pay close attention to the private sector's inflation expectations, in standard models inflation expectations of the private sector are of little independent interest to policymakers (Orphanides and Williams, 2005). Private expectations do not appear to have any role in most of the small-to-medium scale monetary policy models used in the literature. One potential source of the apparent disconnection between policy practice and policy modeling may be identified in the rigid imposition of rational expectations in macroeconometric models that ties down all categories of inflation expectations. The policy evaluations generally assume a fixed and perfectly known structure of the economy and specify that expectations be model-consistent. In such linear fixed-parameter models, once the monetary policy rule is specified, inflation expectations can be represented as a linear function of economic outcomes.

These assumptions greatly simplify the analysis but entail significant costs in terms of realism. Actually, there are many factors that can give rise to persistent deviations between private and central bank forecasts. If agents are less than perfectly certain about the structure of the model, its time invariance, or simply the values of the model parameters, that is, once imperfect knowledge is acknowledged, the tight mechanical link from economic outcomes to the expectation-formation process breaks down.

In this case, forecasts from several sources may well contain valuable information for policymakers. The identification of the explicit learning process that economic agents employ to form expectations should then be a basic component of a successful monetary policy (Sargent, 1993). It is along these lines that the "adaptive learning literature" has developed (Orphanides and Williams, 2005; Evans and Honkapohja, 2003a, 2003b). In this literature, the assumption of rational expectations with perfect knowledge is relaxed and the role of inflation expectations in the economy and in the conduct of monetary policy is re-examined. Under rational expectations, inflation expectations equal a linear combination of macroeconomic variables and as such provide no additional information to the policymaker. By contrast, under learning, private inflation expectations follow a

time-varying process and provide useful information for the conduct of monetary policy. The precise structure of the economy and the policymakers' preferences are not perfectly known to agents, and expectations are governed by a perpetual learning technology. Within this framework, disturbances can give rise to significant and persistent endogenous deviations of inflation expectations from those implied by rational expectations which are characterized by Goodfriend (1993) (and Orphanides and Williams, 2005) as inflation scares. Inflation expectations can then move substantially away from the policymaker's target. Through this disconnection, learning models imply an important role for learning-induced inflation-expectations dynamics in explaining the excess sensitivity of inflation expectations to economic shocks.

In the present paper, a straightforward way of taking into account forecast heterogeneity is suggested. We loosen the tight link between private and central bank inflation expectations, arguing that the central bank reacts to the difference between expectations from these two sources. On the assumption that the central bank forecasts inflation while being aware of the actual model of the economy and of the shocks hitting it in real time, and that the private sector forms its inflation expectations on the basis of professional forecasts (using only a subset of the information at the disposal of the central bank), inflation-forecast heterogeneity is introduced. This heterogeneity, expressed as deviation between private and central bank forecasts, is identified as a factor increasing inflation persistence and thus calling for a policy reaction. In this respect, the forecast deviation is modeled as part of the stochastic process driving the supply shock. We focus on the implications that these deviations may have for the conduct of discretionary monetary policy. According to the policy rule derived, if private forecasts are inconsistent with central bank forecasts, the central bank will react by adjusting its monetary policy instrument with a view to reducing the deviation, and thereby speeding up the convergence of inflation to its target.

2.3 Private inflation expectations as a propagation mechanism of supply-side shocks

The disconnection between central bank and private sector inflation forecasts is due to the fact that, contrary to the standard modeling assumptions, the private sector does not have full knowledge of the "true macroeconomic model" (as proxied by the

central bank's model) and does not continuously update its own inflation forecasts on the basis of new data releases, but uses only a subset of the central bank's information. The private sector appears to form its inflation expectations on the basis of a rule of thumb using professional forecasts that incorporate part of the information available to the central bank as well as private forecasters' judgmental adjustments. This behavior is described by Akerlof and Yellen (1985) as a near-rational approach to forecasting that reduces the costs of gathering and processing information by the private sector. Specifically, Carroll (2003) shows that, even though private sector expectations formed in this way are not rational in a theoretical sense, expectational dynamics are well-captured by a model in which private forecasts are based on the published views of professional forecasters, which in turn may be closer to rational expectations. Given that the diffusion of professional inflation forecasts to the population may be gradual, often taking place through probabilistic access of the private sector to new forecast releases, private inflation expectations may persistently deviate from central bank forecasts.

Mankiw and Reis (2001) also provide a justification for the slow adjustment of private expectations through a mechanism of price adjustment described as the sticky-information model, which is also based on the assumption that information is disseminated slowly throughout the private sector. This gradual forecast update appears to account for at least part of the inflation persistence not accounted for by standard New Keynesian Phillips-curve specifications. The larger the deviation between forecasts, the larger the informational advantage of the central bank due to its privileged access to some data categories (e.g. industrial production, inflation and banking sector data obtained through its supervision activities). Moreover, the central bank is able to condition its forecasts on the future path of its instrument rate thus having a clear forecasting advantage over private forecasters. Evidently, deviations of inflation forecasts tend to slow down the dissipation of supply shocks, turning into an autonomous factor in monetary policy making.

3. A model of optimal policy with heterogenous forecasts

In this section we present a modification of an optimal forecast-based discretionary rule which allows us to analyze the role of inflation-forecast heterogeneity in the conduct of monetary policy. We begin by setting up the framework for monetary policy analysis. This framework is a standard New Keynesian model similar to that of King (2000), Clarida, Gali and Gertler (1999) and Gomes (2005) that constitutes the workhorse for modern monetary policy analysis.

The model consists of a forward-looking IS equation and a New Keynesian Phillips curve (derived on the basis of staggered price contracts in a monopolistically competitive environment, see Fischer, 1977; Taylor, 1980; Calvo, 1983). The relations are respectively:

$$x_t = -\varphi\left[i_t - \pi_{t+1|t}\right] + x_{t+1|t} + g_t \tag{1}$$

$$\pi_t = \lambda x_t + \beta\pi_{t+1|t} + u_t \tag{2}$$

The output gap x_t and the inflation rate π_t in period t are the endogenous variables of the system (1)-(2). The output gap is defined as the deviation of output from its potential level: $x_t = y_t - \overline{y}_t$, where y_t is the actual level of output and $\overline{y}_t$ is its potential level (both are in logs). The variables $\pi_{t+1|t}$ and $x_{t+1|t}$ correspond to the expected values of inflation and output gap at time t+1 that are conditional on the information set available at time t, and i_t is a short-term nominal interest rate that corresponds to the monetary policy instrument. Parameter φ *is* the interest elasticity of aggregate demand and reflects the intertemporal substitution of consumption implying a negative effect of the real interest rate on output, λ represents the inflation-output trade-off and β is the discount factor reflecting the sensitivity of current inflation to expected inflation ($0 < \beta < 1$). Finally, g_t and u_t are disturbance terms defined as AR(1) processes:

$$g_t = \mu g_{t-1} + \hat{g}_t \tag{3}$$

$$u_t = \rho u_{t-1} + \hat{u}_t \tag{4}$$

where $0 \leq \mu, \rho \leq 1$. The variables g_t and u_t correspond to the aggregate demand and aggregate supply shocks respectively. The variables $\hat{g}_t$ and $\hat{u}_t$ are i.i.d. random variables with zero mean and variances σ_g^2 and σ_u^2.

A well-known shortcoming of the description of the supply side of the economy by a New Keynesian Phillips curve is related to the latter's inability to reproduce the significant degree of inflationary persistence observed in the data (Roberts, 1997,1998). Several proposals, often lacking concrete microeconomic foundations, have been made for bringing Phillips-curve specifications closer to the data. These suggestions include the adaptive inflation-expectations formation put forth by Fuhrer and Moore (1995), the near-rational expectation-formation assumptions by Roberts (1998) and the sticky-information approach of Mankiw and Reis (2002).

Along the lines of the near-rational approach to inflation modeling, we assume that private inflation forecasts are based on an information set that falls short of the central bank's information set and is gradually updated on the basis of professional forecasts (Carroll, 2003). More importantly, it is assumed that the private sector is not aware in real time of the size and the nature of the inflationary shocks and thus, when it becomes aware of the previous-period shock, it initiates a gradual process of adjustment that increases inflation persistence. The central bank is also assumed to know this sluggish expectation adjustment mechanism used by the private sector. Specifically, we make the assumption that there is a forecastable – by the central bank – component of the aggregate supply shock (corresponding to the autoregressive term of eq. (4)) that can be decomposed into one part that represents the gradual adjustment of private forecasts to the central bank forecasts and one that corresponds to the autoregressive behavior of structural supply shocks. The deviation between private and central bank forecasts is associated with a lengthening of the time horizon over which supply shocks dissipate. Thus, equation (4) describing the evolution of the supply shock can be written as :

$$u_t = d_t + z_t = q d_{t-1} + s z_{t-1} + \hat{u}_t \qquad (5)$$

where qd_{t-1} is the forecastable component of the supply shock that describes the persistence of the deviation between private and central bank forecasts, and sz_{t-1} reflects the structural supply shock. The parameter q is restricted to be lower than one, ensuring the convergence of private and central bank forecasts in the long run.

Equations (1) and (2) are the constraints for the central bank in setting monetary policy. The central bank's objective function includes two arguments reflecting its main targets of price stability and output stabilization around its potential level.

$$L_t = \frac{1}{2} E_t \left\{ \sum_{j=0}^{\infty} \beta^j \left[\alpha x_{t+j}^2 + \pi_{t+j}^2 \right] \right\} \tag{6}$$

Parameter α reflects the relative weight on output gap and is expected to be less than one and closer to zero to the extent that price stability emerges as the main target for monetary authorities in all modern central banks. The policy problem for the central bank is to choose the time path of the instrument i_t in order to engineer the time paths of the target variables x_t and π_t that minimize the objective function L_t subject to the constraints (1) and (2).

The optimal rule under discretion can be derived as a solution to a sequence of static optimization problems. The Lagrangean function takes the following form:

$$L_t = \sum_{j=0}^{1} \beta^j \left(-\frac{1}{2} \right) \left[\left(\alpha x_{t+j|t}^2 + \pi_{t+j|t}^2 \right) + \Xi_{t+j} \left(\beta \pi_{t+j+1|t} + \lambda x_{t+j|t} - \pi_{t+j|t} \right) \right] \tag{7}$$

Differentiating with respect to $\pi_{t+1|t}$ and $x_{t+1|t}$ for any t≥0 gives the following first-order conditions:

$$\beta \left(\Xi_t + \pi_{t+1|t} - \Xi_{t+1} \right) = 0 \tag{8}$$

and $$\alpha x_{t+1|t} + \lambda \Xi_{t+1} = 0 \tag{9}$$

Given that $\Xi_t=0$ for t=0, we eliminate Ξ_{t+1} from (8) and (9) and get the consolidated first-order condition:

$$\pi_{t+1|t} + \frac{\alpha}{\lambda} x_{t+1|t} = 0 \qquad (10)$$

Combining eq. (10) with the aggregate supply equation (2) we have:

$$\pi_t = \frac{\alpha\beta}{\alpha + \lambda^2} \mathrm{E}_t \pi_{t+1} + \frac{\alpha}{\alpha + \lambda^2} u_t \qquad (11)$$

By substituting eq. (10) into (1) and making use of (11), we obtain the expression for the optimal interest rate rule under discretion:

$$i_t = \left[1 + \frac{\lambda\beta}{\varphi(\alpha + \lambda^2)} \right] \pi_{t+1|t} + \frac{1}{\varphi} x_{t+1|t} + \frac{\lambda}{\varphi(\alpha + \lambda^2)} u_t + \frac{1}{\varphi} g_t \qquad (12)$$

or, equivalently, after taking into account the decomposition of the supply shock described by (5):

$$i_t = \left[1 + \frac{\lambda\beta}{\varphi(\alpha + \lambda^2)} \right] \pi_{t+1|t} + \frac{1}{\varphi} x_{t+1|t} +$$

$$+ \frac{\lambda q}{\varphi(\alpha + \lambda^2)} d_{t-1} + \frac{\lambda}{\varphi(\alpha + \lambda^2)} (s z_{t-1} + \hat{u}_t) + \frac{1}{\varphi} g_t \qquad (13)$$

where $d_t = \pi^P_{t|t-1} - \pi_{t|t-1}$ and $\pi^P_{t|t-1}$ denotes the private inflation forecast for period t formed at t-1.

Equation (13) is the optimal discretionary rule which we are going to estimate in the following section. The distinctive feature of this rule is related to the existence of the lagged forecast deviation as an additional argument to which monetary policy responds. According to this rule, when private forecasts deviate from central bank forecasts, the forecast-targeting central bank should react to this by differentiating the interest rate it sets. The policy response to the deviation is intuitive: if the private inflation forecast exceeds that of the central bank, the latter responds by increasing the policy instrument. In this respect, having identified the inflation-forecast deviation as a factor delaying the adjustment of private inflation expectations to the target, monetary authorities react more,

the larger the size of the deviation during the previous period. This policy reaction speeds up the adjustment of inflation toward the targeted path. Specifically, the increase in the policy instrument leads to an increase in the real interest rate by a factor greater than one, ensuring a contraction in aggregate demand (i.e. a decline in the output gap). This contraction acts toward offsetting the inflationary impact due to the autoregressive behavior of the supply shock. Thus, the disinflation period is shortened at the cost of increased output volatility. The policy behavior implied by this rule, in the case of a positive deviation between private and central bank forecasts, appears to be consistent with the "shock" approach to disinflation (De Grauwe, 1989) followed *inter alia* by Volcker during the 1980-1984 period.

The response coefficient is positively related to the persistence of inflation due to the inflation-forecast deviation (reflected in parameter q). On the other hand, the responsiveness of monetary policy to the inflation-forecast deviation declines as the degree of intertemporal substitution of consumption (φ), the sensitivity of prices to output changes (λ, provided that $\lambda>1$) and the central bank's weight on output stabilization (α) become larger. The last three parameters determine the cost of disinflation in terms of increased output volatility implying that the central bank will be less eager to respond strongly to inflation-forecast deviations, the larger the costs are in terms of output stabilization and the smaller the persistence of this deviation is.

Although it is known that the discretionary rule is time-inconsistent, as the central bank will re-optimize in each period having a motive to create an inflationary surprise, it is straightforward to modify the rule in order to avoid stabilization bias. Along the lines of the optimal delegation literature[1], the anti-inflationary stance of a conservative central banker (Rogoff, 1985) could be ensured by the use of an asymmetric policy reaction

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[1] It is a standard result in the literature on monetary policy that a better outcome (in terms of inflation and output stabilization) can often be obtained if the central bank is assigned an objective different from the true social objective (Woodford, 2002). The problem of choosing an appropriate objective is sometimes called the problem of "optimal delegation". Famous examples include the proposal by Rogoff (1985) that a central banker should be chosen who is "conservative", in the sense of placing a greater weight on inflation stabilization than does the social loss function, or the proposal by King (1997) that the central bank should aim at stabilizing the output gap around the level consistent with achieving its inflation target on average, even when a higher level of output relative to potential would be socially optimal. In both cases, modification of the central bank's objective can eliminate the bias toward higher-than-optimal average

function. Such a reaction function entails an increase in the monetary policy instrument only in the case of a positive deviation between private and central bank inflation forecasts, whereas negative deviations do not lead to a policy reaction.

The central bank has in general an imperfect ability to influence inflation expectations in the way it would like (Tarkka and Mayes, 1999). There is uncertainty not just about the size of the impact of policy and on how fast it works but also about the whole model of monetary transmission, the actual policy targets and the time horizon over which monetary policy targets should be achieved. This uncertainty is higher in periods of serious shocks that may disconnect private expectations from fundamentals. Even though the central bank can indicate what it would like to see as an outcome, it cannot ensure it. Thus, the monetary policy reaction, in the form of instrument changes, to the forecast deviations arises as a prerequisite for speeding up the convergence of inflation expectations, and thus, actual inflation toward the policy target in a reasonable time horizon.

4. An empirical evaluation of the Fed's policy rule during the 1974-1998 period

The central bank's policy rule plays a central role in a wide variety of macroeconomic analyses, describing *inter alia* the conduct of monetary policy and its links to macroeconomic outcomes. In this section we evaluate the ability of the optimal policy rule derived above to describe US monetary policy during the 1974-1998 period.

4.1 The Fed's monetary policy rule and macroeconomic outcomes during the past three decades

With respect to economic developments in the US during the past thirty years, it is generally agreed that from the late 1960s through the early 1980s the US economy displayed high and volatile inflation along with several recessions. Since the early 1980s, however, the US has experienced a significant decline in the inflation rate and a

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inflation resulting from discretionary policy when the central bank seeks to minimize the true social loss function.

considerable reduction in output volatility, with the latter becoming increasingly evident from the mid-1980s.

Many economists cite supply shocks -- and, in particular, oil price shocks -- as the main force underlying the instability of the earlier period. It is unlikely, however, that supply shocks alone could account for the differences observed between the two periods in the absence of an accommodating monetary policy. A related question is to what extent the benign inflationary outlook of the 1980s can be attributed to a change in the conduct of monetary policy during this period. Several developments, including the monetarist influence of the late 1970s, the appointment of a new Chairman of the Fed in 1979 and specific changes in monetary policy implementation are often cited as factors that have fundamentally influenced monetary policy strategy in the US over the past three decades (Boivin, 2004). Along these lines, Clarida, Gali and Gertler (2000) suggest the accommodating monetary policy stance during the 1970s as the main factor behind the upsurge of inflation and Volcker's appointment as the beginning of an anti-inflationary turn in US monetary policy (Boivin, 2004). Boivin (1999) and Cogley and Sargent (2001) argue that these changes in the Fed's strategy, which related *inter alia* to its evolving views about the economy, were gradual.

Numerous attempts have been made to specify and estimate the Fed's reaction function reflected in the large theoretical and empirical literature in this field. However, researchers have not been particularly successful in providing a definitive representation of the Fed's behavior in the form of a single, stable reaction function (Judd and Rudebusch, 1998). In most cases, there is evidence of significant instability in the estimated reaction functions and several explanations have been provided. The most common refers to the difficulties in adequately capturing in a simple linear regression the complex decision-making process of a central bank. Other explanations are related to changes in policy preferences, often reflected in the composition of the Federal Open Market Committee as well as to changes in the transmission mechanism of monetary policy. Nevertheless, the large amount of empirical research on monetary policy rules did not lead to a consensus on the nature or even the existence of these hypothesized changes. Moreover, other criticisms to the standard approaches to monetary policy modeling using policy rules have also been voiced. Such criticisms refer, *inter alia,* to the inability of the

estimated policy rules to take sufficiently into account issues related to the real-time observability of the data used for the estimation of the rules and the forward-looking aspect of monetary policy conduct. For instance, Orphanides (2002,2003) argues that estimating monetary policy rules by using *ex post* data, which were not available to policymakers in real time, may provide a very distorted picture of the conduct of monetary policy at that time. He estimates a rule by using real-time data on inflation and unemployment and challenges the conventional view according to which the conduct of monetary policy during the 1970s is not greatly different from the one thereafter.

4.2 Specifying and estimating a modified policy rule

The aim of the empirical part of this paper is to contribute to this debate by evaluating the relevance of the rule derived in the previous section which incorporates the lagged inflation-forecast deviation as an additional factor considered by the Fed in monetary decision-making. This factor, which has not been taken explicitly into account in the existing literature appears to explain part of the persistence of the supply shocks and, thus, of the underlying inflationary pressures to which policy responded. An additional distinctive feature of our specification is that it assumes forward-looking behavior which is reflected in the various forecasts. For the estimation of the policy rule, forecast data are used as a proxy of the Fed's as well as of private expectations. These forecasts have only been used interchangeably for the estimation of policy rules by McNees (1992) and, more recently, by Boivin (2004), Orphanides (2001, 2004) and Romer and Romer (2002).

Hence, our specification responds to criticisms related to the observability of forecasts of the target variables, data availability in real time and the inability of the standard approaches to take into account the actual information available to policymakers. The use of forecasts allows us to incorporate in a single equation specification a broader array of timely available information that closely approximates the information actually used by the central bank in order to assess the future state of the economy. Moreover, our paper casts some light on the weakly substantiated conventional view that monetary policy in the United States has gone through a structural change since

late 1979, when Paul Volcker took over as a Chairman of the Fed, by identifying the role of inflation-forecast deviations in the conduct of monetary policy.

We estimate the policy rule using real-time quarterly data for the 1974-1998 period[2]. The data is obtained from the FRED and Federal Reserve Bank of Philadelphia Databases. We use as the policy rate the average effective federal funds rate. The central bank's forecasts of inflation -- as measured by the annual rate of change of the GDP deflator -- are those used by staff economists of the Board of Governors before each FOMC meeting and published in what is known as the Greenbook. The forecasts correspond to the average annualized rate of change of the GDP deflator over the next four quarters[3]. On the assumption that private inflation expectations are formed on the basis of published survey measures, private inflation expectations are approximated by the mean forecast included in the Survey of Professional Forecasters (reflecting the average annualized rate of change of the GDP deflator over the next four quarters). The inflation-forecast deviation is calculated as the difference between private and central bank forecasts during the same period.

4.3 A real-time estimate of the output gap

Data on the expected output gap is calculated on the basis of the output series at the disposal of the Fed at each point in time and of the relevant Greenbook forecasts of output over the next four quarters. The potential output series is constructed by applying sequentially in each quarter a Hodrick-Prescott filter[4] to the historical sequence of real output data (including Greenbook forecasts of the level of output in the next four quarters). The concept of output used for the calculation of the output gap was the one in use at the time, namely GNP before 1992, GDP until 1996 and GDP in chained dollars since 1996 until the end of the sample. Hence, the series constructed incorporates

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[2] The period corresponds to the Chairmanships of Arthur Burns and George Miller (1974 Q1 through 1978 Q1 and 1978 Q2 through 1979 Q2 respectively, given that 1974 Q1 is the earliest date for which data on private inflation forecasts is available from the Survey of Professional Forecasters), Paul Volcker's (1979 Q3 through 1987 Q2) and Alan Greenspan's (1987 Q3 through 1998 Q2, when the latest Greenbook data release is available).

[3] We used GDP deflator forecasts since data on CPI inflation forecasts from the Survey of Professional Forecasters is available from 1980 onwards.

information that was actually available to the Fed and could therefore influence policy decisions.

The use of forecasts as measures of the relevant policy target variables has two important advantages worth noting from the outset. First, as emphasized by Orphanides (2001, 2002), these forecasts are based on the information that was actually available whenever policy decisions were made, reflecting the real-time perception by the central bank and the private sector of the state of the economy. Second, in the presence of parameter instability, the use of these forecasts makes the analysis robust to the Lucas (1976) critique. In this respect, Romer and Romer (2000) and Bernanke and Boivin (2003), argue that the conditioning of these forecasts on a large set of timely available information justifies estimating the policy rule as a single equation avoiding explicitly modeling and estimating the actual expectation-formation process. The latter approach has been followed by Clarida, Gali and Gertler (2000), who assume that the Fed has rational expectations, which implies a set of moment conditions that can be used in a GMM framework (Boivin, 1999).

4.4 Estimates of the reaction function

In this section we present estimates of the policy reaction function derived in Section 3 and evaluate its ability to describe US monetary policy making during the 1974-1998 period. We achieve two main objectives. First, we demonstrate the existence of a systematic relationship between the federal funds rate and inflation-forecast deviations as well as forecasts of future inflation and output gap along the lines suggested by our model. Second, we identify the role of forecast deviations in the conduct of monetary policy and perform a counterfactual experiment deriving the policy rate path implied by the application of a modified version of the original policy rule that admits an instrument movement only when private inflation forecasts are higher than central bank forecasts.

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[4] To guard against the possibility that potential output may have undergone trend shifts, we use an algorithm such as the H-P filter that assigns more weight on recent data in constructing the end-of-sample estimate. The result is a flexible trend that can adapt to shifts in true potential output (Lansing, 2002).

The empirical version of the policy rule represented by equation (13) is the following:

$$ffr_t = c + \theta\pi_t^e + \tau x_t^e + \mu FD_{t-1} + w_t \qquad (16)$$

with $\qquad \pi_t^e = \frac{1}{4}\sum_{j=1}^{4}\pi_{t+j|t}$, $\quad x_t^e = \frac{1}{4}\sum_{j=1}^{4}x_{t+j|t}^e$, $\quad FD_t = \pi_t^{ep} - \pi_t^e$

where π_t^e and π_t^{ep} denote the central bank's and private forecasts respectively, in period t, of the average annual rate of change of the GDP deflator over the next four quarters, $x_{t+j|t}^e$ represents the respective central bank forecast of the output gap and FD_t is the deviation between the private sector's (π_t^{ep}) and the central bank's (π_t^e) inflation forecasts. Finally, c is by construction the equilibrium nominal interest rate and w_t stands for an autoregressive error term reflecting the combined influence of demand and supply shocks.

Instrumental variables are used for the estimation of the policy rule, as this rule includes current-period measures of expectations and is estimated on a relatively small sample. These measures of expectations, reflected in the central bank's and private forecasts, are probably characterized by measurement errors that make them noisy indicators of the actual economy-wide expectations. Moreover, these measurement errors are likely to be serially correlated thus calling for the use of an instrumental variables estimator (Roberts, 1998).

The instrument set includes lagged changes of the federal funds rate, the price level, the M2 monetary aggregate as well as the spread between the 10-year bond rate and the three-month Treasury bill rate, and lagged values of the real-time output gap. The lagged inflation-forecast deviation is not used as an instrument due to the possibility of serially correlated measurement errors in these forecasts. The equation is estimated with GMM allowing for up to sixth-order serial correlation, with the Newey-West adjustment to the weighting matrix.

The parameter estimates of the policy rule, their standard errors, and the J-test for instrument exogeneity are given in Table 1. Our main hypothesis that the inflation-forecast deviation helps account for changes in monetary policy appears to be confirmed by the empirical results. An important finding is the statistical significance of the coefficient μ on the inflation-forecast deviation suggesting that the latter constituted a distinct source of information to monetary policymakers leading to policy adjustments beyond those justified by developments in the forecasts of the main target variables.

Dummy-type stability tests as well as split-sample estimates do not provide any indication for the occurrence of a break in the late 1970s, as is usually claimed in the literature[5]. The stability of the estimated policy rule over the whole sample period indicates that our specification accounts satisfactorily for the most important factors feeding into the Fed's policy decisions. The coefficient θ, reflecting the instrument response to changes in expected inflation exceeds one, being fairly close to the Taylor's benchmark of 1.5 and is somewhat lower compared to the estimated value of 2 in the forward-looking specification of Clarida *et al.* (2000). The coefficient on the expected output gap (0.18) is at the lower bound of the respective estimates derived from forward-looking rules reported in the literature (ranging from 0.25 to 1.2). Finally, the statistical significance of the coefficient on the forecast-deviation term (0.97) reflects the empirical relevance of forecast heterogeneity as a key consideration in US monetary policy actions during the sample period. More specifically it appears that a deviation of one percentage point between private sector and central bank inflation forecasts implies an average adjustment of the federal funds rate by about the same magnitude.

To assess the contribution of our preferred rule specification to our understanding of US policy making, we also present estimates of three alternative specifications which include only the expected or contemporaneous values of inflation and the output gap. Thus, we estimate i) the forecast-based policy rule of eq.(16) by omitting the inflation-forecast deviation term, ii) a forward-looking rule in which final data are substituted for

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[5] Nevertheless, as it is widely believed that US monetary policy took an important anti-inflationary turn with the appointment of Volcker that marked the beginning of an apparently successful and long-lasting (though costly in terms of output stabilization) disinflation, we also estimated separate rules corresponding to the three different Fed Chairmanships. The results are broadly similar to those obtained for the full

real-time forecasts and iii) a simple Taylor rule that contains as arguments only the current-period realization of inflation and output gap. Both the measures of expectations and output gap that are used in the alternative forward-looking specifications are, by construction, directly comparable with the respective variables included in the original specification.

As can be seen from the estimates presented in Table 1, the forecast-based rule without the inflation-forecast deviation term provides a qualitatively similar picture of the Fed's behavior although, as suggested by the relevant literature (see among others Orphanides, 2003), it is characterized by a high degree of instability across different regimes of US monetary policy. As regards the rule estimated on final data, the coefficient on expected inflation is slightly greater than one whereas the coefficient on output gap is significantly higher than that of the real-time forecast-based specification (0.66 against 0.20) mainly reflecting the high output gap coefficient in the Burns period. Similar results are obtained from the simple Taylor rule, although in this rule we get more indications of a structural break in the late-1970s.

The policy reaction to the inflation-forecast deviation together with the change in the sign of this deviation emerge as the main factors behind the significant Fed policy reversal of the late 1970s. As shown in Fig. 1, the private sector had consistently underestimated inflationary pressures during the 1970s, with the average deviation being of the order of 0.3 per cent and peaking at 1.3 per cent in 1979. The Fed appears to have taken advantage of the room for maneuver provided by lower private inflation expectations by setting the federal funds rate target at a lower level than the one implied by its internal forecasts of the main policy target variables. Fig 2. presents our estimate of the policy instrument path derived from a modified version of the policy rule represented by eq. (16) in which we restrict the policy reaction to take place only in the case of a positive inflation-forecast deviation (i.e. when the private forecast was higher that the central bank forecast). Evidently, the federal funds rate implied by the modified rule appears to be about 4 percentage points higher than its actual level, indicating the importance of the reaction to the negative forecast deviation in explaining the

sample with the exception of the Burns period where the relatively small sample is likely to have induced

accommodating monetary policy stance during the 1970s. The lower coefficient on the real-time output gap forecast relative to the coefficient obtained from specifications including measures of the contemporaneous output gap appears to reflect the gradualism characterizing monetary policy decisions based on expectations of target variables which are surrounded by a significant degree of uncertainty.

4.5 Interest-rate smoothing

Central banks often appear to adjust interest rates in a gradual fashion, taking small, distinct steps toward a desired instrument setting and reverse course only at infrequent intervals (Rudebusch, 2002). Several arguments have been put forward in the literature to explain the gradual response of the Fed's policymakers to changes in inflation and the output gap, including the existence of forward-looking strategies and uncertainties about economic data that are subject to revision, the structural model of the economy and the monetary policy transmission mechanism. Accordingly, we allow for the possibility that the federal funds rate adjusts gradually to achieve the level suggested by the optimal rule. Thus, the rule takes the following form:

$$ffr_t = s \ ffr_{t-1} + \left(1 - s\right)\left(c + \theta\pi_t^e + \tau x_t^e + \mu FD_{t-1} + w_t\right) \qquad (17)$$

As is evident from Table 2, the coefficient on the interest-rate smoothing term is considerably lower (0.26) compared to that estimated from standard Federal Reserve's policy rule specifications which typically find a coefficient on lagged federal funds rate of the order of 0.80. This coefficient is also significantly lower than those obtained from our specification estimated on final data (0.74) and from the simple Taylor rule (0.60). Hence, according to our preferred specification, the Fed makes 75 per cent of the necessary adjustment (implied by developments in expected inflation and the output gap) in one quarter instead of about 4 to 5 quarters reported by most studies. The persistence in the inflation forecast deviation to which the Fed responds rather than policy inertia appears to be the main mechanism that often leads to the observed repetitive policy instrument movements in the same direction.

upward bias in the coefficient estimates.

Nevertheless, our results appear to accord well with a number of studies using real-time data for the estimation of the policy rules (Lansing, 2002; Rudebusch, 2002). These studies show that attempts to identify the Fed's rule using final data (as opposed to real-time data) can create the spurious result of an extremely high degree of interest-rate inertia when, in fact, interest-rate smoothing by the central bank is only modest[6]. Lansing (2002) shows that the lagged federal funds rate can enter spuriously with a very high coefficient in final-data policy rule regressions because it helps pick up the Fed's serially correlated real-time measurement errors which are not taken into account in standard rule specifications. He finds that this misspecification problem can explain as much as half of the apparent degree of ''inertia'' or ''partial adjustment'' in the US federal funds rate. Rudebusch (2002) notes that while the concept of interest-rate smoothing applies to the federal funds rate movements over the course of several weeks or months, it does not necessarily imply a large regression coefficient on the lagged federal funds rate at the quarterly frequency. He also presents evidence from the term structure of US interest rates to reject the hypothesis of a large degree of monetary policy inertia. Under the assumption that longer-term interest rates are governed by agents' rational expectations of future short-term rates, Rudebusch argues that ''quarterly interest-rate smoothing is a very modest phenomenon in practice and thus, the interest-rate-smoothing term should not exceed 0.4''. In this respect, the inclusion in our optimal rule of the inflation-forecast deviation term and the use of a real-time output gap forecast appear to improve the empirical relevance of the rule by taking into account the persistent nature of forecast errors, and thus reducing monetary policy inertia.

5. Conclusions

This paper questioned the common practice in monetary policy modeling of ignoring the role of inflation-forecast heterogeneity in forward-looking policy making. We investigated the existence of a link between observed inflation persistence and the

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[6] Nevertheless, other studies, such as Orphanides (2001) and Perez (2001), continue to find a large and statistically significant coefficient on the lagged federal funds rate even when policy rules are estimated by using real-time data.

deviation between central bank and private inflation forecasts that motivates policy reactions additional to those related to developments in the main policy target variables.

The deviation between the Fed's and private inflation forecasts was considered as a basic determinant of inflation persistence leading to a slowdown in the pace at which supply shocks fade away. In this vein, the autoregressive error term of the Phillips curve corresponding to supply shocks was decomposed into a part related to the persistence of the forecast deviation and a remaining part reflecting structural supply factors. An optimal policy rule was obtained by the minimization under discretion of a standard central bank loss function subject to the constraints provided by the modified Phillips curve, including the forecast deviation, and a standard forward-looking aggregate demand equation. The rule includes the forecast deviation as an additional argument. This deviation leads to monetary policy adjustments above and beyond those justified by changes in the forecasts of the target variables. The rule was estimated on US data covering the period 1974-1998 on the basis of real-time inflation and output gap forecasts obtained by using the FOMC's Greenbook and the Survey of Professional Forecasters.

The monetary policy reaction to the forecast deviation appears to have been an important factor underlying the successful disinflation of the 1980s as well as the persistence of inflationary pressures during the 1970s. In particular, the FOMC appears to have tightened whenever the private inflation forecast was higher than the Fed's forecast, and to have eased when it was lower.

The estimated rule remains remarkably stable over the whole sample period, a situation that appears to be at odds with the conventional wisdom. Notably, the coefficient on expected inflation is greater than one, exceeding by a wide margin the response coefficient obtained from the forward-looking rule estimated on final data or from the simple Taylor rule. The coefficient on the expected output gap is lower than the corresponding coefficient we get from rules estimated on final data, reflecting the gradualism that characterizes monetary policy decisions based on expectations of target variables which are surrounded by a significant degree of uncertainty.

Overall, our paper challenges the widely held view that monetary policy in the US has gone through a structural change since late 1979, when Paul Volcker took over as a Chairman of the Fed, by identifying the role of inflation-forecast deviations in the conduct of monetary policy. The novel explanation put forward for the pre-1980 high-inflation period is that it cannot be attributed to activist policies aiming at output gap stabilization, as is usually argued, but to the insufficient monetary policy tightening in a period in which private inflation forecasts were lower than the respective central bank forecasts. Similarly, the success of Volcker's disinflation is attributed *inter alia* to the forceful Fed reaction to this deviation in a period when private expectations exceeded central bank forecasts. Finally, the small coefficient on the lagged interest rate variable in the estimated rule appears to lend support to the growing view that interest rate inertia may, to a large extent, be an artifact of serially correlated forecast errors which are not taken into account by conventional rule specifications but feed into monetary policy decisions in real time.

Appendix. Data sources

All data series are quarterly, beginning in 1974:1 and ending in 1998:2. Data on the federal funds rate, the GDP deflator, the M2 monetary aggregate and the spread between the 10-year bond yield and the three-month Treasury bill rate are all from the Federal Reserve System's Database (FRED). Data on GDP deflator forecasts were taken from the FOMC's Greenbook and the Survey of Professional Forecasters datasets available at the Federal Reserve Bank of Philadelphia.

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Table 1
Alternative specifications of the Fed's reaction function: Specifications without interest-rate smoothing

	π_t^e	x_t^e	FDt-1	Const.	$\bar{R}^2$	Q	J-test
Forecast-based rule with real-time output gap forecast and inflation-forecast deviation	1.48 (21.48)	0.18 (4.82)	0.97 (3.27)	5.41 (26.48)	0.91	12.78 (0.016)	0.12
Forecast-based rule with real-time output gap forecast	1.55 (15.58)	0.20 (4.16)	…	5.74 (25.89)	0.86	16.38 (0.040)	0.19
Forward-looking rule estimated on final data	1.01 (8.07)	0.66 (2.57)	…	3.95 (6.77)	0.68	18.34 (0.021)	0.11
Simple Taylor rule	1.12 (17.06)	0.54 (2.99)	…	3.54 (10.43)	0.77	21.34 (0.016)	…

Table 2
Alternative specifications of the Fed's reaction function: Specifications with interest-rate smoothing

	π_t^e	x_t^e	FD_{t-1}	Const.	i_{t-1}	$\bar{R}^2$	Q	J-test
Forecast-based rule with real-time output gap forecast and inflation-forecast deviation	1.58 (23.32)	0.20 (6.25)	0.83 (2.74)	5.49 (28.63)	0.26 (3.12)	0.92	10.78 (0.036)	0.09
Forecast-based rule with real-time output gap forecast	1.56 (16.73)	0.19 (4.15)	…	5.68 (26.71)	0.32 (2.46)	0.87	15.68 (0.039)	0.10
Forward-looking rule estimated on final data	0.98 (6.01)	0.73 (2.56)	…	4.80 (5.84)	0.74 (11.07)	0.81	16.98 (0.026)	0.06
Simple Taylor rule	0.96 (10.77)	0.76 (5.53)	…	4.13 (9.89)	0.60 (6.89)	0.83	19.34 (0.028)	…

Notes for Tables 1 and 2: π_t^e denotes the central bank forecast in period t of the average annual rate of change of the GDP deflator over the next four quarters and x_t^e stands for central bank output gap forecast. In the cases of the forward-looking rule and the simple Taylor rule (lines 3 - 4 in Tables 1 and 2), π_t^e and x_t^e correspond to the actual data on the rate of change of the GDP deflator and the output gap in the next four quarters and in the current quarter respectively. FD_t stands for the deviation between the Survey of Professional Forecasters and the Greenbook forecasts of the rate of change of the GDP deflator over the next four quarters, *Const.* denotes constant and i_{t-1} stands for the interest-rate smoothing term. *J-test* reports the p-values for the relevant test statistic under the null hypothesis that the overidentifying restrictions are satisfied.

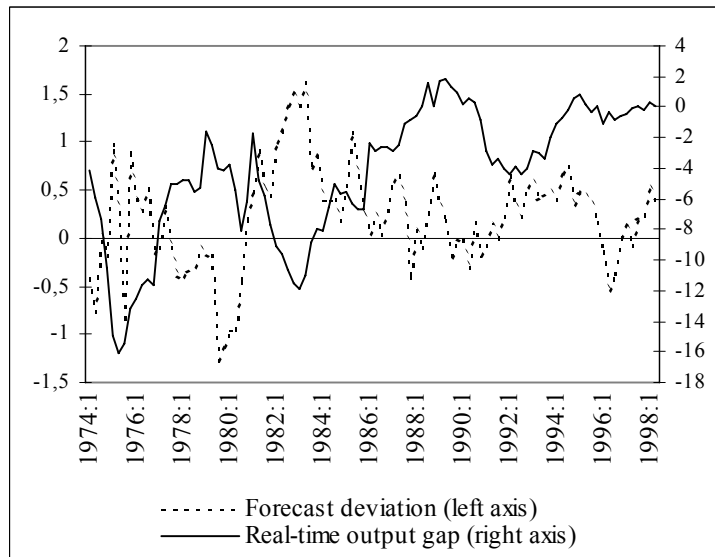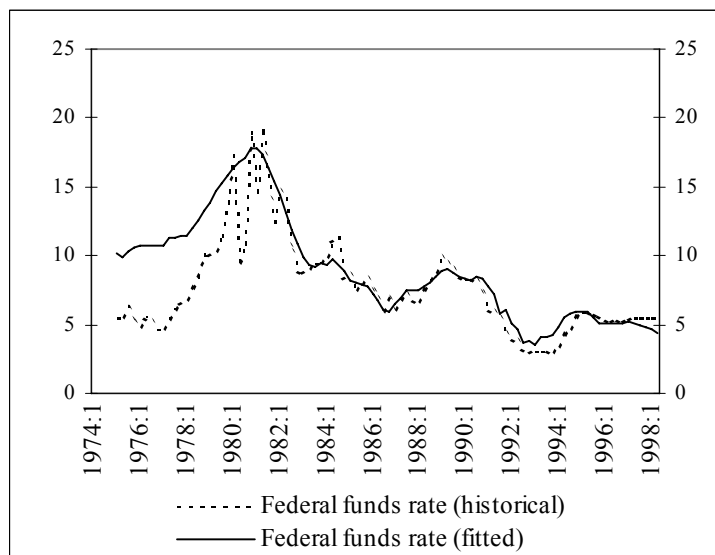**Figure 1: Inflation-forecast deviation and real-time output gap forecast**

Forecast deviation (left axis)
Real-time output gap (right axis)

Figure 2: Federal funds rate – actual and fitted under an asymmetric rule

Federal funds rate (historical)
Federal funds rate (fitted)

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