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Assessing Monetary Accommodation: A Simple Empirical Model of Monetary Policy and its Implications for Unemployment and Inflation

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Abstract

This note suggests that household wealth growth and a long-forward interest rate can be used to construct a simple and convenient reference standard for assessing the current stance of monetary policy. It shows that the difference between the federal funds rate and this reference interest rate is a powerful predictor of the unemployment rate and inflation, producing real-time forecasts that are competitive with consensus-based forecasts from surveys of forecasting professionals. Moreover, one can understand past FOMC policy actions as efforts to adjust the stance of policy, so measured, in response to unemployment and inflation gaps. There is little evidence of inertia in this version of the Taylor rule, in contrast to Taylor-rule specifications that assume a fixed reference real federal funds rate.

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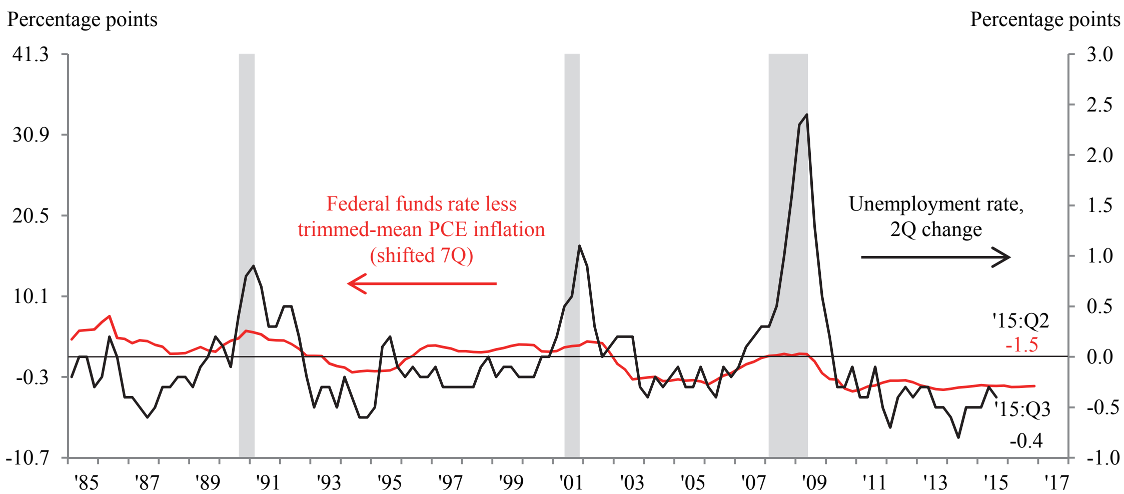
The basic idea behind the Taylor rule (Taylor 1993) is that monetary policy ought to be restrictive, or "tight," whenever a weighted sum of inflation and unemployment gaps is positive, and accommodative, or "easy," whenever that weighted sum is negative. This prescription ties in nicely with the Federal Reserve's dual mandate to promote full employment and price stability and with the FOMC's professed desire to take a "balanced approach" toward meeting its mandate. Typically, policy is judged tight when the real federal funds rate (the target funds rate, less inflation) is elevated relative to a fixed reference value (i.e., a neutral rate, usually assumed to be around 2 percent) and easy whenever the real federal funds rate is depressed relative to that reference value.

All else equal, one would expect below-trend economic growth (a rising unemployment rate) to follow tight monetary policy and above-trend growth (a falling unemployment rate) to follow accommodative policy. Figure 1 shows that movements in the real federal funds rate do, indeed, tend to lead movements in the unemployment rate. The relationship is not tight, however. This is not entirely surprising, as it is not the current level of the funds rate so much as it is the rule according to which the funds rate (and other policy instruments) will respond to future shocks that influences private consumption and investment decisions. A proper assessment of its stance, then, requires that one look at near-term policy in the context of a well-specified dynamic economic model, and that one know by what rule people believe policy will be determined in the medium and long runs. That's a tall order. One can hope, though, that a small number of variables, collectively, serve as summary statistics for private expectations about the future conduct of policy and its impact on the economy, and these variables can be used to define a reference rate against which the current federal funds rate can be compared to determine whether policy is currently tight. Asset prices seem most likely to fit the bill: they are forward-looking and respond quickly to new information.

Figure 1: The real federal funds rate is a leading indicator of changes in the unemployment rate

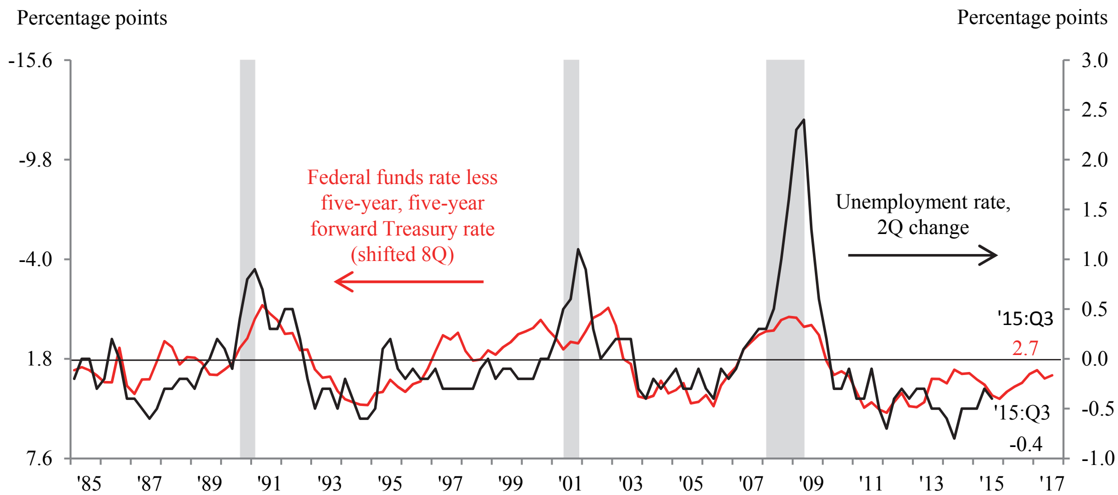


NOTE: Gray bars represent recessions.
SOURCES: Bureau of Labor Statistics; Federal Reserve Bank of Dallas; Federal Reserve Board.

This note suggests that household wealth growth and a long-forward interest rate can be used to construct a simple and convenient reference standard for assessing near-term policy. It shows that the difference between the funds rate and this reference interest rate is a powerful predictor of the unemployment rate, producing real-time forecasts that are competitive with consensus-based forecasts from Blue Chip Economic Indicators ("Blue Chip") and the Federal Reserve Bank of Philadelphia's Survey of Professional Forecasters (SPF). Moreover, one can understand past FOMC actions as efforts to adjust the stance of policy, so measured, in response to unemployment and inflation gaps. There is little evidence of inertia in this version of the Taylor rule, in contrast to Taylor-rule specifications that assume a fixed reference real funds rate. Inertia's prominent role in estimated Taylor rules has been a nagging source of dissatisfaction and unease (Rudebusch 2002).

The slope of the yield curve is known to be a powerful and reliable early recession indicator (Estrella and Mishkin 1998; Rudebusch and Williams 2009). More generally, there is evidence that it is useful as a leading indicator of real growth (Kishor and Koenig 2014). Intuitively, a steep yield curve signals that bank intermediation is profitable, encouraging the expansion of bank credit. It signals that short-term borrowing costs are more-than-usually favorable and, so, encourages people to borrow short term and lend or invest long term. Figure 2 shows the relationship between the yield curve's slope and subsequent changes in the unemployment rate. The unemployment rate clearly tends to fall following periods when the federal funds rate is low relative to the level of long-term interest rates, and to rise following periods when the federal funds rate is high relative to the level of long-term rates.

Figure 2: The yield curve's slope is a powerful leading indicator of changes in the unemployment rate, too



NOTE: Gray bars represent recessions.
SOURCES: Bureau of Labor Statistics; Federal Reserve Board.

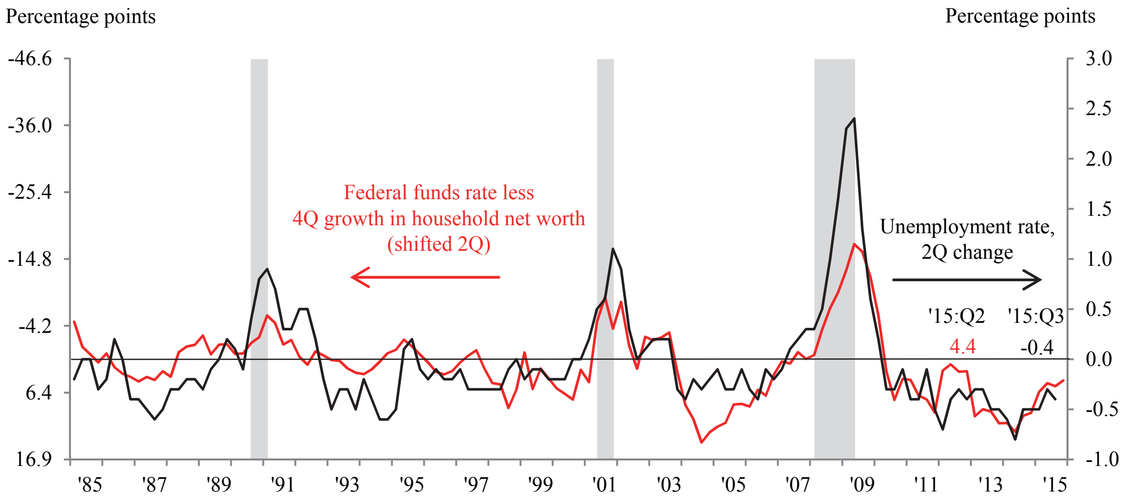
Short- and medium-term variation in asset values is chiefly due to variation in asset prices. If expected asset-price appreciation is high relative to the level of short-term interest rates, there will be an incentive to borrow short term in order to add to asset holdings. Over time, this behavior will put upward pressure on short-term rates, bid up asset prices, and drive down expected future asset returns. Initially, though, real investment will be stimulated. Theory suggests, too, that increases in wealth will be accompanied by increases in consumption demand, leading to increases in production. Moreover, increases in wealth relax collateral constraints, reducing the shadow cost of borrowing for any given market interest rate. In practice, the higher the federal funds rate is relative to household wealth growth, the greater the subsequent increase in the unemployment rate. See Figure 3.

We argue, quite simply, that instead of assessing monetary policy as tight if, and only if, the federal funds rate is elevated relative to the inflation rate, one ought to compare the funds rate to a weighted average of the inflation rate, a long-forward interest rate, and the rate of household wealth growth. Formally, the standard approach is to assess policy as tight if, and only if, $R(t) - \pi(t) > \delta_0$, where $R(t)$ is the federal funds rate, $\pi(t)$ is the inflation rate, and δ_0 is a fixed reference rate. Here, instead, policy is assessed as tight if, and only if, $\delta_1[R(t) - LR(t)] + \delta_2[R(t) - DW(t)] + (1 - \delta_1 - \delta_2)[R(t) - \pi(t)] > \delta_0$, where $LR(t)$ is a long-forward interest rate, $DW(t)$ is the growth rate of household wealth, and $\delta_1 \geq 0$ and $\delta_2 \geq 0$ are parameters, with $\delta_1 + \delta_2 \leq 1$. In practice, δ_1 and δ_2 are both strictly positive.

An advantage to using wealth growth and a long-forward interest rate as references against which to compare the federal funds rate is that each may compensate, from time to time, for weaknesses in the other. Purchases of longer-term Treasuries and Mortgage-Backed Securities pursued at the zero bound, for example, seem to have been effective at raising stock and bond prices and may also have contributed to a recovery in home prices. A reference standard for assessing policy that includes the growth rate of household wealth stands a chance of picking up these accommodative effects, even though the yield curve may have flattened as a result of central-bank actions. Similarly, international capital inflows are likely to drive down longer-term interest rates and drive up asset values. In contrast, expectations of robust, productivity-led growth drive up long-term interest rates (assuming an unchanged long-run inflation target), which steepens the yield curve but has an ambiguous effect on asset values.

The plan of this note is as follows. Section 1 lays out a simple three-equation empirical model of unemployment, inflation, and the federal funds rate, and it presents estimates of the model obtained using latest-vintage data. Section 2 narrows the focus of the analysis to the funds-rate equation and what it has to say about policy inertia. Sections 3 and 4 discuss real-time data issues, present real-time forecasts of unemployment and inflation, conduct head-to-head "horse races" against comparably timed professional

Figure 3: The difference between the federal funds rate and the growth rate of household wealth also seems to lead changes in the unemployment rate



NOTE: Gray bars represent recessions.
SOURCES: Bureau of Labor Statistics; Federal Reserve Board.

forecasts, and display real-time estimates of monetary policy accommodation. Section 5 shows how the model can be recursively simulated, generating multi-year economic projections. Section 6 is the conclusion.

1. THE MODEL

Specification. The model has three main equations and a fourth, nonstochastic equation that defines a reference federal funds rate, used to gauge the current stance of monetary policy.

• Unemployment Equation: The model's first main equation relates the unemployment rate to lagged unemployment rates and the lagged stance of monetary policy, as measured by the gap between the real federal funds rate and the reference real rate:

$$U(t) = U^* + \alpha_1[U(t-4) - U^*] + \alpha_2[U(t-8) - U^*] + \alpha_3[r(t-4) - r^*(t-4)] + \alpha_4[r(t-8) - r^*(t-8)] + \alpha_5[r(t-12) - r^*(t-12)] + \varepsilon_U(t). \quad (1)$$

One would expect $|\alpha_1 + \alpha_2| < 1$, so that $U(t)$ follows a stationary process, and that $\alpha_3 + \alpha_4 + \alpha_5 > 0$, so that tight policy ($r > r^*$) eventually tends to produce an elevated unemployment rate.

• Inflation Equation: The second main equation relates the gap between Dallas Fed Trimmed Mean PCE inflation and a survey measure of long-run inflation expectations to labor-market slack and changes in labor-market slack, with some additional short-run adjustments. Trimmed-mean inflation strips out high-frequency noise, while subtracting long-run inflation expectations removes inflation's long-run trend. So, we are left with an equation that explains movements in inflation's cyclical component:

$$\pi(t) - \pi^e(t) = \beta_1[U(t-4) - U^*] + \beta_2[U(t-8) - U^*] + \beta_3[\pi(t-4) - \pi^e(t-4)] + \beta_4[\pi^{pce}(t-4) - \pi(t-4)] + \beta_5[\pi^{cpi}(t-4) - \pi(t-4)] + \varepsilon_P(t). \quad (2)$$

The rate of inflation expected over the long-term, $\pi^e(t)$, is one of the variables through which expectations of future monetary policy affect the current economy in this model. Changes in $\pi^e(t)$ have an immediate and one-for-one impact on current inflation. One would expect $\beta_1 + \beta_2 < 0$, so that an elevated unemployment rate tends to restrain inflation.

• Taylor-Rule Equation: The third main equation relates the stance of monetary policy to inflation and unemployment gaps, with a dummy variable to capture the extra accommodation signaled by policymakers from 2003:Q3 through 2005:Q3. (In late 2003, the FOMC promised that policy would be accommodative "for a considerable period"; in early 2004, it indicated that it would be "patient" in removing accommodation;

and from spring 2004 through fall 2005, the FOMC said that accommodation would be "removed at a pace that is likely to be measured.")

$$r(t) = r^*(t) + \gamma_1[\pi(t) - \pi^*] + \gamma_2[U(t) - U^*] + \gamma_3 FWD(t) + \varepsilon_R(t). \quad (3)$$

Here, one would expect $\gamma_1 > 0$ and $\gamma_2 < 0$: The FOMC tends to pursue a restrictive policy when inflation is above target and/or the unemployment rate is below the natural rate.

Equation 3—like the original Taylor rule—is not an operational instrument rule, because it relates the federal funds rate to variables that are not directly observed by the FOMC in real time. Implicitly, the FOMC tries to maintain the relationship shown in Equation 3 (but without the error term), using whatever information is available. An implication is that the error term will be uncorrelated with information that would have been available to the FOMC in quarter t − 1. (In practice, we use information that would have been available in quarter t − 4.)

• Reference Federal Funds Rate: The fourth equation in the system asserts that the reference real federal funds rate—the rate against which the actual rate is compared to determine the stance of policy—is a function of a real long-forward interest rate and real growth in household net worth:

$$r^*(t) = \delta_0 + \delta_1[LR(t) - \pi(t)] + \delta_2[DW(t) - \pi(t)]. \quad (4)$$

The conventional Taylor-rule specification, which assumes a constant reference real rate, is the special case where $\delta_1 = \delta_2 = 0$. Equation 4 allows expectations of future monetary policy to affect the current economy through $LR(t)$ and $DW(t)$. Even if the policy rate is constrained by the zero bound, it may be possible to provide current stimulus through unconventional monetary policies that raise expectations of future inflation or expected real growth (increasing $LR(t)$), or by increasing asset prices (increasing $DW(t)$).

The variables in the above equations are defined as follows:

$U(t)$	Civilian unemployment rate, quarterly average, percent
$R(t)$	Target federal funds rate, third-month-of-quarter average, percent
$\pi(t)$	4-quarter Dallas Fed trimmed-mean PCE inflation rate, percent
$r(t)$	Real target federal funds rate, third month of quarter, defined as $R(t) - \pi(t)$
$\pi^e(t)$	Blue Chip 10-yr. CPI inflation expectation less 0.3 (1984:Q1-1991:Q3); SPF 10-yr. CPI inflation expectation less 0.3 (1991:Q4-2006:Q4); SPF 10-yr. PCE inflation expectation (2007:Q1-present)
$\pi^{pce}(t)$	4-quarter headline PCE inflation, percent
$\pi^{cpi}(t)$	4-quarter Cleveland Fed trimmed-mean CPI inflation less 0.25 (to reflect the tendency for trimmed-mean CPI inflation to run higher than trimmed-mean PCE inflation), percent
$LR(t)$	5-yr., 5-yr. forward rate, from 10-yr. and 5-yr. Treasury rates, third-month-of-quarter average
$DW(t)$	(4-quarter change in the log of household net worth)∗100
$FWD(t)$	Dummy variable equal to 1 from 2003:Q3 through 2005:Q3, and 0 otherwise.

Estimation. In practice, we substitute from Equation 4 to eliminate the r^* terms from Equations 1 and 3. We use generalized method of moments (GMM) to estimate the resultant system, with Newey-West adjusted standard errors. The sample period starts in 1985:Q1 and ends in 2008:Q2, before the financial crisis associated with the collapse of Lehman Brothers and before policy came up against the zero bound. All variables included on the right-hand sides of Equations 1 and 2 are included as instruments for estimation of those equations. Instruments used for estimation of the Taylor-rule equation (Equation 3) are lagged 4 quarters and are drawn from vintages that would have been available to policymakers in real time. All other data are vintage 2015:Q2. In an initial estimation, the weights, δ_1 and δ_2, put on the real long-forward interest rate and on real wealth growth in the formula for r^* are not forced to be the same in Equation 1 as in Equation 3. Equation 2 identifies the natural rate of unemployment, U^*, and given that identification, Equation 1 produces an estimate of δ_0. Equation 3 is assigned an independent constant term. (According to the model, this constant depends on δ_0, U^*, and π^*.) Results are presented in Table 1, Column A.

• According to the table, the long-forward interest rate and wealth growth matter both for predicting movements in the unemployment rate and for understanding movements in the federal funds rate (δ_1, δ_1', δ_2, $\delta_2' > 0$). The two variables seem a bit more important for unemployment than for policy, but the hypothesis that their coefficients are equal across equations cannot be rejected at the 5 percent level. (The p-value for the hypothesis that $\delta_1 = \delta_1'$ and $\delta_2 = \delta_2'$ is 0.06.)

• The model produces a reasonable estimate of the natural rate of unemployment (5.3 percent).

• Inflation-equation results are much as those reported in Koenig and Atkinson (2012): Both slack and changes in slack help explain deviations in trimmed-mean inflation away from its long-run trend. (The coefficients β_1 and β_2 are opposite in sign and both are statistically significant.) In addition, trimmed-mean inflation shows a tendency to run above trend if headline inflation exceeds the trimmed mean ($\beta_4 > 0$), and for reasons presumably having to do with the different weights used in calculating CPI and PCE inflation, a positive gap between trimmed-mean CPI and trimmed-mean PCE inflation tends to be followed by a low value of the latter ($\beta_5 < 0$).

• The Taylor-rule coefficient estimates suggest that the FOMC places roughly equal weights on the inflation and unemployment gaps when adjusting monetary policy ($\gamma_1 + \gamma_2 \approx 0$). Policy was systematically biased toward ease from late 2003 through early 2005 ($\gamma_3 < 0$).

Imposing the constraint that the reference real funds rate relevant for policy is the same as that which is important for predicting the unemployment rate yields the results shown in Table 1, Column B. The natural rate of unemployment is only slightly different from before (5.19 percent instead of 5.3 percent), and most other coefficient estimates are also little changed. We are now able to identify the target inflation rate, π^*, implied by the FOMC's policy actions: It is 1.86 percent, with a standard error of 0.42 percentage points. Weights on the long-forward interest rate and on wealth growth, δ_1 and δ_2, remain highly statistically significant.

Pegging the inflation target at 2 percent produces the estimation results shown in Table 1, Column C. (The p-value for the hypothesis that $\pi^* = 2.0$ is 0.73.) As might be expected, coefficients are little-affected by this restriction: The estimated natural rate of unemployment is revised upward, slightly, to 5.28 percent, and it remains the case that the inflation and unemployment gaps receive roughly equal weight in the Taylor-rule equation.

We have, so far, assumed that the natural rate of unemployment is a constant to be estimated. Table 1, Column D shows the consequences of using Congressional Budget Office (CBO) natural-rate estimates, instead. (We retain the assumption that $\pi^* = 2$, and as an instrument for estimation of the Taylor-rule equation, we include real-time Blue Chip forecasts of the unemployment rate 5-to-10 years out.) The standard errors of the inflation and policy equations improve as a result of the substitution, but the standard error of the unemployment equation deteriorates. The long-forward interest rate and wealth growth remain statistically significant, and their coefficients are not greatly altered.

Summary: There is strong evidence that the evolution of the unemployment rate depends on the gap between the real federal funds rate and a reference real rate that is a function of long-forward rates and household wealth growth. Moreover, it appears that Federal Reserve policymakers have attempted to adjust this interest-rate gap in response to deviations of inflation from target inflation and of the unemployment rate from the natural rate of unemployment. The estimated target inflation rate is approximately 2 percent. The estimated natural rate of unemployment is a bit over 5 percent. Deviations in trimmed-mean PCE inflation from long-term inflation expectations depend on the unemployment gap and, possibly, also on changes in that gap.

2. IS FEDERAL RESERVE POLICYMAKING INERTIAL?

Empirical studies of Federal Reserve policymaking consistently find evidence that the target policy rate is "sticky," in that lagged policy rates seem to have important explanatory power even after accounting for the influence of inflation and resource utilization. This section looks at whether evidence suggesting inertia in Federal Reserve policymaking holds up when policy is made contingent on the level of long-term interest rates and household wealth growth. It does not.

To allow for inertial policymaking, Equation 3 is generalized to:

$$R(t) = \theta R(t-4) + (1-\theta)\{r^*(t) + \pi(t) + \gamma_1[\pi(t) - \pi^*] + \gamma_2[U(t) - U^*] + \gamma_3 FWD(t)\} + \varepsilon_R(t). \qquad (3')$$

Here, θ measures the strength of policy inertia. Equation 3 is the special case where $\theta = 0$. After substituting from Equation 4 to eliminate $r^*(t)$, Equation $3'$ is estimated by GMM. Instruments consist only of lagged variables as they would have appeared in real time, recognizing that the right-hand-side variables in Equation $3'$would not have been available to policymakers.

Table 2, Columns A and B, shows estimation results when the Taylor-rule equation is restricted to have a constant reference real rate, as is conventional. Formally, δ_1 and δ_2 are both set equal to 0. In Column A, the natural rate of unemployment is treated as a constant and is assumed to equal 5.28 percent—the estimate reported in Table 1, Column C. In Column B, CBO natural-rate estimates are used. In both columns, the target inflation rate is assumed to equal 2 percent, consistent with Table 1. Assumptions about π^* and (in Column A) U^* affect only the estimated reference real federal funds rate, δ_0. They do not affect estimated inertia, θ. Nor do they affect the estimated weights on the inflation and unemployment gaps, γ_1 and γ_2.

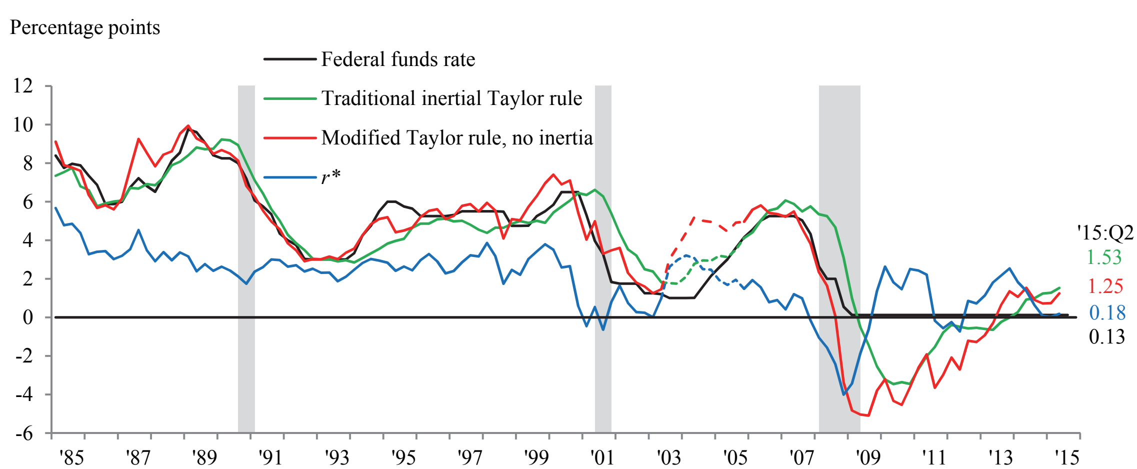
In Column A, the estimated reference or "equilibrium" real federal funds rate is 1.7 percent, and the inflation and unemployment gaps receive roughly equal weight in FOMC policy deliberations. In Column B, the reference rate is 2.1 percent, and the unemployment gap receives substantially greater weight than the inflation gap. There is strong evidence of inertia in both columns, with a weight of 0.42 attached to the 4-quarter lagged funds rate in Column A and a weight of 0.36 in Column B. These coefficient estimates are highly statistically significant.

Columns C and D show the effects of dropping the $\delta_1 = \delta_2 = 0$ restriction, allowing the FOMC to respond to financial conditions as summarized in the level of the long-forward interest rate and the rate of household wealth growth. As in Columns A and B, Column C shows results with a fixed natural rate of unemployment, and Column D shows results with a variable natural rate. In both, the estimated inertia coefficient is small and statistically insignificant. In contrast, statistically significant positive weight is placed on both the long-forward interest rate and household wealth growth. In Column C, the FOMC pays roughly equal attention to the inflation and unemployment gaps. In Column D, the weight attached to the unemployment gap is three times the size of that attached to the inflation gap. In both columns, policy is found to have been exceptionally easy during the 2003-05 forward-guidance period.

Figure 4 plots the actual target federal funds rate along with fitted funds-rate values from the regression displayed in Table 2, Column A—a traditional Taylor-rule equation with inertia—and from a regression identical to that in Table 2, Column C except that the inertia parameter, θ, is constrained to equal zero. Outside the 2003-05 forward-guidance period, the equation with a time-varying reference rate and no inertia clearly better explains FOMC behavior than the conventional Taylor rule with inertia. As of June 2015, both rules were prescribing a positive federal funds rate: $1\frac{1}{2}$ percent according to the conventional inertial Taylor rule and $1\frac{1}{4}$ percent according to the modified rule with no inertia.

Included in Figure 4 is a plot of the time-varying reference real federal funds rate, r^*, implied by our "modified Taylor rule, no inertia" estimation. Between 1985 and 1999, this r^* holds relatively steady, with a mean of 2.97 percent and standard deviation of 0.75 percentage points. After 1999, the mean of r^* drops to 0.90 percent, and the standard deviation explodes to 1.56 percentage points. Swings in r^* are important for explaining movements in the nominal federal funds rate (the correlation between r^* and R is 0.38 between 1985 and 1999, and 0.37 from 2000 through 2008:Q2), but swings in inflation and unemployment clearly matter greatly, too.

Figure 4: With a variable reference rate, explaining movements in the federal funds rate doesn't require *ad hoc* policy inertia



NOTE: Gray bars represent recessions.
SOURCES: Federal Reserve Board; authors' calculations.

Summary: Much of the seeming inertia in FOMC rate setting disappears when policy is allowed to be conditioned on financial conditions—as summarized by the long-forward interest rate and household wealth growth—in addition to inflation and unemployment gaps.

3. REAL-TIME FORECASTS OF INFLATION AND UNEMPLOYMENT

If Equations 1 and 2 are accurate descriptions of the economy, they ought to produce accurate forecasts of unemployment and inflation. This section reports results of recursive, real-time forecasting exercises and head-to-head "horse races" against professional forecasts. We find that our simple model has statistically significant predictive power beyond professional forecasts and is competitive with them at a 4-quarter forecast horizon.

There are three data series feeding into Equations 1 and 2 that are subject to significant revision: trimmed-mean PCE inflation, headline PCE inflation, and growth in household net worth. (Other series are revised only as a result of updates to seasonal factors. We use 2015:Q3-vintage data for these variables.) First estimates of inflation are available approximately 1 month after the end of each quarter. A first revision is released 1 month later, and a second revision 1 month after that. There are no subsequent changes until the National Income and Product Accounts undergo their annual revision. Household wealth data for a given quarter are typically published with a lag of $2\frac{1}{2}$ months, and undergo revision 3 months later, when the following quarter's wealth estimates are released. With these schedules in mind, we estimate two different versions of our model—one that uses data available 1 month after quarter's end and another that uses data available $2\frac{1}{2}$ months after quarter's end.

The first version of the model uses first-release inflation data for the quarter just ended, and wealth for the quarter before that. These are the most recent wealth data that would have been available in real time. Formally, Equation 4 is modified, slightly, to take the form:

$$r^*(t) = \delta_0' + \delta_1'[LR(t) - \pi_{fr}(t)] + \delta_2'[DW_{fr}(t-1) - \pi_{fr}(t)], \tag{4'}$$

where the "fr" subscripts indicate first-release estimates. Similarly, Equation 2 is estimated with first-release lagged inflation data on its right-hand side:

$$\begin{aligned}\pi(t) - \pi^e(t) = {}& \beta_1'[U(t-4) - U^*] + \beta_2'[U(t-8) - U^*] + \beta_3'[\pi_{fr}(t-4) - \pi^e(t-4)] \\ & + \beta_4'[\pi_{fr}^{pce}(t-4) - \pi_{fr}(t-4)] + \beta_5'[\pi^{cpi}(t-4) - \pi_{fr}(t-4)] + \varepsilon_P(t).\end{aligned} \tag{2'}$$

These equations are estimated jointly and recursively along with Equation 1 by three-stage-least-squares. We call this the "first-release" version of the model.

The second version of the model uses second-release inflation data for the quarter just ended and uses first-release wealth data for that same quarter:

$$r^*(t) = \delta_0'' + \delta_1''[LR(t) - \pi_{sr}(t)] + \delta_2''[DW_{fr}(t) - \pi_{sr}(t)], \tag{4''}$$

where the "sr" subscripts indicate second-release estimates. Equation 2 is estimated with second-release lagged-inflation data on its right-hand side:

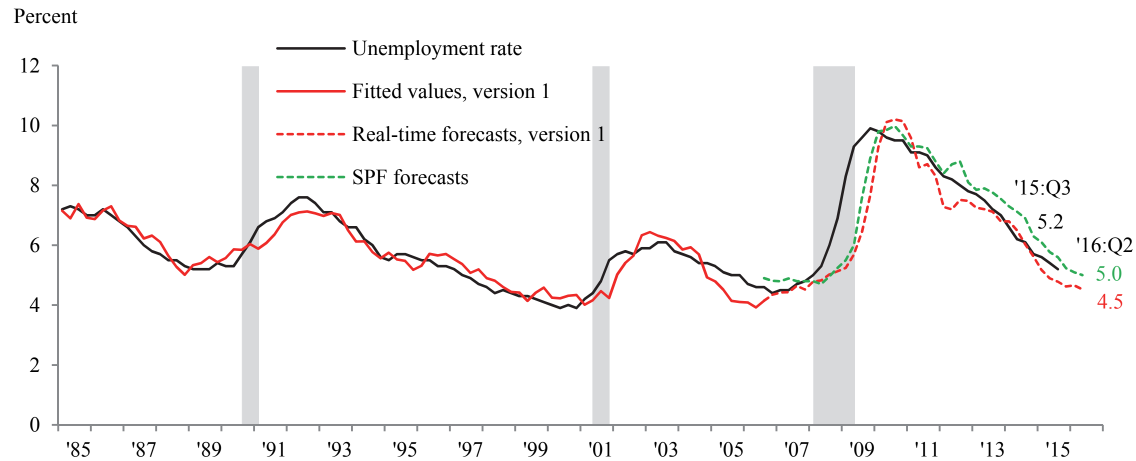
$$\begin{aligned}\pi(t) - \pi^e(t) = {}& \beta_1''[U(t-4) - U^*] + \beta_2''[U(t-8) - U^*] + \beta_3''[\pi_{sr}(t-4) - \pi^e(t-4)] \\ & + \beta_4''[\pi_{sr}^{pce}(t-4) - \pi_{sr}(t-4)] + \beta_5''[\pi^{cpi}(t-4) - \pi_{sr}(t-4)] + \varepsilon_P(t).\end{aligned} \tag{2''}$$

These equations are estimated jointly and recursively with Equation 1 by three-stage-least-squares. We call this the "second-release" version of the model.

In both versions of the model, third-release trimmed-mean inflation is used as the left-hand-side variable in the inflation equation and is treated as "actual" inflation for purposes of comparing forecast performance. In both versions of the model, the quarters from 2008:Q4-09:Q3 are "dummied out" of Equation 1 to ensure that the unemployment rate surge that immediately followed Lehman Brothers' collapse—which could not reasonably have been anticipated 4 quarters in advance—does not unduly influence coefficient estimates. These quarters are also dummied out of our forecast comparisons for much the same reason.

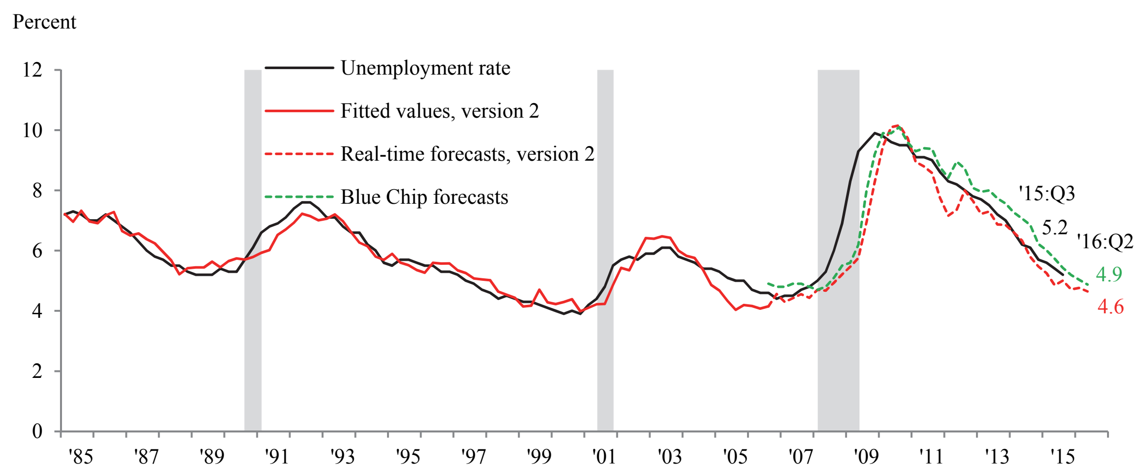
The limited availability of real-time trimmed-mean PCE inflation data constrains our forecasting exercise. Our first estimation runs from t = 1985:Q1 through t = 2005:Q2, and the estimated equations produce a forecast of the 2006:Q3 unemployment rate and of trimmed-mean inflation over the 4 quarters ending 2006:Q3. We then add another quarter of real-time data, re-estimate, and produce forecasts for 2006:Q4. We proceed in this fashion until we have forecasts that extend through 2016:Q2—which gives us 40 forecasts in all. Our first-release model is updated at the end of January, end of April, end of July, and end of October each year, and Blue Chip and SPF reports happen to closely align with each of these updates. However, there are no Blue Chip PCE inflation forecasts, and Blue Chip and SPF unemployment forecasts are quite similar. So, we only report comparisons with the SPF. Our second-release model is updated mid-March,

Figure 5A: Model with a variable reference rate predicts the unemployment rate about as well as professional forecasts



NOTE: Gray bars represent recessions.
SOURCES: Bureau of Labor Statistics; Federal Reserve Bank of Philadelphia; authors' calculations.

Figure 5B: Model with a variable reference rate predicts the unemployment rate about as well as professional forecasts

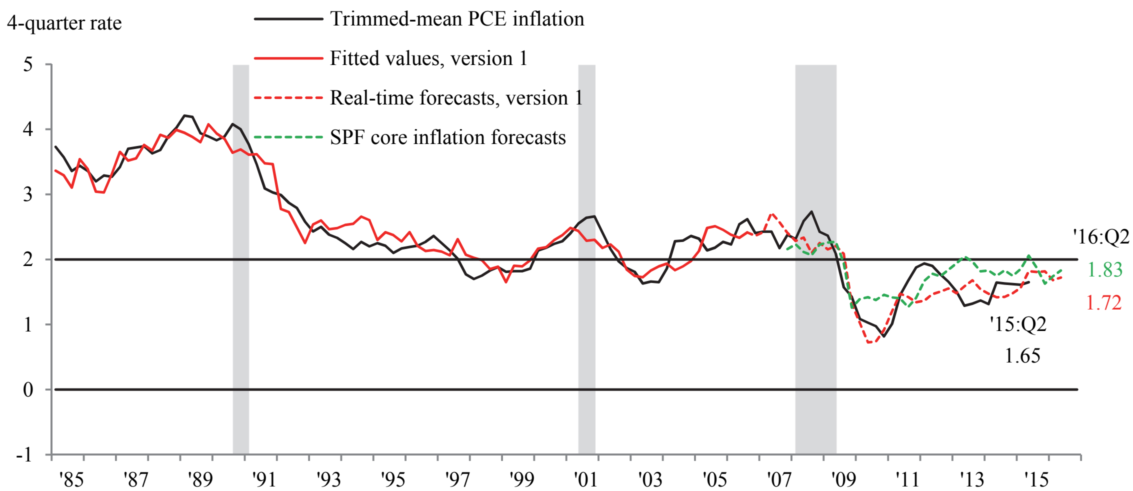


NOTE: Gray bars represent recessions.
SOURCES: Blue Chip Economic Indicators; Bureau of Labor Statistics; authors' calculations.

mid-June, mid-September, and mid-December each year. In this case, there are no similarly timed SPF reports, so we compare our second-release-model unemployment forecasts with those of the Blue Chip.

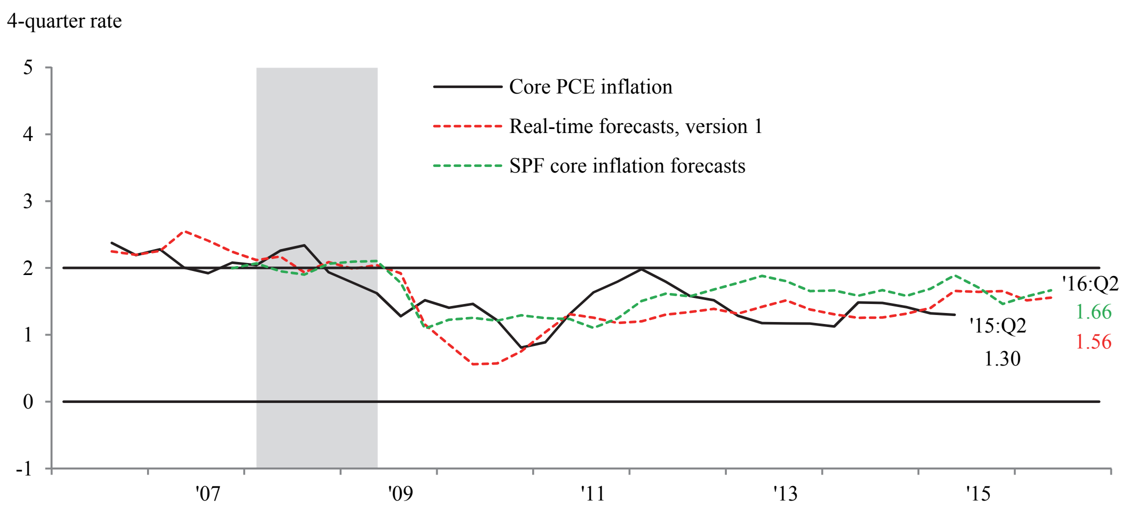
Figures 5A and 5B show the real-time unemployment forecasts produced by the first-release and second-release versions of our model, along with actual unemployment rates and the comparably timed SPF and Blue Chip forecasts, respectively. Similarly, Figure 6 shows real-time trimmed-mean inflation forecasts produced by our model, along with actual (third-release) trimmed-mean inflation data. For comparison we, include comparably timed SPF forecasts of core PCE inflation, adjusted upward by 0.17 percentage points to offset conventional core inflation's downward bias relative to the trimmed mean. Finally, Figure 7 shows real-time trimmed-mean inflation forecasts produced by our model, adjusted downward by 0.17 percentage points, along with actual (third-release) core PCE inflation data and comparably timed SPF core PCE inflation forecasts. (Trimmed-mean PCE inflation is much more highly correlated with core PCE inflation than it is with headline PCE inflation: The correlation with core inflation is 0.93 over the period from 2006:Q3-2015:Q1, while the correlation with headline inflation is only 0.51.)

Figure 6: Professional forecasts of core inflation are of no value in predicting trimmed-mean PCE inflation, given version-1 model forecasts



NOTE: Gray bars represent recessions.
SOURCES: Federal Reserve Bank of Dallas; Federal Reserve Bank of Philadelphia; authors' calculations.

Figure 7: Version-1 model and professional forecasts about equally successful at predicting core PCE inflation



NOTE: Gray bars represent recessions.
SOURCES: Bureau of Economic Analysis; Federal Reserve Bank of Philadelphia; authors' calculations.

In Table 3, Rows A and B show results from head-to-head comparisons of the unemployment forecasts generated by the models developed here with comparably timed forecasts from SPF and Blue Chip, respectively. The results indicate that our unemployment forecasts have significant marginal predictive power beyond the professional forecasts and would receive approximately 40 percent weight in a combination forecast.

Rows C and D in Table 3 show results from inflation forecast-comparison exercises. In comparing inflation forecasts, a problem is that the SPF collects forecasts of ex-food-and-energy core PCE inflation rather than trimmed-mean PCE inflation. So, one must decide which inflation gauge is of greatest interest. Row C assumes that the objective is to forecast trimmed-mean inflation. Row D assumes that the objective is to forecast core inflation. Row C adjusts core-inflation forecasts upward by 0.17 percentage points to offset the historical differential between trimmed-mean and core inflation. Row D, similarly, adjusts trimmed-mean inflation forecasts downward by 0.17 percentage points.

Row C indicates that bias-adjusted SPF core inflation forecasts have no marginal predictive power for trimmed-mean inflation, given our first-release-model forecast, and would be assigned only 17 percent weight in a combination forecast. (Without bias adjustment, the weight on the SPF forecast falls to less than 5 percent.)

When the objective is to forecast core PCE inflation, our (bias-adjusted) inflation forecasts and SPF forecasts are about equally useful (Row D). Both forecasts have statistically significant marginal predictive power, and the forecasts would be assigned equal weight in a combination forecast. (Without bias adjustment, the weight assigned to our first-release-model forecast increases slightly but is estimated with less precision.)

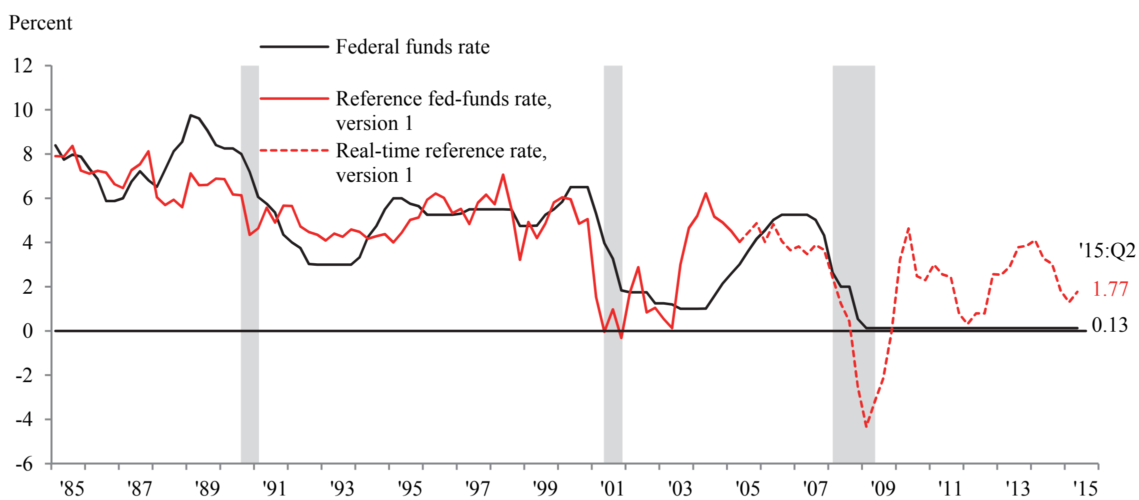
Forecast comparisons that assume that the analyst's objective is to forecast headline inflation are inconclusive: Headline inflation has such a large noise component that a long forecast history is required to reach meaningful conclusions about relative forecast accuracy.

Summary: Monetary policy's stance should be helpful for predicting real activity and inflation. By measuring the stance of policy as the gap between the policy rate and a reference rate that is sensitive to forward-looking measures of financial conditions (a long-forward interest rate and growth in household net worth), we are able to produce real-time forecasts of the unemployment rate and core PCE inflation that hold their own against professional forecasts: Both our forecasts and the professional forecasts are valuable; in fact, they are about equally valuable. In forecasting trimmed-mean inflation, our model dominates the SPF.

4. REAL-TIME ESTIMATES OF MONETARY POLICY ACCOMMODATION

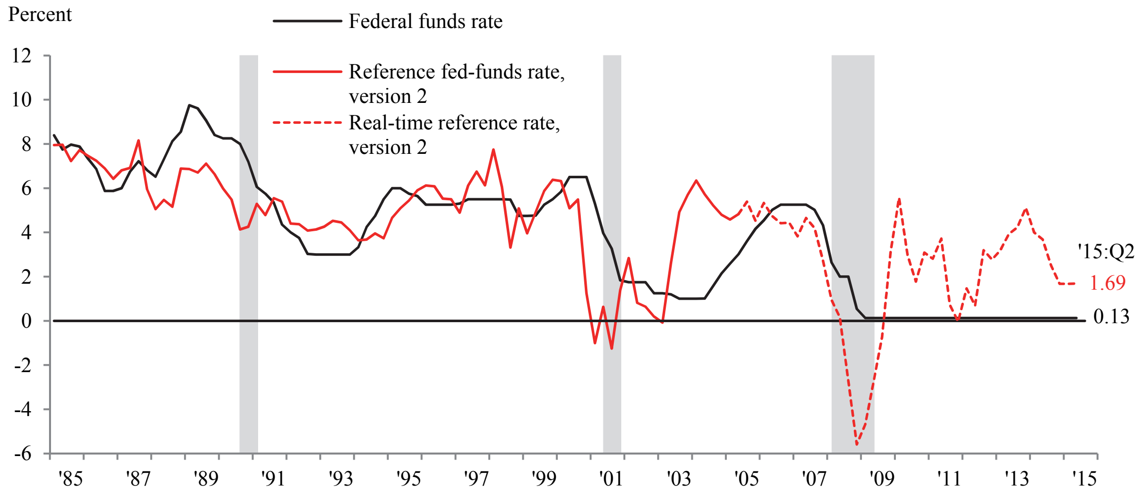
Figures 8A and 8B display the actual target federal funds rate and the reference rate, $R^*(t) \equiv r^*(t)+\pi(t)$, from the first-release and second-release versions of our unemployment and inflation equations. The dashed portions of the reference-rate plots, which start in 2005:Q3 and run through 2015:Q2, are based on real-time recursive estimation results—the same results that generated the unemployment and inflation forecasts discussed in Section 3. They show how the stance of policy would have been assessed in real time over the past ten years. Policy is judged accommodative whenever the actual target funds rate (the black line) is below the reference rate (in red). It is judged restrictive whenever the actual target funds rate is above the reference rate. The figures show policy to have been highly restrictive leading up to the 1990 and 2001 recessions and in late 2008 and early 2009. Policy was exceptionally accommodative in 2004 and again in 2010 and 2013. Policy accommodation has diminished over the past 4 quarters but has not disappeared. "Positive" plots like these—and normative, Taylor-rule prescriptions similar to those shown in Figure 4—are of potential use to policymakers in their deliberations.

Figure 8A: Monetary policy is accommodative when the fed-funds rate is below the reference rate, and restrictive when the fed-funds rate is above the reference rate



NOTE: Gray bars represent recessions.
SOURCES: Federal Reserve Board; authors' calculations.

Figure 8B: Monetary policy is accommodative when the fed-funds rate is below the reference rate, and restrictive when the fed-funds rate is above the reference rate



NOTE: Gray bars represent recessions.
SOURCES: Federal Reserve Board; authors' calculations.

5. THE ECONOMY'S LONGER-RUN DYNAMICS

With a few simple assumptions, the model developed in this paper can be used to generate simulated paths for the unemployment rate, inflation, and the stance of monetary policy that extend arbitrarily far into the future. To begin, note that Equations 1, 2, and 3 can be rearranged as follows:

$$U(t) - U^* = \alpha_1[U(t-4) - U^*] + \alpha_2[U(t-8) - U^*] + \alpha_3[r(t-4) - r^*(t-4)] + \alpha_4[r(t-8) - r^*(t-8)] + \alpha_5[r(t-12) - r^*(t-12)] + \varepsilon_U(t) \quad (1)$$

$$\pi(t) - \pi^e(t) = \beta_1[U(t-4) - U^*] + \beta_2[U(t-8) - U^*] + \beta_3[\pi(t-4) - \pi^e(t-4)] + \beta_4[\pi^{pce}(t-4) - \pi(t-4)] + \beta_5[\pi^{cpi}(t-4) - \pi(t-4)] + \varepsilon_P(t) \quad (2)$$

$$r(t) - r^*(t) = \gamma_1[\pi(t) - \pi^*] + \gamma_2[U(t) - U^*] + \gamma_3 FWD(t) + \varepsilon_R(t). \quad (3)$$

Looking ahead, the forward-guidance dummy variable, $FWD(t)$, can be dropped from Equation 3. Provided long-term inflation expectations remain well anchored, $\pi^e(t) = \pi^*$ in Equation 2. Provided that deviations of headline PCE inflation and trimmed-mean CPI inflation from trimmed-mean PCE inflation [$\pi^{pce}(t) - \pi(t)$ and $\pi^{cpi}(t) - \pi(t)$, respectively] cannot be forecast, these deviations can be rolled into an expanded inflation-equation error term for stochastic simulation purposes. With these assumptions, Equations 1–3 become:

$$U(t) - U^* = \alpha_1[U(t-4) - U^*] + \alpha_2[U(t-8) - U^*] + \alpha_3[r(t-4) - r^*(t-4)] + \alpha_4[r(t-8) - r^*(t-8)] + \alpha_5[r(t-12) - r^*(t-12)] + \varepsilon_U(t) \quad (1.a)$$

$$\pi(t) - \pi^* = \beta_1[U(t-4) - U^*] + \beta_2[U(t-8) - U^*] + \beta_3[\pi(t-4) - \pi^*] + \varepsilon'_P(t) \quad (2.a)$$

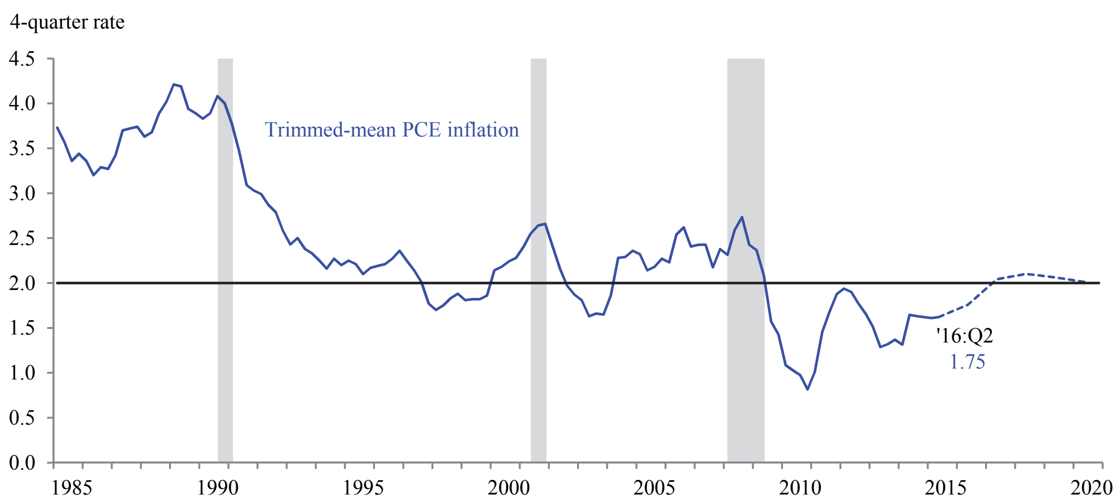
$$r(t) - r^*(t) = \gamma_1[\pi(t) - \pi^*] + \gamma_2[U(t) - U^*] + \varepsilon_R(t), \quad (3.a)$$

where $\varepsilon'_P(t) \equiv \varepsilon_P(t) + \beta_4[\pi^{pce}(t-4) - \pi(t-4)] + \beta_5[\pi^{cpi}(t-4) - \pi(t-4)]$. This system of stochastic linear difference equations can be simulated into the future, taking draws from the historical distribution of shocks. The main danger is that the federal funds rate will, at some point, become constrained by the zero bound. Then, Equation 3.a will likely cease to capture the evolution of monetary policy.

Figure 9A: The unemployment rate is projected to approach the natural rate from below

NOTE: Gray bars represent recessions.
SOURCES: Bureau of Labor Statistics; authors' calculations.

Figure 9B: The inflation rate is projected to approach 2 percent from above

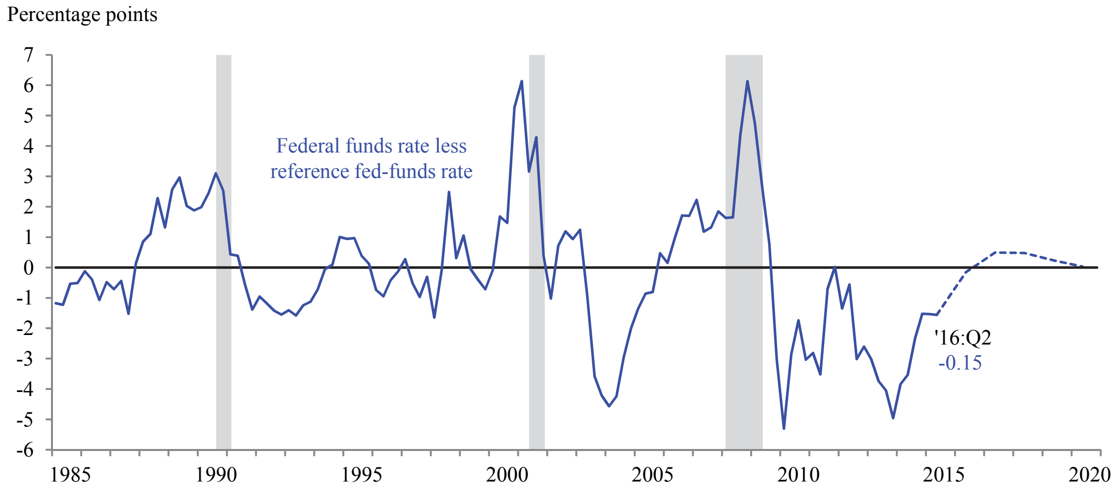


NOTE: Gray bars represent recessions.
SOURCES: Federal Reserve Bank of Dallas; authors' calculations.

Figures 9A-C show, respectively, actual and simulated unemployment, actual and simulated trimmed-mean PCE inflation, and the actual and simulated stance of monetary policy. These are nonstochastic simulations: They show how the model says the economy would evolve in the absence of new shocks. Taylor-rule coefficients (γ_1 and γ_2) are from three-stage-least-squares estimation of Equations 1, 2, and 3 over a sample that ends in 2008:Q2—before the financial crisis and before policy became constrained by the zero bound. Implicitly, the simulations assume that policy will be conducted in the future as it had typically been conducted before the financial crisis. All other coefficients are from three-stage-least-squares estimation of Equations 1 and 2 over a sample that ends in 2015:Q1. Real-time-vintage data are used in both estimations to the extent possible.

The unemployment simulation shows the jobless rate reaching the estimated natural rate (4.8 percent) in 2016:Q1 and falling to 4.4 percent in 2017:Q2 (Figure 9A). Then, the unemployment rate begins to rise, and by the end of the simulation period (2020:Q2), it is back at the natural rate. In the meantime, trimmed-mean inflation edges above 2.0 percent in 2017:Q2 and hits 2.1 percent in 2018:Q2 (Figure 9B). At the end of the simulation period (2020:Q2), inflation is back at 2.0 percent. Finally, policy accommodation is nearly eliminated by 2016:Q2 (Figure 9C). Policy then becomes restrictive, and the gap between the

Figure 9C: Policy, as measured by $r - r^*$, is projected to transition from an accommodative to a restrictive stance



NOTE: Gray bars represent recessions.
SOURCES: Federal Reserve Board; authors' calculations.

actual and reference real interest rates reaches a maximum of 0.5 percentage points in 2017:Q2. At the end of the simulation period (2020:Q2), with both halves of the dual mandate satisfied, monetary policy is neutral. (If the simulations are extended, all three variables—the unemployment rate, inflation, and monetary policy—exhibit damped oscillations.)

Summary: The baseline model developed in this paper suggests that the U.S. economy is on track to achieve full employment and price stability in the medium term, in the absence of new shocks and assuming that the FOMC conducts policy much as it did from 1985 to 2008. Under those assumptions, the FOMC can be expected to move gradually to a neutral policy stance in 2016:Q2, and then transition to a restrictive policy stance. However, the model does not provide guidance on the implied path of the federal funds rate. That path depends on the evolution of household wealth and the long-forward interest rate—variables about which the model is silent.

6. CONCLUDING REMARKS

Folk wisdom and historical experience suggest that a different economic dynamic kicks in once the unemployment rate increases sufficiently—a dynamic which linear models similar to that developed here fail to capture. In still-preliminary empirical work, we've found strong evidence favoring such a dynamic. However, in nonstochastic simulations similar to those displayed in Figures 9A-C, we've not found that allowing for nonlinearity in unemployment behavior produces a radically different medium-term adjustment path for the economy. It may be, though, that such an economy is substantially more vulnerable to adverse shocks. We plan to examine this possibility in stochastic simulations.

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Table 1: Joint model of unemployment, inflation, and monetary policy

Coefficient	A		B		C		D	
U^*	5.30***		5.19***		5.28***		–	
	(0.26)		(0.27)		(0.10)		–	
α_1	1.08***		1.18***		1.18***		1.27***	
	(0.10)		(0.10)		(0.10)		(0.09)	
α_2	-0.20**		-0.29***		-0.29***		-0.33***	
	(0.10)		(0.07)		(0.07)		(0.08)	
α_3	0.13***		0.15***		0.15***		0.16***	
	(0.03)		(0.03)		(0.03)		(0.03)	
δ_0	-2.16***		-1.49***		-1.44***		-0.77***	
	(0.71)		(0.30)		(0.25)		(0.22)	
δ_1	0.81***		0.73***		0.73***		0.65***	
	(0.23)		(0.08)		(0.08)		(0.08)	
δ_2	0.33***		0.19***		0.19***		0.16***	
	(0.08)		(0.02)		(0.02)		(0.02)	
α_4	0.07**		0.07***		0.07***		0.07***	
	(0.03)		(0.02)		(0.02)		(0.02)	
α_5	0.00		0.01		0.01		-0.01	
	(0.03)		(0.03)		(0.03)		(0.02)	
β_1	-0.22***		-0.20***		-0.20***		-0.23***	
	(0.05)		(0.05)		(0.04)		(0.04)	
β_2	0.09**		0.08*		0.08*		0.05	
	(0.05)		(0.04)		(0.04)		(0.04)	
β_3	0.37***		0.39***		0.40***		0.33***	
	(0.06)		(0.06)		(0.06)		(0.05)	
β_4	0.28***		0.24***		0.24***		0.27***	
	(0.05)		(0.05)		(0.04)		(0.04)	
β_5	-0.52***		-0.48***		-0.48***		-0.58***	
	(0.10)		(0.10)		(0.10)		(0.09)	
Eq. 3 constant	-3.82***		–		–		–	
	(0.41)		–		–		–	
δ'_1	0.69***		–		–		–	
	(0.08)		–		–		–	
δ'_2	0.19***		–		–		–	
	(0.02)		–		–		–	
γ_1	1.26***		1.18***		1.18***		0.63***	
	(0.08)		(0.08)		(0.08)		(0.10)	
π^*	–		1.86***		$\equiv$2		$\equiv$2	
	–		(0.42)		–		–	
γ_2	-1.30***		-1.31***		-1.31***		-1.46***	
	(0.08)		(0.08)		(0.08)		(0.09)	
γ_3	-2.55***		-2.51***		-2.50***		-2.23***	
	(0.29)		(0.29)		(0.28)		(0.30)	
	Adj. R^2	$S.E.$	Adj. R^2	$S.E.$	Adj. R^2	$S.E.$	Adj. R^2	$S.E.$
Eq. 1	0.83	0.41	0.82	0.41	0.82	0.41	0.81	0.43
Eq. 2	0.64	0.25	0.64	0.25	0.64	0.25	0.67	0.24
Eq. 3	0.80	0.78	0.80	0.79	0.80	0.79	0.82	0.74

Estimated over 1985:Q1 to 2008:Q2, using GMM and with Newey-West adjusted standard errors in parentheses.
* Significant at 10 percent level.
** Significant at 5 percent level.
*** Significant at 1 percent level.

Table 2: Inertia disappears when policy is conditioned on financial variables

Coefficient	A		B		C		D	
θ	0.42***		0.36***		0.09		0.08	
	(0.08)		(0.07)		(0.08)		(0.07)	
δ_0	1.70***		2.12***		-1.21***		-0.81***	
	(0.37)		(0.34)		(0.36)		(0.28)	
δ_1	–		–		0.66***		0.70***	
	–		–		(0.12)		(0.11)	
δ_2	–		–		0.19***		0.15***	
	–		–		(0.03)		(0.03)	
γ_1	1.81***		1.03***		1.27***		0.53***	
	(0.39)		(0.30)		(0.12)		(0.16)	
γ_2	-1.54***		-1.85***		-1.33***		-1.61***	
	(0.30)		(0.26)		(0.10)		(0.12)	
γ_3	-1.53***		-1.34***		-2.50***		-2.13***	
	(0.55)		(0.45)		(0.49)		(0.39)	
	Adj. R^2	$S.E.$	Adj. R^2	$S.E.$	Adj. R^2	$S.E.$	Adj. R^2	$S.E.$
	0.74	1.11	0.78	1.01	0.89	0.73	0.89	0.72

Estimated over 1985:Q1 to 2008:Q2, using GMM and with Newey-West adjusted standard errors in parentheses.
* Significant at 10 percent level.
** Significant at 5 percent level.
*** Significant at 1 percent level.

Table 3: "Horse races" against professional forecasts

	Forecasted variable	Weight on model forecast	Model version	Competing forecast
A	Unemployment rate	0.38**	1^{st} release	SPF
		(0.17)		
B	Unemployment rate	0.43***	2^{nd} release	Blue Chip
		(0.12)		
C	Trimmed-mean PCE inflation	0.83***	1^{st} release	SPF
		(0.15)		
D	Ex-food-and-energy core PCE inflation	0.52**	1^{st} release	SPF
		(0.20)		

Unemployment rate equations estimated 2006:Q3 to 2015:Q3, with 2008:Q4 to 2009:Q3 excluded.
Inflation rate equations estimated 2007:Q4 to 2015:Q2.
Standard errors, in parentheses, are Newey-West adjusted.
Weights of model forecasts and competing forecasts restricted to sum to 1.
* Significant at 10 percent level.
** Significant at 5 percent level.
*** Significant at 1 percent level.

Table 4: List of instruments for Table 1, Columns A-C estimations

Equation 1
$U(t-4)$, $U(t-8)$, $r(t-4)-\pi(t-4)$, $LR(t-4)-\pi(t-4)$, $DW(t-4)-\pi(t-4)$, $r(t-8)-\pi(t-8)$, $LR(t-8)-\pi(t-8)$, $DW(t-8)-\pi(t-8)$, $r(t-12)-\pi(t-12)$, $LR(t-12)-\pi(t-12)$, $DW(t-12)-\pi(t-12)$
Equation 2
$U(t-4)$, $U(t-8)$, $\pi(t-4)-\pi^e(t-4)$, $\pi^{pce}(t-4)-\pi(t-4)$, $\pi^{cpi}(t-4)-\pi(t-4)$
Equation 3
$U(t-4)$, $U(t-8)$, $r(t-4)$, $\pi_{sr}(t-4)$, $LR(t-4)$, $DW_{fr}(t-4)$, $r(t-8)$, $\pi_{sr}(t-8)$, $LR(t-8)$, $DW_{fr}(t-8)$, $\pi^e(t-4)$, $\pi^{pce}_{sr}(t-4)$, $\pi^{cpi}(t-4)$, $CWRATIO_{sr}(t-4)$, $FWD(t)$

All instrument sets include a constant.

$CWRATIO(t)$ is a consumption-wealth ratio, defined here as the log ratio between nominal nondurable goods and services personal consumption expenditures and household net worth. We include it in the Taylor-rule instruments because it is useful in predicting future wealth growth.

Table 5: List of instruments for Table 1, Column D estimation

Equation 1
$U(t-4)-U^*_{CBO}(t-4)$, $U(t-8)-U^*_{CBO}(t-8)$, $r(t-4)-\pi(t-4)$, $LR(t-4)-\pi(t-4)$, $DW(t-4)-\pi(t-4)$, $r(t-8)-\pi(t-8)$, $LR(t-8)-\pi(t-8)$, $DW(t-8)-\pi(t-8)$, $r(t-12)-\pi(t-12)$, $LR(t-12)-\pi(t-12)$, $DW(t-12)-\pi(t-12)$
Equation 2
$U(t-4)-U^*_{CBO}(t-4)$, $U(t-8)-U^*_{CBO}(t-8)$, $\pi(t-4)-\pi^e(t-4)$, $\pi^{pce}(t-4)-\pi(t-4)$, $\pi^{cpi}(t-4)-\pi(t-4)$
Equation 3
$U(t-4)-U^*_{BC}(t-4)$, $U(t-8)-U^*_{BC}(t-8)$, $r(t-4)$, $\pi_{sr}(t-4)$, $LR(t-4)$, $DW_{fr}(t-4)$, $r(t-8)$, $\pi_{sr}(t-8)$, $LR(t-8)$, $DW_{fr}(t-8)$, $\pi^e(t-4)$, $\pi^{pce}_{sr}(t-4)$, $\pi^{cpi}(t-4)$, $CWRATIO_{sr}(t-4)$, $FWD(t)$

U^*_{CBO} and U^*_{BC} are current-vintage CBO and real-time Blue Chip natural-rate estimates, respectively.

Table 6: List of instruments for Table 2 estimations

Columns A and C
$U(t-4)$, $U(t-8)$, $r(t-4)$, $\pi_{sr}(t-4)$, $LR(t-4)$, $DW_{fr}(t-4)$, $r(t-8)$, $\pi_{sr}(t-8)$, $LR(t-8)$, $DW_{fr}(t-8)$, $\pi^e(t-4)$, $\pi^{pce}_{sr}(t-4)$, $\pi^{cpi}(t-4)$, $CWRATIO_{sr}(t-4)$, $FWD(t)$
Columns B and D
$U(t-4)-U^*_{BC}(t-4)$, $U(t-8)-U^*_{BC}(t-8)$, $r(t-4)$, $\pi_{sr}(t-4)$, $LR(t-4)$, $DW_{fr}(t-4)$, $r(t-8)$, $\pi_{sr}(t-8)$, $LR(t-8)$, $DW_{fr}(t-8)$, $\pi^e(t-4)$, $\pi^{pce}_{sr}(t-4)$, $\pi^{cpi}(t-4)$, $CWRATIO_{sr}(t-4)$, $FWD(t)$