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**Abstract**

In a simple New Keynesian model, we derive a closed form solution for the inflation persistence parameter as a function of the policy weights in the central bank's Taylor rule. By estimating the time-varying weights that the FED attaches to inflation and the output gap, we show that the empirically observed changes in U.S. inflation persistence during the period 1975 to 2010 can be well explained by changes in the conduct of monetary policy. Our findings are in line with Benati's (2008) view that inflation persistence should not be considered a structural parameter in the sense of Lucas.

**Keywords**: inflation persistence, Great Moderation, monetary policy, New Keynesian model, Taylor rule.

**JEL Classification**: C22, E31, E52, E58.

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# 1 Introduction

The degree of U.S. inflation persistence varied considerably during the last forty years (Cogley and Sargent, 2005, Cogley et al., 2010, and Kang et al., 2009). While inflation persistence was high during the 1970s, it fell sharply in the early 1980s and, thereafter, remained at a considerably lower level than in the 1970s. It is often informally argued that the observed changes in persistence are related to changes in the FED's monetary policy (see, e.g., Clarida et al., 2000). In particular, the strong decline in persistence in the early 1980s is associated with the Volcker disinflation. In this paper, we analyze the link between a Taylor rule for monetary policy and inflation persistence in a simple New Keynesian type of model, which allows for a closed form solution of the inflation persistence parameter as a function of the weights that the central bank attaches to inflation and the output gap.

Our model can be considered a closed-economy version of the model discussed in Clarida and Waldman (2008). It consists of three equations: a forward looking aggregate demand curve, a backward looking supply curve and a standard Taylor rule. In this setting, the reduced form representation of the inflation rate is a stationary autoregressive process of order one. The degree of inflation persistence, which is given by the first order autoregressive coefficient, strictly decreases in the Taylor rule coefficient on the deviation of inflation from its target and strictly increases in the Taylor rule coefficient on the output gap. That is, our model predicts that the more aggressively the central bank reacts to deviations of inflation from its target, the faster does the inflation rate converge to the target. This central property of our model is then tested empirically for the U.S.

In a first step, we estimate a forward looking Taylor rule for a rolling window of twenty years of quarterly observations. The estimated weights on inflation and the output gap reveal substantial variation during the period 1975:Q1 to 2010:Q1. In particular, we find the highest weight on inflation during the early years of the Volcker era. For that period the output gap coefficient estimate was insignificant, but significantly positive thereafter. In a second step, we obtain rolling window estimates of the degree of inflation persistence. Interestingly, the estimated persistence was lowest in the period for which we estimated the highest values for the reaction coefficient on inflation. Also, inflation persistence increased during a period in which the FED increased its weight on the output gap. A more formal test of our model's implications is performed by regressing the estimated inflation persistence on the estimated reaction coefficients on inflation and the output gap. In line with the model's predictions, we find that a higher weight on inflation (the output gap) significantly decreases (increases) inflation persistence. Finally, we utilize the estimated reaction coefficients to generate a series of inflation persistence measures as predicted by our theoretical model and then compare this series with the actually observed inflation persistence. Again, the predictions of the model are confirmed by the observed data.

In summary, our empirical analysis strongly supports the hypothesis that the changes in U.S. inflation persistence can be well explained by changes in the conduct of the FED's monetary policy. Our findings can be considered complementary to other recent evidence provided by, e.g., Carlstrom et al. (2008), Davig and Doh (2009) and Kang et al. (2009).

The remainder of this article is organized as follows. In Section 2 we introduce the model and derive a closed form solution for the inflation persistence parameter. Section 3 presents the data and the empirical analysis. A short discussion closes the paper.

# 2 Theoretical Model

We consider a simple New Keynesian model consisting of three equations: aggregate demand, aggregate supply and a monetary policy rule that specifies how the central bank sets the interest rate as a function of the output gap and of deviations of inflation from its target. Our model is motivated by Clarida and Waldman (2008) and can be viewed as a closed economy version of their model. The simple structure of the model allows us to investigate how changes in monetary policy (changes in the weights in the monetary policy rule) affect the degree of inflation persistence in the reduced form solution of the model.

Let aggregate demand be given by

$$y_t = \mathbf{E}_t \{y_{t+1}\} - (i_t - \mathbf{E}_t \{\pi_{t+1}\}) + u_t, \tag{1}$$

where $y_t$ is the output gap, $i_t$ the nominal interest rate, $\mathbf{E}_t \{\pi_{t+1}\}$ expected inflation, and $u_t$ a demand shock which is assumed to be white noise. The nominal interest rate is linked to the real rate through the Fisher equation $i_t = r_t + \mathbf{E}_t \{\pi_{t+1}\}$. The forward looking aggregate demand equation (1) can be derived by log-linearizing the consumption Euler equation that arises from the household's optimal savings decision.[1] Following Clarida

[1] See, for example, Woodford (1996) or Bernanke, Gertler and Gilchrist (1998).

and Waldman (2008), aggregate supply is given by

$$\pi_t = \pi_{t-1} + y_t + e_t, \tag{2}$$

where $e_t$ is a white-noise aggregate supply shock ("cost-push" shock). Two comments are in order. First, we assume that the coefficients on lagged inflation and on the output gap are both equal one. This assumption simplifies our model but does not affect its qualitative predictions. We will discuss the implications of this assumption in more detail in Section 3.2. Second, the aggregate supply curve is assumed to be backward looking, that is, current inflation depends on lagged inflation. In the literature, both backward and forward looking aggregate supply curves are common. A purely forward looking aggregate supply curve is not appropriate for our setting because it does not generate the degree of inflation persistence we typically observe in the data.[2] A compromise would be a "hybrid" aggregate supply curve in which both lagged and expected inflation appear on the right hand side. The reason why we focus on a backward looking aggregate supply curve (sometimes called an "accelerationist" Phillips curve) is that it allows for a simple closed form solution of the inflation persistence parameter.

We close the model by assuming that the central bank conducts monetary policy according to the following Taylor rule

$$i_t = \gamma_0 + \gamma_\pi(\mathbf{E}_t\left\{\pi_{t+1}\right\} - \bar{\pi}) + \gamma_y y_t, \tag{3}$$

where $\bar{\pi}$ is the central bank's inflation target. Under this forward looking rule, policy responds to the current output gap and to expected deviations of inflation from the target. The constant $\gamma_0$ is, by construction, the desired nominal interest rate, when both inflation and output are at their target levels. Taylor rules of this type are standard in the literature and are in line with the optimal rules derived, for example, in Clarida at al. (1999). The weight on the output gap is assumed to be positive ($\gamma_y > 0$) and the weight on inflation is assumed to be greater than one ($\gamma_\pi > 1$). The assumption that $\gamma_\pi > 1$, is referred to as the Taylor condition and is necessary for a stable solution. To get an intuition for this principle, use the Fisher equation above and rewrite the policy rule in terms of the real rate

$$r_t = (\gamma_0 - \bar{\pi}) + (\gamma_\pi - 1)\left(\mathbf{E}_t\left\{\pi_{t+1}\right\} - \bar{\pi}\right) + \gamma_y y_t.$$

[2] Cogley et al. (2008) show that even a forward looking supply curve can generate sufficient persistence, when inflation is replaced by the inflation gap, i.e. the difference between the actual inflation and the time-varying trend inflation.

The Taylor condition states that the central bank needs to respond more than one for one to deviations of expected inflation from the target in order for the real rate to rise. The term $(\gamma_0 - \bar{\pi})$ corresponds to the long-run equilibrium real interest rate.

In the following proposition we show that the reduced form representation of the inflation rate is an *autoregressive process of order one* (AR(1)). Following Pivetta and Reis (2005), we then measure inflation persistence by the autoregressive coefficient.[3]

**Proposition 1.** *If the Taylor condition is satisfied and if the weight on the output gap is positive, there exists - conditional on the minimum set of state variables - a unique rational expectations solution of the form*

$$\pi_t = c + d\pi_{t-1} + \kappa_t, \tag{4}$$

*where $c$ is a constant, $\kappa_t$ is white noise and the persistence parameter $d$ can be expressed as*

$$d = \sqrt{2\chi + \chi^2 - \frac{1}{\gamma_\pi}} - \chi, \tag{5}$$

*where $\chi \equiv (2 + \gamma_y)/(2\gamma_\pi)$.*

The proof of Proposition 1 can be found in the Appendix. For analyzing the effects of changes in $\gamma_\pi$ and $\gamma_y$ on the persistence parameter $d$, take the partial derivatives to find:

$$\frac{\partial d}{\partial \gamma_\pi} < 0 < \frac{\partial d}{\partial \gamma_y} \tag{6}$$

Thus, inflation persistence is strictly decreasing in $\gamma_\pi$, the Taylor rule coefficient on the inflation gap, and strictly increasing in $\gamma_y$, the Taylor rule coefficient on the output gap.[4] The more aggressively the central bank reacts to the inflation gap, the faster the inflation rate converges to its long-run value (the target). However, the larger the weight placed on output stabilization, the higher the degree of inflation persistence. In the limit, when $\gamma_\pi$ approaches one and when $\gamma_y$ increases indefinitely, inflation approaches a random walk ($d \to 1$). On the other hand, as the weight on inflation goes to infinity, inflation approaches a white noise process ($d \to 0$). Figure 1 plots the persistence parameter $d$ as a function of $\gamma_\pi$, while $\gamma_y$ is fixed at 0.1, 0.5 and 1.0 respectively. Note, that the effect of a change in $\gamma_\pi$ on $d$ is stronger, the smaller the initial value of $\gamma_\pi$.

[3] As discussed in Pivetta and Reis (2005) this measure can be viewed as an unconditional measure of persistence. In contrast, conditional persistence measures would be derived from equations that in addition to lagged inflation include other explanatory variables. Since we are interested in measuring persistence and not predictability we focus on the former.

[4] Note, that this result is qualitatively the same as in Clarida and Waldman (2008).

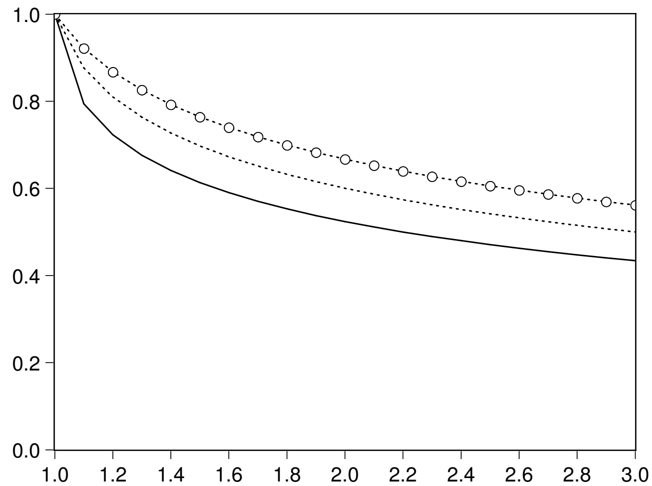


Figure 1: Inflation persistence $d$ ($y$-axis) as a function of the reaction coefficient $\gamma_\pi$ ($x$-axis) with $\gamma_y$ fixed at 0.1 (solid line), 0.5 (dashed line) and 1.0 (dotted line).

# 3 Empirical Analysis

In the following section, we will empirically test the implications of our theoretical model using U.S. data. For the estimation of the forward looking Taylor rule, we will employ inflation expectations data from the Survey of Professional Forecasters (SPF). Regarding the output gap, we follow Orphanides (2004) and rely on real-time instead of revised data. That is, we make use of the data available to the FED at the time the monetary policy decisions were made. Since the survey respondents participating in the SPF are asked about their expectations regarding the GDP deflator, we also use the GDP deflator for estimating our measures of inflation persistence.

## 3.1 Data

We employ quarterly data for the period 1975:Q1 to 2010:Q1. The federal funds rate ($i_t$) and the GDP deflator ($p_t$) data are obtained from the FRED database at the Federal Reserve of St. Louis. Inflation expectations are constructed as either annualized one-quarter-ahead predictions $\hat{\pi}_{t+1|t}$ or one-year-ahead predictions $\hat{\pi}_{t+4|t}$.[5] The corresponding realized inflation rates are calculated as $\pi_{t+1,t} = 400 \times [\log(p_{t+1}) - \log(p_t)]$ and $\pi_{t+4,t} =$

[5]The expectations data are collected in the second month of each quarter. The SPF has set the deadline for the responses at late in the second to third week of the second month. The data we are using are the median expectations among the survey participants.

$100 \times [\log(p_{t+4}) - \log(p_t)]$, respectively. The real-time output data were retrieved from the Federal Reserve of Philadelphia. For each vintage the output gap is calculated as the deviation of actual output from a quadratic time trend.[6] Since the real-time dataset contains estimates for output in quarter $t-1$ (and before) based on information up to quarter $t$, we obtain a real-time output gap series $y_{t-1|t}$ by collecting the last observations from each vintage.[7] In order to obtain estimates for quarter $t$, we fit an AR(2) model to the series $y_{t-1|t}$ and construct $\hat{y}_{t|t}$ as the one-step-ahead predictions.

## 3.2 Estimation Results

We begin the empirical analysis by estimating a standard Taylor rule of the form

$$i_t = \gamma_0 + \gamma_\pi(\hat{\pi}_{t+k|t} - \bar{\pi}) + \gamma_y \hat{y}_{t|t} + \varepsilon_t, \tag{7}$$

where $\varepsilon_t$ is a stochastic innovation.[8] Throughout the analysis we set the inflation target $\bar{\pi}$ equal to 2%.[9] In order to control for the effects of the different time horizons $k$ on the estimation results, we consider two specifications: a first one which employs the one-year-ahead inflation expectations ($\hat{y}_{t+4|t}$) and a second one which employs the annualized one-quarter-ahead inflation expectations ($\hat{y}_{t+1|t}$). The results for the *whole sample*, i.e. for the period 1975:Q1 - 2010:Q1, are presented in the second and third column of Table 1 and provide reasonable estimates for the inflation and output gap reaction coefficients. In both cases the reaction coefficient on inflation is well above one, i.e. satisfies the Taylor principle, and the reaction coefficient on the output gap is significantly greater than zero. Note, that the estimates of $\gamma_\pi$ and $\gamma_y$ are quite close to 1.5 and 0.5, the values suggested in Taylor (1993). Columns four and five contain estimates for the Volcker era and the post-Volcker period (both for $k = 4$). Interestingly during the Volcker years the coefficient on the output gap is virtually zero and statistically insignificant. On the other hand, the coefficient on inflation is highly significant and close to 1.5. Thus, our estimates for the

[6]For a discussion of alternative methods for estimating the output gap see Orphanides and van Norden (2002).

[7]The "advance" estimate of GDP in quarter $t$ is released near the end of the first month in quarter $t+1$.

[8]As an alternative to equation (7), we also considered a specification which allows for interest rate smoothing and obtained similar results. However, in order to be as close as possible to our theoretical model introduced in Section 2, we prefer to work with the simpler specification.

[9]Since we are only interested in identifying the parameters $\gamma_\pi$ and $\gamma_y$, this assumption is innocuous because it only affects the constant $\gamma_0$.

Volker era are in line with the usual interpretation that in these years the focus of the FED's policy was on inflation. During the post-Volcker years both reaction coefficients are highly significant and even slightly higher than in the whole sample. That is, in the post-Volcker years the FED shifted its focus to both inflation and growth. Clearly, the sub-sample analysis shows that the FED's monetary policy changed considerably over time (see also Clarida et al., 2000).

Table 1: Taylor Rule Reaction Coefficient Estimates.

| | 1975:Q1-2010:Q1 | | Volcker | post-Volcker | 79:Q4-10:Q1 | 80:Q3-10:Q1 |
|---|---|---|---|---|---|---|
| | $\hat{\pi}_{t+4\|t}$ | $\hat{\pi}_{t+1\|t}$ | $\hat{\pi}_{t+4\|t}$ | $\hat{\pi}_{t+4\|t}$ | $\hat{\pi}_{t+4\|t}$ | $\hat{\pi}_{t+1\|t}$ |
| $\gamma_0$ | 2.876*** (0.341) | 3.179*** (0.370) | 4.833*** (0.811) | 2.536*** (0.304) | 2.746*** (0.300) | 2.991*** (0.309) |
| $\gamma_\pi$ | 1.589*** (0.208) | 1.442*** (0.191) | 1.619*** (0.269) | 1.873*** (0.212) | 2.025*** (0.165) | 2.001*** (0.142) |
| $\gamma_y$ | 0.321*** (0.098) | 0.331*** (0.110) | 0.011 (0.133) | 0.436*** (0.073) | 0.344*** (0.067) | 0.364*** (0.079) |
| $\bar{R}^2$ | 0.70 | 0.66 | 0.72 | 0.78 | 0.86 | 0.83 |

Notes: The table shows the parameter estimates for the Taylor rule given in equation (7). The columns refer to different sample periods and different choices of $k$ in $\hat{\pi}_{t+k|t}$. The first row presents the periods for which the model is estimated. The columns "Volcker" and "post-Volker" contain the estimations for the samples 1979:Q3-1987:Q3 and 1987:Q4-2010:Q1. The numbers in parenthesis are Newey-West robust standard errors. ***, ** and * indicate significance at the 1%, 5% and 10% level.

Next, we investigate the changes of the reaction coefficients in the FED's Taylor rule in more detail. For this, the estimation of the Taylor rule is performed for a *rolling window* of $M$ observations, which leads to a series of estimates $(\hat{\gamma}_\pi^1, \hat{\gamma}_y^1), \ldots, (\hat{\gamma}_\pi^M, \hat{\gamma}_y^M)$. Figure 2 shows the estimates for $\gamma_\pi^i$ and $\gamma_y^i$ from regressions with $M = 80$, which corresponds to twenty years of quarterly observations.[10] Note, that the estimates denoted by $\hat{\gamma}_\pi^{75:Q1}$ and $\hat{\gamma}_y^{75:Q1}$ are based on observations ranging from 1975:Q1 to 1995:Q1. Similarly, the final estimates $\hat{\gamma}_\pi^{90:Q1}$ and $\hat{\gamma}_y^{90:Q1}$ are based on observations ranging from 1990:Q1 to 2010:Q1. The upper panel of Figure 2 is based on data with $k = 4$ (one-year-ahead inflation expectations), the lower panel on data with $k = 1$ (annualized one-quarter-ahead inflation expectations). For both choices of $k$ the estimates of $\gamma_\pi^i$ are steadily increasing from a value of about

[10]In choosing $M$ one faces a trade-off between obtaining precise estimates of the reaction coefficients on the one hand and detecting changes in the coefficients as quickly as possible on the other hand. Our choice of $M = 80$ balances the two desires.

1.5 when $i$ = 1975:Q1 and reach a maximum of about 2.2 (2.0) when $i$ = 1982:Q1 ($i$ = 1981:Q2), respectively.[11] Interestingly, the steepest increase in $\gamma_\pi^i$ occurs when we use a sample that begins in the early eighties (i.e. does not contain data from the seventies). Thus, this strong increase coincides with the period of the Volcker disinflation starting in 1979:Q3. Thereafter, the estimates for $\gamma_\pi^i$ are slightly decreasing but remain at a level well above 1.5. With $k = 4$ ($k = 1$) the estimates for $\gamma_y^i$ are insignificant before $i$ = 1979:Q4 (1980:Q3) and significantly positive thereafter. The estimate for $\gamma_y^i$ is steadily increasing towards a value of about 0.5 when $i$ = 1984:Q1 and then remains at this level.

In summary, the rolling window estimates of the reaction coefficients provide strong support for the existence of time-varying weights in the FED's Taylor rule. Hence, combining the parameter estimates with the predictions of our theoretical model, we would expect that $\gamma_\pi^i$ should have a strong *negative* effect on inflation persistence in the period $i$ = 1975:Q1, ..., 1982:Q1 for $k = 4$ ($i$ = 1975:Q1, ..., 1981:Q2 for $k = 1$), but a positive although considerably weaker effect thereafter. On the other hand, we would expect no effect from $\gamma_y^i$ before $i$ = 1979:Q4 ($i$ = 1980:Q3), but a *positive* and significant effect until 1984. In columns six and seven of Table 1 we present the Taylor rule parameter estimates for the periods in which $\hat{\gamma}_y$ was significant in the rolling window regressions. In these periods $\gamma_\pi$ is estimated to be 2.0, i.e. higher than in the whole sample, and $\gamma_y$ is estimated around 0.35. Note, that in the two sub-samples the adjusted $R^2$ is considerably higher than in the full sample.

Next, we construct our empirical measure of inflation persistence. We model the inflation series as an AR($p$) process

$$\pi_{t+k,t} = \phi_0 + \phi_1 \pi_{t+k-1,t-1} + \ldots + \phi_p \pi_{t+k-p,t-p} + \eta_t \tag{8}$$

and define inflation persistence as the sum of estimated autoregressive coefficients, i.e.

$$\hat{d} = \hat{\phi}_1 + \ldots + \hat{\phi}_p. \tag{9}$$

We estimate the AR($p$) model by OLS and – on the basis of standard information criteria – choose $p = 1$ for the year-to-year inflation rates and $p = 4$ for the annualized quarterly

[11] At first sight, it may be surprising that $\gamma_\pi^i$ is estimated to be greater than one for $i <$ 1979:Q3 already, while studies such as Clarida et al. (2000) have shown that the FED's behavior was "accommodative" in the pre-Volcker years. However, one has to recall that, e.g., $\hat{\gamma}_\pi^{75:Q1}$ is based on observations from 1975:Q1 to 1995:Q1 and, hence, only the first four years of this period are from the pre-Volcker era. When we perform a recursive estimation (instead of the rolling window), we also find that $\hat{\gamma}_\pi$ is below one before 1980.

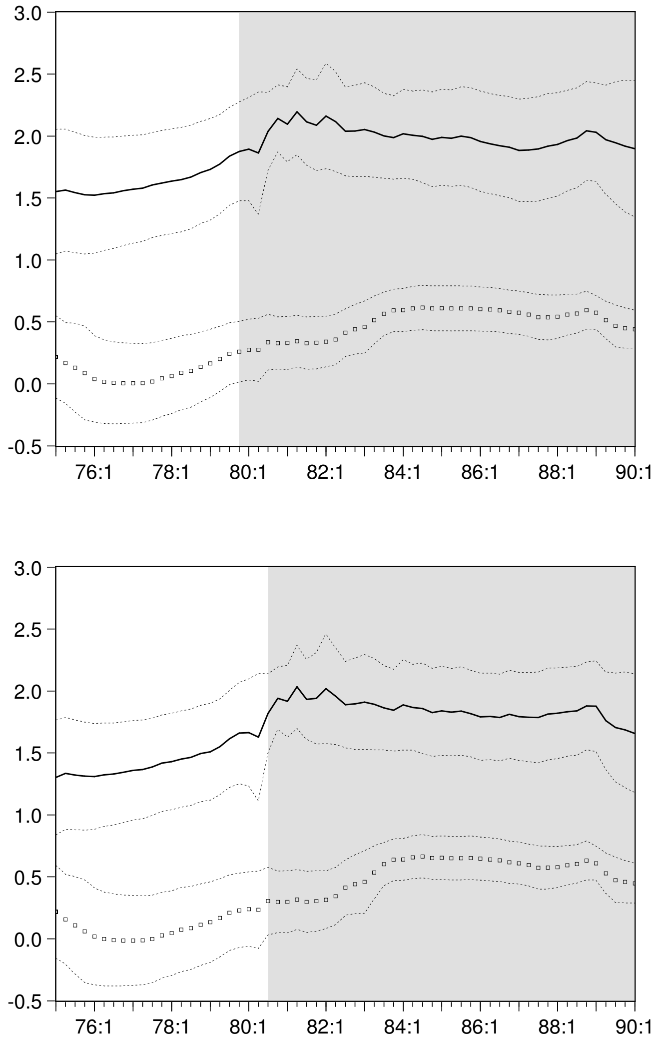


Figure 2: Estimates of $\gamma_\pi$ (solid) and $\gamma_y$ (squares) with corresponding 95% confidence bands (dashed) for $k = 4$ (upper panel) and $k = 1$ (lower panel). Using inflation expectations with $k = 4$ ($k = 1$) $\hat{\gamma}_y$ is insignificant for $i <$ 1979:Q4 (1980:Q3), but significant thereafter (shaded area).

inflation rates. When $p = 1$ the empirical measure of inflation persistence coincides with the theoretical one derived in Section 2. Again, performing the estimation for the rolling sample leads to a series $\hat{d}^1, \ldots, \hat{d}^M$ of persistence parameters. Figure 3 shows the estimated degree of persistence for $\pi_{t+4,t}$ (with $p = 1$) and $\pi_{t+1,t}$ (with $p = 4$). The estimated values $\hat{d}^i$ are starting at a high level of persistence and then sharply decrease until they reach a minimum for $i =$ 1981:Q4 (1981:Q2). The sharp decrease occurs exactly in the period for which $\gamma_\pi$ was estimated to be strongly increasing. The minimum degree of inflation

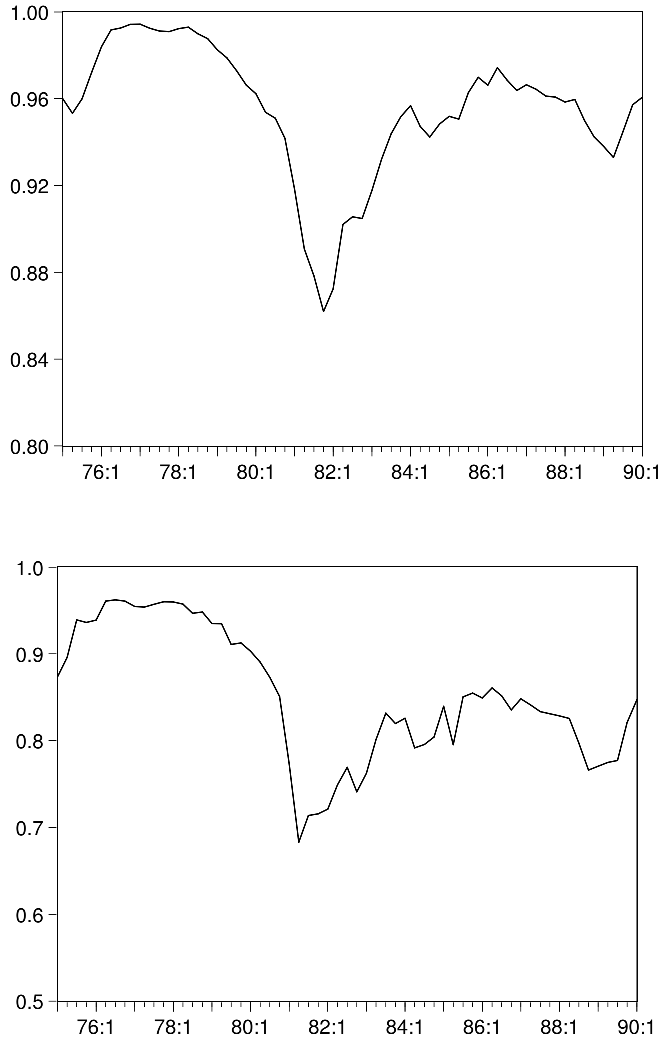


Figure 3: Inflation persistence measured from $\pi_{t+4,t}$ with $p = 1$ (upper panel) and $\pi_{t+1,t}$ with $p = 4$ (lower panel). The lowest degree of inflation persistence is reached for $i =$ 1981:Q4 (1981:Q2).

persistence is reached when the reaction coefficient on inflation was approximately at its maximum value. Thereafter, inflation persistence is again increasing but towards a lower level than in the mid-seventies. The increase in inflation persistence now coincides with the raising value of $\hat{\gamma}_y$ until the mid-1980s. The fact that inflation persistence stabilizes from the mid-1980s onwards is in line with the observation that thereafter both $\hat{\gamma}_\pi$ and $\hat{\gamma}_y$ remained stable. Thus, the visual inspection of Figures 2 and 3 appears to support the theoretical predictions of our model. As expected, the degree of persistence estimated from $\pi_{t+4,t}$ is generally higher than that estimated from $\pi_{t+1,t}$.[12]

As a more formal check of our theory we run the regression

$$\hat{d}^i = \delta_0 + \delta_\pi \hat{\gamma}_\pi^i + \delta_y \hat{\gamma}_y^i + \xi^i, \tag{10}$$

$i = 1, \ldots, M$, and then test whether $\delta_\pi < 0$ and $\delta_y > 0$. Table 2 shows that for all specifications $\hat{\delta}_\pi$ is negative and highly significant. That is, in line with our theory, inflation persistence is lower the stronger the central bank reacts to deviations of actual inflation from the target. The estimate $\hat{\delta}_y$ is positive and significant at the 5% level in the specification based on $\hat{\pi}_{t+4|t}$, but insignificant in the specification based on $\hat{\pi}_{t+1|t}$. As before, we rerun both regressions for the periods in which $\hat{\gamma}_y$ was found to be significant in the rolling window regressions. The resulting estimates of $\delta_y$ are positive and significant (at the 5% and 10% level). Thus, our estimation results support the hypothesis that increases in $\hat{\gamma}_\pi$ ($\hat{\gamma}_y$) lower (raise) the degree of inflation persistence.

For checking the robustness of our results with respect to changes in the estimation procedure of the persistence measure, we re-estimate the autoregressive parameters (i) by the approximately median unbiased estimator of Andrews and Chen (1994) and (ii) by assuming that $\eta_t$ follows a GARCH$(1,1)$ process. The results are presented in Table 2 for the full sample with $k = 4$.[13] Clearly, the parameter estimates confirm our previous findings of a negative (positive) effect of $\gamma_\pi$ ($\gamma_y$) on $d$.

In order to connect our parameter estimates more closely to the theoretical framework, we use the estimates of the Taylor rule coefficients, $(\hat{\gamma}_\pi^i, \hat{\gamma}_y^i)$, $i = 1, \ldots, M$, to construct a series of persistence parameters $\hat{d}^{i,M}(\hat{\gamma}_\pi^i, \hat{\gamma}_y^i)$ as predicted by the theoretical model in Section 2. Then we compare the model-implied persistence with the empirical estimates $\hat{d}^i$. While the solid line in Figure 4 corresponds to $\hat{d}^i$, the dashed line represents $\hat{d}^{i,M}$ as stated in equation (5) but with the theoretical parameters $(\gamma_\pi^i, \gamma_y^i)$ replaced by $(\hat{\gamma}_\pi^i, \hat{\gamma}_y^i)$. The general shape of $\hat{d}^{i,M}$ is quite similar to the one of $\hat{d}^i$, however the decrease in model-implied persistence in the late seventies and early eighties is much less sharp than the strong decline in $\hat{d}^i$. A likely explanation for this effect is that in the calculation of $\hat{d}^{i,M}$ the estimated coefficients on the output gap enter even in the period in which this coefficient

[12]Although economically significant, the observed changes in the degree of inflation persistence could be viewed as being small relative to the overall level of persistence. Because of this observation, e.g., Pivetta and Reis (2007) or Stock and Watson (2007) argue that U.S. inflation persistence did not change significantly during the period under consideration.

[13]The results for $k = 1$ are similar and omitted for brevity.

Table 2: Empirical Test of Model Predictions

| | 1975:Q1-2010:Q1 | | 79:Q4-10:Q1 | 80:Q3-10:Q1 | 75:Q1-10:Q1 | |
|---|---|---|---|---|---|---|
| | $\hat{\pi}_{t+4\|t}$ | $\hat{\pi}_{t+1\|t}$ | $\hat{\pi}_{t+4\|t}$ | $\hat{\pi}_{t+1\|t}$ | MUE | GARCH |
| $\delta_0$ | $1.263^{***}$ | $1.371^{***}$ | $1.378^{***}$ | $1.170^{***}$ | $1.272^{***}$ | $1.255^{***}$ |
| | (0.075) | (0.104) | (0.072) | (0.172) | (0.073) | (0.057) |
| $\delta_\pi$ | $-0.178^{***}$ | $-0.309^{***}$ | $-0.237^{***}$ | $-0.237^{***}$ | $-0.170^{***}$ | $-0.171^{***}$ |
| | (0.045) | (0.072) | (0.041) | (0.081) | (0.046) | (0.031) |
| $\delta_y$ | $0.066^{**}$ | 0.011 | $0.074^{**}$ | $0.134^{*}$ | $0.106^{***}$ | $0.054^{**}$ |
| | (0.030) | (0.058) | (0.031) | (0.080) | (0.033) | (0.023) |
| $\bar{R}^2$ | 0.66 | 0.75 | 0.70 | 0.43 | 0.60 | 0.59 |

Notes: The table shows the estimates for the coefficients in equation (10). The first row presents the periods for which the model is estimated. MUE (GARCH) refer to the situation in which $\hat{d}^i$ is estimated with the median unbiased estimator (conditionally heteroskedastic innovations). The numbers in parenthesis are Newey-West robust standard errors. $^{***}$, $^{**}$ and $^{*}$ indicate significance at the 1%, 5% and 10% level.

was not significant.[14]

Thus, for obtaining a better understanding of the individual contribution of $\hat{\gamma}^i_\pi$ and $\hat{\gamma}^i_y$ to the model-implied persistence, we plot the model-implied persistence for the case that only $\hat{\gamma}^i_\pi$ is varying and $\gamma^i_y$ is fixed at 0.5 ($\hat{d}^{i,M}(\hat{\gamma}^i_\pi, 0.5)$, dotted line) or that $\hat{\gamma}^i_y$ is varying and $\hat{\gamma}^i_\pi$ is fixed at 1.5 ($\hat{d}^{i,M}(1.5, \hat{\gamma}^i_y)$, squares). Clearly, the dotted line closely follows the behavior of the solid line until inflation persistence reaches its minimum, i.e. when we fix $\gamma^i_y$ the changes in $\hat{\gamma}^i_\pi$ can explain the sharp decrease in inflation persistence towards the early eighties. Similarly, the subsequent increase in $\hat{d}^i$ is reflected in the increase of $\hat{d}^{i,M}(1.5, \hat{\gamma}^i_y)$ (squares). This is the effect of an increasing weight on the output gap while holding the weight on inflation constant. In summary, as suggested by our theoretical model changes in the conduct of monetary policy can explain the changes in inflation persistence. More specifically, the sharp decrease in inflation persistence at the beginning of the eighties was a result of the aggressive disinflation policy in the Volcker era, while persistence is moderately increasing thereafter because of an increasing weight that was put on the output gap.

[14]Note that the absolute levels of the two persistence measures differ considerably. While capturing the general shape quite well, the model-implied persistence is lower than the estimated one throughout the sample period. This low level of the model-implied persistence is caused by our assumption of unit coefficients on lagged inflation and the output gap in the aggregate supply curve in eq. (2). Adjusting these coefficients appropriately, we would obtain similar levels of persistence from both measures.

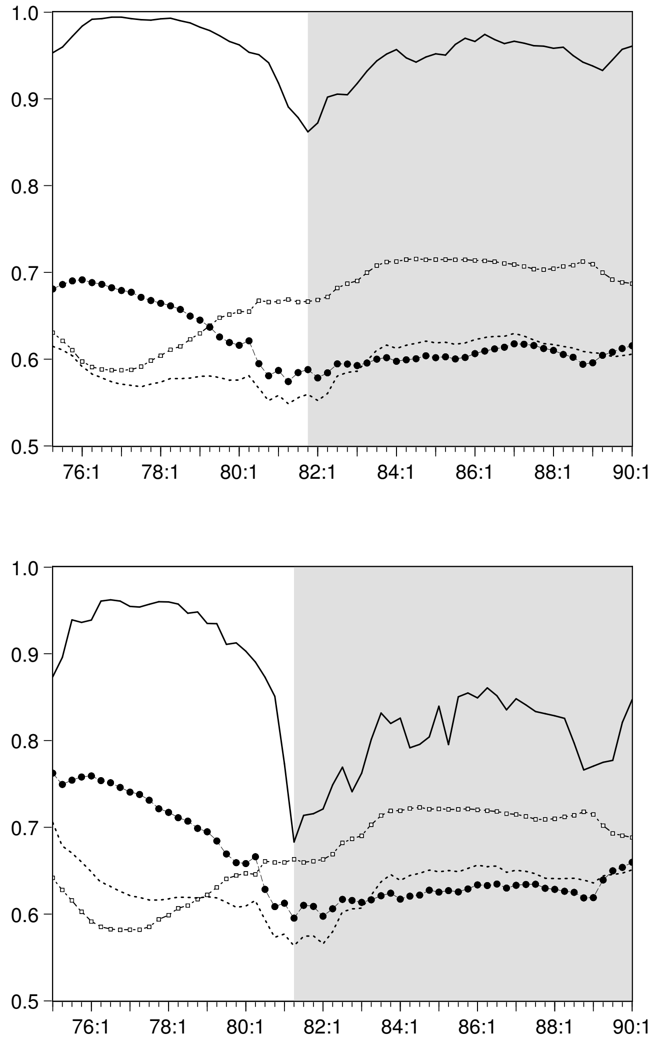


Figure 4: Empirical and model implied inflation persistence. Solid line: $\hat{d}^i$, dashed line: $\hat{d}^{i,M}(\hat{\gamma}_\pi^i, \hat{\gamma}_y^i)$, dotted line: $\hat{d}^{i,M}(\hat{\gamma}_\pi^i, 0.5)$, squares: $\hat{d}^{i,M}(1.5, \hat{\gamma}_y^i)$.

# 4 Discussion

This paper studies how monetary policy affects inflation persistence. U.S. inflation persistence has declined considerably since the early 1980s and one explanation for this phenomenon is that the Federal Reserve responded more aggressively to inflationary pressure. In a simple three equation model we derive a closed form solution of the inflation persistence parameter and show how it is affected by the weights in the FED's Taylor rule. Inflation persistence is strictly decreasing in the coefficient on the output gap and strictly increasing in the coefficient on inflation. The more aggressively the central bank reacts to inflationary shocks, the faster the inflation rate converges to its target. However, the larger the weight placed on output stabilization, the higher inflation persistence.

The predictions of the theoretical model are confirmed by our empirical analysis. Using simple rolling window regressions, we obtain time-varying parameter estimates of the Taylor rule reaction coefficients on inflation and the output gap and the degree of U.S. inflation persistence. It is then shown that increases in the response coefficient on inflation (the output gap) significantly decrease (increase) inflation persistence. By comparing the empirically estimated changes in U.S. inflation persistence with the persistence implied by our model, we can show that the sharp decrease in inflation persistence in the early 1980s can be attributed to a strong increase in the weight that the FED attached to inflation during the Volcker disinflation.

It is worth mentioning, that while in our model we treat inflation persistence as being endogenous, there is also a strand of the literature that treats inflation persistence as a structural parameter. Under this assumption, the optimal reaction coefficients in the Taylor rule are functions of the degree of inflation persistence (see, e.g., Clarida et al., 1999). However, as suggested by Benati (2008), the question whether persistence is structural or not can only be judged empirically by investigating inflation persistence over different policy regimes. Our results thus deliver further support for the view that inflation persistence is not a structural parameter.

Finally, we would like to link our findings to another ongoing debate, namely the discussion on the sources of the Great Moderation, i.e. the strong decline in the volatility of many macroeconomic series – including inflation – from the mid-1980s onwards. Since in our model the reduced form inflation rate follows an autoregressive process, changes on the degree of persistence directly affect the unconditional variance of the process. A monetary policy which decreases the degree of inflation persistence (while holding the variance of the innovation term constant) also reduces the volatility of the inflation rate. Thus, our analysis also provides evidence for the good policy interpretation of the Great Moderation.

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# Appendix

*Proof of Proposition 1.*

In order to derive equation (4), we reduce the three equation model above to a second order difference equation in $\pi$ of the form

$$-a_0 E_t\left\{\pi_{t+1}\right\} + \pi_t - a_1 \pi_{t-1} = x_t, \tag{11}$$

where $a_0$ and $a_1$ are functions of $\gamma_y$ and $\gamma_\pi$

$$a_0 \equiv \frac{2-\gamma_\pi}{2+\gamma_y} \quad \text{and} \quad a_1 \equiv \frac{1+\gamma_y}{2+\gamma_y}$$

and $x_t \equiv \frac{u_t + \left(1+\gamma_y\right) e_t - \gamma_0 + \gamma_\pi \bar{\pi}}{2+\gamma_y}$. It is then straightforward to solve equation (11), for example, by factorization. The result will be of the form

$$\pi_t = c + d\pi_{t-1} + \kappa_t,$$

where $d$ is the stable root of

$$\gamma_\pi d^2 + \left(2+\gamma_y\right) d - \left(1+\gamma_y\right) = 0, \tag{12}$$

$c$ is some constant and $\kappa_t$ a white-noise innovation. Note that the two roots of equation (12) are given by $d_1 + d_2 = \frac{1}{a_0}$ and $d_1 d_2 = \frac{a_1}{a_0}$. The model is saddle path stable with one root larger and the other smaller than one. By choosing $d$ to be the smaller of the two roots, we are choosing the stable, non-explosive solution. The constant and the innovation are given by

$$c = \frac{\gamma_\pi \bar{\pi} - \gamma_0}{\left(2+\gamma_y\right) - \left(2-\gamma_\pi\right) d}$$

and

$$\kappa_t = \frac{1}{\left(2+\gamma_y\right) - \left(2-\gamma_\pi\right) d} u_t + \frac{1+\gamma_y}{\left(2+\gamma_y\right) - \left(2-\gamma_\pi\right) d} e_t.$$

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