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Abstract

In a simple New Keynesian model, we derive a closed form solution for the inflation-gap 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-gap 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-gap 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-gap persistence varied considerably during the last forty years (see Levin and Piger, 2004, Cogley and Sargent, 2005 and Cogley et al., 2010).[1] While inflation-gap 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-gap persistence in a simple New Keynesian type of model, which allows for a closed form solution of the 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 gap is a stationary autoregressive process of order one. The degree of inflation-gap 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 was insignificant, but significantly positive thereafter. In a second step, we obtain rolling window estimates of the degree of inflation-gap persistence whereby we control for potential changes in the inflation target. We find evidence for two changes in the target: a first one in 1980:Q4 and a second one in 1992:Q. Neglecting such changes leads to an overestimation of the true degree of persistence.[2] Interestingly,

[1]The inflation-gap is defined as the difference between actual inflation and the central bank's inflation target.

[2]This finding is in line with Cogley and Sbordone (2008) who argue that inflation itself is highly

the estimated persistence was lowest in the period for which we estimated the highest values for the reaction coefficient on inflation. Also, inflation-gap 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-gap 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 (on the output gap) significantly decreases (increases) persistence. Finally, we utilize the estimated reaction coefficients to generate a series of persistence measures as predicted by our theoretical model and then compare this series with the actually observed 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-gap persistence can be well explained by changes in the conduct of the FED's monetary policy. Stated differently, the paper supports the view that inflation persistence is not inherent in the structure of the economy, but rather influenced by monetary policy (e.g., Benati, 2008). Our findings can be considered complementary to other recent evidence provided by, e.g., Levin and Piger (2004), 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-gap 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-gap persistence in the reduced form solution of the model.

persistent because of changes in trend inflation. By controlling for such changes they also find that the inflation gap is less persistent.

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.[3] Following Clarida 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-gap persistence we typically observe in the data. 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-gap persistence parameter.

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

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

where $\bar{\pi}_j$ is the central bank's inflation target. In the subsequent (empirical) analysis we will allow for $j = 1, \ldots, J$ discrete changes in the inflation target which will be associated with different monetary policy regimes. Under the forward looking policy rule given by equation (3), policy responds to the current output gap and to expected deviations of

[3] See, for example, Woodford (1996) or Bernanke et al. (1998).

inflation from the target. When both expected inflation and output are at their target levels, then the constant γ_0 is equal to the desired nominal interest rate. 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

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

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 $(\gamma_0 - \bar{\pi}_j)$ corresponds to the long-run equilibrium real interest rate within regime j.

In the following proposition we show that the reduced form representation of the inflation-gap $\pi_t - \bar{\pi}_j$, i.e. the difference between the actual inflation rate and the inflation target, is an *autoregressive process of order one* (AR(1)). Following Pivetta and Reis (2005), we then measure inflation-gap persistence by the autoregressive coefficient.[4] We focus on inflation-gap persistence rather than on inflation persistence because a change of the inflation target implies a change of the constant in the reduced form AR(1) process and, hence, neglecting such changes in the empirical analysis will lead to biased estimates of the persistence parameter. Since we believe that these changes are due to shifts in monetary policy, we consider $j = 1, \ldots, J$ discrete regimes and our theoretical result holds within each regime (see also Cogley and Sbordone, 2008). Obviously, if a single policy regime with a constant inflation target is assumed, there is no difference between measuring inflation-gap persistence and inflation persistence.

Proposition 1. *If the Taylor condition is satisfied and if the weight on the output gap is positive, then within each monetary policy regime j there exists – conditional on the minimum set of state variables – a unique rational expectations solution of the form*

$$\pi_t = (1-d)\bar{\pi}_j + d\pi_{t-1} + \kappa_t, \tag{4}$$

[4]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.

or, equivalently,

$$(\pi_t - \bar{\pi}_j) = d(\pi_{t-1} - \bar{\pi}_j) + \kappa_t, \tag{5}$$

where κ_t is white noise and the persistence parameter d is the stable root of

$$(\gamma_\pi - 2)\, d^2 + \left(2 + \gamma_y\right) d - \left(1 + \gamma_y\right) = 0. \tag{6}$$

The proof of Proposition 1 can be found in the Appendix. For analyzing the effects of

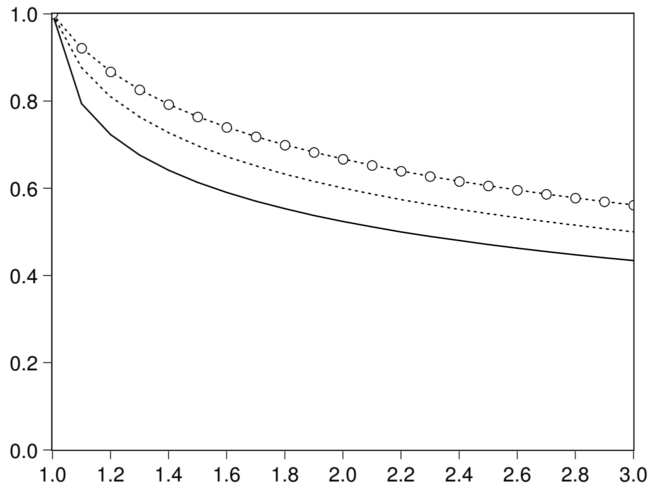

Figure 1: Inflation persistence d (y-axis) as a function of the reaction coefficient γ_π (x-axis) with γ_y fixed at 0.1 (solid line), 0.5 (dashed line) and 1.0 (dotted line).

changes in γ_π and γ_y on the persistence parameter d, take the partial derivatives to find:

$$\frac{\partial d}{\partial \gamma_\pi} < 0 < \frac{\partial d}{\partial \gamma_y}. \tag{7}$$

Thus, inflation-gap persistence is strictly decreasing in γ_π, the Taylor rule coefficient on the inflation gap, and strictly increasing in γ_y, the Taylor rule coefficient on the output gap.[5] 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-gap persistence. In the limit, when γ_π approaches one and when γ_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 γ_π, while γ_y is fixed at 0.1, 0.5 and 1.0 respectively. Note that the effect of a change in γ_π on d is stronger, the smaller the initial value of γ_π.

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

3 Empirical Analysis

In the following section, we will test empirically 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. The SPF one-year-ahead inflation expectations are denoted by $\hat{\pi}_{t+4|t}$.[6] The corresponding realized inflation rates are calculated as $\pi_{t+4,t} = 100 \times [\log(p_{t+4}) - \log(p_t)]$. 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.[7] Since the real-time dataset contains estimates for output in quarter $t-1$ (and before) based on information up to quarter t, we follow Molodtsova et al. (2008) and obtain our real-time output gap series y_t by collecting the last observations from each vintage.[8]

3.2 Estimation Results

We begin the empirical analysis by estimating a standard Taylor rule for the full sample and two selected subsamples. In this preliminary analysis we assume that the inflation

[6]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.

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

[8]More precisely, we could denote this series by $y_{t-1|t}$, since it represents the preliminary estimate of the output gap in $t-1$ given the information available in t. This is, because the "advance" estimate of GDP in quarter $t-1$ is released near the end of the first month in quarter t.

target is constant. The estimated rule is of the form

$$i_t = \alpha_0 + \gamma_\pi \hat{\pi}_{t+4|t} + \gamma_y \hat{y}_t + \varepsilon_t \tag{8}$$

where $\alpha_0 = \gamma_0 - \gamma_\pi \bar{\pi}$ and ε_t is a stochastic innovation.[9] The results for the full sample, i.e. for the period 1975:Q1 - 2010:Q1, are presented in the second column of Table 1 and provide reasonable estimates for the inflation and output-gap reaction coefficients. 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 γ_π and γ_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. 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 Volker era are in line with the usual interpretation that in these years the focus of the FED's policy was exclusively 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, these sub-sample estimates suggest that the FED's monetary policy changed considerably during the last 35 years (see also Clarida et al., 2000).

3.2.1 Time-Varying Taylor-Rule Reaction Coefficients

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 $(\hat{\gamma}_\pi^1, \hat{\gamma}_y^1), \ldots, (\hat{\gamma}_\pi^M, \hat{\gamma}_y^M)$. Note that here we allow the inflation target to vary from one window to the other. Figure 2 shows the estimates for γ_π^i and γ_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

[9] As an alternative to equation (8), 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 the theoretical framework introduced in Section 2, we prefer to work with the simpler specification.

[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.

Table 1: Taylor Rule Reaction Coefficient Estimates.

	full sample 1975:Q1-2010:Q1	Volcker 1979:Q3-1987:Q3	post-Volcker 1987:Q4-2010:Q1
α_0	-0.313 (0.623)	1.747 (1.075)	$-1.166^{\star}$ (0.652)
γ_π	$1.590^{\star\star\star}$ (0.211)	$1.576^{\star\star\star}$ (0.222)	$1.872^{\star\star\star}$ (0.218)
γ_y	$0.319^{\star\star\star}$ (0.101)	0.016 (0.138)	$0.415^{\star\star\star}$ (0.065)
$\bar{R}^2$	0.70	0.69	0.78

Notes: The table shows the parameter estimates for the Taylor rule given in equation (8). The numbers in parenthesis are Newey-West robust standard errors. ***, ** and * indicate significance at the 1%, 5% and 10% level.

$\hat{\gamma}_\pi^{90:Q1}$ and $\hat{\gamma}_y^{90:Q1}$ are based on observations ranging from 1990:Q1 to 2010:Q1. Clearly, the estimates of γ_π^i are steadily increasing from a value of about 1.5 when i = 1975:Q1 and reach a maximum of about 2.2 when i = 1982:Q1, respectively.[11] Interestingly, the steepest increase in γ_π^i occurs when we use a sample that begins in the early eighties. Thus, this strong increase coincides with the period of the Volcker disinflation starting in 1979:Q3. Thereafter, the estimates for γ_π^i are slightly decreasing but remain at a level well above 1.5. The estimates for γ_y^i are insignificant before i = 1980:Q2 and significantly positive thereafter. The estimate for γ_y^i is steadily increasing towards a value of about 0.5 when i = 1984:Q1 and then remains at this level.

Hence, combining the parameter estimates with the predictions of our theoretical model, we would expect that γ_π^i should have a strong *negative* effect on inflation-gap persistence in the period i = 1975:Q1, ..., 1982:Q1, but a positive although considerably weaker effect thereafter. On the other hand, we would expect no effect from γ_y^i before i = 1980:Q2, but a *positive* and significant effect thereafter.

In order to strengthen the evidence of time-varying Taylor rule coefficients, we formally test for breaks in the γ_π and γ_y coefficients. For this, we consider again the full sample

[11] At first sight, it may be surprising that γ_π^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.

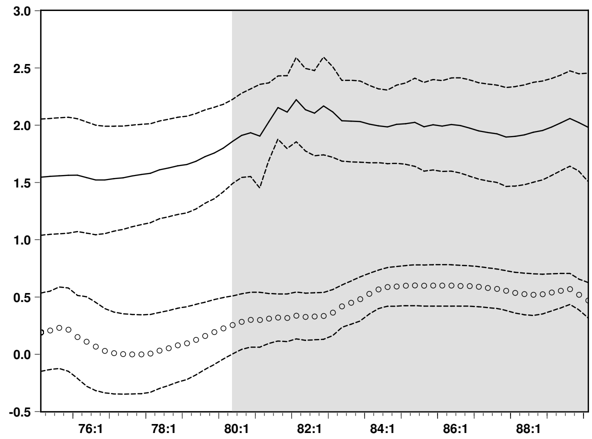

Figure 2: Estimates of γ_π (solid) and γ_y (dotted) with corresponding 95% confidence bands (dashed). $\hat{\gamma}_y$ is insignificant for $i <$ 1980:Q2, but significant thereafter (shaded area).

and apply the Quandt-Andrews likelihood ratio (QLR) statistic for unknown break dates individually to the two reaction coefficients (for details see Andrews, 1993). In both cases the null hypothesis of no break in the respective coefficient can be rejected at the 1% level. The QLR test identifies a break in the γ_π coefficient in 1980:Q4 and in the γ_y coefficient in 1983:Q3. The corresponding pre/post-break parameter estimates are presented in Table 2. Clearly, the estimated break dates as well as the size of the pre/post-break parameter estimates are in line with the above interpretation of Figure 2.

Table 2: QLR Test for Breaks in the Taylor Rule Reaction Coefficients.

	break date	pre-break estimate	post-break estimate
γ_π	1980:Q4	1.480*** (0.130)	2.292*** (0.102)
γ_y	1983:Q3	-0.169 (0.326)	0.503*** (0.085)

Notes: The table reports the estimated break dates in the γ_π and γ_y coefficients and the corresponding pre/post-break parameter estimates. In both cases the null hypothesis of no break was rejected at the 1% level. ***, ** and * indicate significance at the 1%, 5% and 10% level. A 15% trimming of the sample period is applied; the critical values are based on Hansen (1997).

In summary, both the rolling window estimates of the reaction coefficients and the QLR tests provide strong support for the existence of time-varying weights in the FED's Taylor rule.

3.2.2 Measuring Inflation-Gap Persistence

As discussed in Section 2, we focus on inflation-gap persistence and allow for discrete changes in the target over time. This is important because in our theoretical model the unconditional expectation of inflation is equal to the inflation target and, hence, neglected structural breaks in the target will lead to biased estimates of the true degree of inflation-gap persistence (see Peron, 1990). Since we associate changes in the inflation target with discrete shifts in the policy regime, we first estimate the different target levels $\bar{\pi}_j$, $j = 1, \ldots, J$. Two complementary strategies are possible for identifying the potential break dates. First, we can test for changes in the constant $\alpha_0 = \gamma_0 - \gamma_\pi \bar{\pi}$ in the Taylor rule in equation (8) and, second, we can test for a change in the unconditional mean of the inflation series $\pi_{t+4,t}$. While the second approach has the advantage that (in our model) the unconditional mean of inflation is equal to the target, empirically a shift in the target will lead to a change in the mean only with some time delay. On the other hand, while a shift in the target may be detected more timely by testing for breaks in the constant in the Taylor rule, looking at the parameter α_0 does not allow to separate changes from $\bar{\pi}$ and γ_π. Since the approaches have their pros and cons we apply both.

As a baseline scenario we consider the case with no change in the inflation target. Figure 3, top panel, shows the inflation series, $\pi_{t+4,t}$, together with the implied inflation target, $\bar{\pi}$, as derived from the estimated α_0 (left figure) or as the mean of the inflation rate (right figure).[12] The target level is close to 4% in both cases. Next, we allow for one shift in the policy regime. The inflation targets corresponding to this scenario are presented in the middle panel of Figure 3. The QLR test provides strong evidence for a break in α_0 in the fourth quarter of 1980 (left figure), while the break in the mean of the inflation series is dated 1983:Q2 (right figure). As expected, both figures show a sharp decrease in the inflation target which we associate with the Volcker disinflation policy. Finally, we allow for two regime changes. In both cases we now identify 1992:Q2 as the second break date.[13] The corresponding inflation targets are presented in the lower panel

[12]The target rate implied by $\hat{\alpha}_0$ is calculated as $\hat{\bar{\pi}} = (\bar{\gamma}_0 - \hat{\alpha}_0)/\hat{\gamma}_\pi$, where $\bar{\gamma}_0$ is the average value of the federal funds rate within the estimation period (see also Clarida et al., 2000).

[13]This second break roughly coincides with the end of the Savings and Loan Crisis.

of Figure 3. Interestingly, both strategies lead to estimates of the inflation targets that are of roughly comparable size. The main difference lies in the dating of the first break of the target rate. As expected, the change in the target in the early 1980s is first detected as a change of the constant in the Taylor rule.

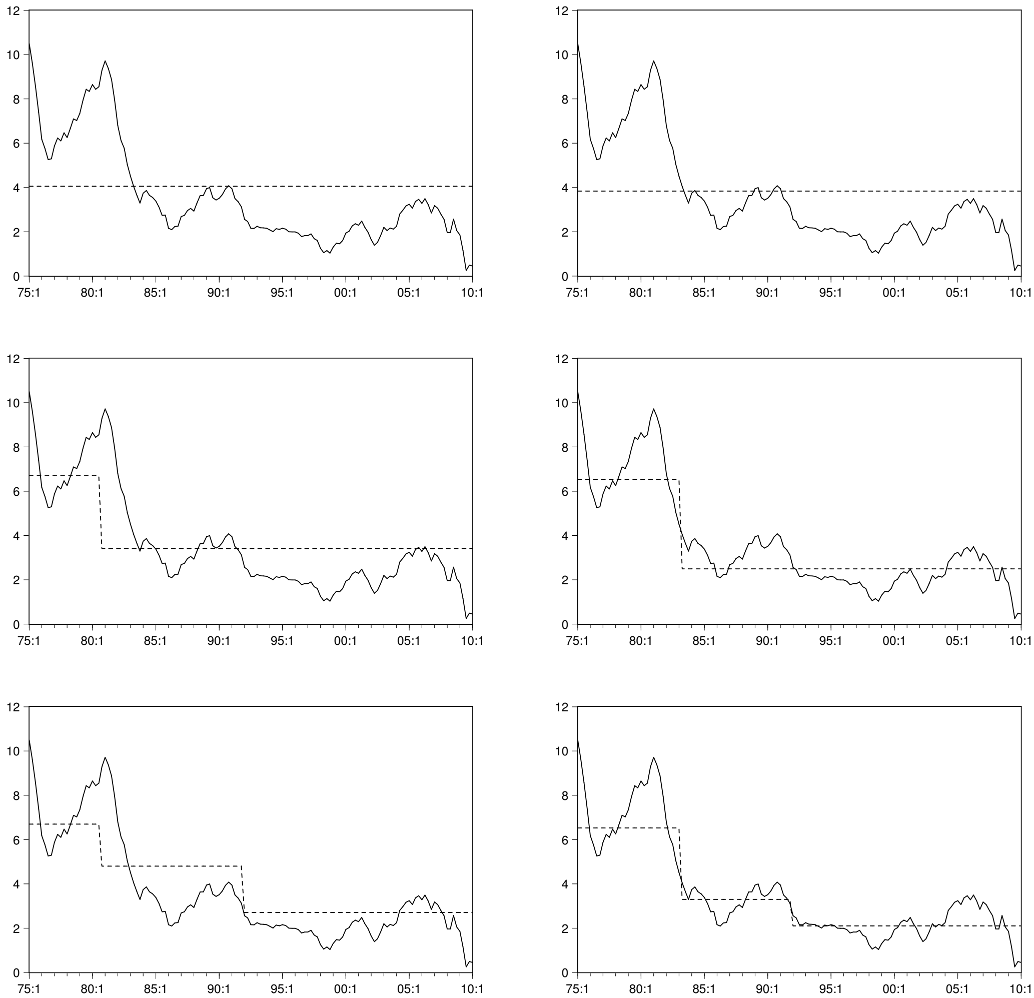

Figure 3: US inflation (solid line) and inflation targets (dashed line) when accounting for no/one/two changes in the target. The inflation targets in the left/right figures are obtained from the Taylor rule/inflation series respectively.

Next, we construct the empirical measure of inflation-gap persistence. As suggested by our theoretical model, we specify the inflation gap series as an AR(1) process

$$(\pi_{t+4,t} - \hat{\bar{\pi}}_j) = c + d(\pi_{t+3,t-1} - \hat{\bar{\pi}}_j) + \eta_t, \tag{9}$$

whereby the time-varying inflation targets $\hat{\bar{\pi}}_j$ are given by the estimates presented in Figure 3. That is, we run the above regression separately for the five alternative inflation target scenarios discussed above.[14] We then define inflation-gap persistence as the estimated first order autoregressive coefficient.[15]

As before, we perform the estimation for the rolling sample and obtain a series $\hat{d}^1, \ldots, \hat{d}^M$ of persistence parameters. Figure 4 shows exemplary the estimated degree of persistence of $\tilde{\pi}_{t+4,t}$ for the case that a single inflation target is assumed throughout the sample (solid line) and for the α_0-scenario with two changes in the target (dashed line).[16] While in both cases the general course of inflation-gap persistence is quite similar over time, the persistence estimates from the specification with two target changes are somewhat lower than the ones from the regime with no change in the target. As discussed above, this finding is reasonable since neglected structural breaks will lead to an overestimation of persistence. More specifically, in both cases 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. The sharp decrease occurs exactly in the period for which γ_π was estimated to be strongly increasing. The minimum degree of inflation 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 4 appears to support the theoretical predictions of our model.[17]

[14] Although the two scenarios with no regime change imply different target levels, they obviously lead to the same persistence estimates.

[15] As a robustness check, we also estimated higher order autoregressive models and defined gap persistence as the sum of autoregressive coefficients. However, it appears that our focus on the first order coefficient is innocuous and the subsequent results are robust to, e.g., considering in AR(2) process instead.

[16] Note that in the scenario with a single inflation target there is no difference between inflation-gap persistence and inflation persistence.

[17] 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.

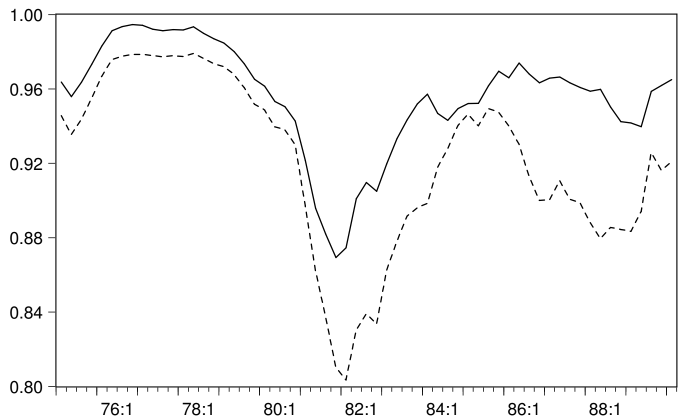

Figure 4: The solid/dashed lines refer to the inflation-gap persistence measures as obtained from the inflation gap series with no/two changes (α_0-scenario) in the inflation target. In both cases the lowest degree of persistence is reached for i = 1981:Q4.

3.2.3 Testing the Model Predictions

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

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

$i = 1, \ldots, M$, and then test whether $\delta_\pi < 0$ and $\delta_y > 0$. Table 3 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. Similarly, the estimate $\hat{\delta}_y$ is positive and significant at the 5% level in all five specifications. Thus, our estimation results clearly support the hypothesis that increases in $\hat{\gamma}_\pi$ ($\hat{\gamma}_y$) lower (raise) the degree of inflation persistence.[18]

In order to connect our parameter estimates more closely to the theoretical framework, we use the estimated Taylor rule coefficients, $(\hat{\gamma}^i_\pi, \hat{\gamma}^i_y)$, $i = 1, \ldots, M$, to construct a series of persistence parameters $\hat{d}^{i,M}(\hat{\gamma}^i_\pi, \hat{\gamma}^i_y)$ as predicted by the theoretical model in Section 2. Then we compare the model-implied persistence with the empirical estimates $\hat{d}^i$ from the scenario with two changes in the inflation target. While the solid line in Figure 5 corresponds to $\hat{d}^i$, the dashed line represents $\hat{d}^{i,M}$ as implicitly defined in equation (6)

[18]For checking the robustness of our results with respect to changes in the estimation procedure, we re-estimated the inflation-gap persistence parameter (i) by the approximately median unbiased estimator of Andrews and Chen (1994) and (ii) by assuming that η_t follows a GARCH(1, 1) process. The results (not reported) clearly confirm the findings in Table 3 of a negative (positive) effect of γ_π (γ_y) on d.

Table 3: Empirical Test of Model Predictions.

		Breaks determined by			
		Taylor rule		inflation series	
# breaks	0	1	2	1	2
break date	-	80:Q4	80:Q4 & 92:Q1	83:Q2	83:Q2 & 92:Q1
δ_0	1.255^{***} (0.058)	1.137^{***} (0.069)	1.271^{***} (0.086)	1.060^{***} (0.114)	1.493^{***} (0.157)
δ_π	-0.177^{***} (0.035)	-0.122^{***} (0.042)	-0.207^{***} (0.054)	-0.136^{***} (0.067)	-0.414^{***} (0.093)
δ_y	0.086^{***} (0.027)	0.103^{***} (0.032)	0.087^{*} (0.050)	0.280^{***} (0.048)	0.422^{***} (0.067)
$\bar{R}^2$	0.73	0.45	0.58	0.62	0.59

Notes: The table shows the estimates for the coefficients in equation (10). The numbers in parenthesis are Newey-West robust standard errors. ***, ** and * indicate significance at the 1%, 5% and 10% level.

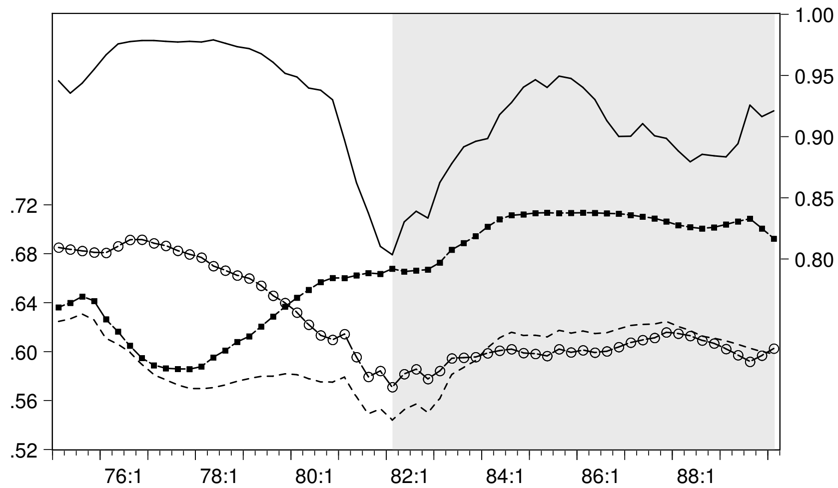

Figure 5: Model implied (left scale) and empirical (right scale) inflation-gap persistence. Solid line: $\hat{d}^i$, dashed line: $\hat{d}^{i,M}(\hat{\gamma}^i_\pi, \hat{\gamma}^i_y)$, dotted line: $\hat{d}^{i,M}(\hat{\gamma}^i_\pi, 0.5)$, squares: $\hat{d}^{i,M}(1.5, \hat{\gamma}^i_y)$.

but with the theoretical parameters $(\gamma^i_\pi, \gamma^i_y)$ replaced by $(\hat{\gamma}^i_\pi, \hat{\gamma}^i_y)$. 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 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 was not significant.[19]

Thus, for obtaining a better understanding of the individual contribution of $\hat{\gamma}_\pi^i$ and $\hat{\gamma}_y^i$ to the model-implied persistence, we plot the model-implied persistence for the case that only $\hat{\gamma}_\pi^i$ is varying and γ_y^i is fixed at 0.5 ($\hat{d}^{i,M}(\hat{\gamma}_\pi^i, 0.5)$, dotted line) or that $\hat{\gamma}_y^i$ is varying and $\hat{\gamma}_\pi^i$ is fixed at 1.5 ($\hat{d}^{i,M}(1.5, \hat{\gamma}_y^i)$, squares). Clearly, the dotted line closely follows the behavior of the solid line until inflation persistence reaches its minimum, i.e. when we fix γ_y^i the changes in $\hat{\gamma}_\pi^i$ 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 $\hat{d}^{i,M}(1.5, \hat{\gamma}_y^i)$ (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.

4 Discussion

This paper studies how monetary policy affects inflation-gap persistence. U.S. inflation-gap persistence (and inflation persistence per se) 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-gap persistence parameter and show how it is affected by the weights in the FED's Taylor rule. Inflation-gap 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

[19]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 likely to be 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.

simple rolling window regressions, we obtain time-varying parameter estimates of the Taylor rule reaction coefficients on the inflation and output gap and estimates of the degree of U.S. inflation-gap 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-gap persistence with the persistence implied by our model, we can show that the sharp decrease in inflation-gap 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-gap 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 (5), we reduce the three equation model above to a second order difference equation in π_t of the form

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

where a_0 and a_1 are functions of γ_y and γ_π

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

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

$$\pi_t = \bar{\pi}_j (1-d) + d\pi_{t-1} + \kappa_t,$$

where d is the stable root of equation (6) in the main text and κ_t a white-noise innovation. Note that the two roots of equation (6) 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 innovation is given by

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

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