Why are target interest rate changes so persistent?

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Abstract: While the degree of policy inertia in central banks' reaction functions is a central ingredient in theoretical and empirical monetary economics, the source of the observed policy inertia in the U.S. is controversial, with tests of competing hypotheses such as interest-smoothing and persistent-shocks theories being inconclusive. This paper employs real time data; nested specifications with flexible time series structures; narratives; interest rate forecasts of the Fed, financial markets, and professional forecasters; and instrumental variables to discriminate competing explanations of policy inertia. The presented evidence strongly favors the interest-smoothing explanation and thus can help resolve a key puzzle in monetary economics.

Keywords: Taylor rules, interest rate smoothing, monetary policy shocks.
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"In their discussion of the relative merits of smaller and more frequent adjustments versus larger and less frequent adjustments …, [FOMC] participants generally agreed that large adjustments had been appropriate when economic activity was declining sharply in response to the financial crisis. In current circumstances, however, most saw advantages to a more incremental approach that would involve smaller changes … calibrated to incoming data."

Minutes of the FOMC videoconference meeting, October 15th, 2010.

"The debate about the sources of gradualism is ongoing and I cannot hope to render a definitive verdict today on the relative merits of these rationales."

Ben Bernanke, May 20th, 2004 Speech.

I Introduction

As the U.S. economy slowly recovers from the deepest recession since the Great Depression, attention is increasingly turning to the Federal Reserve's "exit strategy." At what pace will the Federal Reserve reverse measures deployed to combat the financial crisis, how rapidly will the Fed allow excess reserves to be drawn down, and at what speed will interest rates rise in the coming years? While the Fed demonstrated a willingness to act with remarkable speed in the heart of the financial crisis, central banks have traditionally been characterized as being subject to significant inertia in the policy-making process, consistent with the quote above. In a 2004 speech devoted precisely to the question of monetary policy inertia, then-Governor Bernanke noted that this form of gradualism (or interest rate smoothing) in monetary policy has several potential benefits: it may be optimal when policymakers are uncertain about the quantitative effects of policy changes (as in Brainard 1967), it gives policymakers more control over long-term interest rates via the expectations channel (Woodford 2003a), and it may reduce financial sector instability because of the increased predictability of interest rates. While little evidence is available for nontraditional monetary policy actions, a long literature has argued that the Federal Reserve's historical interest rate decisions have followed precisely this modus operandi. Starting with Clarida et al. (2000), much of the literature characterizing the Fed's historical reaction function has found that interest rate decisions can be closely replicated by modeling the current interest rate as a weighted average of the lagged interest rate and the desired interest rate for the central bank, where the latter depends on current and expected macroeconomic conditions as in Taylor (1993), with empirical estimates consistently finding large weights on lagged interest rates consistent with the policy inertia motive.

At the same time, the apparent willingness of the Federal Reserve to respond rapidly to certain episodes, particularly in its role of lender-of-last-resort such as after the 1987 stock market crash, suggests that this apparent conservatism in decision-making may be more fiction than fact. This point has been made most forcibly by Rudebusch (2002, 2006) who argues that the inertia identified in previous work is likely a reflection of omitted variables in the Fed's reaction function. If the central bank reacts to factors other than those included in stylized Taylor rules, such as asset prices, liquidity conditions, or market

uncertainty, then to the extent that these variables are persistent, this will misleadingly lead to the appearance of inertia in estimated Taylor rules when none is in fact present. Rudebusch documents that a standard Taylor rule augmented to include persistent shocks as a proxy for other factors is statistically indistinguishable from a reaction function characterized by interest smoothing. Subsequent work using nested specifications with both policy inertia and persistent shocks has confirmed that there is little statistical basis for rejecting either hypothesis, but that allowing for persistent shocks significantly lowers the estimated degree of monetary policy inertia.[1] In his speech on the topic, Bernanke summarizes the literature by concluding that this question remains unresolved.

Yet breaking this empirical impasse and characterizing the inherent degree of inertia in monetary policy is important for a number of reasons. First, the amount of policy inertia plays a key role in forecasting not just the unwinding of the Fed's many actions during the financial crisis but the response of monetary policymakers to shocks more generally. For example, the degree of policy inertia would significantly affect one's forecast of the pace of the endogenous response of the central bank (and therefore of macroeconomic conditions more generally) to non-monetary policy innovations such as technology or oil price shocks. Second, the underlying parameters of structural macroeconomic models are effectively estimated by comparing their predicted impulse responses to those observed in the data. Understanding whether the conditional response of the economy to shocks is subject to policy inertia will therefore matter for the estimates of all parameters of the model, not just those related to the policy rule. Third, whether one assumes policy inertia or persistent shocks in the specification of the Fed's reaction function matters for historical interpretations. For example, we document in section 2 that the Taylor Principle would have been satisfied during the Greenspan era under the policy inertia specification, but not under the persistent shocks view. The monetary policy interpretation of the Great Moderation advocated by Lubik and Schorfheide (2004) and others in which changes in the monetary policy rule during the Volcker and Greenspan eras moved the U.S. economy away from indeterminacy is therefore dependent on the assumed source of the persistence in interest rates. Similarly, Ireland (2011) shows that determining whether interest rates were too accommodative in the mid-2000s, as suggested by Taylor (2007), hinges on the degree of policy inertia in the Fed's reaction function. More broadly, the fact that much of the recent macroeconomics literature has simply assumed interest-smoothing on the part of central bankers implies that, if the Rudebusch hypothesis is correct, many recent results on a wide range of macroeconomic topics relying on interest-smoothing as a component of the endogenous response of monetary policymakers to economic fluctuations could be called into question.

[1] English et al. (2003), Gerlach-Kristen (2004) and Consolo and Favero (2009) all estimate Taylor rules nesting both interest smoothing and persistent shocks using single-equation methods and report evidence for both motives, albeit to differing degrees. Carrillo et al. (2007) and Smets and Wouters (2007) estimate nested specifications within fully specified DSGE models and reach divergent conclusions about the relative importance of each explanation.

Using a variety of methods, we present new evidence which decisively favors the policy inertia interpretation of the Fed's historical behavior. First, we revisit empirical estimates of nested specifications of the Taylor rule which previous research has found to be unable to conclusively discriminate between the two hypotheses. However, this prior research restricted interest smoothing and persistent shocks to first order autoregressive processes even though theoretical models of policy inertia suggest that higher order smoothing could be optimal (Woodford 2003b) and there is no a priori reason to believe that persistent shocks are best described as an AR(1) process. By allowing for more general forms of each, we show that the data is much more informative about the underlying source of interest rate persistence than previously uncovered. Using information criteria to select across a wide set of nested specifications with higher order interest smoothing and persistent shocks, the data strongly support specifications with only interest smoothing, with two lags of interest rates being the preferred specification. In addition, we show that when one allows for second order interest smoothing in the Taylor rule, autoregressive parameters in the error term either become insignificantly different from zero or negative.

Our second contribution is to provide a new method to test the relative merit of the two hypotheses. The key insight is that while both interest smoothing and persistent monetary policy shocks can adequately account for the observed persistence in interest rates, they have different implications for the conditional response of interest rates to non-monetary policy shocks. Specifically, interest rate smoothing implies that an inertial policy response should be observable after any shock, whereas this should not be the case under persistent monetary shocks. With the latter, the extra persistence in interest rates should obtain only after monetary policy shocks. Thus, we propose to test the hypothesis that persistent interest rates reflect persistent monetary policy shocks by identifying the conditional response of policymakers to non-monetary policy shocks. To do so, we employ an instrumental variables strategy in which our instruments are identified non-monetary policy shocks, including technology shocks, oil supply shocks, news shocks and exogenous fiscal shocks. These instruments serve to identify historical innovations to the Federal Reserve's forecasts of inflation, output growth and the output gap driven by shocks other than monetary policy. As a result, they allow us to assess whether policy inertia is present in response to these shocks, a finding confirmed in the data. All of the estimates of interest smoothing are high, close to those obtained under least squares, and statistically significant at standard levels. Hence, this alternative approach also strongly supports the interest rate smoothing motive.

Our third contribution is to revisit the primary source of support for the persistent shocks explanation, namely the evidence provided by Rudebusch (2002) that future interest rate changes are largely unpredicted by financial market participants. His key insight was that if policy inertia is as high as implied by typical Taylor rule estimates, then interest rate changes two to three quarters in the future should be fairly predictable given current information. Using Eurodollar futures prices, he documents

little predictability of interest rates at these horizons by financial market participants. We present similar evidence using professional forecasts of future short term interest rate changes. However, there are several factors that could reduce the ability of private agents to forecast future interest rate changes even if policy inertia is strong. First, there could be uncertainty on their part about the form of the policy rule, such as whether the central bank responds to the output gap or output growth, what measure of inflation it focuses on, or whether policy inertia is important. Second, private agents typically have a more restricted information set than the Federal Reserve. Third, even with the same information, agents may use different models than the staff of the Fed to formulate forecasts, leading to different predictions about the future path of policy. Romer and Romer (2000), for example, document that Greenbook forecasts systematically outperform professional forecasters, which indicates that the Fed either has access to superior information about the economy or is more successful in converting that information into accurate forecasts.

These informational constraints potentially facing private-sector forecasters imply that the extent to which these agents can predict subsequent interest rate changes may not be adequate to identify the presence of policy inertia. On the other hand, the Federal Reserve staff should be better able to predict future interest rate changes because internal members of the Fed are more likely to correctly identify the policy rule and employ the same information as that utilized by the FOMC in its interest rate decisions. As a result, we revisit the predictability of interest rate changes using the assumptions about future Federal Funds Rates and other short-term interest rates made by the Fed staff in generating the Greenbook forecasts as proxies for their expectations of future interest rates. Because these need not represent the staff's unconditional best forecasts of future interest rates, they provide only a lower bound on the predictability of future interest rates changes by members of the Federal Reserve. Despite this, we find that the Greenbook assumptions about the path of future interest rates can predict a larger fraction of future interest rate changes (both Fed Funds Rate and 3-month T-Bill rate) than private sector forecasts, and that these forecasts are unbiased even at two and three quarter forecasting horizons, unlike private sector forecasts. Thus, we find that even the empirical strategy which previously yielded the strongest evidence for persistent shocks is actually consistent with the presence of significant inertia in historical interest rate decisions.

Further evidence that the inability of private agents to forecast interest rates as well as the Fed likely reflects informational constraints comes from the fact that when we extend the end of the sample from 1999 to the mid-2000's, both financial market and professional forecasts are better able to predict future interest rate changes even though the overall predictability of interest rates, as measured by the Greenbook forecasts' accuracy, is unchanged over this extended time period. This is suggestive of informational constraints on private sector forecasters because the Fed began to include statements about its perceptions of future risks after each FOMC meeting in 2000. These statements likely provided an

important guide to the private sector as to the likely direction of future interest rate changes which resulted in an improvement in their ability to predict the path of policy decisions.

Our fourth approach is to consider the statements of policymakers themselves about the interest-rate setting process. We present suggestive narrative evidence from FOMC discussions during which monetary policymakers explicitly framed their decisions in a policy smoothing context. In particular, we focus on the 1994-1995 period when the Federal Reserve significantly raised interest rates to preempt a resurgence of inflation. During internal policy discussions in this period, Greenspan and other FOMC members made explicit statements about their perceptions of the optimal level of interest rates but made no suggestions to move directly to these levels. Instead, any disagreement among FOMC members was almost exclusively about the speed at which interest rates should move toward the desired level, with the consensus view favoring a very gradual adjustment of policy rates toward desired levels. A similar pattern occurred in 2004 as the Federal Reserve began systematically raising interest rates after a prolonged period of low interest rates. Then-Governor Bernanke clearly advocated—both in FOMC meetings and in his May 20th, 2004 speech—a gradual process for raising interest rates which is not only consistent with the policy inertia interpretation but also strongly suggests that the unwinding of the Fed's accommodative stance in the coming years is again likely to be "measured" (2004 Fed speak) and "incremental" (2010 Fed speak).

Finally, we consider the broader possibility that the excess persistence observed in interest rates relative to the predictions of simple Taylor rules is the result of the Federal Reserve responding to other economic factors above and beyond their effects on the Fed's expectations of current and future macroeconomic conditions. Controlling for different measures of financial market conditions, the estimated degree of interest smoothing is unaffected. Similarly, controlling for the revisions in the Fed's forecasts also does not qualitatively affect the results. A third possibility is that the missing persistence could stem from a time-varying inflation target. Using different target inflation measures from Cogley et al. (2010), Ireland (2007) and Coibion and Gorodnichenko (2011), we again find that the estimated degree of interest smoothing is unchanged while the role of persistent policy shocks is diminished. We also document that any evidence of persistent policy shocks disappears after we incorporate into the Taylor rule the difference between Greenbook and private consensus forecasts thus suggesting that the serial correlation in policy shocks may simply reflect informational flows between agents. This would be consistent with the notion that the central bank utilizes the information in private forecasts along with its internal forecasts as well as the possibility that the central bank considers how private forecasters may try to learn about the central bank's information from its policy actions or announcements. In addition, the fact that the central bank responds to both its own and private sector forecasts combined with the informational asymmetry between the central bank (which has access to the private sector's forecasts) and

private forecasters (who do not have access to the central bank's forecasts) provides another potential reason why the Federal Reserve has been more successful in predicting future policy decisions than the private sector. Once these factors are incorporated in the estimated policy reaction function, interest rate smoothing may be reasonably described as AR(1) rather than a higher order autoregressive process. Hence, these results suggest that the correlated policy shocks found in the previous work may have stemmed from movements in unobservable targets and/or sensitivity on the part of policymakers to the private sector's expectations.

The rest of the paper is organized as follows. Section 2 presents preliminary evidence on the performance of estimated Taylor rules assuming either interest rate smoothing or persistent shocks and illustrates how simple nested specifications do not convincingly differentiate between the two in the data. Section 3 considers more general forms of interest smoothing and persistent shocks and documents that interest rate smoothing is strongly preferred to persistent shocks once one allows for higher order descriptions of each process. Section 4 proposes and applies an instrumental variable procedure to assess the support for the two explanations of interest rate persistence while section 5 presents new evidence on the predictability of interest rate changes by private agents versus Federal Reserve forecasts. Section 6 considers narrative evidence about policymakers' decisions and section 7 allows for the possibility of other factors being responsible for the persistence in interest rates. Finally, section 8 concludes.

II Interest Rate Smoothing vs. Persistent Monetary Policy Shocks

In this section, we first consider simple versions of Taylor rules with interest rate smoothing and/or persistent monetary policy shocks using real-time measures of the Federal Reserve's forecasts of macroeconomic conditions. We document the near statistical equivalence of reaction functions with either interest smoothing or persistent shocks despite their remarkably different implications for the historical behavior of the Federal Reserve. In addition, we show that nested specifications relying on first-order autoregressive specifications of each motive fail to decisively differentiate between the two hypotheses.

2.1 Baseline Evidence on the Sources of Persistent Interest Rate Changes

Since Taylor (1993), macroeconomists have relied on simple interest rate reaction functions to characterize the endogenous response of monetary policy-makers to economic fluctuations. While early work assumed that policy-makers responded to contemporaneous inflation and output gaps, more recent work has emphasized the importance of controlling for the real-time expectations of the central bank (Orphanides 2003, Coibion and Gorodnichenko 2011). In this spirit, we consider the following baseline specification for monetary policy-makers' desired interest rate (i_t^*) based on fundamentals

$$i_t^* = c + \phi_\pi^* E_{t-}\pi_{t+h} + \phi_{dy}^* E_{t-} dy_{t+h} + \phi_x^* E_{t-} x_{t+h} \quad (1)$$

where E_{t-} denotes the central bank's forecast of macroeconomic variables formed prior to the choice of the interest rate, π is inflation, dy is the growth rate of output, and x is the output gap. The rule allows for the central bank to respond to the forecast of future macroeconomic variables (horizon h), consistent with the notion that monetary policy changes take time to affect the economy so policy-makers should be forward-looking in their policy decisions. The rule also departs from the classical Taylor (1993) specification in that it allows for responses to both the output gap and the growth rate of output, a feature that receives strong empirical support as first documented in Ireland (2004).

The actual policy rate set by policymakers is given by

$$i_t = i_t^* + u_t \tag{2}$$

where u_t represents monetary policy shocks and which we assume to be i.i.d. for now. Note that we consistently rely on Greenbook forecasts generated by staff members of the Board of Governors *prior* to FOMC meetings at which interest rate decisions are set, so equation (2) can be estimated by least squares as in Coibion and Gorodnichenko (2011). For example, estimating this rule from 1987Q4 until 2004Q4 using the target Federal Funds Rate (FFR) for the interest rate yields

$$\begin{aligned} i_t &= \underset{(0.50)}{1.06} + \underset{(0.14)}{1.76}\, E_{t-}\pi_{t+2,t+1} - \underset{(0.09)}{0.11}\, E_{t-}dy_t + \underset{(0.07)}{0.64}\, E_{t-}x_t + u_t \\ \sigma_u &= 0.75, \quad \bar{R}^2 = 0.89 \end{aligned}$$

where Newey-West HAC standard errors are in parentheses.[2] As emphasized by Taylor (1993), a simple specification such as this can account for much of the policy changes over this time period, with an R^2 of nearly 90%. The point estimate on inflation is greater than one, implying that the Federal Reserve satisfied the Taylor Principle over this time period, while also responding with higher interest rates to rising output gaps. The response to output growth is not significantly different from zero. Figure 1 plots the actual time path of the target FFR over this time period, the predicted time path from the estimated reaction function, as well as the residuals from the regression, illustrating how well the Taylor rule can account for historical policy changes over this time period. However, the predictions of the Taylor rule are noticeably more volatile than actual interest rates: the average size of the predicted change in interest rates (in absolute value) is approximately sixty percent larger than actual changes in interest rates (57bp to 35bp). Actual interest rates are also significantly more persistent than predicted interest rates (AR(1) parameter of 0.98 versus 0.93). Finally, the residuals are serially correlated: the Durbin-Watson statistic is well under 1 and we can reject the null of no serial correlation of the residuals at standard levels.

The fact that these results obtain even when using the real-time forecasts of the Federal Reserve is noteworthy. Goodhart (2005) suggests that the excess persistence of actual interest rates relative to

[2] For all quarterly estimates of the Taylor rule, we use data from the meeting closest to the middle of each quarter. We find similar results using data at the frequency of FOMC meetings. Real-time estimates of the output gap follow Orphanides (2003).

predictions of Taylor rules could reflect the fact that central bankers adjust interest rates in response to their forecasts of future economic conditions. If Taylor rules are estimated using final data and central bankers adjust their forecasts only gradually to economic developments, one may observe excess persistence. Coibion and Gorodnichenko (2008) document evidence consistent with the FOMC members' inflation forecasts responding only gradually to economic shocks. However, because the estimates of equation (2) above are done *conditional* on the potentially gradually evolving forecasts of the Federal Reserve, the excess persistence in interest rate decisions exists above and beyond the potential source emphasized by Goodhart (2005).

The often-noted gradualism in actual interest rate targets has led many to adopt an alternative representation of monetary policy actions, in which the actual interest rate is a weighted average of the current desired rate and the previous period's interest rate:

$$i_t = (1-\rho_i)i_t^* + \rho_i i_{t-1} + u_t \quad = c^{sr} + \phi_\pi E_{t-}\pi_{t+h} + \phi_{dy} E_{t-} dy_{t+h} + \phi_x E_{t-} x_{t+h} + \rho_i i_{t-1} + u_t$$

where ρ_i is the degree of *interest rate smoothing* and the coefficients on expected inflation, output growth and the output gap are short-run responses (e.g., $\phi_\pi = (1-\rho_i)\phi_\pi^*$). This type of inertia in monetary policy implies that central bankers will move interest rates toward their desired levels in a sequence of steps rather than in an immediate fashion as predicted by the baseline Taylor rule. Estimating this equation by least squares using the same data and time period as before yields

$$\underset{}{i_t} = \underset{(0.16)}{-0.57} + \underset{(0.05)}{0.42}\ E_{t-}\pi_{t+2,t+1} + \underset{(0.03)}{0.18}\ E_{t-}dy_t + \underset{(0.02)}{0.14}\ E_{t-}x_t + \underset{(0.03)}{0.82}\ i_{t-1} + u_t$$

$$\sigma_u = 0.26, \quad \bar{R}^2 = 0.99$$

The implied long-run response to inflation (0.42/(1-0.82)) is greater than 2 so that the Taylor Principle was satisfied by the Federal Reserve. Allowing for interest smoothing yields a positive estimated response of interest rates to both the output gap and output growth. The estimated degree of interest rate smoothing of 0.82 is similar to those found in the literature, such as Clarida et al. (2000) and points to a very significant degree of policy inertia. While the presence of interest smoothing at the weekly or even monthly frequency is widely acknowledged, such a high degree of policy inertia implies that policy changes are smoothed over a number of *quarters*. Yet allowing for interest smoothing raises the ability of the specification to account for historical policy changes by a significant amount, with the R^2 rising to 99%. Furthermore, allowing for interest smoothing eliminates much of the serial correlation in the residuals. For these reasons, interest smoothing has become a central feature of how monetary policy rules are characterized in modern macroeconomic models that play an increasingly important role in policy analysis.

An alternative explanation for the apparent inertia in interest rates suggested by Rudebusch (2002) is that it reflects *persistent monetary policy shocks* (or persistent deviations from the Taylor rule)

rather than policy inertia. Under this interpretation, policy follows the Taylor rule in equations (1) and (2) but the shocks to the interest rate follow a persistent process such as

$$u_t = \rho_u u_{t-1} + \varepsilon_t$$

Applying the same data and time sample, we re-estimate equation (1) allowing for AR(1) errors and find

$$\underset{}{i_t} = \underset{(4.38)}{-1.91} + \underset{(0.11)}{0.28}\ E_{t-}\pi_{t+2,t+1} - \underset{(0.03)}{0.05}\ E_{t-}dy_t + \underset{(0.11)}{0.47}\ E_{t-}x_t + u_t, \quad u_t = \underset{(0.03)}{0.98}\ u_{t-1} + \varepsilon_t$$

$$\sigma_u = 0.39, \quad \bar{R}^2 = 0.97$$

As with the specification under interest smoothing, we find strong evidence for extra persistence in interest rates, in this case measured by an autoregressive parameter of 0.98 for the error term.[3] Allowing for persistent errors also significantly improves the fit of the empirical specification, with the R^2 rising to 97%, and eliminates much of the serial correlation in the error ε_t. Strikingly, the implied response of interest rates to inflation is strictly less than one, suggesting that the Federal Reserve may not have satisfied the Taylor Principle during the Greenspan era, a finding which is in sharp contrast to that obtained under the baseline Taylor rule or the rule augmented with interest smoothing.

Figure 2 plots the actual target Federal Funds Rate over this time period as well the predicted levels from the specifications with either interest-smoothing or persistent shocks. As can readily be seen, the two specifications are nearly indistinguishable to the naked eye and both interest rate smoothing and persistent monetary policy shocks are able to account for the excessive volatility of interest rate changes predicted by the baseline Taylor rule, improve the fit of the empirical reaction function, and control for much of the observed persistent deviations of actual interest rates from the predicted rates of the baseline Taylor rule. Yet, as discussed above, determining whether the persistence of interest rates reflects interest rate smoothing or persistent shocks is a crucial determinant in a variety of macroeconomic analyses.

2.2 The Limited Informativeness of Nested Specifications

Because both approaches appear to fit the data so well, empirically determining the relative importance of interest rate smoothing and persistent shocks has been challenging. Rudebusch (2002) proposes a nested specification

$$i_t = c + \phi_\pi E_{t-}\pi_{t+h} + \phi_{dy} E_{t-}dy_{t+h} + \phi_x E_{t-}x_{t+h} + \rho_i i_{t-1} + u_t, \quad u_t = \rho_u u_{t-1} + \varepsilon_t \quad (3)$$

but finds that the data are not sufficiently informative to reject either hypothesis and that small changes to the time period under consideration can lead to evidence that favors either hypothesis. Subsequent work using this approach has yielded similar results. English et al. (2003) find that both serially correlated shocks and interest rate smoothing are important, while Gerlach-Kristen (2004) similarly finds a role for

[3] Despite serially correlated error terms, this equation can still be consistently estimated by least squares by rewriting the specification in nonlinear terms. For example, the basic Taylor rule with AR(1) error term can be estimated using Nonlinear Least Squares as $i_t = \rho_u i_{t-1} + i_t^* - \rho_u i_{t-1}^* + \varepsilon_t$ where i_t^* is defined as in (1).

both mechanisms but indicates that interest smoothing appears to be less important than suggested by the previous literature. Estimation of equation (3) in the context of fully-specified DSGE models has also failed to deliver unambiguous answers: Smets and Wouters (2007) find high interest smoothing and only weakly autocorrelated shocks while Carrillo et al. (2007), using a similar structural model, argue that serially correlated shocks significantly reduce the importance of policy inertia.

One limitation common to each of these studies is their reliance on ex-post data rather than the ex-ante expectations of the Federal Reserve. Orphanides (2003), for example, emphasized the importance of the real-time measurement of the output gap for interpretation of policy decisions while Goodhart (2005) documented how controlling for real-time forecasts could significantly affect estimates of the degree of interest-smoothing. As a result, we present nested specifications estimated on real-time data in Table 1. The point estimate for the degree of interest rate smoothing is 0.81, almost identical to the original specification without persistent shocks, and is statistically significantly different from zero. The coefficient on the persistence of monetary policy shocks, however, is now much lower at 0.46 but remains statistically different from zero. Hence, conditional on the Federal Reserve's real-time information set, the data favors the interest smoothing motive over the persistent shock interpretation, but does not unambiguously reject either specification. Thus, like much of the previous literature, we find that a simple nested specification cannot overwhelmingly differentiate between the two explanations.

Table 1 presents additional results of the nested Taylor rule using different specifications of the Taylor rule. For example, using the Greenbook forecast of inflation in the next quarter rather than in the next two quarters (column 2) does not qualitatively affect the results. However, as noted by Rudebusch (2002), the results of the nested specifications are generally not very robust. For example, assuming that the central bank responds to the forecast of the current quarter's inflation rate (column 5), the coefficient on interest smoothing declines to 0.70 while the persistence of monetary policy shocks is now estimated to be 0.89. Thus, this specification points to a stronger role for persistent shocks, although both the AIC and SIC indicate that our baseline specification is statistically preferred to one in which the central bank is assumed to respond to contemporaneous inflation. Similarly, allowing for a response to expected output growth in the next quarter rather than the current quarter or eliminating the response to output growth altogether (columns 3 and 4) leads to higher point estimates of the persistence of monetary policy shocks. In all cases, we can reject the null of either interest smoothing or persistent shocks being the sole mechanism that accounts for the excess persistence in interest rates observed in the data.

Table 2 presents additional results from estimating our preferred specification of the Taylor rule over different time periods. First, if we restrict the time sample to end in 1999Q4, as in Rudebusch (2002), the results are almost identical: we find evidence for both interest smoothing and persistent shocks, although the coefficient on interest smoothing is much larger than the estimated persistence of the

shocks. Extending the sample to 1983Q1 strengthens the case for interest-smoothing, as the estimated persistence of monetary policy shocks falls and becomes insignificantly different from zero. Table 2 also includes results when we estimate the baseline Taylor rule at the frequency of FOMC meetings, approximately every six weeks over this time period, rather than at the quarterly frequency. Over the Greenspan period, the results point more strongly toward the interest smoothing motive: the coefficients on lagged interest rates are around 0.90 and statistically significant at conventional levels, in line with the estimates at the quarterly frequency once one adjusts for the different frequency of the data, while the estimated persistence of monetary shocks is small and insignificantly different from zero. One interpretation of these results is that previous work, having focused exclusively on analysis at the quarterly frequency, may have overstated the evidence of persistent shocks. Using the entire post-1982 era yields slightly more mixed evidence, with the autoregressive parameter governing the dynamics of the error term becoming positive and statistically significant at the 10% level. Thus, across specifications and time periods, the results are remarkably mixed: while most of the specifications point to an important role for policy inertia, it is difficult to systematically rule out persistent shocks as an alternative explanation for the interest rate inertia apparent in the data.

III Generalized Specifications of Interest Rate Smoothing and Persistent Shocks

While the evidence from the previous section suggests that interest rate smoothing is a somewhat more potent explanation for the persistence of interest rate changes observed in the data than persistent shocks, the evidence is mixed at best as minor variations in the specification of the Taylor rule can move the relative importance of the two mechanisms substantially. However, an important caveat is that, like previous work, we have only considered the simplest forms of each specification, namely first-order autoregressive specifications for both interest rate smoothing and persistent monetary policy shocks. On the other hand, other work on estimating Taylor rules has identified evidence that interest smoothing could be higher order: Coibion and Gorodnichenko (2011), for example, find that interest smoothing is best characterized as a second order autoregressive process but do not consider the possibility that monetary policy shocks are persistent. Furthermore, Woodford (2003b) proves that the optimal interest rate rule should have an AR(2) interest rate smoothing and, therefore, there are theoretical arguments to have interest rate smoothing with higher autoregressive orders. There is also no a priori reason to suspect that the persistence of monetary policy shocks, or more broadly deviations from the Taylor rule, is best characterized as a first order autoregressive process. In this section, we allow for higher order processes for both interest smoothing and persistent shocks, i.e. we consider empirical specifications of the form

$$i_t = c + \phi_\pi^{sr} E_{t-}\pi_{t+h} + \phi_{dy}^{sr} E_{t-} dy_{t+h} + \phi_x^{sr} E_{t-} x_{t+h} + \sum_{i=1}^{I} \rho_i \, i_{t-i} + u_t, \qquad (4)$$

$$u_t = \sum_{j=1}^{J} \rho_{u,j} u_{t-j} + \varepsilon_t.$$

where $\phi_\pi^{sr} \equiv \left(1 - \sum_{i=1}^{I} \rho_i\right)\phi_\pi$ and similarly for ϕ_{dy}^{sr} and ϕ_x^{sr}.

We assess the relative merit of interest rate smoothing and persistent shocks using two methods. First, we compute the BIC criteria associated with the same specifications of the desired interest rate as in the previous section, but now allowing both I and J to range from zero to four. Thus, we include specifications with only interest-smoothing, only persistent shocks, neither, and a variety of specifications with both interest-smoothing and persistent shocks. As a result, this kind of model-selection criterion can shed some light on the relative merit of the two approaches while allowing for more general forms of both interest smoothing and persistent shocks than in the previous section. The results are presented in Table 3 for different time periods using data at both the quarterly frequency and the FOMC meetings frequency. The results strongly favor the interest smoothing motive: all but one of the specifications of the Taylor rule estimated at the quarterly frequency achieve the lowest BIC with two lags of the interest rate and no persistence in monetary policy shocks. The sole exception, when the central bank is assumed not to respond to output growth, yields a specification with one lag of the interest rate and first-order autoregressive shocks. However, the BIC for this specification of the Taylor rule is substantially higher than for versions of the Taylor rule which include output growth. The results using data at the frequency of the FOMC meetings are similar. Most of the preferred specifications since 1987 include no persistent shocks. Only when the time period is extended to 1983 do we find some evidence for persistent shocks.

As a second approach, we present in Table 4 results from estimating equation (3) assuming two lags of the interest rate and a second order autoregressive process for monetary policy shocks for each of the Taylor rule specifications considered before over the time period 1987Q4 to 2004Q4. Consistent with the results in Table 3, both interest rate lags are statistically significant for each of the Taylor rule specifications, and the sum of the coefficients is between 0.75 and 0.95 so that the degree of interest smoothing is always high. On the other hand, the first autoregressive parameter for shock persistence is never statistically different from zero, while the second autoregressive parameter, when different from zero, is negative.[4] Hence, whereas previous work has found that nested specifications could not decisively differentiate between the two explanations for interest rate persistence, we find that *once one allows for higher order interest smoothing, the evidence robustly favors the interest smoothing motive.* In addition, one should note that the fact that second-order interest smoothing fares well in the data is qualitatively consistent with the optimal interest smoothing rules in Woodford (2003b). However, the point estimates differ quantitatively from optimal policy inertia: Woodford (2003b) shows that an optimal interest rate rule would be super-inertial, a feature which is consistently absent in our empirical estimates of historical reaction functions.

[4] Similar results obtain using higher order autoregressive specifications of the error term: the coefficients are either insignificantly different from zero or negative.

IV Conditional Monetary Policy Reaction Functions

While the nested specifications lend greater support to the interest rate smoothing motive than previously noted, we want to consider alternative approaches which might shed light more directly on what the underlying source of persistent interest rate changes is. In this section, we consider a novel test of the two hypotheses. If the persistence of interest rate changes observed in the data is primarily driven by persistent monetary policy shocks, then the conditional response of interest rates should be slow after monetary policy shocks but not other macroeconomic shocks. Intuitively, interest rate smoothing implies policy inertia regardless of the source of the underlying fluctuations, whereas the persistent monetary policy shocks explanation imposes additional interest rate persistence in response only to monetary policy shocks.

To see this more formally, note that after log-linearization and solving for the rational expectations solution, variables (z) in macroeconomic models can generically be expressed in MA(∞) form

$$E_t z_{t+h} = \sum_{i=0}^{\infty} \sum_{s=1}^{S} \delta_{i,s} \varepsilon_{s,t-i} \tag{5}$$

where i refers to periods and ε refers to structural shocks denoted by s, here ordered numerically from 1 to S. We can then define the component of z driven by monetary policy shocks as

$$E_t z_{t+h}^{mp} = \sum_{i=0}^{\infty} \delta_{i,mp} \varepsilon_{mp,t-i} \tag{6}$$

and the component driven by all other shocks as

$$E_t z_{t+h}^{-mp} = E_t z_{t+h} - E_t z_{t+h}^{mp} \tag{7}$$

Assuming structural shocks are uncorrelated with each other and across time, then the component of z driven by exogenous monetary policy shocks and that driven by all other shocks will be uncorrelated as well. The desired interest rate can then be expressed as

$$i_t = i_t^{-mp} + i_t^{mp} + u_t \tag{8}$$

which decomposes changes in the desired interest rate into two components capturing the endogenous responses of monetary policy to macroeconomic fluctuations (i_t^{-mp} for non-monetary policy shock driven fluctuations and i_t^{mp} for monetary-policy driven fluctuations) and the exogenous shocks to interest rates (u).

This decomposition provides an alternative approach to assess the source of the interest rate persistence in the data. In the case with persistent monetary policy shocks but no interest smoothing, the endogenous response of interest rates to non-monetary policy shocks should not be subject to excess persistence, whereas under interest smoothing, the need for additional persistence should be apparent in response to non-monetary policy shocks. This insight can be applied to the analysis of the Taylor rule if one can identify variations in the endogenous response of interest rates to shocks other than monetary policy. This can be done by instrumental variables estimation of the Taylor rule, using exogenous structural shocks as instruments. The latter will be uncorrelated with monetary policy shocks and the endogenous response of

interest rates to policy shocks ($i_t^{mp} + u_t$), thereby allowing us to assess whether interest smoothing is present in the face of non-monetary policy driven fluctuations in macroeconomic conditions.[5]

To apply this method to historical monetary policy, we estimate equation (3) using instrumental variables. Specifically, our instruments are permanent technology shocks from Gali (1999), purified innovations to the Solow residual as in Basu, Fernald and Kimball (2006), news shocks as in Beaudry and Portier (2006), oil supply shocks as identified by Kilian (2009), and tax shocks from Romer and Romer (2010). We could not reject the null that these non-monetary shocks are uncorrelated with popular measures of monetary shocks identified via a conventional VAR approach or as in Romer and Romer (2004) and the overidentifying restrictions test could not reject the null that the instruments are uncorrelated with the error term in the estimated equation. Therefore, one may reasonably expect that the exclusion restriction is satisfied for our instrumental variables. Results from applying this procedure to different time samples at the quarterly frequency are presented in Table 5.[6] In each case, the coefficient on interest smoothing is high, on the order of 0.7-0.8, and statistically different from zero. Hence, inertia in policy actions exists in response to variations in macroeconomic conditions arising from non-monetary policy shocks. This result indicates that interest-rate smoothing likely does not simply reflect persistent monetary policy shocks, but rather captures a fundamental component of the policy process of the Federal Reserve, consistent with the results using nested specifications of interest smoothing and persistent shocks.

V Predictability of Interest Rate Changes

While the evidence from the analysis of Taylor rules using real-time data clearly favors the interest-smoothing explanation, Rudebusch (2002) suggests an alternative metric to assess the two explanations which he argues is consistent with the persistent shocks interpretation. His insight is that if policy was driven by interest rate smoothing, then interest rate changes should be quite predictable. Using futures markets for interest rates, he finds that markets are quantitatively unable to predict future interest rate changes, a result that he argues is difficult to reconcile with policy inertia.

The specific test employed by Rudebusch (2002) uses the following empirical specification:

$$i_{t+h} - i_{t+h-1} = c + \beta\left[ED_{t,t+h} - ED_{t,t+h-1}\right] + \varepsilon_t \qquad (9)$$

[5] We verified in Monte Carlo simulations that IV estimation of the Taylor rule using exogenous shocks as instruments could correctly identify the absence of interest smoothing when the data generating process is driven entirely by persistent shocks. Results available upon request. Note that our IV procedure is valid even if persistent u_t are standing in for unobserved variables. This is because once the linear specification is expressed in non-linear terms by quasi-differencing out the persistent errors, the orthogonality condition is that the structural shocks be uncorrelated with the *innovations* to the u_t process.

[6] We do not present equivalent results at the FOMC meetings frequency because most of the shocks used as instruments are only available at the quarterly frequency. We use the contemporaneous value of each shock and two lags as instruments, but the results are robust to using different numbers of lags of the shocks in the first stage.

where $ED_{t,t+h}$ are the interest rate on Eurodollar deposits during quarter $t+h$ that is expected at the end of quarter t. Eurodollar futures have been the trading vehicle of choice for hedging short-run interest rate movements since the mid-1980s and therefore provide one measure of financial market participants' forecasts of future interest rate changes. Assuming a constant risk premium (incorporated in the intercept), efficient markets and full information on the part of market participants imply a null hypothesis of $\beta = 1$. Furthermore, if interest rate decisions exhibit significant inertia, then market forecasts should be able to predict a non-trivial component of future interest rate changes.

In Table 6, we reproduce the original results of Rudebusch (2002) over the time sample of 1987Q4 to 1999Q4. At the one quarter ahead forecasting horizon, β is not different from one but significantly greater than zero. With an R^2 of more than 50%, this indicates that markets are able to predict short-term changes in the FFR quite well. However, as emphasized by Rudebusch (2002), these results rapidly deteriorate at longer forecasting horizons. At the two and three quarter forecasting horizons, the null of $\beta = 1$ can be rejected and the R^2's fall to 11% and 3% respectively. Using simulations from a New Keynesian model with a Taylor rule containing interest smoothing, Rudebusch finds that such a low predictability of future interest rate changes is an unlikely outcome, i.e. outside the 95% confidence intervals of R^2 from the simulations, for levels of interest smoothing like those estimated in the data. Thus, the low predictability of interest rates at the two and three quarter forecasting horizons suggests that policy inertia may not be the key driving source of interest rate persistence in the data.

On the other hand, there are several factors which could, even in the presence of policy inertia, lead financial market futures to be poor predictors of subsequent interest rates. One such factor emphasized by Rudebusch (2002) is the possibility of a time-varying risk premium. But there are also a number of informational constraints facing private sector forecasters which could systematically reduce their ability to predict future interest rate decisions by the Fed even in the presence of significant policy inertia. One such constraint is uncertainty about what the policy rule actually is, e.g. does the central bank respond to output growth or the output gap, by how much does the central respond to different macroeconomic variables, is there policy inertia in the decision making process, etc. Second, private agents could have less information than the Federal Reserve. The Federal Reserve has a much larger staff of economists available to digest and process incoming economic information than any private organization, likely leaving the latter at an informational disadvantage. Evidence of this is documented by Romer and Romer (2000) in the case of professional forecasters: they find that Greenbook forecasts systematically outperform professional forecasts of inflation. Ang et al. (2007) show that professional forecasts of inflation dominate asset-price based forecasts of inflation, so Greenbook forecasts likely have a significant informational advantage over financial market forecasts. Finally, agents could be unsure about the underlying model used by the Federal Reserve to translate its information set into forecasts of macroeconomic variables. In this case, even if

agents had the same information about current and past macroeconomic conditions, this might lead them to generate different forecasts than the Federal Reserve, which would translate into additional interest rate prediction errors. As a result, the inability of financial market participants to forecast future interest rate changes could reflect a variety of factors other than a lack of policy inertia.

To evaluate the importance of these factors, we re-assess the predictability of future interest rate changes using the forecasts of the FFR embodied in the Greenbook forecasts of the Federal Reserve. The staff of the Board of Governors makes assumptions about the future path of the FFR in generating forecasts of other macroeconomic variables, which can be interpreted as forecasts of future policy actions. Because these forecasts are generated at the same time as the forecasts of other macroeconomic variables in the Greenbooks, they should embed consistent assumptions about the policy rule, consistent information sets, and a consistent model used to convert information into forecasts. In short, these forecasts of the FFR should possess much more information about the predictability of interest rates driven by policy inertia than market forecasts. However, because these assumptions do not necessarily represent the staff's best unconditional forecasts of future policy actions, they should be interpreted as a *lower bound* on the ability of Federal Reserve staff to predict subsequent policy decisions. Figure 3 plots the historical FFR and selected forecasts from both financial markets and the Greenbooks (from the first quarter of each year). Overall, forecasts from the Greenbooks seem to dominate other forecasts. Only since 2000 do the financial market forecasts appear to do nearly as well as Greenbook forecasts.

Table 6 shows the estimated parameters from estimating equation (9) using the Greenbook assumptions about future interest rates in lieu of financial market forecasts over the same time sample. The results are in stark contrast to those obtained using financial market forecasts. Even at the two and three quarter forecasting horizons, the point estimates of β are very close to one and statistically different from zero at standard levels. The R^2 of 20% and 12% at the two and three quarter ahead forecasting horizons are also significantly higher than obtained using financial market forecasts and lie within the 95% confidence intervals constructed by Rudebusch (2002) that one would expect to find in the presence of substantial policy inertia. This result implies that future interest rate changes are in fact approximately as predictable as one would expect under significant interest rate smoothing, conditional on having sufficient information about the policy rule and macroeconomic conditions. The inability of financial market forecasts to predict future interest rate changes is thus likely to primarily reflect variations in the risk premium or informational constraints, not an absence of inertia in interest rate setting decisions. Thus, the ability of Federal Reserve staff to predict future changes in interest rates is further evidence that interest smoothing is an inherent component of the policy-making process rather than a statistical artifact of estimated Taylor rules.

We also produce analogous results for changes in 3-month T-Bill rates using the Greenbook forecasts of the latter as well as the median forecasts from the Survey of Professional Forecasters (SPF).

Professional forecasts present an additional source of information about the ability of private agents to forecast future policy changes and are typically of high quality: Ang et al. (2007) document that professional forecasts of inflation outperform most time series models and financial market forecasts. Figure 3 plots the 3-month T-Bill rate, along with forecasts from professional forecasters and Greenbooks. While the SPF appear to do better than financial market forecasts, the Greenbooks still appear to give better forecasts of the path of future interest rates. The empirical results from estimating equation (8) using both SPF and Greenbook forecasts of the 3-month T-Bill rate, presented in Table 6, are qualitatively similar to those using FFR forecasts. Professional forecasters, like financial market participants, are unable to predict interest rate changes much beyond the one quarter ahead forecasting horizon, while the Greenbook forecasts continue to yield point estimates of β which are significantly greater than zero and close to one, with R^2's of the same order as that obtained using financial market forecasts.

The inability of financial markets and professional forecasters to predict future interest rates as well as the Federal Reserve during this time period has also been noted, albeit informally, by Fed insiders as illustrated by Blinder (1998)

> "Here are two clear examples from recent U.S. history. I was not at the Federal Reserve in late 1993 and early 1994, just before it started tightening monetary policy. But I am fairly certain that the Fed's own expectations of future Federal funds rates were well above those presumably embedded in the term structure at the time, which seemed stuck at the unsustainably low level of 3%. A year later, I was at the Fed and I am certain that the market's expectations of how high the funds rate was likely to go – to as high as 8% according to various asset prices and Wall Street predictions – were well above my own. In both cases, the markets got it wrong – once on the high side and once on the low side. In both cases, the faulty estimate was largely attributable to misapprehensions about the Fed's intentions. And in both cases, the bond market swung wildly when it corrected. Such misapprehensions can never be eliminated, but they can be reduced by a central bank that offers markets a clearer vision of its goals, its 'model' of the economy, and its general strategy."

Blinder attributes the superior forecasting ability of Fed forecasts to informational factors: a better understanding of the Fed's model and the basis for its forecasts, as well as the policy objectives and the way in which policymakers respond to incoming information. This recognition that greater transparency on the part of the central bank could help financial markets and other economic agents better forecast future policies, thereby stabilizing expectations, played an important role in increasing the information released by the Federal Reserve during this time period. For example, the Federal Reserve began to release post-FOMC meeting statements in 1994 and augmented this with statements about the perceived balance of risks in 2000.[7]

[7] The November 14th, 2007 speech by Bernanke (available on the Fed's website) describes past and current changes in Federal Reserve disclosures.

One way to assess the importance of these informational constraints on the part of both financial market participants and professional forecasters is to compare their forecasting performance with respect to the Fed using a longer sample when communications from the Fed were expanded. Table 6 therefore presents estimates of equation (8) for each type of forecast for the extended time sample of 1987Q4 to 2004Q4. The results using the Greenbook forecasts are qualitatively unchanged, with estimates of β remaining close to one at all forecasting horizons and R^2's of similar, if slightly lower, magnitudes. The results for financial market and professional forecasts, on the other hand, are improved relative to the period ending in 1999. Coefficient estimates on forecasted changes are consistently closer to one and the R^2's are all larger than over the restricted sample. Thus, the ability of financial markets and professional forecasters to predict subsequent interest rate changes went up after the increased information disclosures on the part of the Fed, even though the overall predictability of interest rates, as measured by the Fed's own forecasts, was largely unchanged. This is consistent with Swanson (2006) who documents improved predictability of US monetary policy by both professional forecasters and Fed funds futures after communications reforms and Bauer et al. (2006) who find that the increased transparency by the Fed reduced the dispersion of T-bill rate forecasts from professional forecasters. In the same spirit, Hamilton et al. (2010) extract estimates of the market-perceived monetary policy rule before and after 2000 and document that after 2000, markets perceived the monetary policy rule as being significantly more inertial than what they thought prior to 2000.

In short, these results suggest several conclusions. First, the Federal Reserve's ability to forecast subsequent interest rate changes is consistent with the presence of significant policy inertia. Second, the inability of financial markets and professional forecasters to predict interest rates as well as the Federal Reserve during the sample studied by Rudebusch likely reflects informational constraints on these agents such as more limited information sets and uncertainty about the policy rule, not the absence of inertia in policy. This point is consistent with the evidence from a longer time period during which the Federal Reserve expanded its communications: even though the overall predictability of interest rates was unchanged, as measured by the Fed's own forecasts, private sector forecasts of future interest rates improved significantly and in a manner consistent with the presence of policy inertia. More broadly, this suggests that future research should be careful to distinguish between the actual reaction function followed by policymakers and the rule perceived by other economic agents.

VI Narrative Evidence on Policy Changes

The source of the inertia in interest rates could in principle be identified from policymakers themselves. While it is beyond the scope of this paper to pursue a full narrative history of the motives behind each policy change during the Greenspan era, we present suggestive evidence which illustrates that

policymakers explicitly formulated their policy decisions in line with the interest smoothing interpretation. As a particularly revealing example, we first focus on the March 22nd, 1994 meeting of the FOMC. After a year of the target Federal Funds Rate remaining at 3%, the Federal Reserve began a prolonged period of increasing target rates in February of 1994 in response to rising inflationary pressures, culminating in a target rate of 6% in 1995. During the March 22nd meeting, the discussion among FOMC members concentrated on the question of how high and how rapidly rates should rise.[8]

Chairman Greenspan began this discussion by highlighting his preferred action and reasons,

> "My own view is that eventually we have to be at 4 to 4-1/2 percent. The question is not whether but when. If we are to move 50 basis points, I think we would create far more instability than we realize, largely because a half-point is not enough to remove the question of where we are ultimately going. I think there is a certain advantage in doing 25 basis points because the markets, having seen two moves in a row of 25 basis points at a meeting, will tend almost surely to expect that the next move will be at the next meeting – or at least I think the probability of that occurring is probably higher than 50/50. If that is the case and the markets perceive that – and they perceive we are going to 4 percent by midyear, moving only at meetings – then we have effectively removed the Damocles Sword because our action becomes predictable with respect to timing as well as with respect to dimension."

This statement contains the key ingredients of the interest smoothing motive: the Chairman has a desired target rate in mind based on his expectations of future macroeconomic conditions and suggests moving to toward that target in a sequence of small incremental steps to stabilize the private sector's expectations. The subsequent discussion by other FOMC members illustrates similar considerations. For example, Governor Lindsey offered the following justification for his agreement with the Chairman,

> "We definitely want to send a signal to the market, and I think that there are two ways of doing that. One, which is not an option before us, is to go to a number that is a credible – a round number that people would say is the natural rate. One might contemplate a 75 basis point increase to 4 percent. I'm not recommending that, but one could suggest that. It would be clear to market participants that we had stopped. Going to 3.75 percent in my mind doesn't indicate anything. It doesn't suggest that we are going to stop at 4 percent; it doesn't suggest that we are going to stop at 4-1/4 percent; it doesn't suggest that we are going to stop at 4-1/2 percent. It does suggest that we have another increase coming down the road. Since I don't think a 75 basis point move is credible and I don't think 50 basis points sends the signal of certainty, I found your suggestion of 25 basis points preferable… So, while I have no disagreement at all that we want to get there as quickly as possible, in my mind a move of 25 basis points now, 25 in May and 25 on July 5th seems to be a pattern that will get us there in splendid time. No one can accuse us of upsetting the markets, and we will establish more certainty in the market that we are headed to a fixed point that is higher than I think we would achieve with 50 basis points."

Governor Lindsey's statement is particularly illustrative because he explicitly considers the possibility of moving interest rates immediately to the desired rate, but rejects it out of hand as "not an option" and "not

[8] The minutes of FOMC meetings are available on the website of the Federal Reserve Board.

credible". Like Greenspan, he emphasizes the stabilizing effect on market expectations of a gradual adjustment of interest rates. President Stern of the Minneapolis Fed suggests an alternative justification,

> "As most people have already stated, it certainly seems appropriate to act now. How far we ought to go and how fast we ought to try and get there, are the difficult questions. My best judgment is that we'll be at this for some time; it may well be that the funds rate has to go to 4 percent or more by the time we are done. But I don't have a strong conviction about how far we will need to go. As for the timing issue, it seems to me that we are probably going to be at this until we are either more confident than we are today that we have established an environment for renewed disinflation or until we actually see renewed disinflation. It may surprise us and occur earlier or something else may happen that changes our view about appropriate policy. But having said all that, I think we should bear in mind, and I'm certainly willing to be humble about all this, that the confidence interval around any forecast is very wide. And I think that argues for caution. So, I'm comfortable with your ¼ point recommendation now. I think that is the appropriate magnitude."

While Chairman Greenspan and Governor Lindsey emphasize the stabilizing effects of gradualism on market expectations, President Stern expresses concern about the uncertainty surrounding future conditions and views that as justifying "caution" in altering policy. This motivation, originally formalized in Brainard (1967), was also emphasized by Alan Blinder (1998) (who served as Vice-Chairman of the Federal Reserve Board during part of this time period) as a guiding strategy for monetary policymakers after he left the FOMC,

> "Step 1: Estimate how much you need to tighten or loosen monetary policy to "get it right." Then, do less.
> Step 2: Watch developments.
> Step 3a: If things work out about as expected, increase your tightening or loosening toward where you thought it should be in the first place.
> Step 3b: If the economy seems to be evolving differently from what you expected, adjust policy accordingly."

Furthermore, while some members of this particular FOMC meeting disagreed with the policy advocated by Greenspan in favor of a more aggressive response to rising inflationary pressures, none advocated a complete adjustment to the desired rate and instead called for a larger increase of 50 basis points. Thus, no FOMC member proposed to act in a manner inconsistent with the interest smoothing motive; any disagreement was about the degree of interest smoothing. The statement by President Boehne of the Philadelphia Fed makes this clear,

> "Well, I think the case for a less accommodative policy today is quite persuasive. We did press hard on the monetary accelerator to get the economy moving, and now as the economy approaches cruising speed we have to ease off the accelerator to avoid having to slam on the brakes down the road. The real issue – the major issue as you point out, Mr. Chairman – is how much to move. I prefer a ½ percentage point increase in the federal funds rate compared to ¼ because I think we have some distance to go to get to a neutral policy, and it's better to cover that distance earlier rather than later."

Other narrative evidence suggests that this characterization of monetary policy decisions is representative of other periods as well. For example, Stephen Axilrod was responsible for presenting and defending policy alternatives (i.e. the Bluebooks) at FOMC meetings from the time of Burns to the end of Volcker's tenure. In describing the policy-making process that he observed for over a decade, he relates (Axilrod 2009),

> "[Policymakers] have an inherent disposition to conservatism in decision making. They usually prefer to adjust policies gradually, which is a far from irrational way of operating. Given all of the uncertainties they face, gradual changes more often than not guard them against finding themselves too far off base when circumstances turn unexpectedly."

Similarly, in his 2004 speech on monetary policy inertia (which he refers to as "gradualism"), then-Governor Bernanke indicated a preference for the inertial policy interpretation of historical Fed actions[9]

> "My sense … is that policymakers' caution in the face of many forms of uncertainty and their desire to make policy as predictable as possible both contribute to the gradualist behavior we seem to observe in practice."

Bernanke's views are, of course, particularly important because they are indicative of how important policy inertia is likely to be during the recovery from the Great Recession. While no detailed transcripts are available from recent FOMC meetings, his presence on the Board of Governors between 2002 and 2005 implies that one can study both his public statements as well as views expressed in FOMC meetings to get a sense of how he characterized the policy choices facing the Fed during this time. Because interest rates were at historic lows in 2003 and early 2004 (the FFR was at 1%) in response to the jobless recovery and the possibility of deflation, this time period also bears some similarities to current times. Bernanke's May 20th speech in 2004 on policy inertia preceded the first in a long line of interest rate increases by a month and was clearly, at least ex-post, meant to serve as an indicator of the likely path of policy in the coming months and years, a path which he implied in "Fed speak" was going to follow the historical pattern of monetary policy inertia

> "As I have discussed today, given the highly uncertain environment in which policy operates, a gradual adjustment of rates has the advantage of allowing the FOMC to monitor the evolution of the economy and the effects of its policy actions, making adjustments along the way as needed. On the margin, a more gradual process may also help ease the transition to higher rates for participants in money markets and bond markets, as well as for households, banks, and firms. In my own view, economic developments over the next year are reasonably likely to be consistent with a gradual adjustment of policy."

In FOMC meetings, Bernanke was more direct. In the June 29th-30th, 2004 meeting in which the first 25bp increase in the FFR was announced (the FFR would eventually rise by 400 bp over the next two years), he stated "Given these uncertainties, it seems to me that the best tactic is to temporize, embarking

[9] The equivalence between "gradualism" as used by Bernanke and our terminology is clearly laid out in Bernanke's speech: "This relatively slow adjustment of the policy rate has been referred to variously as interest-rate smoothing, partial adjustment, and monetary policy inertia. In today's talk, I will use the term gradualism."

on a program of gradual rate increases but remaining alert and ready to adjust in response to incoming information." In the August 10th meeting, he argued "Overall, our plan to tighten at a measured pace looks pretty good right now. The gradualist approach moves us predictably toward rate neutrality yet leaves the economy some breathing space and gives us time to observe economic developments." Finally, in the September 21st, 2004 FOMC meeting, Bernanke provided the following assessment of the previous and future path of interest rates,

> "Overall, I think our strategy of removing accommodation at a measured pace has worked out well, not only in providing support to the economy and avoiding nasty surprises in financial markets but also in allowing us time to assess ongoing developments. I support our plan of measured withdrawal of emergency stimulus… As we go forward, however, we should remain flexible in slowing or speeding up the process as dictated by incoming data. Financial markets are well prepared for this type of flexibility, and I believe it fits well with our declared strategy of removing accommodation at a measured but not mechanistic pace."

Thus, the narrative evidence is also supportive of a clear historical role for policy inertia in the decision-making process of the Federal Reserve. The statements from Bernanke in mid-2004 when the Federal Reserve began raising interest rates indicate that he advocated this style of policy-adjustment. The opening quote from the October 20th, 2010 FOMC meeting's minutes expressing that "In current circumstances, however, most [FOMC participants] saw advantages to a more incremental approach that would involve smaller changes … calibrated to incoming data." is clearly reminiscent of the language employed in 2004 and therefore strongly suggests that the Bernanke Fed will, in the absence of a dramatic change in economic conditions, follow a very similar qualitative policy path.

VII Omitted Variables and the Persistence of Interest Rates

While much of the evidence strongly supports the interest smoothing motive over the persistent monetary policy shocks explanation of interest rate persistence, a broader interpretation of the latter is difficult to rule out. For example, Rudebusch (2002, 2006) suggests that the excess persistence in interest rates is most likely to come from historical responses of the central bank to factors not typically included in the Taylor rule. Credit conditions are one particularly prominent example of such an omitted factor likely to elicit a central bank response, and their exclusion from standard Taylor rules could give the appearance of either inertial policy or persistent shocks. Similarly, the gradual adjustment of the central bank's information set, and their need to adjust policy based on their revised estimates of the state of the economy, could point to either policy inertia or persistent shocks. In this section, we consider a variety of factors which, when omitted from the estimated reaction function of the central bank, could lead to the appearance of excessive interest rate persistence.

We first consider the role of credit and asset price conditions. These are particularly likely to have played an important historical role in affecting interest decisions. For example, the October 1987 stock

market crash led the Federal Reserve to lower the effective FFR by fifty basis points between October 19th and October 20th and engage in a variety of other activities to maintain liquidity in financial markets (Carlson 2007). To assess whether credit and asset market conditions can account for either interest smoothing or persistent shocks, we consider estimates of equation (3) augmented with lagged measures of financial conditions using quarterly data from 1987Q4 to 2004Q4. We use three such measures: 1) the spread between Moody's Baa corporate bond rate and the ten-year U.S. Treasury note, 2) the log of the quarterly average of the S&P500 index, and 3) Bloom's (2009) measure of financial market uncertainty. Table 7 presents empirical estimates of our baseline Taylor rule allowing for two lags of interest smoothing, a second order autoregressive process for the error term, and our three measures of financial market conditions. All three measures are insignificantly different from zero and have no qualitative effects on interest smoothing and shock persistence. Thus, there is little evidence that systematic responses by the Federal Reserve to financial market conditions, *above and beyond their effects on expectations of current and future macroeconomic conditions*, account for the persistence in interest rates in the data.

An alternative explanation could come from imperfect information on the part of the central bank. Because of lags in the release of data as well as data revisions, the Fed can revise its forecasts of the current state by significant amounts. Interest rate changes could therefore arise not just from changes in the central bank's expectations about future economic developments but also from revisions to its expectations about the current state. To assess whether this source of interest rate changes could account for the excess persistence in interest rates, we follow Romer and Romer (2004) and augment the baseline Taylor rule with revisions in the central bank's forecasts of inflation, output growth and the output gap. Results from this specification are in Table 7. As with financial market controls, we find no evidence of a systematic response to forecast revisions and controlling for these measures does not alter the relative importance of interest smoothing and persistent shocks.

A third possible explanation for the excess persistence in interest rates relative to simple Taylor rule predictions is persistent variation in the central bank's target rates of inflation, output gap and output growth. In the baseline specifications of the Taylor rule, each of these targets is assumed to be constant and integrated into the intercept of the regression. However, Boivin (2006), Kozicki and Tinsley (2009) and Coibion and Gorodnichenko (2011) estimate versions of the baseline Taylor rule with time-varying coefficients and document non-trivial changes in the intercept, and therefore in the targets of the FOMC.[10] Kozicki and Tinsley (2009) and Coibion and Gorodnichenko (2011) further document that, controlling for time-variation in both the intercept and the response coefficients, the degree of interest-smoothing after the early 1980s has remained high, statistically significant, and stable. Since much of this time-variation

[10] Time variation in the intercept can also reflect changes in the equilibrium real rate of interest, as in Trehan and Wu (2007).

in targets is likely to emanate from changes in the inflation target, we consider estimates of equation (3) in which we replace the measure of expected inflation with a measure of the expected deviation of inflation from a time-varying target. We employ three measures of the target rate of inflation: 1) Cogley et al.'s (2010) measure extracted from a VAR with drifting parameters and stochastic volatility; 2) Coibion and Gorodnichenko's (2011) measure extracted from Taylor rule estimates with drifting parameters; and 3) Ireland's (2007) measure constructed from an estimated New Keynesian dynamic stochastic general equilibrium model. Figure 4 plots these three measures of target inflation, which exhibit broadly similar patterns despite the different approaches employed to estimate them. By and large, Table 7 documents that in this alternative specification of the policy reaction function the serial correlation in the error terms becomes less important and for two out of three measures statistically insignificant. The fit of this alternative specification is somewhat worse than the fit of the baseline specification which probably reflects the fact that these measures of the target inflation rate are constructed and may contain measurement errors. In any case, to the extent that these measures capture salient movements in the target inflation rate, these results support the hypothesis that serial correlation in the error term could be absorbing variation in the inflation target rate.

The final possibility that we consider is that the central bank responds not just to its expectations of current and future macroeconomic conditions but also to those of private sector agents. There are several reasons why the central bank might wish to pursue such policies. First, while the Federal Reserve's forecasts are typically superior to those of professional forecasters, as documented by Romer and Romer (2000), policy-makers may be concerned about the quality of their forecasts when they differ substantially from those of other agents. This could lead policymakers to respond less strongly to their own forecasts to hedge against the possibility that their forecasts are incorrect. As a result, this phenomenon could also account for why actual interest rates appear to be less volatile than interest rates predicted from a Taylor rule employing only Greenbook forecasts. Second, policymakers could be concerned about the effect of their decisions on the expectations of other agents. For example, if the central bank has superior information than private agents, then its interest rate decisions will reveal part of the central bank's information to the rest of the population and therefore alter their expectations, as considered in e.g. Walsh (2010). This could be potentially destabilizing: if the central bank is concerned about rising inflation but observes no movement in the private sector's expectations of inflation, it could be optimal on the part of the central bank to avoid raising interest rates too rapidly so that agents do not infer from the policy actions that the central bank is concerned about rising inflation, a result which could exacerbate inflationary pressures as higher private sector inflation expectations would increase wage and price pressures. Indeed, section VI shows that such arguments could be an important part of policy making at the Fed.

Figure 5 illustrates the deviations in the Greenbook forecasts from equivalent forecasts from professional forecasters in the Philadelphia Fed's Survey of Professional Forecasters for both inflation and output growth. In addition, Figure 5 includes the residuals from the simple Taylor rule with no smoothing or persistent shocks, i.e. equation (1) in section 2. There is a clear negative correlation between the Taylor rule residuals and the deviation of Greenbook forecasts from professional forecasts. The periods in 1989, 1995, 1998 and 2000-2001 when actual interest rates were above those predicted by the baseline Taylor rule all coincide with periods in which Greenbook forecasts of inflation were lower than professional forecasts of inflation, and the reverse pattern occurs in 1990, 1996, and late 2001 during which interest rates were below those predicted by the Taylor rule while professional forecasters were expecting lower inflation than staff members of the Fed's Board of Governors. The relationship between Taylor rule residuals and output growth forecast differentials may appear less systematic to the naked eye, but there are episodes where negative comovement is clear such as from 1991 to 1996 and again from 1998 to 2001.

We evaluate the statistical strength of these relationships by estimating equation (3) augmented with the difference between the Greenbook forecast of future inflation and that of professional forecasters in the SPF, and the analogous measure for the difference in forecasts of contemporaneous output growth. We do not control for potential differences in the estimates of the output gap between the Fed and professional forecasters because no forecast of the output gap is available for the latter. The results, presented in Table 7, are consistent with the described mechanisms. The coefficients on both the inflation forecast and output growth forecast differentials are negative and statistically significant, indicating smaller interest rate changes when the Fed forecasts point to more expansionary and/or inflationary conditions than private sector forecasts. Furthermore, controlling for these informational elements eliminates the persistence of the errors: the coefficients on both autoregressive parameters are insignificantly different from zero. At the same time, the degree of interest smoothing is now well represented by an AR(1). Thus, the higher order autoregressive process for interest smoothing may have been capturing the central bank's response to the private sector's information set. This suggests a novel potential explanation for deviations of actual interest rates from standard Taylor rule prescriptions. In addition, the fact that the Fed responds to both its own forecasts and private sector forecasts, combined with the information asymmetry arising from the public nature of professional forecasts versus the secretive nature of Greenbook forecasts, suggests another reason why central bankers have been better able to predict subsequent policy decisions than private agents, as shown in section 5. Understanding the basis for this systematic response of monetary policymakers to private agents' forecasts is an important topic for future research.

VIII Conclusion

The way in which policymakers endogenously respond to economic fluctuations plays a key role in determining the dynamic effect of shocks to the economy. Understanding the historical contribution of endogenous policy reactions to economic fluctuations therefore requires a careful characterization of the nature of policy decisions and the rate at which policy changes occur. The gradual adjustment of interest rates by the Fed is one issue that has been a source of contention among monetary economists. We provide novel evidence using a variety of methods that consistently supports the notion that inertia in monetary policy actions has indeed been a fundamental and deliberate component of the decision-making process by monetary policymakers. More specifically, our evidence strongly favors interest-rate-smoothing theory over serially-correlated-policy-shocks theory as an explanation of highly persistent policy rates set by the Fed.

This result has several important implications. First, it should help guide forecasters in more accurately predicting the path of future interest rates. For example, the expected duration of near-zero interest rates and the pace at which interest rates will rise upon exiting the zero-bound hinge on the amount of monetary policy inertia. In particular, Bernanke's clear advocacy of a gradual rise in interest rates in 2004 suggests that a similar policy path is likely to be followed in coming months and possibly years. In addition, the extra uncertainty about the effects of new policy tools such as changing interest rates on reserves suggests that the incentive to be inertial will be particularly high during this period, as in Brainard (1967). Second, assuming that policy inertia in interest rate decisions is likely to transfer to other monetary tools, the evidence provided in this paper indicates that the exit strategy with respect to tools other than interest rates is likely to be gradual, even if the economy recovers more rapidly than currently expected. Third, our results should help guide future research using structural macroeconomic models as to how best to formulate the endogenous response of monetary policymakers to endogenous economic fluctuations. Fourth, from a normative perspective, our results imply that the degree of policy inertia in historical Federal Reserve interest rate decisions, while large, is still significantly less than theory suggests would be optimal.

In addition, two results in the paper are particularly noteworthy. First, the superiority of the Greenbook assumptions about the path of future interest rates over financial market and professional forecasts is strongly suggestive of important informational frictions facing these agents, as found in Coibion and Gorodnichenko (2010) in the case of inflation forecasts from both professional forecasters and financial markets. Consistent with the presence of significant information rigidities, we document an increase in the ability of financial markets and professional forecasters to predict subsequent interest rate changes after the Federal Reserve began to release more detailed information about the basis for their interest rate decisions. This suggests that further transparency on the part of the Federal Reserve, such as releasing its internal forecasts on a more frequent basis, could likely improve the ability of private sector agents to forecast future policy actions and help dampen market reactions to perceived policy surprises.

In a similar vein, the finding that the Federal Reserve systematically responds to deviations of its forecasts from those of private forecasters raises a number of questions that call for further research. The most basic concerns the source of this relationship. One potential explanation is that FOMC members are hedging their bets when private sector forecasts differ markedly from the Greenbook forecasts. Alternatively, this could reflect a desire on the part of FOMC members to reduce the possibility that private sector agents will draw conclusions from the Fed's policy decisions that run counter to the Fed's objectives. For example, if the central bank's forecasts of inflation exceed those of the private sector, preemptive tightening on the part of the Fed could reveal their expectation of inflation to the private sector, thereby generating additional inflation pressures via the expectations channel, as suggested in Walsh (2010). Quantifying these mechanisms would yield a better understanding of the implications of imperfect information on the part of different economic agents, as well as their interaction.

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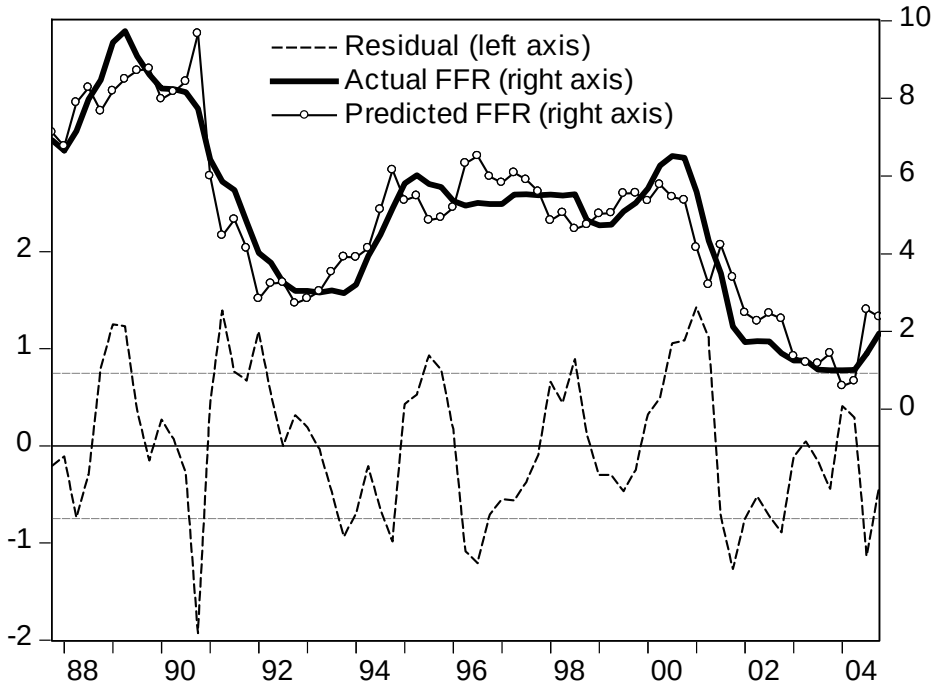
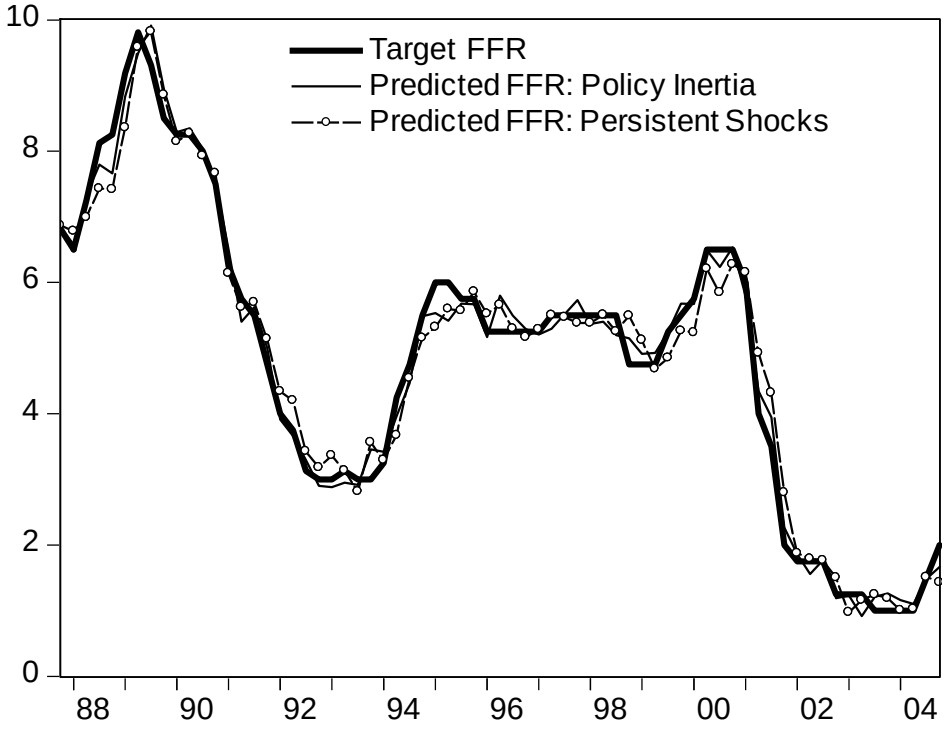
Figure 1: Target Federal Funds Rate and the Prediction of a Simple Taylor Rule



Note: The figure plots the actual target FFR, the predicted FFR from equation (1) in section 2, and the residuals of the regression. See section 2.1 for details.

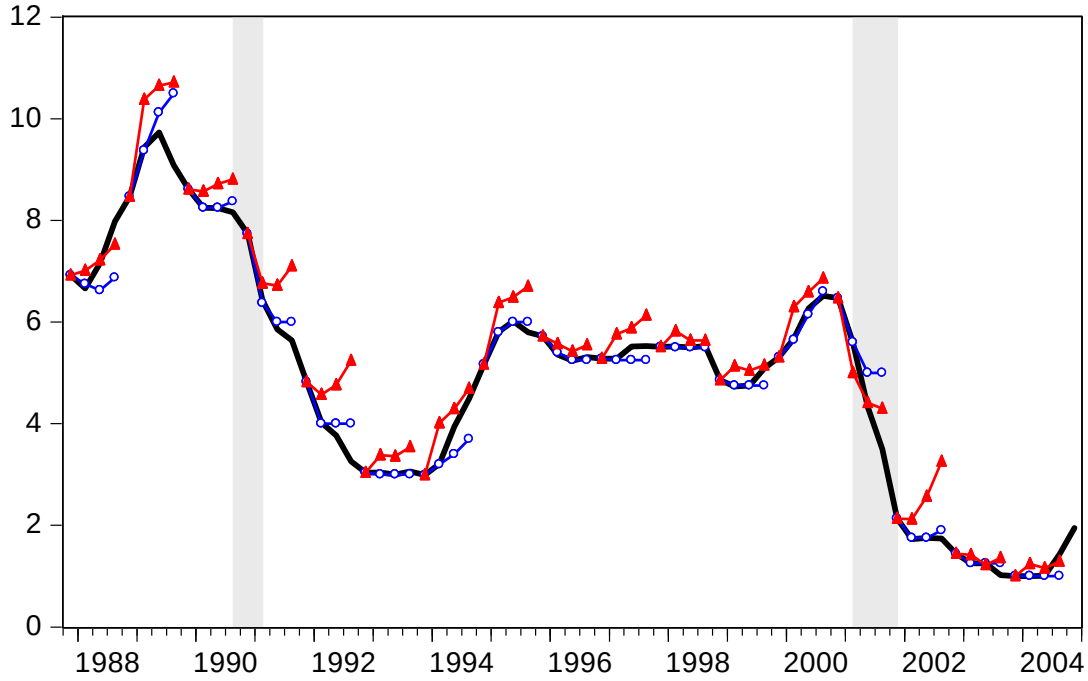
Figure 2: Target Federal Funds Rate and the Predictions of Augmented Taylor Rules



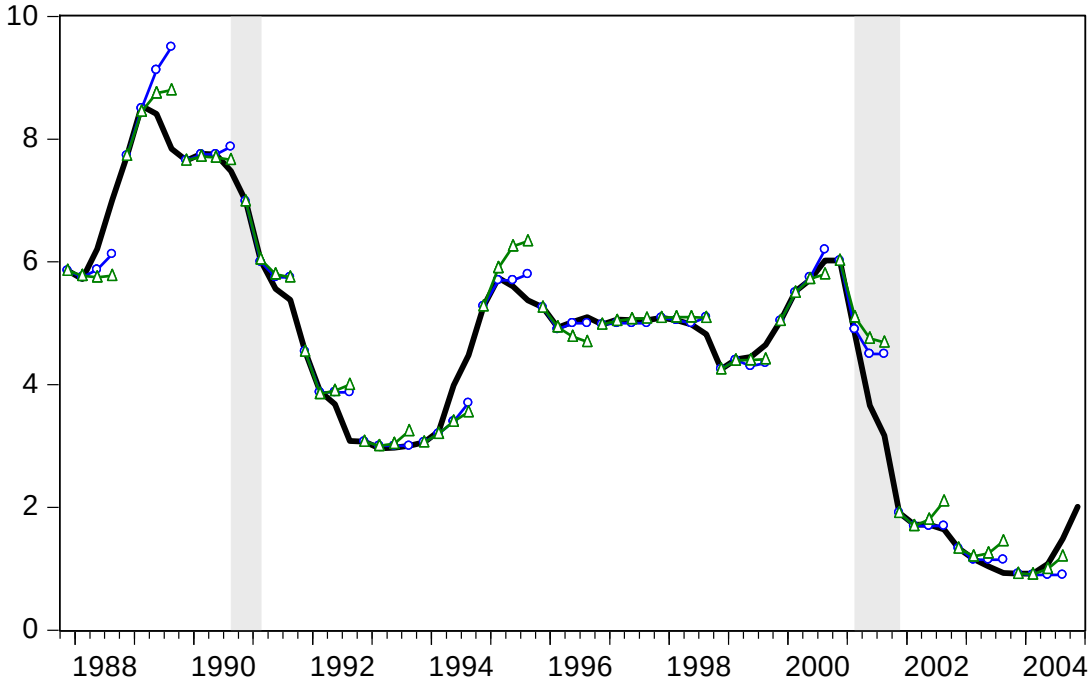
Note: The figure plots the actual target FFR and the predicted FFR's from estimating augmented versions of the Taylor rule including either interest smoothing (policy inertia) or persistent shocks. See section 2.1 for details.

Figure 3: Interest Rate Forecasts of the Fed, Financial Markets, and Professional Forecasters

Panel A: Forecasts of the FFR from Financial Markets and Greenbooks

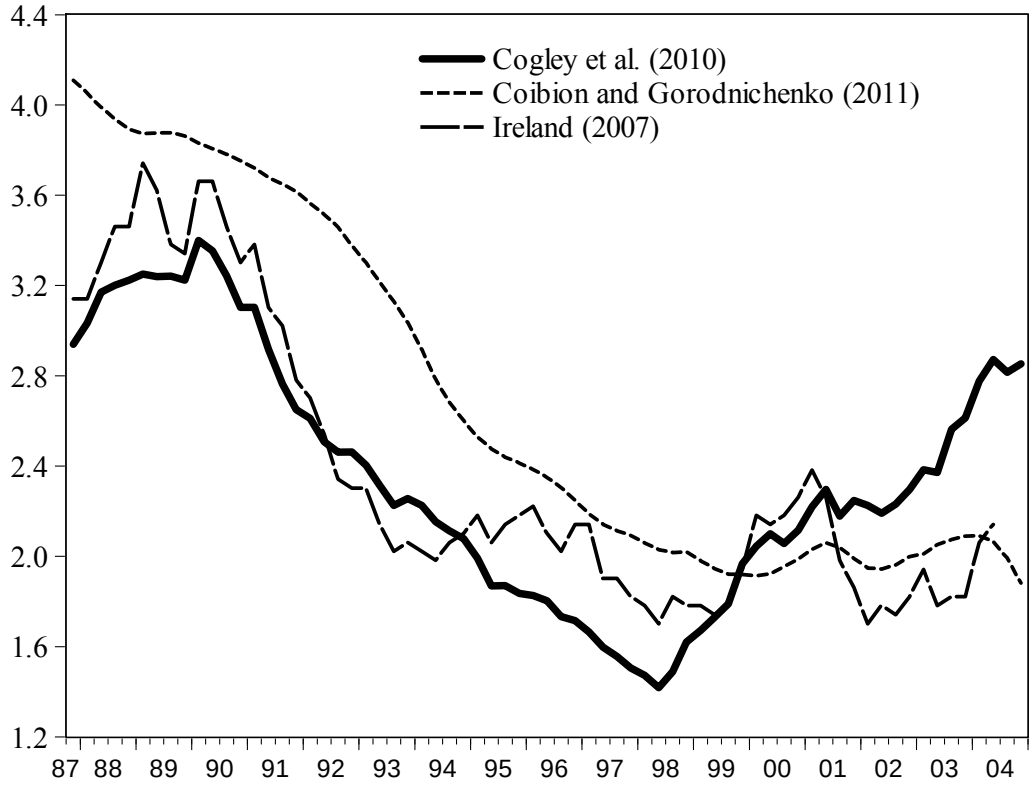


Panel B: Forecasts of the 3-Month TBill Rate from Professional Forecasters and Greenbooks



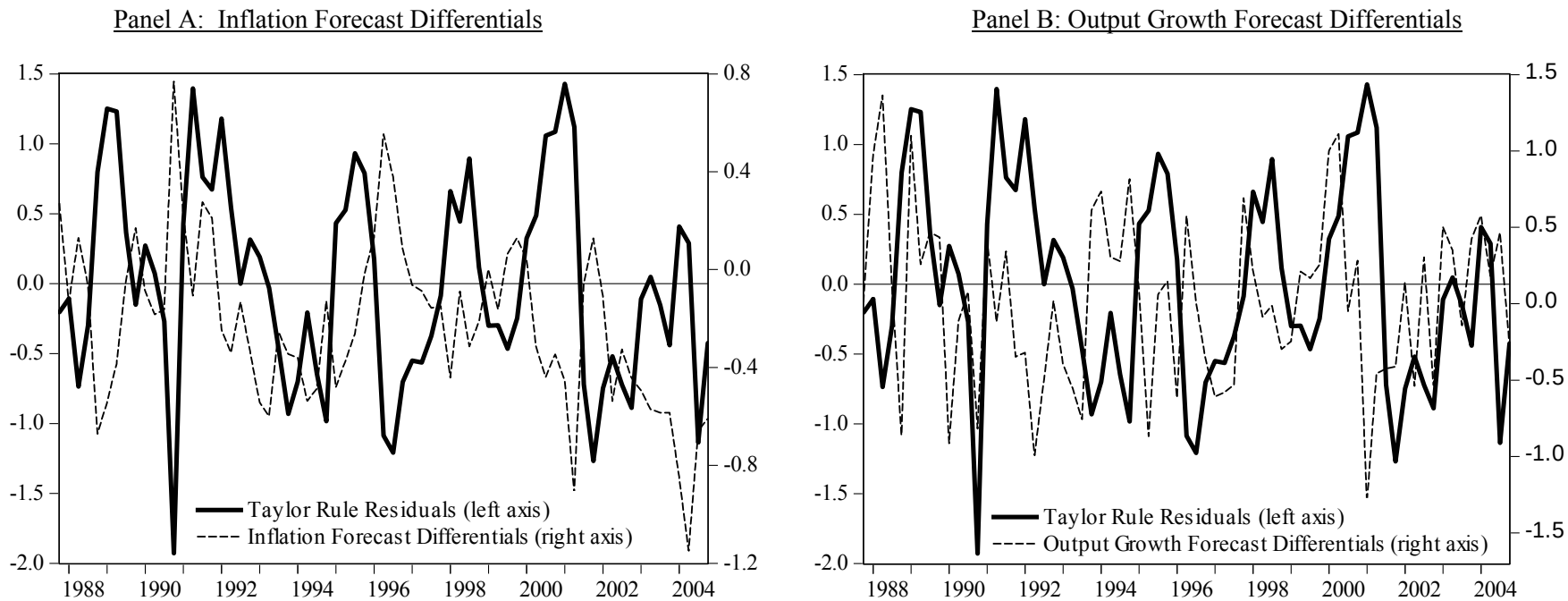
Note: The top figure plots the Federal Funds Rate (black solid line) and the forecasts from the first quarter of each year from financial markets using Eurodollar futures (red lines with triangles) and Greenbooks of the Federal Reserve (blue lines with circles). The bottom figure plots the 3-month TBill rate (solid black line) and the forecasts from the first quarter of each year from the Survey of Professional Forecasters (green lines with triangles) and Greenbooks of the Federal Reserve (blue lines with circles).

Figure 4: Measures of the Federal Reserve's Target Inflation Rate



Note: The figure plots the estimates of the annualized inflation target rate of the Federal Reserve from Cogley et al. (2010), Ireland (2007), and Coibion and Gorodnichenko (2011).

Figure 5: Deviations from the Taylor Rule and Forecast Differentials between Greenbooks and Professional Forecasters



Note: Each figure plots the residuals from the simple Taylor rule in equation (1) in the text, which represent the deviation of actual interest rates from predicted interest rates using only Greenbook forecasts of inflation, output growth, and the output gap. Panel A also includes the difference between the Greenbook forecast of inflation over the next two quarters and the equivalent median forecast from professional forecasts in the SPF. Panel B includes the difference between the Greenbook forecast of output growth in the current quarter and the equivalent median forecast from professional forecasts in the SPF.

Table 1: Taylor Rule Estimates Nesting Interest Smoothing and Persistent Shocks

	(1)	(2)	(3)	(4)	(5)
$\phi_\pi: \pi_{t+2,t+1\|t}$	0.37***		0.48***	0.27***	
	(0.06)		(0.08)	(0.08)	
$\phi_\pi: \pi_{t+1\|t}$		0.25***			
		(0.05)			
$\phi_\pi: \pi_{t\|t}$					-0.00
					(0.05)
$\phi_x: x_{t\|t}$	0.16***	0.13***	0.25***	0.32***	0.25***
	(0.02)	(0.03)	(0.03)	(0.05)	(0.07)
$\phi_{dy}: dy_{t\|t}$	0.12***	0.14***			0.07**
	(0.02)	(0.03)			(0.03)
$\phi_{dy}: dy_{t+1\|t}$			0.10***		
			(0.03)		
$\rho_i: i_{t-1}$	0.81***	0.87***	0.72***	0.65***	0.74***
	(0.03)	(0.04)	(0.03)	(0.07)	(0.09)
$\rho_u: u_{t-1}$	0.46***	0.44***	0.59***	0.85***	0.89***
	(0.11)	(0.12)	(0.09)	(0.08)	(0.06)
R^2	0.989	0.988	0.988	0.987	0.987
s.e.e.	0.246	0.258	0.257	0.270	0.274
AIC	0.120	0.213	0.206	0.292	0.330
SIC	0.314	0.407	0.401	0.454	0.524

Notes: The table presents least squares estimates of the Taylor Rule equation (3) in section 2.2 of the text. ϕ_π is the short-run response to inflation expectations, ϕ_x is the short-run response to the expected output gap, and ϕ_{dy} is the short-run response to expected output growth. ρ_i is the degree of interest smoothing while ρ_u is the persistence of monetary policy shocks. All estimates are done using Greenbook forecasts from 1987Q4 until 2004Q4. *,**, and *** denote statistical significance at the 10%, 5% and 1% levels respectively, using Newey-West HAC standard errors. See section 2.2 for details.

Table 2: Taylor Rules Nesting Interest Smoothing and Persistent Shocks for Different Time Samples

	Quarterly data			Data by FOMC meeting		
	1987Q4-2004Q4	1987Q4-1999Q4	1983Q1-2004Q4	1987Q4-2004Q4	1987Q4-1999Q4	1983Q1-2004Q4
	(1)	(2)	(3)	(4)	(5)	(6)
$\phi_\pi: \pi_{t+2,t+1\|t}$	0.37***	0.35***	0.35***	0.26***	0.19***	0.20***
	(0.06)	(0.07)	(0.07)	(0.06)	(0.06)	(0.05)
$\phi_x: x_{t\|t}$	0.16***	0.15***	0.08***	0.09***	0.07***	0.05***
	(0.02)	(0.03)	(0.02)	(0.02)	(0.02)	(0.01)
$\phi_{gy}: dy_{t\|t}$	0.12***	0.11***	0.20***	0.09***	0.08***	0.12***
	(0.02)	(0.03)	(0.02)	(0.01)	(0.02)	(0.02)
$\rho_i: i_{t-1}$	0.81***	0.80***	0.87***	0.88***	0.90***	0.92***
	(0.03)	(0.05)	(0.03)	(0.03)	(0.04)	(0.02)
$\rho_u: u_{t-1}$	0.46***	0.46***	0.19	0.07	0.02	0.18*
	(0.11)	(0.12)	(0.12)	(0.08)	(0.10)	(0.09)
R^2	0.989	0.981	0.981	0.992	0.986	0.989
s.e.e.	0.246	0.260	0.359	0.210	0.218	0.266
AIC	0.120	0.256	0.856	-0.241	-0.148	0.220
SIC	0.314	0.488	1.029	-0.114	0.010	0.331

Notes: The table presents least squares estimates of the Taylor Rule equation (3) in section 2.2 of the text. ϕ_π is the short-run response to inflation expectations, ϕ_x is the short-run response to the expected output gap, and ϕ_{dy} is the short-run response to expected output growth. ρ_i is the degree of interest smoothing while ρ_u is the persistence of monetary policy shocks. *,**, and *** denote statistical significance at the 10%, 5% and 1% levels respectively, using Newey-West HAC standard errors. See section 2.2 for details.

Table 3: Information Criteria Selection of Interest Rate Smoothing vs Persistent Shocks

	87Q4-04Q4			87Q4-99Q4			83Q1-04Q4		
	IS	AR	BIC	IS	AR	BIC	IS	AR	BIC
Panel A: Quarterly data									
$i_t^* = c + \phi_\pi E_t \pi_{t+1,t+2} + \phi_{dy} E_t dy_t + \phi_x E_t x_t$	**2**	**0**	**0.116**	**2**	**0**	**0.365**	**2**	**0**	**0.983**
$i_t^* = c + \phi_\pi E_t \pi_{t+1} + \phi_{dy} E_t dy_t + \phi_x E_t x_t$	2	0	0.193	2	0	0.405	2	0	1.064
$i_t^* = c + \phi_\pi E_t \pi_{t+1,t+2} + \phi_{dy} E_t dy_{t+1} + \phi_x E_t x_t$	2	0	0.274	2	0	0.480	2	0	1.279
$i_t^* = c + \phi_\pi E_t \pi_{t+1,t+2} + \phi_x E_t x_t$	1	1	0.454	1	1	0.556	1	1	1.239
$i_t^* = c + \phi_\pi E_t \pi_t + \phi_{dy} E_t dy_t + \phi_x E_t x_t$	2	0	0.447	2	0	0.468	3	0	1.131
Panel B: Data by FOMC meeting									
$i_t^* = c + \phi_\pi E_t \pi_{t+1,t+2} + \phi_{dy} E_t dy_t + \phi_x E_t x_t$	1	0	-0.146	1	0	-0.036	**1**	**1**	**0.331**
$i_t^* = c + \phi_\pi E_t \pi_{t+1} + \phi_{dy} E_t dy_t + \phi_x E_t x_t$	1	0	-0.083	1	0	0.012	1	1	0.385
$i_t^* = c + \phi_\pi E_t \pi_{t+1,t+2} + \phi_{dy} E_t dy_{t+1} + \phi_x E_t x_t$	**3**	**0**	**-0.256**	**3**	**0**	**-0.158**	1	1	0.464
$i_t^* = c + \phi_\pi E_t \pi_{t+1,t+2} + \phi_x E_t x_t$	3	0	0.004	2	2	0.034	3	2	0.603
$i_t^* = c + \phi_\pi E_t \pi_t + \phi_{dy} E_t dy_t + \phi_x E_t x_t$	2	0	0.065	1	0	-0.086	1	1	0.414

Notes: The table presents the results from specification searches over equation (4) in the text allowing for up to 4 lags of interest smoothing and 4 lags of persistent shocks. For each time period and interest rate rule, we report the preferred specification using the BIC in terms of number of lags for interest smoothing (*IS*), number of lags for persistent monetary policy shocks (*AR*) and the BIC statistic associated with the selected specification. Bold values indicate the preferred specification of the Taylor rule according to the BIC criterion for each time sample. See section 3 for details.

Table 4: Estimates of Taylor Rules with Higher Order Nested Specifications

	(1)	(2)	(3)	(4)	(5)
$\phi_\pi: \pi_{t+2,t+1\|t}$	0.39***		0.50***	0.46***	
	(0.05)		(0.06)	(0.07)	
$\phi_\pi: \pi_{t+1\|t}$		0.35***			
		(0.05)			
$\phi_\pi: \pi_{t\|t}$					0.11**
					(0.05)
$\phi_x: x_{t\|t}$	0.11***	0.11***	0.18***	0.16***	0.04
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
$\phi_{dy}: dy_{t\|t}$	0.13***	0.13***			0.17***
	(0.02)	(0.02)			(0.03)
$\phi_{dy}: dy_{t+1\|t}$			0.11***		
			(0.04)		
$\rho_{i,1}: i_{t-1}$	1.22***	1.26***	1.21***	1.30***	1.31***
	(0.08)	(0.08)	(0.10)	(0.07)	(0.14)
$\rho_{i,2}: i_{t-2}$	-0.40***	-0.41***	-0.45***	-0.55***	-0.36***
	(0.07)	(0.07)	(0.08)	(0.07)	(0.12)
$\rho_{u,1}: u_{t-1}$	-0.01	-0.08	0.00	0.01	0.13
	(0.14)	(0.14)	(0.13)	(0.13)	(0.20)
$\rho_{u,2}: u_{t-2}$	-0.30***	-0.36***	-0.19*	-0.31***	0.06
	(0.09)	(0.13)	(0.11)	(0.09)	(0.11)
R^2	0.992	0.992	0.990	0.987	0.988
s.e.e.	0.217	0.222	0.241	0.268	0.266
SIC	0.148	0.199	0.363	0.528	0.558
AIC	-0.111	-0.060	0.104	0.302	0.299

Notes: The table presents estimates of equation (3) in the text assuming two lags of the interest rate for the interest smoothing component ($\rho_{i,1}$ and $\rho_{i,2}$) and an autoregressive process for the error term of order 2 ($\rho_{u,1}$ and $\rho_{u,2}$). All estimates are quarterly, done using Greenbook forecasts, and over the period 1987Q4 to 2004Q4. *,**, and *** denote statistical significance at the 10%, 5% and 1% levels respectively, using Newey-West HAC standard errors. See section 3 for details.

Table 5: Instrumental Variable Estimation of the Taylor Rule

	1987Q4-2004Q4			1983Q4-2004Q4		
	Least squares	IV inertia only	IV nested case	Least squares	IV inertia only	IV nested case
	(1)	(2)	(3)	(4)	(5)	(6)
$\phi_\pi: \pi_{t+2,t+1\|t}$	0.42***	0.58***	0.69***	0.34***	0.70***	0.50***
	(0.05)	(0.14)	(0.17)	(0.07)	(0.14)	(0.09)
$\phi_x: x_{t\|t}$	0.14***	0.14	0.22***	0.07***	0.13**	0.10***
	(0.02)	(0.09)	(0.07)	(0.01)	(0.06)	(0.02)
$\phi_{dy}: dy_{t\|t}$	0.18***	0.28***	0.23***	0.22***	0.33***	0.28***
	(0.03)	(0.05)	(0.03)	(0.02)	(0.05)	(0.03)
$\rho_i: i_{t-1}$	0.82***	0.80***	0.71***	0.88***	0.77***	0.83***
	(0.03)	(0.10)	(0.09)	(0.03)	(0.07)	(0.03)
$\rho_u: u_{t-1}$			0.19			0.11
			(0.12)			(0.09)
R^2	0.988	0.981	0.981	0.981	0.969	0.977
s.e.e.	0.262	0.328	0.316	0.361	0.442	0.381
AIC	0.225			0.857		
SIC	0.387			0.998		

Notes: The table presents least squares and instrumental variable (IV) estimates of the Taylor rule in equation (4) in the text. In columns (2), (3), (5) and (6), instruments include a constant and two lags of technology shocks from Gali (1999), TFP residuals from Basu, Fernald and Kimball (2004), oil supply shocks from Kilian (2008), news shocks from Beaudry and Portier (2006), and fiscal shocks from Romer and Romer (2010). *,**, and *** denote statistical significance at the 10%, 5% and 1% levels respectively, using Newey-West HAC standard errors. See section 4 for details.

Table 6: The Predictability of Interest Rate Changes

	1987Q4-1999Q4			1987Q4-2004Q4		
	$i_{t+1} - i_t$	$i_{t+2} - i_{t+1}$	$i_{t+3} - i_{t+2}$	$i_{t+1} - i_t$	$i_{t+2} - i_{t+1}$	$i_{t+3} - i_{t+2}$
	(1)	(2)	(3)	(4)	(5)	(6)
Euro-dollar forecasts	0.81***	0.44**	0.35	0.99***	0.70***	0.47
of FFR	(0.17)	(0.18)	(0.29)	(0.11)	(0.22)	(0.30)
R^2	0.563	0.110	0.032	0.676	0.203	0.050
Greenbook forecasts	1.21***	0.95***	1.02**	1.29***	0.96***	1.00**
of FFR	(0.16)	(0.24)	(0.50)	(0.12)	(0.22)	(0.44)
R^2	0.653	0.196	0.115	0.703	0.159	0.088
SPF forecasts	1.45***	0.65	0.30	1.69***	0.85*	0.54
of 3mo T-Bills	(0.36)	(0.64)	(0.53)	(0.29)	(0.46)	(0.36)
R^2	0.330	0.042	0.010	0.425	0.066	0.040
Greenbook forecasts	1.13***	0.79***	0.97*	1.15***	0.86***	1.00**
of 3mo T-Bills	(0.16)	(0.25)	(0.53)	(0.11)	(0.21)	(0.47)
R^2	0.527	0.145	0.121	0.562	0.135	0.095

Notes: The table reports estimates of equation (9) in the text. The reported coefficients are for the slope of expected changes in future interest rates on the ex-post changes in interest rates for forecasting horizons ranging from one quarter to three quarters. *,**, and *** denote statistical significance at the 10%, 5% and 1% levels respectively, using Newey-West HAC standard errors. See section 5 for details.

Table 7: Omitted Variables and the Persistence of Interest Rates

Dependent variable: r_t	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\phi_\pi: \pi_{t+2,t+1\|t}$	0.39***	0.31***	0.36**	0.51***			
	(0.05)	(0.07)	(0.06)	(0.07)			
$\phi_\pi: \pi_{t+2,t+1\|t} - \pi_t^*$					0.23***	0.28***	0.32***
					(0.06)	(0.10)	(0.07)
$\phi_{dy}: dy_{t\|t}$	0.13***	0.12***	0.12***	0.15***	0.17***	0.18***	0.17***
	(0.02)	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)	(0.02)
$\phi_x: x_{t\|t}$	0.11***	0.13***	0.11***	0.16***	0.03	-0.01	0.03*
	(0.02)	(0.03)	(0.02)	(0.03)	(0.02)	(0.02)	(0.01)
$\phi_{r1}: r_{t-1}$	1.22***	1.17***	1.24***	0.98***	1.28***	1.31***	1.31***
	(0.08)	(0.11)	(0.09)	(0.14)	(0.11)	(0.11)	(0.08)
$\phi_{r2}: r_{t-2}$	-0.40***	-0.35***	-0.40***	-0.19	-0.35***	-0.34***	-0.36***
	(0.07)	(0.09)	(0.08)	(0.13)	(0.10)	(0.11)	(0.08)
$\rho_{u1}: u_{t-1}$	-0.01	-0.01	-0.01	0.19	0.20	0.20	0.12
	(0.14)	(0.16)	(0.14)	(0.14)	(0.15)	(0.15)	(0.16)
$\rho_{u2}: u_{t-2}$	-0.30***	-0.26***	-0.29***	-0.08	-0.06	-0.02	-0.18*
	(0.09)	(0.08)	(0.09)	(0.08)	(0.11)	(0.11)	(0.11)
BLOOMSHOCKS_{t-1}		0.20					
		(0.57)					
SPREAD_{t-1}		-0.02					
		(0.08)					
$\text{S\&}P500_{t-1}$		-0.16					
		(0.12)					
$\pi_{t+2,t+1\|t} - \pi_{t+2,t+1\|t-1}$			0.14				
			(0.11)				
$dy_{t\|t} - dy_{t\|t-1}$			-0.01				
			(0.04)				
$x_{t\|t} - x_{t\|t-1}$			0.01				
			(0.06)				
$\pi_{t+2,t+1\|t} - \pi_{t+2,t+1\|t}^{SPF}$				-0.31**			
				(0.14)			
$dy_{t\|t} - dy_{t\|t}^{SPF}$				-0.11***			
				(0.04)			
R^2	0.992	0.992	0.992	0.993	0.988	0.988	0.989
s.e.e.	0.217	0.219	0.219	0.210	0.253	0.260	0.248
AIC	-0.111	-0.058	-0.048	-0.148	0.200	0.256	0.163
SIC	0.148	0.298	0.307	0.176	0.459	0.515	0.426

Notes: Target inflation rate π_t^* in columns (5), (6), and (7) are taken from Cogley et al. (2010), Coibion and Gorodnichenko (2011), and Ireland (2007) respectively. $\pi_{t+2,t+1|t}^{SPF}$ and $dy_{t|t}^{SPF}$ are mean forecasts of inflation (two quarters ahead) and output growth rate (current quarter) reported in the Survey of Professional Forecasters. BLOOMSHOCKS are Bloom's (2009) measure of financial uncertainty, SPREAD is the difference between Moody's corporate Baa bonds and 10-year Treasury notes, and S&P500 is the log of the quarterly average of the S&P 500 index. *,**, and *** denote statistical significance at the 10%, 5% and 1% levels respectively, using Newey-West HAC standard errors. See section 7 for details.