Describing the Fed's Conduct with Taylor Rules: Is Interest Rate Smoothing Important?*

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Abstract

In this paper we employ models in level and first differences to gain some insights into the presence and significance of the degree of partial adjustment as opposed to a serially correlated policy shock in simple Taylor (1993) rules. In performing our exercise, we consider potentially important (and usually omitted) regressors such as the quadratic output gap and the credit spread. While we cannot exclude that serially correlated policy shocks may play a role in describing the federal funds rate path, our findings significantly support the importance of the lagged interest rate also in 'enriched' Taylor-type models.

JEL classification system: E4, E5.

Keywords: Taylor rules, interest rate smoothing, omitted variables, serial correlation, survey data.

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1 Introduction

Researchers involved in monetary policy analyses have been discussing the Taylor (1993) rule for a decade now. This simple rule, which links the inflation rate and a measure of output gap to the monetary policy rate, has turned out to be a satisfactory approximation of the various Central Banks' policy conducts all over the world. In fact, numerous researchers have focussed their attention on a modified Taylor rule, i.e. $i_t = (1-\rho)\overset{\backsim}{i}_t + \rho i_{t-1}$, with i_t identifying the short term nominal interest rate controlled by the Central Bank (CB henceforth), while $\overset{\backsim}{i}_t$ is the original 'Taylor rate', i.e. a linear combination of inflation and output gap. The modified Taylor rule suggests a partial, gradual adjustment to the Taylor rate after a shock has hit the economy. Notably, the estimated degree of partial adjustment ρ has typically been very high, so suggesting the existence of interest rate smoothing, or monetary policy inertia.[1]

Indeed, the literature has offered various sensible reasons to interpret the estimated policy gradualism, e.g. optimal monetary policy inertia, uncertainties about the dynamics of the economy, data uncertainty, and financial market disruptions.[2] Nevertheless, Rudebusch (2002) criticizes this conventional wisdom. In his stimulating contribution, he claims that the interest rate smoothing behavior at quarterly frequencies is just an illusion. By employing US data, Rudebusch tests the Partial Adjustment (PA hereafter) hypothesis, i.e. the interest rate smoothing one, versus the Serial Correlation (SC) alternative, which relates to persistent deviations of the policy variable from the Taylor rate due to extraordinary episodes, such as persistent shocks or financial turmoils. In fact, he goes for an indirect proof. In a nutshell, his reasoning is the following: If the partial adjustment strategy

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[1] Clarida, Galí, and Gertler (1999,2000) estimate such a partial adjustment degree with various specifications of the Taylor rule with US data, finding a magnitude $\simeq 0.8$. The same magnitude is found e.g. by Kozicki (1999), Amato and Laubach (1999), Domenéch, Ledo, and Taguas (2002). Estimates for some other industrialized countries are offered by Clarida, Galí, and Gertler (1998), while for the Euro area as a whole are offered by Gerlach and Schnabel (2000), and Domenéch, Ledo, and Taguas (2002).

[2] Discussions concerning the interest rate smoothing issue may be found in Lowe and Ellis (1997), Goodhart (1999), Sack and Wieland (2000), Cecchetti (2000), Srour (2001), and Woodford (2003).

had such a high importance in the policy rate setting, then rational agents should be capable of predicting future values of the quarterly rate with a high degree of precision. By contrast, standard term structure regressions show how unpredictable the policy rate is over one quarter. Rudebusch relies on this evidence to claim that the quarterly interest rate smoothing is just negligible, and that the estimated persistency of the federal funds rate is mainly due to serially correlated deviations from the Taylor rate.[3] As far as the FOMC conduct under Greenspan's regime is concerned, such deviations could be due to particular circumstances such as commodity price scares (1988-89 and 1994-95), credit crunches (1992-93), and financial crises (1998-99).

A reply to Rudebusch (2002)'s conjecture is offered by English, Nelson, and Sack (2003, ENS hereafter). These authors, working on a Taylor rule in first differences, show that it is possible to test directly the null of SC versus the alternative of PA. Their findings indicate a significant role for the latter; nevertheless, a nested model seems to be better suited for capturing the policy rate behavior.

Interestingly, some authors (e.g. Söderlind, Söderstrom, and Vredin, 2002) suggest that the standard Taylor rule might indeed be misspecified. About this point, Rudebusch (2002, p. 1166) states that "[Taylor-type rules] may be misspecified because of the *omission* of a *persistent, serially correlated variable* that influences monetary policy*. Such an omitted variable could also produce the spurious appearance of partial adjustment in the estimated rule.*" (Italics added.) But which are the omitted variables that we might want to consider in order not to attribute any spurious relevance to the interest rate smoothing argument? In this sense, two recent, different strands of the monetary policy literature call for a serious evaluation of the role of omitted variable in Taylor rules. One of these strands refers to asymmetric preferences of the Central Banker on the output gap argument (Surico, 2002; Cukierman and Muscatelli, 2003; Cukierman and Gerlach,

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[3] Söderlind, Söderström, and Vredin (2002) clarify that the federal funds rate predicability requires *both* a high level of interest rate smoothing *and* a high predictability of the Taylor rate components, i.e. inflation and output gap. Since the latter seems to be verified, Söderlind et al (2002) support either a low degree of interest rate smoothing or a mis-specification of the Taylor rule.

2003). In particular, Surico (2002) shows that with i) monetary authorities having an asymmetric (Linex-type) concern over the output gap argument, ii) a standard New-Keynesian representation of the economy, the optimal (in first-order approximation) monetary policy turns out to be Taylor-type rule 'enriched' by the presence of the *quadratic output gap*, a variable not belonging to the standard set of Taylor-rules regressions. A different story regards the discussion on the importance of financial markets' fluctuations for monetary policy decisions (Bernanke and Gertler, 1999; Bordo and Jeanne, 2002; Cecchetti, Genberg, and Wadhwani, 2002). Does the Fed react to financial markets fluctuations in order to 'burst the bubble' and potentially anticipate its future nominal and real effects ('proactive' monetary policy), or instead does it just react to fluctuations of expected and realized inflation and the output gap ('reactive' monetary policy')? Indeed, this distinction seems to be important also for our study, given that a 'proactive' monetary policy would assign an independent role for a measure of financial stress in Taylor type rules. To take this issue into account, Gerlach-Kristen (2002) considers a measure of *credit-spread* as a proxy for financial stress, measure whose properties of leading indicator for the business cycle have been put in evidence by Guha and Hiris (2002).

Interestingly enough, both the quadratic gap and the credit spread are autocorrelated in the US data. Then, in the light of Rudebusch (2002)'s (previously quoted) statement, are ENS's results reliable or just spuriously induced by model misspecification?

In this paper we aim at answering these questions. To do so, we exploit ENS's modeling strategy, but we consider a richer set of alternative Taylor rate definitions, so offering an important robustness check of their results. In doing so, we take into account both revised data and data coming from the Survey of Professional Forecasters, in order to control for possible misspecifications coming from the imposition of the rational expectations hypothesis when GMM estimates are performed.

Our regressions indicate that US data largely supports the partial adjustment mechanism hypothesis. Indeed, if it is hard to rebut the importance of a serially correlated policy shock in a Taylor type scheme, it seems even harder to reject that of the lagged interest rate. Notably, this conclusion turns out to be quite robust across the different Taylor rates specifications we employed.

The structure of the paper reads as follows. Section 2 explains Rudebusch (2002)'s position regarding the conventional wisdom on monetary policy inertia. In the same Section, the identification problem affecting a test performed with a model in levels is underlined, and English, Nelson, and Sack (2003)'s alternative strategy is described. In Section 3 we present the various specifications of the Taylor rate we employ in our analysis, while in the following Section we discuss our findings, that confirm that the lagged interest rate deserves a role *per se* in the description of the American monetary policy conduct in the last two decades. Section 5 concludes. A Data appendix illustrating the sources of the time-series and the construction of the variables employed in our analysis is provided. References follow.

2 A direct test for partial adjustment versus serial correlation

The issue of dynamics is important from a policy perspective. In fact, in the last two decades we have observed an improvement of the inflation-output gap trade-off in many industrialized countries. Part of this improvement is surely attributable to better monetary-policy management, as remarked by Cecchetti, Flores-Lagunes, and Krause (2001) and Favero and Rovelli (2003).[4] In general, it is necessary to understand the determinants of this successful management, in order to possibly replicate this success in presence of similar macroeconomic conditions. Among these determinants, has monetary policy gradualism played an important role? Recent research has indicated various possible reasons for a CB to move in a moderate manner its policy rate. In particular, uncertainties concerning the monetary policy transmission dynamics, agents' expectations on future monetary policy moves, monetary policy maker's learning of the economic environment

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[4] Both Cecchetti et al (2001) and Favero and Rovelli (2003) acknowledge that the improved inflation-output gap trade-off has probably not been uniquely caused by a better monetary policy management. In fact, there is a evidence of a change in monetary policy preferences, and of more favourable sequences of supply shocks. Still, better monetary policy management seems to have been quite significant for the last two years now.

features, and financial market reactions to announcements and implementations of the monetary policy strategy may be a rationale for 'acting gradually'. By contrast, Rudebusch (2001) estimates the importance of parameter and model uncertainty, and finds it to be insufficient for generating the commonly estimated interest rate persistence. Moreover, serially correlated extraordinary episodes such as credit crunches or financial crises might suggest to a 'non-gradualist' monetary policy-makers to persistently deviate from the Taylor rate in order to face these episodes. Finally, Lansing (2002) shows that an econometrician estimating a Taylor rule in levels and with i.i.d. policy shocks might spuriously attribute independend importance to the lagged interest rate when, in fact, the lagged interest rate is just capturing the serially correlated measurement error of the potential output. Therefore, a test on the relevance of interest rate smoothing vs. serial correlation capable to take these issues into account is of great importance for better understanding the commonly measured monetary policy gradualism.

Interest rate smoothing vs. serially correlated policy shocks: Econometric strategy

Rudebusch (2002) performs an *indirect* test on the importance of PA versus SC. He exploits standard term structure regressions in order to show that the predictive power of the market regarding future changes of the short-term interest rate over a quarter is very low.[5] Then, Rudebusch's claim is that interest rate levels cannot be explained by a large degree of PA, because this would lead to a easily forecastable variation of the policy rate. In fact, Rudebusch (2002) also tries to test *directly* the non-significance of the PA hypothesis. Formally, he builds up an empirical model nesting the PA specification

$$i_t = (1-\rho)\tilde{i}_t + \rho i_{t-1} + \eta_t \tag{1}$$

(η_t = white noise process) with the SC specification

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[5] The standard term structure regressions run by Rudebusch (2002) refer to the following model: $\Delta i_{t+j} = \delta + \gamma E_t \Delta i_{t+j} + \psi^j_{t+j}$, for $j \geqslant 1$, where the left-hand side difference refers to realized interest rate, while the right-hand side one relates to 'markets' expectations (Eurodollar futures).

$$i_t = \tilde{i}_t + \varepsilon_t,\ \varepsilon_t = \rho_\varepsilon \varepsilon_{t-1} + \eta_t \tag{2}$$

(with $0 < \varepsilon_t < 1$).[6] The nested model reads as follows:

$$i_t = (1-\rho)\overset{\frown}{i}_t + \rho i_{t-1} + \varepsilon_t,\ \varepsilon_t = \rho_\varepsilon \varepsilon_{t-1} + \eta_t \tag{3}$$

As far as the Taylor rate $\tilde{i}_t$ is concerned, Rudebusch concentrates on two different formalizations. The first one is the original Taylor (1993) rate, which reads as follows:

$$\tilde{i}_t = c + b_\pi \overline{\pi}_t + b_y y_t \tag{4}$$

where c is a constant, $\overline{\pi}_t$ is the annualized quarterly inflation rate, and y_t stands for the output gap.[7] This is a natural benchmark definition of the Taylor rate.[8] A different specification of the Taylor rate has been popularized by CGG (1998,1999,2000). These authors have underlined the importance for the CB to adjust the policy rate with respect to *future*, forecast movements of both inflation and output gap. Their idea finds its rationale in the lags affecting the monetary policy transmission, lags documented by e.g. Christiano, Eichembaum, and Evans (1998). Their definition of the Taylor rate can be captured by the following formalization:

$$\tilde{i}_t = c + b_\pi E_{t-1}\overline{\pi}_{t+4} + b_y E_{t-1} y_t \tag{5}$$

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[6] We performed some econometric exercises in order to measure the order of serial correlation featuring the residuals of simple backward and forward looking Taylor rules without smoothing. Our findings suggest that an AR(1) process is a good approximation of the policy shocks behavior. We did not include these figures in the paper for sake of brevity; however, these figures are available upon request.

[7] The variables definition may be found in the Data appendix. About the Taylor rate definitions, notice that they do not have any error term, since the policy deviations with respect to the suggested rate are already captured by η_t.

[8] In Taylor (1993), the policy rule reads as follows: $i_t = r^* + \overline{\pi}_t + 0.5 y_t + 0.5(\overline{\pi}_t - \pi^*)$, with $\pi^* = r^* = 2\%$. Then, the constant c in the various Taylor rates is a linear convolution of the inflation target π^* and the real interest rate of equilibrium r^*, i.e. $r^* - (b_\pi - 1)\pi^*$. Neither in Rudebusch (2002)'s nor in our study the focus is the one of assessing these elements. For investigations concentrating on these components, see Judd and Rudebusch (1998), and Domenéch, Ledo, and Taguas (2002).

Then, by working with equation (3) and - alternatively - (4) or (5), Rudebusch (2002) tests first the significance of the PA hypothesis, then that of SC. The test suggests rejection neither for PA nor for SC. Why so? Rudebusch explains that there is an *identification problem* at this point. In fact, it is very difficult to distinguish between the dynamics deriving from a PA mechanism and those induced by a SC specification when observing at the realizations of the policy rate, since both these processes (which are very different from an economic standpoint) may induce the same (or similar) path of the policy rate.

The importance of the contribution by ENS (2003) relates exactly to this identification issue. They notice that while the two different specifications (1) and (2) have similar implications for the behavior of the interest rate *level*, this similarity does not hold anymore when *first differences* are taken into account. To see why, consider equation (1). By making some algebra, it is possible to arrive at the following formulation:

$$\Delta i_t = (1-\rho)\Delta \overset{\backsim}{i}_t + (1-\rho)(\overset{\backsim}{i}_{t-1} - i_{t-1}) + \eta_t \tag{6}$$

Differently, the SC specification (2) leads to this alternative equation:

$$\Delta i_t = \Delta \overset{\backsim}{i}_t + (1-\rho_\varepsilon)(\overset{\backsim}{i}_{t-1} - i_{t-1}) + \eta_t \tag{7}$$

The latter equation sheds some light on the implications of the SC engine. Here, shocks on one of the components of the Taylor rate triggers an immediate and full reaction of the policy rate change; by contrast, an inertial adjustment is present in equation (6) via the coefficient $(1-\rho)$. This detail is quite important, because it allows the econometrician to overcome the identification problem pointed out by Rudebusch (2002).

In fact, it is possible to build up a direct test on the PA versus SC hypotheses. The test is performed by estimating the empirical model

$$\Delta i_t = \gamma_2 \Delta \overset{\backsim}{i}_t + \gamma_3(\overset{\backsim}{i}_{t-1} - i_{t-1}) + \eta_t \tag{8}$$

and testing the null hypothesis

$$H0_{SC} : \gamma_2 = 1 \tag{9}$$

Under the null (9), the SC specification holds true. If the null is rejected, then it is possible to state that the SC model *per se* is not sufficient for replicating the commonly observed interest rate inertia. ENS verify that the null is undoubtedly rejected, and conclude that the SC model is not sufficient to replicate the observed federal funds rate persistence. Then, they check if the PA model alone is sufficient to replicate the policy rate pattern, and test the null

$$H0_{PA} : \gamma_2 = \gamma_3 \tag{10}$$

Interestingly, also this null hypothesis turns out to be rejected, even if with a smaller statistical confidence. In fact, there is no reason to believe that only one of the two hypotheses holds. Indeed, both PA and SC could be important in fitting the actual monetary policy rate. ENS build up and test a nested structure equivalent to (3), finding that both PA and SC are supported by the data. So, even in the presence of a SC component, the data seem not to discard the PA specification.

To summarize, ENS (2003) successfully tackle the identification problem raised by Rudebusch (2002). Indeed, their test directly supports the importance of the PA hypothesis in describing the Fed's decisions during Greenspan's regime. But is their result robust to different specifications of the Taylor rate? Is the interest rate smoothing still important when considering usually omitted (but potentially important) serially correlated regressors?

For answering these questions, we allow for different 'enriched' specifications of the Taylor rate. The next Section fully describes our approach.

3 PA versus SC: Alternative Taylor rate specifications

Before exploiting the estimation strategy set up by ENS (2003), we have to specify the Taylor rate $\tilde{i}_t$. Naturally, we consider the already commented feedback rules (4) and (5). However, as mentioned above, Rudebusch (2002) suspects that the omission of serially correlated variables could potentially be the cause of the estimated high degree of PA. To check for this, we enrich the original specifications (4) and (5) by adding a third regressor, as follows:

$$\overset{\backsim}{i}_t = c + b_\pi \overline{\pi}_t + b_y y_t + b_z z_t \tag{11}$$

and

$$\tilde{i}_t = c + b_\pi E_{t-1} \overline{\pi}_{t+4} + b_y E_{t-1} y_t + b_z E_{t-1} z_t \tag{12}$$

In our exercise, the regressor z_t plays different roles. A variable that we want to control for is a quadratic transformation of the output gap level, i.e. $z_t = y_t^2$, that captures a (possibly) asymmetric concern by the CB for deviations of the realized output with respect to the target level. In doing so we feel inspired by recent works on CBs' asymmetric preferences, which imply a non-quadratic representation of their loss function.[9] In particular, Surico (2002) shows that, if b_z is statistically relevant and assumes a negative sign, then we may think of that as an indicator of more moderate policy responses in booms than in recessions. Indeed, apart from analytical tractability, there does not seem to be an obvious reason why a CB should symmetrically target the output gap measure (Blinder, 1997; Goodhart, 1999; Mayer, 2002). The importance of a serious investigation of the asymmetric preferences hypothesis is then straightforward.

We also want to control for the impact of financial market conditions. This seems to be an interesting check, given the lively discussion that has been taking place for some years now on the attention that the CB should pose on financial markets. As Bordo and Jeanne (2002) point out, a central bank may either anticipate the effects of stock market fluctuations on targeted variables such as inflation and output gap ('proactive' behavior) or respond to those effects once they have affected prices or the business cycle ('reactive' behavior).[10] As a measure of the financial market stance

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[9] Along with Surico (2002), Cukierman and Muscatelli (2003) and Cukierman and Gerlach (2003) have performed empirical endeavours on this issue. See also the references quoted in those papers.

[10] See also the two stimulating and opposite views by Bernanke and Gertler (1999) and Cecchetti, Genberg, and Wadhwani (2002), and the citations therein.

we consider the *credit spread*, i.e. the spread between corporate and treasury bonds. In fact, an economic *rationale* for the causality going from the spread to the business cycle is the credit channel of monetary policy transmission, formalized first by Bernanke and Blinder (1988), and updated by Bernanke and Gertler (1995) and Bernanke, Gertler, and Gilchrist (1996). Then, the credit-channel view suggests that the credit-spread is a countercyclical, leading indicator of the business cycle. Therefore, a significant and negative sign associated to b_z would make us conjecture that financial indicators played an important role in the Fed's feedback rule as leading indicator of future inflation.[11]

Our exercise aims at testing the PA versus SC hypotheses.[12] To do so, we first estimate equation (8) with the Taylor rate alternatively specified as (4), (5), (11), and (12). As a second step, we estimate the nested model (3) - once more considering all the above indicated Taylor rate specifications - in order to understand if there is evidence of a 'joint significance'. Since we want to compare our results with Rudebusch (2002)'s, we employ his sample choice, i.e. 1987Q4-1999Q4. We adopt a Non-linear Least Square estimator with backward looking models (i.e. when (4) and (11) are considered), while GMM when (5) and (12) are taken into account. A robustness check on our GMM estimates, performed on the basis of Survey data, is also presented. Our results and a discussion follow.

4 Findings

We now present our results. Table 1 collects our findings regarding the PA versus SC test run with a backward looking framework. A few remarks are worthwhile. First of all, the values and the significance of the parameters b_π and b_y seem to be robust across specifications. In particular, the elasticity of the policy rate with respect to inflation is statistically in line with the value

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[11] Another interpretation attributes to the credit spread the role of 'information variable' signalling future economic strength to which the central bank may be willing to respond. For an empirical exercise showing the power of the credit spread in this sense, see Guha and Hiris (2002).

[12] Least squares regressions confirm that both the quadratic output gap and the credit spread may be well approximated by an AR(1) process in the sample analyzed.

proposed by Taylor (1993). Our point-estimates for b_y are slightly larger than the value proposed by Taylor, but are roughly in line with those obtained by Judd and Rudebusch (1998), Kozicki (1999), Amato and Laubach (1999), and Rudebusch (2002). Interestingly enough, the parameter b_z is statistically significant and has got the expected sign both in the case of asymmetric preferences and in the case of financial stress. Indeed, it seems possible to conjecture that the FOMC has reacted asymmetrically to positive and negative deviations of the real gross domestic product with respect to its stochastic trend; in this sense, we share Surico (2002)'s conclusions.[13]

As far as financial fluctuations are concerned, indications coming from the credit market turn out to be statistically important for replicating the observed federal funds rate in the analyzed sample, so confirming Gerlach-Kristen (2002)'s findings.[14] This econometric evidence squares with some policy-makers' statements concerning the impact of financial markets' fluctuations on the US monetary policy. E.g., the easing of policy during late 1998 was commented by the Federal Reserve Governor Laurence Mayer (1999, p.7) as follows: "There are three developments, each of which, I believe, contributed to this decline in the funds rate relative to [standard] Taylor rule prescriptions. The first event was the dramatic financial market turbulence, following the Russian default and devaluation. The decline in the federal funds rate was, in my view, appropriate to offset the sharp deterioration in financial market conditions, including wider private risk spreads, evidence of tighter underwriting and loan terms at banks, and sharply reduced liquidity in financial markets".

[Table 1 about here]

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[13] By constrast, Kim, Osborn, and Sensier (2002) apply a non-parametric technique to the CB's policy function, and cannot reject the null of linearity for the feedback rules they estimate for the post-Volcker era. Apart from the difference in the technique exploited, these authors concentrate on the sample 1979Q3-2000Q4, while we focus our attention on Greenspan's regime.

[14] Notice that there might be an endogeneity problem here. In fact, variations of the dependent variable (short term interest rate) are likely to influence all the term structure of interest rates, so also the long term rates featuring the regressor (credit spread). Nevertheless, GMM estimates (not reported here for sake of brevity) performed by employing the constant and lags 1 up to 4 of the regressors included in the estimated model confirmed the qualitative results proposed in Table 1.

Getting back to our econometric exercise, according to the $\bar{R}^2$ statistic the descriptive power of all the models employed turns out to be high. For our purposes, the most important row of Table 1 is the one where we collect all the p-values concerning the F-test on the null (9). Robustly enough, the null is rejected at the 99% confidence level for all the three cases under investigation, so discarding SC as the unique ex-post descriptive mechanism of the federal funds rate path. By contrast, the null (10) is not rejected, even if the p-values corresponding to the models 'Standard Taylor' and 'Credit Spread' are not overwhelming on average. However, our findings tend to support ENS (2003)'s, and cast some doubts on Rudebusch (2002)'s conclusion.

Table 2 displays our estimates obtained by working with forward looking Taylor rules. From a qualitative viewpoint, these figures tend to confirm those got with the backward looking models. In fact, all the estimated coefficients are statistically significant, and have the expected sign. The Taylor principle is not rejected, and this is a robust finding across rules. The output gap coefficient turns out to be lower when omitted variables are considered**:** This is important, because it seems to suggest that the baseline Taylor rule is forced to capture 'broader' effects, i.e. those attributable to asymmetric preferences of the policy makers on real movements or to movements in the financial markets. Interestingly, the point estimates for the additional regressor are larger when forward looking rules are considered, while the estimated coefficients attached to the expected inflation rate are smaller. This might signal that if a CB is targeting a *forecast* inflation rate then the importance of potentially important leading indicators such as the squared gap or the credit spread rises.[15]

[**Table 2 about here**]

When looking at our testable restrictions, the null (9) of pure SC process is strongly rejected, as well as in the backward looking case. Nevertheless,

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[15] Notice that the J-statistics (p-values) largely confirm the goodness of our instrument choice. However, the number of overidentifying restrictions in the estimations we undertook is high, and might induce biases (Staiger and Stock, 1997). To check for the robustness of our estimates, we ran regressions with survey data employing NLS, as explained later in the text.

with the forward looking formulation also the null (10) is rejected in two cases out of three, so implying that the PA process 'alone' has got hard time in satisfactorily tracking the federal funds rate. This leads us to also estimate the encompassing model (3) in order to assess if the PA and SC hypotheses are jointly important from a positive standpoint.

Our results are presented in Table 3. First of all, the significance of all the regressors in the Taylor rules is confirmed. Moreover, point-estimates of the parameter b_π are now much closer to each other. Also with this encompassing specification, the additional regressor z_t seems to be quite relevant in fitting the path of the federal funds rate; the point estimates present in this Table are statistically in line with those seen in Table 1. In particular, to appreciate the difference existing between the standard backward-looking Taylor rule and the enriched one signalling asymmetric preferences, we plot in Figure 1 the (marginal) reactions of the Fed to output gap oscillations in case of absence vs. presence of an asymmetric motive.[16] A visual inspection allows us to gauge the role played by the asymmetry in setting the policy rate. In fact, monetary policy turns out to be slightly less aggressive when the business cycle is high, while the magnitude of monetary policy easings is much more intense when the cycle is low.

[Figure 1 about here]

About the Fed's reaction to the financial stress indicator, the point-estimate for b_z in the 'Credit spread' model looks indeed quite high. This might indicate 'proactiveness' by the Fed in the period under analysis.[17] However, a more cautious interpretation of this finding calls for the bunch of effects that this indicator might be capturing, e.g. the 'pure credit crunch' effect plus the 'leading indicator for the business cycle' effect.

As far as our key-parameters ρ and ρ_ε are concerned, both are statistically significant. The point-estimate of the coefficient ρ is about 0.6 in all

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[16] In other words, we plotted the (estimated) 'marginal contribution' (with respect to the other regressors considered) that the output gap (in levels vs. levels and squared values) offers for explaining the observed policy rate.

[17] Importantly, Bordo and Jeanne (2002) show that the second part of the '90s may be classified as 'booming period' as far as asset prices are concerned (see their Figure 9 at page 35).

the three backward looking nested models considered here. Notably, this is lower of a magnitude of 0.2 with respect to what it is conventionally found. Indeed, this might be due to the impact exerted by the explicitly modeled serial correlation process. In fact, the corresponding point estimate turns out to be quite robust to the introduction of omitted variables. Interestingly, the same does not hold for that of the AR(1) process, which falls from a value of about 0.58 to values lower than 0.4 (and its estimated volatility falls as well). Of course, this does not necessarily imply that the relative importance of the SC process lowers with respect to the one of the PA mechanisms. However, it seems to bring evidence in favor of a role of the lagged dependent variable *per se* in estimated Taylor rules, as underlined by ENS (2003).

[Table 3 about here]

When moving to the forward looking nested model (Table 4), we find confirmation of some already commented results. In particular, the estimated coefficients of the 1-year ahead inflation rate are lower than those in the backward looking counterpart; by contrast, those of the additional regressors are higher, so confirming their role as leading indicator of future inflation. The significance of both ρ and ρ_ε is confirmed, while the point estimates are higher for ρ (and more in line with the literature, e.g. Clarida, Galí, and Gertler, 2000) and lower for ρ_ε (and its volatility) if compared to those of the backward looking case. Once more, it seems to be difficult to think of a Taylor rule whose persistence is exclusively determined by a SC process.

Robustness check: Approximating inflation expectations with survey-based data

GMM estimates are often seen as being fragile, and may heavily be instrument-dependent (Staiger and Stock, 1997). Actually, all the p-values presented in Tables 2 and 4 seem to suggest that the over-identifying restrictions imposed on our estimated models are statistically valid. However, as a check on the validity of our results, we estimate forward looking Taylor-type rules using a different strategy. Instead of instrumenting our one-year ahead inflation expectations, we exploit a series provided by the Survey of Professional Forecasters (SPF) conducted by the Federal Reserve Bank of Philadelphia.[18] This provides us with an exogenous regressor, that can be employed in our econometric exercise without recurring to any instrument choice. Practically, we consider the following two equations:

$$\begin{aligned}\Delta i_t &= \gamma_2(b_\pi \Delta E_t \pi_{t+4}^{SPF} + b_y \Delta y_t + b_z \Delta z_t) \\ &\quad + \gamma_3(c + b_\pi E_{t-1}\pi_{t+3}^{SPF} + b_y y_{t-1} + b_z z_{t-1} - i_{t-1}) + \eta_t\end{aligned} \tag{13}$$

to test for the PA versus SC dynamic mechanisms, and

$$i_t = (1-\rho)(c + b_\pi E_t \pi_{t+4}^{SPF} + b_y y_t + b_z z_t) + \rho i_{t-1} + \varepsilon_t, \ \varepsilon_t = \rho_\varepsilon \varepsilon_{t-1} + \eta_t \tag{14}$$

to gain some insights on the possible coexistence between PA and SC. Notice that, given the timing assumption underling these two models, and given the exogeneity of the SPF inflation forecasts, we can consistently estimate equations (13) and (14) via NLS. Our new estimates are stored in Tables 5 and 6.

It is natural to compare Tables 2 and 5 (estimated forward looking models in first differences) and Tables 4 and 6 (estimated forward looking models in levels). In particular, from the comparison of the figures displayed in Tables 2 with those in Tables 5 we can get interesting evidence. First of all, the estimated coefficient b_π for inflation is larger when survey data is taken into account, while that for the additional variables (b_z) is lower (and the evidence in favor of a statistically significant output gap does not seem to define any precise tendency). The reason of such differences may be attributed to the nature of the SPF inflation expectations, that are not fully rational from a statistical viewpoint (Roberts, 1998).[19] Anyhow, both the

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[18] For details regarding the survey data on 1-year ahead inflation expectations used in this paper, see the Data appendix.

[19] In fact, a regression like $\pi_{t+4} = \alpha + \beta\pi_{t+4}^{SPF} + \zeta_{t+4}$ delievered an estimated value for β statistically equal to 1, but a a negative and statistically relevant value for α equal to -1.14. This is due to the constant overestimation of the inflation process in the forecasting phase in the sample analyzed here. Then, the null hypothesis of rational expectations turns out to be rejected.

model estimated with revised data and the one estimated by employing survey data support once more the importance of the interest rate smoothing argument also when an 'enriched' version of the Taylor rule is considered.

[**Table 5 about here**]

As already seen in all the previously commented cases, the test on the null (9) suggests a rejection of the hypothesis of SC as the unique engine of the federal funds rate dynamics. By contrast, the PA testable restriction is not rejected, even if the p-values are admittedly pretty low.

Moving to Tables 4 and 6, we observe that the above written considerations regarding the estimated coefficients still hold. In fact, the remarkable result obtained with SPF inflation forecasts is that the SC coefficient is never statistically significant at the 95% confidence interval, while the PA one is always significant at the 99% level. Of course, if this does not necessarily imply that SC is not important for shaping an empirically relevant Taylor rules, *a fortiori* it should not cast doubts on the relevance of the smoothing argument in the estimated Taylor rules.

[**Table 6 about here**]

Finally, a quick note on the discussion concerning the use of revised vs. real time data. In our exercise we employe revised data; this choice is obvious, since one of our goals is that of comparing our results to those by Rudebusch (2002) who also employs revised data. In fact, Mehra (2001) and Lansing (2002) argue that the use of real time data may lead to much lower point estimates of the interest rate smoothing coefficient than those commonly obtained.[20] So, are our results misleading? Our opinion is that the impact of real time data on the estimated value of the smoothing parameter is still to be fully understood, as witnessed by the contributions by

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[20] Lansing (2002) shows that an econometrician who used final, revised data would obtain upward biased estimates of the parameter ρ relative to the true value, given that the lagged interest rate would capture the serially correlated measurement error affecting e.g. the output gap estimates. Mehra (2001) works with real time data, and estimates the potential output as a simple log-linear trend of the GDP. His estimates of the partial adjustment coefficient are indeed low, and sometimes even not significant.

Perez (2001), Orphanides (2001), and English, Nelson, and Sack (2003) in which estimated Taylor rules with real time data are still featured by high figures regarding the interest rate smoothing coefficients. Therefore, from a quantitative point of view, the use of revised data does not imply dramatic consequences for our results.

5 Conclusions

In this paper we focussed our attention on the interest rate smoothing argument in Taylor-type schemes. In a recent contribution, Rudebusch (2002) intriguingly challenges the conventional wisdom, and states that the interest rate smoothing behavior at quarterly frequencies is just an illusion. As indirect proof, he claims that if this was not the case, then rational agents should be capable of predicting future movements of the policy rate. Indeed, this is not what happens in reality.

By applying English, Nelson, and Sack (2003)'s modeling strategy to US data, we assessed the significance of both the interest rate smoothing argument and the serially correlated policy deviations from the Taylor rate prescriptions. In particular, we estimated 9 models in first differences to test for the 'pure' partial adjustment hypothesis versus the one of 'pure' serial correlation. Notably, in all the 9 cases considered in our exercise, the null of pure serial correlation process was rejected. By contrast, the PA mechanism was supported by 7 cases out of 9; however, for some of these cases the p-values suggested cautiousness in the interpretation of these results. Then, we estimated 9 encompassing models, i.e. 9 models admitting both interest rate smoothing and serially correlated policy shocks. While the significance of the interest rate smoothing coefficient turned out to be overwhelming, that of the AR(1) shocks was not supported in 4 cases out of 9.

Indeed, credit crunches or financial crises represent shocks that may very well imply persistent deviations with respect to the policy recommended by the *standard* Taylor (1993) rate; in this sense, we are sympathetic with Rudebusch (2002)'s argument. Nevertheless, our estimates indicate that the lagged interest rate does play a key-role in a Taylor-type model. By contrast, the presence of a serially correlated policy shock, although often statistically relevant, does not seem to be sufficient in explaining the observed interest rate gradualism. Therefore, our results do not necessarily contradict Rudebusch (2002)'s claim on the significance of a serially correlated error term in estimated Taylor rules, but strongly support English, Nelson, and Sack (2003)'s conclusion on the key-role played by the lagged depended variable in this type of policy functions.

Interestingly, the simple average computed on the 9 different estimated interest rate smoothing coefficients is about 0.7, a value lower than the 'standard' 0.8. This may suggest that monetary authorities act gradually, but probably respond faster than claimed in the literature to shocks affecting the Taylor rate. Hence, Rudebusch (2002)'s conjecture on the somewhat 'exaggerated' magnitude usually attributed to the interest rate smoothing component is also supported by our estimates.

Finally, our empirical findings seem to call for further research on non-standard explanatory variables to be included into Taylor type regressions. Asymmetric policy preferences (Surico, 2002) and financial indicators (Gerlach-Kristen, 2002) deserve deeper investigation from both a positive and a normative side, also in the light of some recent contributions on the relationship between asymmetric preferences and ex-ante average inflation bias (Cukierman and Muscatelli, 2003, Cukierman and Gerlach, 2003, and Surico, 2003), and on the importance of financial markets evolution for monetary policy decisions (Cecchetti, Genberg, and Wadhwani, 2002).

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Data appendix

The short term rate used in our analysis is the federal funds rate. The annualized quarterly inflation rate was computed by using the GDP chain-weighted price index P_t, i.e. $\pi_t \equiv 4(p_t - p_{t-1})$, where $p_t = 100 \ln P_t$. Our measure of output Q_t is the chain weighted real GDP, while the potential output Q_t^* series is the one estimated by the Congressional Budget Office. The output gap y_t was computed as $q_t - q_t^*$, where $q_t \equiv 100lnQ_t$, while $q_t^* \equiv 100lnQ_t^*$. The credit spread was built by taking the difference between the Moody's BAA corporate index yield and the 10-year US treasury note yield. Finally, the upper-barred variables indicate simple averages taken over the contemporaneous observation and the previous three quarters of the variable in consideration. The above described data, together with the Producer Price Index (Finished Goods) exploited as an instrument in our GMM estimations, was downloaded from the Federal Reserve Bank of St. Louis web site, i.e. http://research.stlouisfed.org/fred2/ (quarterly averages). Instead, the series on one-year ahead CPI inflation expectations used for estimating the models (13) and (14) was taken from the Federal Reserve Bank of Philadelphia web site, i.e. http://www.phil.frb.org/files/spf/cpie1.txt.

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Taylor rate specification	Standard Taylor	Asymmetric preferences	Credit spread
b_π	1.508^{**} (0.405)	1.438^{**} (0.330)	1.363^{**} (0.241)
b_y	0.864^{**} (0.195)	0.696^{**} (0.135)	0.826^{**} (0.075)
b_z	-	-0.224^{**} (0.075)	-2.611^{**} (0.531)
γ_2	0.440^{**} (0.167)	0.332^{**} (0.151)	0.392^{**} (0.071)
γ_3	0.197^{**} (0.070)	0.301^{**} (0.057)	0.290^{**} (0.073)
$\bar{R}^2$	0.954	0.965	0.979
$H_0 : \gamma_2 = 1$ ($F-test$, $p-value$)	0.002^{**}	0.000^{**}	0.000^{**}
$H_0 : \gamma_2 = \gamma_3$ ($F-test$, $p-value$)	0.186	0.841	0.417

*=95%/**=99% rejection of the null hyp. Estimated model:
$\Delta i_t = \gamma_2 (b_\pi \Delta\bar{\pi}_t + b_y \Delta y_t + b_z \Delta z_t) + \gamma_3 (c + b_\pi \bar{\pi}_{t-1} + b_y y_{t-1} + b_z z_{t-1} - i_{t-1}) + \eta_t$
$z_t = y_t^2$ (Asymmetric preferences); z_t =spread (Credit spread). Estimates performed via NLS estimator. Newey-West correction (3 lags) applied to the standard errors (reported in brackets).
c omitted for brevity. $\bar{R}^2$ refers to the *level* of the federal funds rate.

Table 1: Test for PA versus SC: Backward Looking Taylor Rules

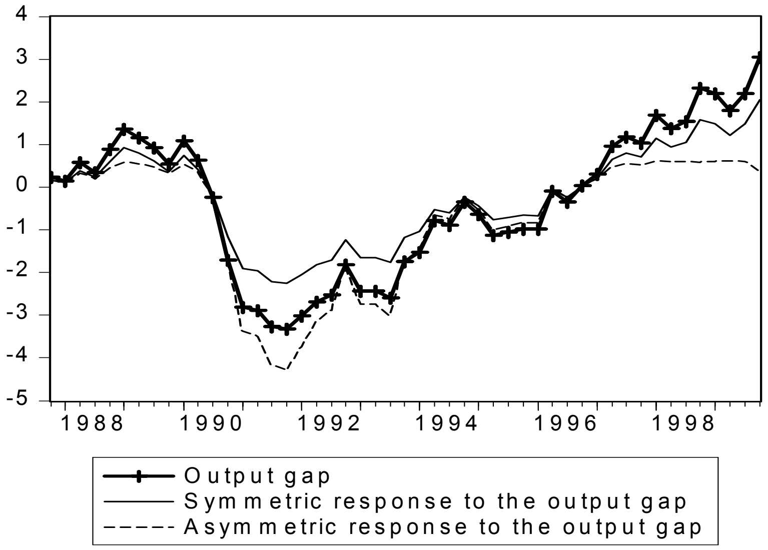

Figure 1: Symmetric (i.e. $b_y y_t$) and Asymmetric (i.e. $b_y y_t + b_z y_t^2$) 'marginal' monetary policy responses to the output gap fluctuations.

Taylor rate specification	Standard Specification	Asymmetric preferences	Credit spread
b_π	1.146^{**} (0.114)	0.967^{**} (0.343)	1.167^{**} (0.042)
b_y	1.066^{**} (0.081)	0.669^{**} (0.109)	0.405^{**} (0.028)
b_z	-	-0.652^{**} (0.166)	-4.836^{**} (0.160)
γ_2	0.219^{**} (0.034)	0.248^{**} (0.032)	0.194^{**} (0.015)
γ_3	0.245^{**} (0.027)	0.123^{**} (0.028)	0.258^{**} (0.012)
$\bar{R}^2$	0.919	0.927	0.972
$H_0:\gamma_2=1$ ($F-test$, $p-value$)	0.000^{**}	0.000^{**}	0.000^{**}
$H_0:\gamma_2=\gamma_3$ ($F-test$, $p-value$)	0.489	0.000^{**}	0.000^{**}
Over. Restr. ($J-statistic$, $p-value$)	0.932 ($\chi^2(12)$)	0.957 ($\chi^2(15)$)	0.940 ($\chi^2(15)$)

*=95%/**=99% rejection of the null hyp. Estimated model:
$\Delta i_t=\gamma_2(b_\pi\Delta E_{t-1}\bar{\pi}_{t+4}+b_y\Delta E_{t-1}y_t+b_z\Delta E_{t-1}z_t)+$
$\gamma_3(c+b_\pi E_{t-1}\bar{\pi}_{t+3}+b_y E_{t-1}y_{t-1}+b_z E_{t-1}z_{t-1}-i_{t-1})+\eta_t$. $z_t=y_t^2$ (As. pref.);
z_t =spread (Credit spread). Estimator: GMM. Instruments:
$[c\ \bar{\pi}_{t-2}..\bar{\pi}_{t-5}y_{t-2}..y_{t-5}\Delta i_{t-2}..\Delta i_{t-5}\Delta\bar{\pi}_{t-2}^{PPI}..\Delta\bar{\pi}_{t-5}^{PPI}\Delta z_{t-2}..\Delta z_{t-5}]$,
$\bar{\pi}_t^{PPI}$ four quarter inflation from the Producer Price Index (Finished Goods).
z instrument introduced when z present in the estimated equation.
Newey-West correction (Bartlett kernel, 3 lags) applied to the st. err. (in brackets).
$\bar{R}^2$ refers to the *level* of the federal funds rate. c omitted for brevity.

Table 2: Test for PA versus SC: Forward Looking Taylor Rules

Taylor rate specification	Standard Taylor	Asymmetric preferences	Credit spread
b_π	1.397^{**} (0.371)	1.433^{**} (0.265)	1.359^{**} (0.195)
b_y	0.749^{**} (0.209)	0.677^{**} (0.132)	0.781^{**} (0.091)
b_z	-	-0.185^{*} (0.072)	-2.346^{**} (0.512)
ρ	0.609^{**} (0.146)	0.637^{**} (0.096)	0.618^{**} (0.065)
ρ_ε	0.578^{**} (0.202)	0.379^{*} (0.175)	0.318 (0.161)
σ_ε	0.333	0.309	0.250
$\bar{R}^2$	0.965	0.970	0.980

*=95%/**=99% rejection of the null hyp. Estimated model:
$\text{i}_t = (1\text{-}\rho)(\text{c}+\text{b}_\pi\overline{\pi}_t+\text{b}_y y_t+\text{b}_z\text{z}_t)+\rho\text{i}_{t-1}+\varepsilon_t$, $\varepsilon_t = \rho_\varepsilon\varepsilon_{t-1} + \eta_t$
$\text{z}_t = y_t^2$ (Asymmetric preferences); z_t =spread (Credit spread).
Estimator: NLS. Newey-West correction (3 lags) applied to the standard errors (in brackets). c omitted for brevity.

Table 3: Nested PA-SC model: Backward Looking Taylor Rules

Taylor rate specification	Standard Specification	Asymmetric preferences	Credit spread
b_π	1.379^{**} (0.521)	1.171^{**} (0.330)	1.024^{**} (0.144)
b_y	0.803^{**} (0.174)	0.546^{**} (0.103)	0.183^{*} (0.073)
b_z	-	-0.293^{**} (0.078)	-4.465^{**} (0.265)
ρ	0.846^{**} (0.037)	0.826^{**} (0.024)	0.794^{**} (0.020)
ρ_ε	0.438^{**} (0.073)	0.319^{**} (0.108)	0.295^{**} (0.043)
σ_ε	0.342	0.303	0.232
$\bar{R}^2$	0.937	0.950	0.971
Over. Restr. (*J−statistic, p−value*)	0.917 ($\chi^2(12)$)	0.962 ($\chi^2(15)$)	0.943 ($\chi^2(15)$)

*=95%/**=99% rejection of the null hyp. Estimated model:

$\mathrm{i}_t = (1\text{-}\rho)(\mathrm{c}+\mathrm{b}_\pi E_{t-1}\bar{\pi}_{t+4}+\mathrm{b}_y \mathrm{E}_{t-1} y_t+\mathrm{b}_z \mathrm{E}_{t-1}\mathrm{z}_t)+\rho \mathrm{i}_{t-1}+\varepsilon_t$, $\varepsilon_t = \rho_\varepsilon \varepsilon_{t-1} + \eta_t$

$\mathrm{z}_t = y_t^2$ (Asymmetric preferences); z_t =spread (Credit spread).

Estimates performed via GMM. Instruments:

$[\mathrm{c}\ \bar{\pi}_{t-2}..\bar{\pi}_{t-5}\ y_{t-2}\ ..y_{t-5}\ \Delta i_{t-2}\ ..\Delta i_{t-5}\ \Delta\bar{\pi}_{t-2}^{PPI}\ ..\Delta\bar{\pi}_{t-5}^{PPI}\Delta z_{t-2}..\Delta z_{t-5}]$,

$\bar{\pi}_t^{PPI}$four quarter inflation from the Producer Price Index (Finished Goods).

Newey-West correction (Bartlett kernel, 3 lags) applied to the stand. errors (reported in brackets). c omitted for brevity.

Table 4: Nested PA-SC model: Forward Looking Taylor Rules

Taylor rate specification	Standard Specification	Asymmetric preferences	Credit spread
b_π	2.157^{**} (0.228)	1.983^{**} (0.239)	1.963^{**} (0.228)
b_y	0.867^{**} (0.141)	0.750^{**} (0.128)	0.841^{**} (0.098)
b_z	-	-0.139^{*} (0.059)	-1.860^{**} (0.445)
γ_2	0.375^{**} (0.056)	0.344^{**} (0.055)	0.375^{**} (0.045)
γ_3	0.274^{**} (0.062)	0.281^{**} (0.059)	0.279^{**} (0.056)
$\bar{R}^2$	0.970	0.973	0.981
$H_0 : \gamma_2 = 1$ $(F{-}test,\ p{-}value)$	0.000^{**}	0.000^{**}	0.000^{**}
$H_0 : \gamma_2 = \gamma_3$ $(F{-}test,\ p{-}value)$	0.098	0.378	0.068

*=95%/**=99% rejection of the null hyp. Estimated model:

$\Delta \mathrm{i}_t = \gamma_2(\mathrm{b}_\pi \Delta \mathrm{E}_t \pi^{SPF}_{t+4} + \mathrm{b}_y \Delta \mathrm{y}_t + \mathrm{b}_z \Delta \mathrm{z}_t) + \gamma_3(\mathrm{c} + \mathrm{b}_\pi \mathrm{E}_{t-1} \pi^{SPF}_{t-3} + \mathrm{b}_y \mathrm{y}_{t-1} + \mathrm{b}_z \mathrm{z}_{t-1} - \mathrm{i}_{t-1}) + \eta_t.$

$\mathrm{z}_t = y_t^2$ (Asymm. pref.); z_t =spread (Credit spread). Estimator: NLS.

π^{SPF}_{t+4} = 1-year ahead Expected Inflation from Survey of Professional Forecasters.

Newey-West correction (3 lags) applied to the st. errors (in brackets).

c omitted for brevity. $\bar{R}^2$ refers to the *level* of the federal funds rate.

Table 5: Test for PA versus SC: Taylor Rules, SPF Expected Inflation

Taylor rate specification	Standard Specification	Asymmetric preferences	Credit spread
b_π	2.110^{**} (0.241)	1.976^{**} (0.215)	1.934^{**} (0.173)
b_y	0.827^{**} (0.118)	0.729^{**} (0.107)	0.812^{**} (0.082)
b_z	-	-0.138^{*} (0.060)	-1.654^{**} (0.437)
ρ	0.652^{**} (0.059)	0.673^{**} (0.050)	0.653^{**} (0.042)
ρ_ε	0.296 (0.154)	0.177 (0.152)	0.141 (0.161)
σ_ε	0.302	0.287	0.258
$\bar{R}^2$	0.973	0.976	0.980

*=95%/**=99% rejection of the null hyp. Estimated model:
$\mathrm{i}_t = (\mathrm{c}+\mathrm{b}_\pi E_t \pi_{t+4}^{SPF} + \mathrm{b}_y y_t + \mathrm{b}_z \mathrm{z}_t) + \rho \mathrm{i}_{t-1} + \varepsilon_t$, $\varepsilon_t = \rho_\varepsilon \varepsilon_{t-1} + \eta_t$
$\mathrm{z}_t = y_t^2$ (Asymmetric preferences); z_t =spread (Credit spread).
Estimator: NLS. Newey-West correction (3 lags) applied to the st. errors (in brackets). c omitted for brevity.

Table 6: Nested PA-SC Model: Taylor Rules, SPF Expected Inflation