How Useful Are Taylor Rules for Monetary Policy?

By Sharon Kozicki

Over the past several years, Taylor rules have attracted increased attention of analysts, policymakers, and the financial press. Taylor rules recommend a setting for the level of the federal funds rate based on the state of the economy. For instance, they may recommend raising the federal funds rate when inflation is above target or lowering the federal funds rate when a recession appears to be more of a threat. Taylor rules have become more appealing recently with the apparent breakdown in the relationship between money growth and inflation (Blinder). But, while Taylor rules have attracted considerable interest, the usefulness of rule recommendations to policymakers has not been well established.

To be useful to policymakers, rule recommendations should be robust to minor variations in the rule specification. While most analysts and policymakers agree on the fundamental features of a monetary policy rule, consensus has not been reached on the details of the specification. The Taylor rule is a specific rule that incorporates several assumptions. Rule recommendations should be robust if these assumptions are replaced by reasonable alternatives. For example, rule recommendations would not be robust if different measures of price inflation yield a wide range of rule recommendations. If recommendations differ considerably depending on whether price inflation is measured using the core consumer price index or the chain price index for GDP, then the rule may not be very useful.

Rule recommendations should also be reliable. A reliable rule might be expected to replicate federal funds rate settings over a period when policymakers thought policy actions were successful. If past policy decisions are regarded favorably, then policymakers may want to base current decisions on a similar strategy. To the extent rule recommendations replicate past favorable policy settings, policymakers may regard the rule as reliable. But, even a rule that can replicate favorable policy actions may not be regarded as reliable if past policy decisions were influenced by economic events beyond the scope of the rule.

This article examines whether recommendations from Taylor rules are useful to policymakers as they decide how to adjust the federal funds rate. The article suggests that the usefulness of Taylor rule recommendations to policymakers faced with real-time policy decisions is limited. Rule

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recommendations are not robust to reasonable minor variations in assumptions and their reliability is questionable.[1] Taylor rules may be useful to policymakers in other ways. For example, because they incorporate the overall characteristics of sound monetary policy generally agreed on by analysts and policymakers, Taylor rules may provide a good starting point for discussions of issues that concern policymakers. Monetary policy rules also play an important role in most forecasting models.

The first section of the article describes the Taylor rule and discusses common generalizations of the Taylor rule. The second section examines the robustness of rule recommendations to small differences in rule specifications. The third section assesses the reliability of rule recommendations.

I. WHAT ARE TAYLOR-TYPE RULES?

This article focuses on a class of policy rules that model the federal funds rate target as a function of the deviation of inflation from a target rate and the deviation of real GDP from potential real GDP (that is, its long-run sustainable trend).[2] The rules assume that policymakers seek to stabilize output and prices about paths that are thought to be optimal and that by changing the federal funds rate target they can influence output and prices (Cecchetti). Such rules are often called Taylor rules because they resemble a simple rule, known as *the Taylor rule*, suggested by John Taylor in 1993. This section reviews the Taylor rule and discusses a class of similar rules that incorporate the same basic framework for policy. In the remainder of the article, this class of similar rules will be referred to as *Taylor-type rules* to distinguish them from the original Taylor rule.

The Taylor rule

The Taylor rule recommends a target for the level of the nominal federal funds rate that depends on four factors.[3] The first factor is the current inflation rate. The second factor is the equilibrium real interest rate. When added together, these two factors provide a benchmark recommendation for the nominal federal funds rate. The third factor is an inflation gap adjustment factor based on the gap between the inflation rate and a given target for inflation.[4] This factor recommends raising the federal funds rate above the benchmark if inflation is above the target for inflation and lowering the federal funds rate below the benchmark if inflation is below the target. The fourth factor is an output gap adjustment factor based on the gap between real GDP and potential real GDP. This factor recommends raising the federal funds rate above the benchmark if the gap is positive (real GDP is above potential real GDP) and lowering the federal funds rate below the benchmark if the gap is negative (real GDP is below potential real GDP). These factors summarize several important aspects of policy.[5]

The sum of the first and second factors provides a benchmark recommendation for the federal funds rate that would keep inflation at its current rate, provided the economy is operating at its potential. Because the benchmark recommendation rises one-for-one with the current rate of inflation, the higher current inflation is, the higher the rule recommendation will be, all else equal. This relationship between current inflation and the benchmark recommendation for the *nominal* federal funds rate keeps the implied *real* interest rate constant.

The use of the equilibrium real rate in the Taylor rule emphasizes that real rates play a central role in formulating monetary policy. Although the nominal federal funds rate is identified as the instrument that policymakers adjust, the real interest rate is what affects real economic activity. In particular, the rules clarify that real interest rates will be increased above equilibrium when inflation is above target or output is above its potential.

The third and fourth factors in the Taylor rule

summarize two objectives of monetary policy—targeting a low and stable rate of inflation while promoting maximum sustainable growth. These adjustment factors can also be seen as incorporating both long-run and short-run goals. The inflation gap adjustment factor incorporates the central bank's long-run inflation goal. The output gap adjustment factor incorporates the view that in the short-run policy should lean against cyclical winds. Weights in the adjustment factors embody a presumed attitude toward the short-run tradeoff between inflation and output.

The output gap adjustment factor may represent another aspect of policy. Some analysts have argued that the output gap adjustment factor brings a forward-looking, or preemptive, motive to policy recommendations. According to this view, a positive output gap signals likely future increases in inflation. Consequently, funds rate recommendations that reflect an output gap adjustment may correspond to policy actions designed to preempt an otherwise anticipated increase in inflation.

Although the Taylor rule incorporates many important aspects of policy, it also is based on several assumptions. Assumptions of some form are necessary to move from a framework for policy to a rule that provides quantitative recommendations.[6] The specific rule discussed by Taylor takes the following form:

$$\begin{aligned} &\textit{funds rate(t)} = \textit{GDP price inflation(t)} \\ &+ 2.0 + 0.5 \times (\textit{GDP price inflation(t)} - 2.0) \\ &+ 0.5 \times (\textit{output gap(t)}). \end{aligned} \quad (1)$$

In this expression, the benchmark recommendation is the sum of GDP price inflation and the 2.0 percent equilibrium real rate. The third term on the right side of the expression is the inflation gap adjustment, which raises the funds rate target by one-half of the gap between GDP price inflation and the 2.0 percent inflation target. The fourth term on the right side of the expression is the output gap adjustment, which raises the funds rate target by one-half of the output gap, where the output gap is defined as the percent deviation of the level of real GDP from the level of potential real GDP.[7]

Assumptions are embedded in all components of the rule. Taylor-rule recommendations in a given quarter are based on the output gap in the *same* quarter and on inflation over the four quarters ending in the *same* quarter. In the Taylor rule, monetary policy targets GDP price inflation measured as the rate of inflation in the GDP deflator over the previous four quarters. The equilibrium real rate, represented by the second term on the right side of the expression, is assumed to equal 2.0 percent. The inflation gap adjustment incorporates a weight equal to one-half. The policy target for inflation is assumed to equal 2.0 percent. The output gap adjustment incorporates a weight equal to one-half. And, the output gap is constructed using a series for potential real GDP that grows 2.2 percent per year.

Taylor-type rules

Taylor presented his rule as a simple, representative specification that captured the general framework for policy discussed earlier. Because there is a lack of consensus about the exact specification, evaluating alternative similar specifications is important when assessing the usefulness of rule recommendations. The details of the specifications of the Taylor-type rules examined in this article differ somewhat from the Taylor rule, although they represent the same general framework for policy. The remainder of this section discusses specification details of the Taylor rule and alternative reasonable assumptions about timing, weights, smoothing, and measurement that may be made in Taylor-type rules.

In the Taylor-type rules examined in this article, the timing of the economic variables on which funds rate settings depend is different than in Taylor's specification. The Taylor rule recommends setting the federal funds rate according to the

contemporaneous output gap and the inflation gap over the previous four quarters. However, this specification inappropriately assumes that the central bank knows the current quarter values of real GDP and a price index when setting the federal funds rate for that quarter (McCallum 1998a,b; Orphanides; McCallum and Nelson). In the United States, the first (or advance) release of real GDP data for each quarter is not available until roughly a month after the end of that quarter. The second (or preliminary) release is not available until roughly two months after the end of that quarter. And, the third (or final) release is not available until roughly three months after the end of that quarter. In addition, historical data may be revised with the annual revisions of the National Income and Product Accounts data, or with the less frequent comprehensive revisions.[8]

To partially address the timing problem, this article assumes that the federal funds rate in a given quarter is set according to the output gap and the inflation gap in the previous quarter. Lagging output gap and inflation data by one quarter is a common practical approach to dealing with lags in the release of data (Stuart).[9] However, because this article uses the version of historical data available at the start of 1999, even rule recommendations based on lagged data will likely differ from those based on real-time data, that is, the version of the data actually available during the quarter of the policy decision (McNees; Orphanides; Ghysels, Swanson, and Callan).

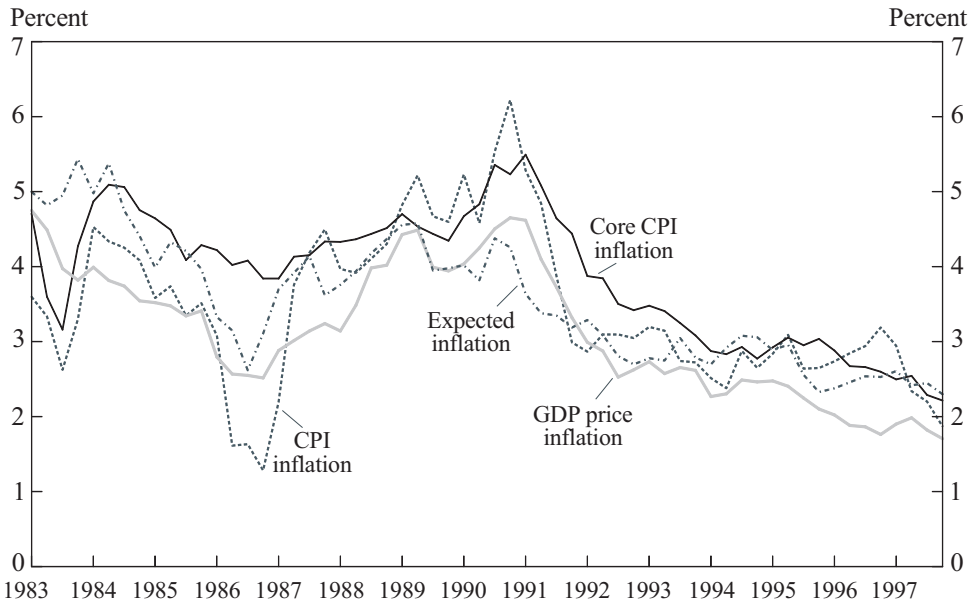
The second potential difference between Taylor-type rules and the Taylor rule is in the *weights* embedded in the inflation and output gap adjustments. The weights represent the responsiveness of monetary policy to deviations of inflation from the inflation target and deviations of output from potential output. In the Taylor rule, the output and inflation gaps are each multiplied by a weight of 0.5, but Taylor noted a lack of consensus about the size of the weights in policy rules. This article explores rule recommendations with weights of 0.5, but also estimates Taylor-type rules to see if alternative weights are more consistent with historical policy.[10]

The third potential difference is that Taylor-type rules may account for smoothing behavior on the part of the Federal Reserve. Many analysts have noted that the Federal Reserve has a tendency to smooth movements of the funds rate (Goodfriend; Orphanides; Clarida, Gali, and Gertler 1998). Concern about the stability of financial markets may lead the Federal Reserve to smooth funds rate changes (McNees).[11] Smoothing may also indicate responsiveness of policy actions to inflation and output gaps observed over several quarters rather than just a single quarter. Alternatively, smoothing may be justified when the economic impact of changes in the funds rate is uncertain (Sack). Smoothing can be incorporated in a Taylor-type rule by assuming that the Federal Reserve puts some weight on the previous level of the funds rate in addition to the inflation and output gaps when deciding on the current level of the federal funds rate. By contrast, the Taylor rule provides recommendations for federal funds rate settings which depend on the output gap and inflation gap but not on the previous level of the federal funds rate.

The final dimension by which the Taylor-type rules analyzed in this article differ from Taylor's 1993 implementation is in the *measurement* of inflation and the output gap. The question of which measure of inflation policymakers should attempt to stabilize may not be as simple as it seems. Often the level and direction of inflation movements differ for different measures of inflation. Furthermore, in face of divergent movements, justifying a given choice of inflation measure may prove difficult.

The Taylor rule uses as its measure of inflation the percent change in the price deflator for GDP over the previous four quarters. This article considers four alternative inflation measures—CPI inflation, core CPI inflation, GDP price inflation, and expected inflation (Chart 1). CPI inflation is

Chart 1
INFLATION MEASURES



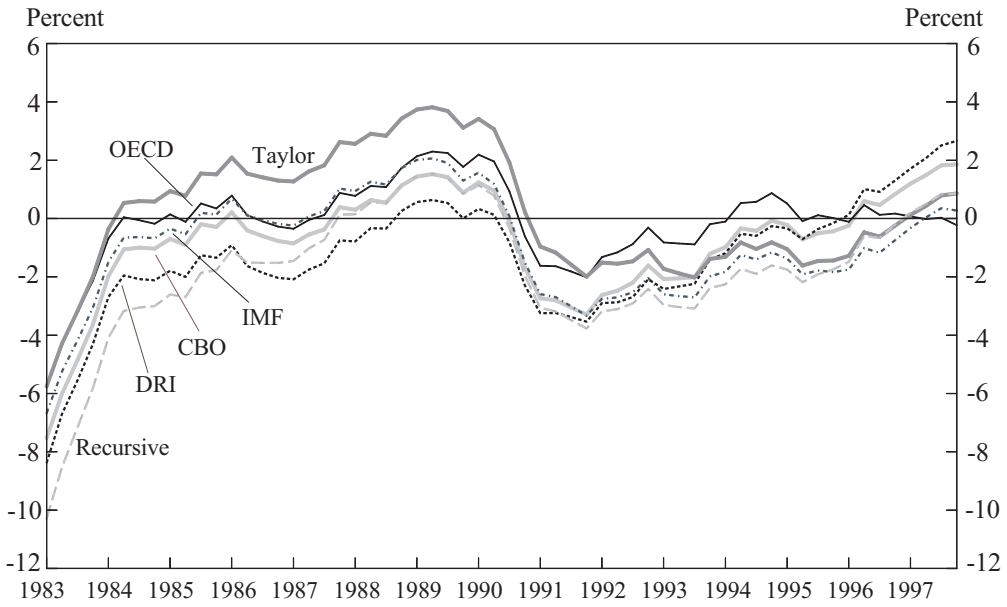
Sources: Bureau of Labor Statistics, Bureau of Economic Analysis, Federal Reserve Bank of Philadelphia.

measured as the percent change in the consumer price index over the previous four quarters. Core CPI inflation is measured as the percent change in the consumer price index excluding food and energy over the previous four quarters. GDP price inflation is measured as the percent change in the chain price index for GDP over the previous four quarters.[12] And, expected inflation is measured as the forecast of the percent change in the chain price index for real GDP over the next four quarters as reported by the Survey of Professional Forecasters.

These four measures represent both backward-looking and forward-looking measures of inflation. The first three inflation measures are backward-looking in that they describe inflation over a time period that has already past. By contrast, the fourth inflation measure is forward-looking in that it describes what a collection of professional forecasters expect inflation to be over a future time period. This last measure provides a direct method to introduce forward-looking policy.[13] Expected inflation was included in the analysis because many analysts and policymakers argue that policy should be forward-looking, with funds rate settings based on expected future inflation rather than on past inflation.[14]

Multiple measures of the output gap are considered because policymakers frequently comment on difficulties in assessing the output gap.[15] The six measures of the output gap considered in this article are shown in Chart 2. Each output gap is the percentage difference between real GDP and an estimate of potential real GDP. The six

Chart 2
OUTPUT GAPS

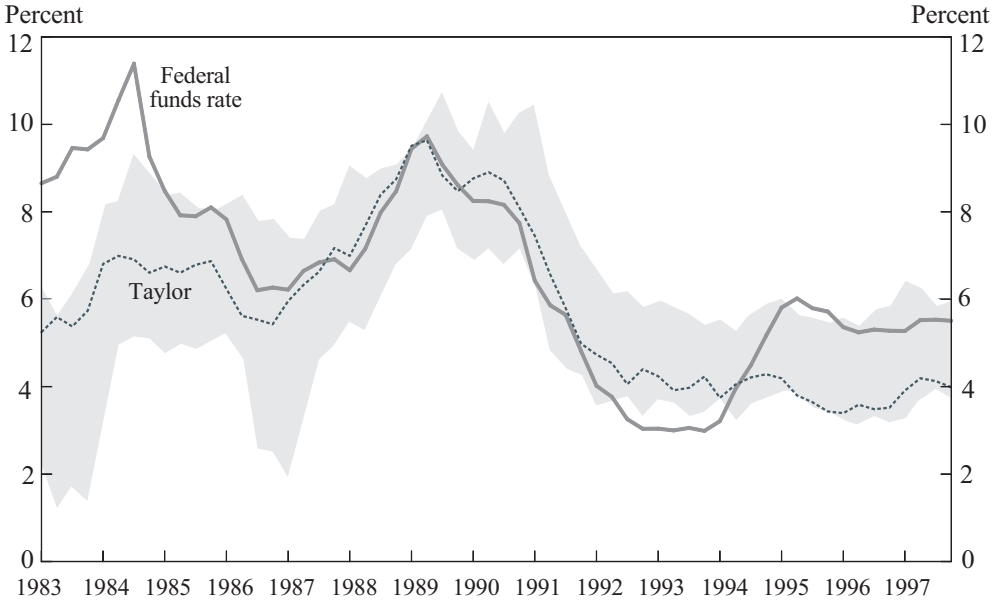


measures of the output gap differ according to estimates of potential real GDP. The measures were chosen because they include different approaches to estimating potential real GDP and can be easily obtained or easily estimated.[16] The measures cover a broad range of sources, including a government agency (the Congressional Budget Office, or CBO), two international institutions (the International Monetary Fund, or IMF, and the Organisation for Economic Cooperation and Development, or OECD), and a corporation that produces commercial forecasts (Standard & Poor's DRI). These four measures are labeled by data source—CBO, IMF, OECD, and DRI, respectively. Two other measures are based on estimates of potential real GDP constructed using standard procedures. These measures are labeled Taylor and Recursive—the former because it provides a reasonably close approximation to the definition of the output gap used by Taylor, and the latter because it represents a "recursive" version of the former. More details on the measures of the output gap are provided in Appendix A.

II. ARE RULE RECOMMENDATIONS ROBUST?

This section investigates the robustness of rule recommendations by examining the sensitivity of Taylor-type rule recommendations to alternative assumptions. Investigating the robustness of rule recommendations can be done by examining the range of rule recommendations that would result across various measures of inflation and the output gap, alternative estimates of the equilibrium real rate, or different choices of weights. The range of rule recommendations may be interpreted, for instance, as the range of recommendations provided to a policymaker by a group of advisors, each using a Taylor-type

Chart 3
THE RANGE OF TAYLOR-TYPE RULE RECOMMENDATIONS FOR DIFFERENT MEASURES OF INFLATION AND THE OUTPUT GAP



Note: The shaded area reflects the range of rule recommendations based on recommendations calculated for each of the six measures of the output gap and each of the four measures of inflation. In each quarter, the maximum of the range corresponds to the maximum of the 24 rule recommendations, and the minimum of the range corresponds to the minimum of the 24 rule recommendations. Taylor recommendations were calculated by the author using the Taylor rule in (1) and the latest version of data for real GDP and the GDP chain price index available in December 1998. These recommendations were based on the Taylor output gap described in Appendix A.
Sources: Board of Governors of the Federal Reserve System, author's calculations.

rule, but each having a different view about the specifics of the rule.[17] The analysis in this article is limited to comparing operational rules, so the timing adjustment discussed in the previous section is used—measures of the output gap and inflation are for the previous quarter.

How robust are rule recommendations to alternative measures of inflation and alternative estimates of the output gap?

The Taylor rule was based on specific choices of inflation and output gap measures. As discussed in the previous section, other reasonable measures of inflation and the output gap are available. To assess how robust rule recommendations are across alternative measures of inflation and the output gap, recommendations of the following rule are examined:

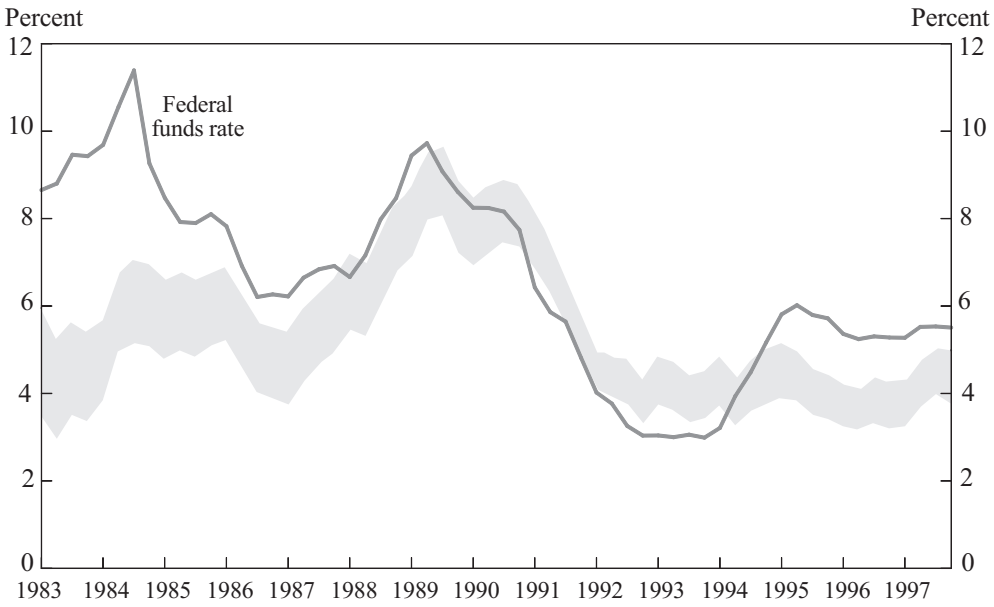
$$\begin{aligned} \textit{funds rate}(t) &= \textit{inflation}(t-1) + 2.0 \\ &+ 0.5 \times (\textit{inflation}(t-1) - 2.0) \\ &+ 0.5 \times (\textit{output gap}(t-1)). \end{aligned} \qquad (2)$$

As in the Taylor rule, the equilibrium real rate and inflation target are set to 2.0 percent and the weights in the adjustment factors are set to 0.5.

Chart 3 shows the range of rule recommendations obtained across inflation and output gap

Chart 4

THE RANGE OF TAYLOR-TYPE RULE RECOMMENDATIONS FOR DIFFERENT MEASURES OF THE OUTPUT GAP AND GDP PRICE INFLATION



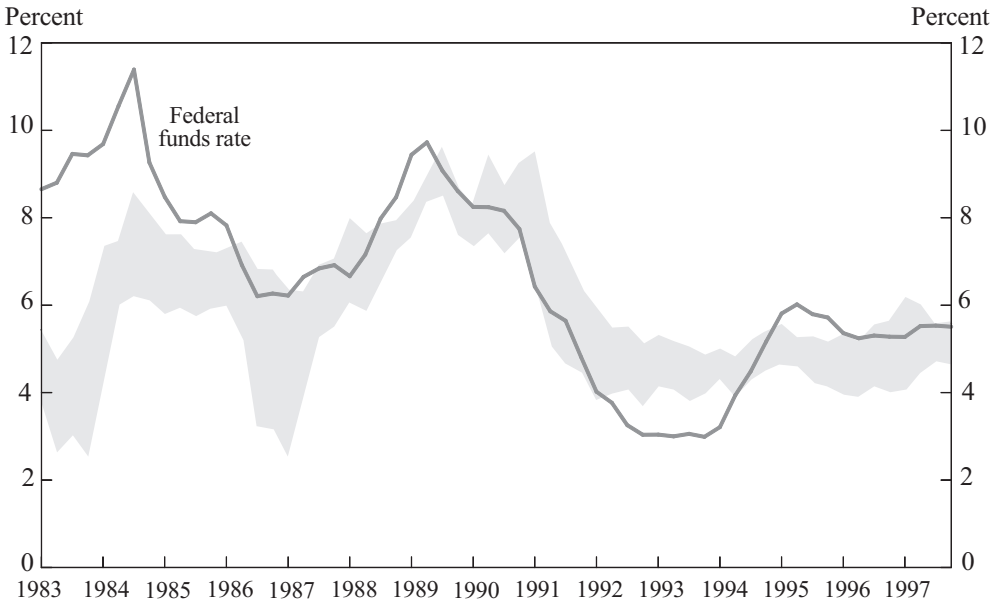
Note: The shaded area reflects the range of rule recommendations based on recommendations calculated for GDP price inflation and each of the six measures of the output gap. In each quarter, the maximum of the range corresponds to the maximum of the six rule recommendations and the minimum of the range corresponds to the minimum of the six recommendations.
Sources: Board of Governors of the Federal Reserve System, author's calculations.

measures.[18] For reference, the chart also includes actual policy as represented by the historical value of the federal funds rate and the recommendations of the Taylor rule.[19] The range of rule recommendations is based on recommendations calculated for each of the six measures of the output gap and each of the four measures of inflation discussed in the previous section— making a total of 24 rule recommendations. In each quarter, the maximum of the range corresponds to the maximum of the 24 rule recommendations for that quarter, and the minimum of the range corresponds to the minimum of the 24 rule recommendations. The range provides a measure of the robustness of the rule recommendation to the measurement of inflation and the output gap. The wider the range is, the less robust the rule recommendations are; and the narrower the range is, the more robust the rule recommendations are.

Rule recommendations are not robust across alternative measures of inflation and the output gap. From 1983 to 1997, the average range is 3.1 percentage points.[20] The range varies considerably, however, reaching its narrowest at 1.8 percentage points in the first quarter of 1994 and reaching its widest at 5.5 percentage points in the first quarter of 1987.

The robustness of rule recommendations to the choice of output gap measure is isolated in Chart 4. All recommendations in this chart

Chart 5
THE RANGE OF TAYLOR-TYPE RULE RECOMMENDATIONS FOR DIFFERENT INFLATION MEASURES AND THE CBO OUTPUT GAP



Note: The shaded area reflects the range of rule recommendations based on recommendations calculated for the CBO output gap and each of the four measures of inflation. In each quarter, the maximum of the range corresponds to the maximum of the four rule recommendations and the minimum of the range corresponds to the minimum of the four recommendations.
Sources: Board of Governors of the Federal Reserve System, author's calculations.

use the GDP price inflation measure of inflation. Rather than showing six sets of rule recommendations, one for each measure of the output gap, only the maximum and minimum recommendation are shown for each quarter. Although the range of recommendations is considerably narrower than in Chart 3, considerable sensitivity of rule recommendations to the measurement of the output gap is still apparent.[21] The average range is 1.4 percentage points, with rule recommendations in each quarter differing by at least 0.9 percentage point and by as much as 2.4 percentage points.[22]

The robustness of rule recommendations to the choice of inflation measure is isolated in Chart 5. All recommendations use the same measure of the output gap—the CBO output gap. For each quarter, only the maximum and minimum recommendation over the four inflation measures is shown. Once again, although the range of recommendations is considerably narrower than in Chart 3, rule recommendations remain sensitive to the measurement of inflation. The average range is 1.7 percentage points. In each quarter, rule recommendations differ by at least 0.6 percentage point and by as much as 3.8 percentage points.[23]

Summarizing, rule recommendations are not robust across measures of inflation or measures of the output gap. On average different assump-

Table 1

ESTIMATES OF THE EQUILIBRIUM REAL RATE

	Inflation measure			
Estimation sample	CPI inflation	Core CPI inflation	GDP price inflation	Expected inflation
1960-97	2.04	1.99	2.40	
1965-97	2.10	2.06	2.51	
1970-97	2.11	2.09	2.60	2.91
1975-97	2.35	2.12	2.89	2.91
1983-97	3.13	2.71	3.44	3.04
1987-97	2.34	2.15	2.86	2.60

Notes: Table entries are estimates of the equilibrium real rate calculated as the average nominal federal funds rate less the average inflation rate. For each entry, the column heading provides the measure of inflation used in the calculation and the row label provides the sample over which averages were taken.

tions on the measure of inflation and different assumptions on the measure of the output gap independently lead to a range of rule recommendations roughly 1½ percentage points wide.

How robust are rule recommendations to estimates of the equilibrium real interest rate?

In addition to depending on inflation and the output gap, recommendations for funds rate settings from Taylor-type rules depend on the equilibrium real rate. Because the equilibrium real rate is not directly observable, however, it must be estimated. Taylor set the equilibrium real rate to 2.0 percent in his implementation. This section provides alternative estimates of the equilibrium real rate that depend on the choice of an inflation measure and the choice of an estimation sample period. The estimates vary widely, implying considerable variation in the rule recommendations.

The equilibrium real rate is commonly estimated as the difference between the average federal funds rate and the average inflation rate, where both averages are calculated over a long sample period.[24] A long sample period is recommended because the *equilibrium* real rate is a long-run concept. By using a long sample, possible cyclical swings in the real rate should be averaged out. Additionally, for the United States, trends in inflation movements evident in short samples may result in misleading estimates of the equilibrium real rate. For instance, if the inflation rate declines on average over a sample period, then the estimate may exceed the equilibrium real rate over the sample. While use of a long sample has advantages, it also has disadvantages. In particular, if the equilibrium real rate has changed over time, then a long sample may include information from periods characterized by different equilibrium real rates.

Estimates of the equilibrium real rate are provided in Table 1 for the four inflation measures and for six sample periods. As seen in the table, estimates are sensitive to the sample period and the measure of inflation.[25] Sensitivity of estimates of the equilibrium real rate to the measure of inflation is evident by examining variation across estimates within each sample period.

Estimates differ across inflation measures by as little as 0.4 percentage point (over the 1960-97 sample) or as much as 0.8 percentage point (over the 1970-97 and 1975-97 samples).

Estimates of the equilibrium real rate are somewhat more sensitive to the sample period than to the measure of inflation. Estimates are least sensitive to the sample period when core CPI inflation is the measure of inflation, displaying a range of 0.7 percentage point across the different periods. Estimates are most sensitive to the sample period when CPI inflation is the measure used, displaying a range of 1.1 percentage points. Estimates calculated over 1983-97 are higher than estimates calculated over any other sample. Since all measures of inflation were declining on average over this sample, the Federal Reserve may have been in a tightening mode, suggesting that estimates based on this sample may overstate the equilibrium real rate.[26]

Rule recommendations are quite sensitive to estimates of the equilibrium real rate. Since the rule recommendation equals the sum of the equilibrium real rate, inflation, and two adjustment factors, any change in an estimate of the equilibrium real rate implies an equal sized change in the recommended federal funds rate in Taylor-type rules without smoothing. For example, rule recommendations based on the highest GDP-price-inflation estimate of the equilibrium real rate are over one percentage point higher than rule recommendations based on the lowest GDP-price-inflation estimate.[27] Rule recommendations based on the highest GDP-price-inflation estimate of the equilibrium real rate are nearly 1½ percentage points higher than rule recommendations based on the Taylor setting of 2.0 percent.[28] Such differences are only slightly smaller than ranges based on different output gaps and ranges based on different inflation measures.

Summarizing, rule recommendations are not very robust to estimates of the equilibrium real rate. Recommendations are almost as sensitive to estimates of the equilibrium real rate as they are to the choice of inflation and output gap measures.

How robust are rule recommendations to alternative weights?

The final assumption with respect to which robustness of rule recommendations is examined refers to the size of weights in the adjustment factors. The Taylor rule used weights of 0.5 in both adjustment factors. Weights of 0.5 represent fairly modest responses of policy to inflation and output gaps. Setting weights to 1.0, for example, would represent a somewhat more aggressive policy response.[29] Equal weights imply that policy is equally responsive to deviations of inflation from the inflation target and deviations of real GDP from potential real GDP. Unequal weights may be more appropriate if one goal is to be emphasized over the other. Also, because the output gap may be seen as a signal of future inflationary pressures, unequal weights may suggest a different emphasis on future inflation than on inflation over the previous four quarters. Views on the appropriate settings for the weights likely differ across policy advisors, and also across policymakers.[30]

To assess how robust rule recommendations are to different assumptions about the responsiveness of policy to the output gap and deviations of inflation from the target, recommendations of the following rule are examined:

$$\begin{aligned} \textit{funds rate}(t) &= \textit{inflation}(t-1) + 2.0 \\ &+ \textit{weight1} \times (\textit{inflation}(t-1) - 2.0) \\ &+ \textit{weight2} \times (\textit{output gap}(t-1)), \end{aligned} \qquad (3)$$

with *weight1* and *weight2* set to either 0.5 or 1.0.[31] Four different weight combinations are considered: *weight1* and *weight2* both set to 0.5; *weight1* set to 0.5 and *weight2* set to 1.0; *weight1* set to 1.0 and *weight2* set to 0.5; and, *weight1* and *weight2* set to 1.0. For a given choice of inflation measure and output gap measure, these

Table 2

ROBUSTNESS OF RULE RECOMMENDATIONS TO ALTERNATIVE WEIGHTS: STATISTICS ON THE RANGE OF RULE RECOMMENDATIONS

Output gap measure		Inflation measure			
		CPI inflation	Core CPI inflation	GDP price inflation	Expected inflation
CBO	Average	1.54	1.73	1.37	1.56
	Minimum	.36	.42	.13	.31
	Maximum	5.21	5.55	5.61	5.74
OECD	Average	1.30	1.48	1.14	1.32
	Minimum	.16	.16	.02	.17
	Maximum	4.41	4.76	4.81	4.94
IMF	Average	1.61	1.79	1.45	1.63
	Minimum	.19	.29	.03	.23
	Maximum	4.73	5.08	5.18	5.26
DRI	Average	1.73	1.92	1.57	1.75
	Minimum	.40	.51	.08	.24
	Maximum	5.69	6.31	6.09	6.22
Taylor	Average	1.68	1.87	1.52	1.70
	Minimum	.39	.31	.11	.37
	Maximum	4.29	4.64	4.69	4.82
Recursive	Average	1.96	2.15	1.79	1.98
	Minimum	.42	.35	.15	.37
	Maximum	6.73	7.08	7.13	7.27

Note: The average, minimum, and maximum width of the range of rule recommendations is calculated over 1983-97. Each quarter, the range of rule recommendations reflects the difference between the maximum and the minimum of the rule recommendations calculated using four different weight assumptions.

four weight combinations imply four rule recommendations each quarter. The average width of the range between the maximum and minimum recommendations for each quarter provides a measure of the robustness of the rule recommendation to the weight assumption. The larger the average, the less robust the rule recommendations; and the smaller the average, the more robust the rule recommendations.

Rule recommendations are not very robust to alternative weight assumptions. Table 2 reports the average range over 1983-97 for different inflation and output gap measures.[32] The average range varies from 1.14 percentage points to 2.15 percentage points depending on the chosen measures of inflation and the output gap. The average range over all pairings of inflation and output gap measures is 1.6 percentage points.[33] When compared to results obtained earlier in this section, this result suggests that rule recommendations are about as sensitive to the weight assumption as to the choice of inflation and output gap measures.

This section has illustrated that Taylor-type

rule recommendations are not very robust across reasonable variations in assumptions. In particular, alternative reasonable assumptions on any one of the measures of inflation, the measure of the output gap, or the choice of weights used in the adjustment factors, lead to roughly a 1½- percentage-point range of rule recommendations. Such a range is quite large when compared to typical policy decisions. For instance, between March 1, 1984, and December 31, 1998, the largest change in the Federal Reserve's target for the federal funds rate at any one time was 0.75 percentage point.[34] Even when policy actions over this period are aggregated to a quarterly frequency, the absolute change in the Federal Reserve's target for the federal funds rate from the last day of one quarter to the last day of the next quarter exceeded 0.75 percentage point only twice.[35]

Policy rules may aid in focusing policy discussions. But, lack of robustness with respect to the measurement of inflation and the output gap, estimates of the equilibrium real rate, and settings for weights limit the usefulness of rules to recommend funds rate settings in real time. [36]

III. ARE RULE RECOMMENDATIONS RELIABLE?

When faced with the decision about how to adjust the federal funds rate, policymakers naturally prefer looking to reliable policy rules for advice. One approach to evaluating the reliability of a policy rule is to assess the ability of the rule to replicate, or fit, past policy settings regarded favorably by policymakers.[37] If past policy actions were successful, policymakers wanting to base current decisions on a similar strategy might find rules whose recommendations are close to past federal funds rate settings more reliable.[38]

However, rules whose recommendations fit historical funds rate settings well may not actually do a reasonable job at describing what motivated policymakers to adjust the funds rate. In particular, even if rule recommendations replicate past federal funds rate settings, the rule may not be reliable if assumptions embedded in the rule specification are inappropriate. For instance, policymakers may have exercised flexibility in setting policy in the past. A preference for flexibility may be signaled, for instance, by evidence that economic events outside the scope of the rule influenced past policy decisions.[39] Consequently, when evaluating the reliability of Taylor-type rules it is important to examine the extent to which Taylor-type rules actually represent the process behind policy decision making.

This section evaluates the ability of Taylor-type rules to fit historical federal funds rate settings. Taylor-type rules with and without smoothing are estimated using regression analysis. Estimating the rule improves the ability of the rule to provide recommendations that replicate historical funds rate settings. Goodness of fit is measured using the average of the absolute deviations (that is, the mean absolute deviation) of historical federal funds rate settings from recommendations of estimated rules. In addition, the appropriateness of assumptions embedded in the rule specifications is discussed.

How well do recommendations from estimated rules fit past federal funds rate settings?

This section compares recommendations from estimated Taylor-type policy rules to historical settings of the federal funds rate. The following Taylor-type rule without smoothing is estimated:

$$\textit{funds rate}(t) = \textit{constant} + (1+\alpha) \times \textit{inflation}(t-1) + \beta \times (\textit{output gap}(t-1)). \quad (4)$$

In this expression, the equilibrium real rate and inflation target are subsumed in *constant*, α is the weight in the inflation gap adjustment factor, and β is the weight in the output gap adjustment factor.[40] For larger values of α, recommended funds rate settings are more responsive to deviations of inflation from the inflation target. For

Table 3

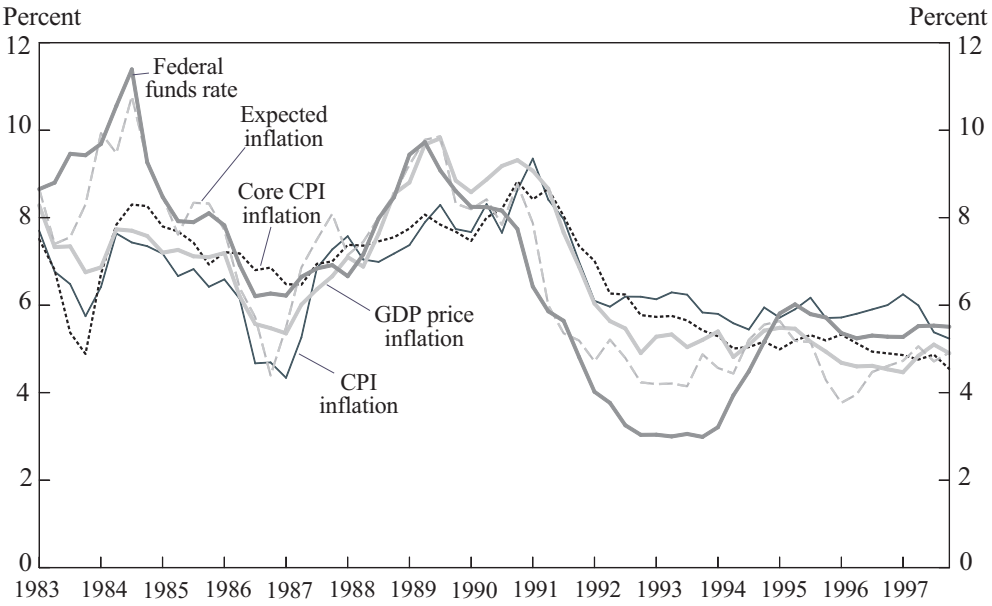
ESTIMATES OF WEIGHTS IN TAYLOR-TYPE RULES

1983 – 97

Output gap measure	Inflation measure	Inflation weight (α)	Output weight (β)	Mean absolute deviation
CBO	CPI inflation	.01	**-.01**	1.50
CBO	Core CPI inflation	.48	.14	1.30
CBO	GDP Price inflation	.88	.32	1.17
CBO	Expected inflation	**1.37**	.38	.70
OECD	CPI inflation	.01	-.02	1.50
OECD	Core CPI inflation	.42	.12	1.33
OECD	GDP Price inflation	.71	.29	1.23
OECD	Expected inflation	**1.21**	.36	.79
IMF	CPI inflation	-.06	.18	1.43
IMF	Core CPI inflation	.36	.22	1.29
IMF	GDP Price inflation	.65	.35	1.14
IMF	Expected inflation	**1.09**	.34	.75
DRI	CPI inflation	-.01	**-.10**	1.49
DRI	Core CPI inflation	.51	.10	1.31
DRI	GDP Price inflation	.94	.28	1.20
DRI	Expected inflation	**1.55**	.39	.68
Taylor	CPI inflation	-.12	.18	1.40
Taylor	Core CPI inflation	.28	.18	1.31
Taylor	GDP Price inflation	.53	.27	1.16
Taylor	Expected inflation	.99	**.26**	.80
Recursive	CPI inflation	.03	**-.10**	1.50
Recursive	Core CPI inflation	.41	**.00**	1.34
Recursive	GDP Price inflation	.70	**.13**	1.24
Recursive	Expected inflation	**1.31**	**.24**	.81

Note: Bold-face entries are significantly different from 0.5, the weight used by Taylor (1993).

Chart 6
RECOMMENDATIONS OF ESTIMATED TAYLOR-TYPE RULES FOR DIFFERENT INFLATION MEASURES AND THE CBO OUTPUT GAP



larger values of β, recommended funds rate settings are more responsive to deviations of real GDP from potential real GDP.

Estimates of *constant*, α, and β are chosen to minimize the squared deviations of the actual funds rate from the rule recommendation.[41] Estimates of α and β obtained using data for 1983-97 are provided in Table 3 for different measures of inflation and the output gap. Estimates obtained using data for 1987-97 are provided in Table 4. Boldface entries are significantly different from 0.5, the weight chosen by Taylor. In both tables, the final column reports the mean absolute deviation of the historical funds rate from recommendations of estimated rules.

Several results are apparent. First, recommendations from estimated rules do not fit historical policy very well. Second, estimated rules that use expected inflation fit historical policy best. Third, estimated weights are similar to the values assumed by Taylor.

The poor fits of estimated policy rules are evident in the sizable differences between rule recommendations and historical federal funds rate settings. With the exception of specifications that used expected inflation, the mean absolute deviation of rule recommendations from historical funds rate settings exceeded one percentage point (Table 3). And, although Taylor-type rules capture the late-1980s increase and subsequent early-1990s decrease in the federal funds rate, rule recommendations, including those based on expected inflation, typically deviate from historical policy for extended periods (Chart 6).[42] Deviations are pronounced in the early 1990s when rule recommendations decline by less than the actual funds rate. With the exception of rules that use expected inflation, recommendations are considerably lower than the actual funds rate

in the mid-1980s, and in the early-1990s rule recommendations decline roughly a year after the funds rate actually declined. And, recommendations from rules that use expected inflation rebound less than the actual funds rate in the mid-1990s.

Although none of the estimated policy rules fit historical policy well, rules that use expected inflation are closer to historical funds rate settings than rules that use other measures of inflation.[43] For each measure of the output gap, the mean absolute deviation of rule recommendations from actual policy is smallest for specifications that use expected inflation (Table 3). This result provides some evidence to suggest that, over the period examined, monetary policy may have been forward- looking.[44] Comments by policymakers support this interpretation. For instance, Chairman Greenspan (1988) commented that for much of 1987, "Federal Reserve policy leaned in the direction of countering potential inflationary tendencies in the economy." And, in a speech on April 24, 1997, Governor Meyer remarked that the 0.25-percentage-point increase in the federal funds rate target on March 26, 1997 was a preemptive one—"undertaken not in response to where the economy and inflation [were] at the time of the policy change, but in response to where the economy and inflation [were] projected to be in the future, absent a policy change."

The third result suggests that weights implemented by Taylor may be empirically justified. When estimated over 1983-97, estimates of weights are, in most cases, insignificantly different from the 0.5 settings assumed by Taylor. However, results are somewhat sensitive to the estimation sample period.[45] Estimates of the weight in the output gap adjustment in Table 3 are insignificantly different from the Taylor weight of 0.5, but all point estimates are smaller than 0.5. When estimated over 1987-97, however, point estimates of the weight in the output gap tend to be larger than 0.5, and in most cases, significantly so. Similarly, although estimates of the weight in the inflation gap adjustment in Table 3 are insignificantly different from 0.5 for all measures of inflation except GDP price inflation, and in most cases significantly larger than 0.5 for GDP price inflation, results differ when estimated over 1987-97. In particular, as shown in Table 4, estimates of the weight on GDP price inflation are significantly larger than 0.5 for only the DRI output gap, and estimates of the weight on the inflation gap are frequently significantly smaller than 0.5 for the other measures of inflation.

A disturbing aspect of the estimates in Table 4 is the frequent appearance of negative inflation weights. Since the negative inflation weights occur for only a subset of inflation measures and output gap measures, these estimates might signal that the corresponding measures of inflation or output gaps do not bear close resemblance to measures used by policymakers. Alternatively, these estimates might signal that the actual policy decision-making process diverged considerably from the simple rules examined in this article. This issue is discussed in more detail later in this section.

Do estimated rules with smoothing fit past policy settings better?

The Taylor-type rules examined so far implicitly assumed that policymakers do not smooth funds rate adjustments. This section examines whether recommendations fit past policy settings better when rules are generalized to incorporate smoothing. In addition, estimates of the degree of smoothness are compared to Taylor's implicit setting of zero.

The following Taylor-type rule without smoothing is estimated:

$$\textit{funds rate (t)} = \rho \times \textit{(funds rate (t-1))} + (1-\rho) \times \textit{(unsmoothed target(t))}$$

$$\textit{unsmoothed target (t)} = \textit{constant} + (1+\alpha) \times \textit{inflation(t-1)} + \beta \times \textit{(output gap(t-1))}. \quad (5)$$

Table 4

ESTIMATES OF WEIGHTS IN TAYLOR-TYPE RULES

1987 – 97

Output gap measure	Inflation measure	Inflation weight (α)	Output weight (β)	Mean absolute deviation
CBO	CPI inflation	**.82**	**-.10**	.79
CBO	Core CPI inflation	**1.05**	.40	.52
CBO	GDP Price inflation	**.92**	.33	.57
CBO	Expected inflation	**.73**	.82	.54
OECD	CPI inflation	**-.37**	**1.10**	.79
OECD	Core CPI inflation	**-.08**	**1.23**	.72
OECD	GDP Price inflation	**-.11**	**1.11**	.77
OECD	Expected inflation	.40	**.90**	.69
IMF	CPI inflation	**-.51**	**.90**	.60
IMF	Core CPI inflation	**-.38**	**.93**	.56
IMF	GDP Price inflation	**-.32**	**.89**	.55
IMF	Expected inflation	**-.03**	**.78**	.57
DRI	CPI inflation	**.09**	.60	.94
DRI	Core CPI inflation	.86	**1.01**	.65
DRI	GDP Price inflation	.68	**.82**	.69
DRI	Expected inflation	**1.29**	.66	.55
Taylor	CPI inflation	**-.76**	**.79**	.59
Taylor	Core CPI inflation	**-.82**	**.82**	.62
Taylor	GDP Price inflation	**-.71**	**.79**	.60
Taylor	Expected inflation	**-.54**	**.74**	.60
Recursive	CPI inflation	**-.39**	**.83**	.72
Recursive	Core CPI inflation	**-.10**	**.91**	.57
Recursive	GDP Price inflation	**-.08**	**.85**	.59
Recursive	Expected inflation	.37	**.71**	.55

Note: Bold-face entries are significantly different from 0.5, the weight used by Taylor (1993).

Table 5

ESTIMATES OF WEIGHTS IN FORWARD-LOOKING TAYLOR-TYPE RULES WITH SMOOTHING

1983-97

Output gap measure	Inflation weight (α)	Output weight (β)	Degree of smoothing (ρ)	Mean absolute deviation
CBO	1.42	.49	**.76**	.34
OECD	1.22	.51	**.80**	.36
IMF	1.05	.42	**.79**	.36
DRI	1.66	.52	**.75**	.32
Taylor	.93	.28	**.82**	.37
Recursive	1.34	.32	**.81**	.36

Notes: Bold-face estimates of α and β are significantly different from 0.5, the weight used by Taylor (1993). Bold-face estimates of ρ are significantly different from 0, the degree of smoothing in the Taylor rule. Results are for expected inflation as a measure of inflation.

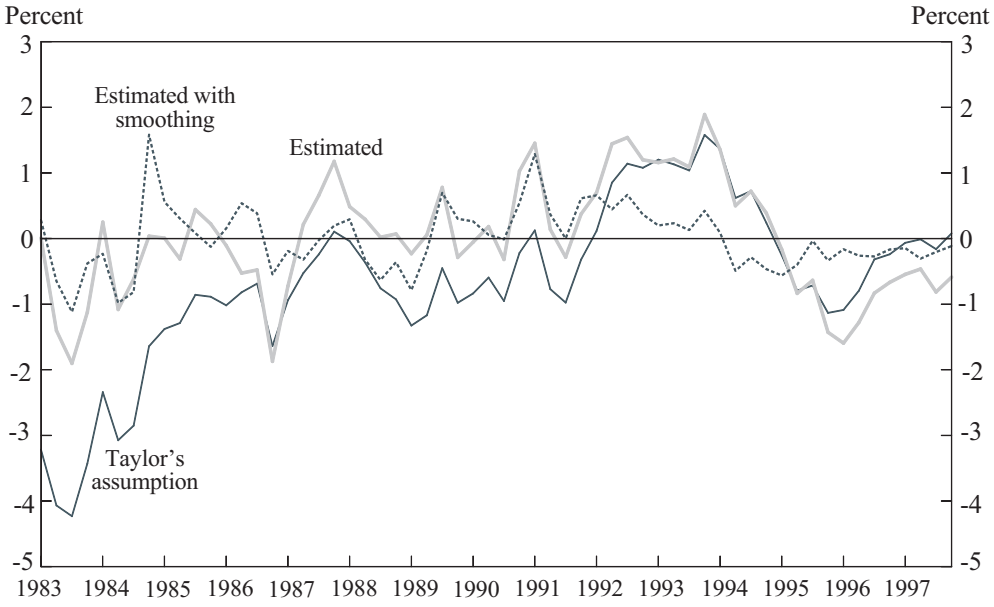
In this specification, ρ represents the degree of smoothness in policy decisions and, as before, the equilibrium real rate and inflation target are subsumed in *constant*, α is the weight in the inflation gap adjustment factor, and β is the weight in the output gap adjustment factor.[46] If the smoothness parameter ρ is set to zero, then the above specification simplifies to a Taylor-type rule without smoothing as in (4). As the smoothness parameter increases from zero to one, the rule recommends a smoother series of federal funds rate settings in the sense that changes in the recommended federal funds rate would occur more gradually.[47]

Estimates based on the 1983-97 sample are provided in Table 5 for expected inflation and the six measures of the output gap.[48] Bold-face estimates of α and β are significantly different from 0.5, the weight chosen by Taylor; and boldface estimates of ρ are significantly different from 0.0, the value implicitly assumed by Taylor.

Estimates of the degree of smoothness are significantly different from zero and suggestive of considerable smoothness in historical policy setting. Other results are broadly similar to those obtained without smoothing. Estimates of the weight in the output gap adjustment are insignificantly different from the Taylor weight of 0.5. And, point estimates of the inflation weight for expected inflation are generally larger than the Taylor weight of 0.5, although not significantly so.

The significance of the smoothness parameter is indicative of a related result. Recommendations from estimated forward-looking rules with smoothing fit historical funds rate settings better than estimated rules without smoothing. Mean absolute deviations in Table 5 are 40-50 percent lower than mean absolute deviations in the corresponding rows of Table 3. In other words, when inflation is measured using expected inflation, allowing for smoothing improves the fit of the rule recommendations by 40-50 percent.

Chart 7
DEVIATION OF RULE RECOMMENDATIONS FROM HISTORICAL POLICY



Note: Deviations are calculated as the rule recommendation minus actual policy. Rule recommendations use the CBO output gap and expected inflation.

Chart 7 shows how deviations of rule recommendations from historical policy are reduced when estimated policy rules account for smoothing of funds rate adjustments. Deviations of three rule recommendations from actual policy are illustrated. Deviations are calculated as the difference between a rule recommendation and actual policy with positive deviations occurring in periods where the rule would have recommended tighter policy. One recommendation corresponds to the rule recommendation with Taylor's weights and settings for the equilibrium real rate and inflation target (Taylor's assumptions), the second corresponds to the rule recommendation with estimated weights (Estimated), and the third corresponds to the rule recommendation with estimated weights and smoothing (Estimated with smoothing). All recommendations were calculated using the CBO output gap and expected inflation. Since recommendations based on other measures of inflation do not come as close to matching historical policy, Chart 7 provides a conservative view of the deviations.

Deviations based on the rule with Taylor weights are persistent and sizable. The rule would have recommended setting the funds rate roughly 3 percentage points lower over 1983-84, roughly 0.7 percentage point lower over 1988-91, roughly 1 percentage point higher over 1992-94, and roughly 0.7 percentage point lower over 1995-96. For the rule with estimated weights, persistent deviations of rule recommendations from policy are somewhat smaller and less frequent. For example, the rule with estimated weights would have recommended setting the funds rate roughly 1 percentage point higher over 1991-94, and roughly 0.8 percentage point lower over

1995-97. Persistent deviations are even smaller for the rule with estimated weights and smoothing. For instance, over 1991-93, the recommended funds rate settings exceed actual policy by only 0.5 percentage point over 1991-93. Although the general contours of rule recommendations appear to match those of actual policy, for the two rules without smoothing, deviations of rule recommendations from actual policy are economically significant.[49]

The results of this section are not overly supportive of the view that Taylor-type rules are reliable. With the possible exception of estimated forward-looking rules with smoothing, deviations of rule recommendations from actual policy tend to be sizable, persistent, and economically significant. However, perhaps an even more important question is whether a rule that happens to do a reasonable job at replicating the path of the funds rate historically also does a reasonable job at describing the policy decision-making process.

Do Taylor-type rules describe the decision-making process of the Federal Reserve?

If rule recommendations happen to match funds rate settings but do not capture the process by which the funds rate was set, then the ability of the rule to continue to match policy in the future is questionable.[50] The Taylor-type rules examined include an implicit assumption that federal funds rate settings were based on the output gap, deviations of inflation from the inflation target, and, possibly, the previous setting of the federal funds rate. Additionally, the equilibrium real rate and the inflation target were assumed to be constant. If any of these assumptions are not valid, then estimated policy rules may misrepresent the decision-making process.

In fact, according to testimony and speeches by members of the Federal Reserve Board, these assumptions are questionable. On many occasions, monetary policy decisions appear to have been influenced by economic events not well summarized by inflation and the output gap. Then-Chairman Volcker, in July 1985 suggested that monetary policy actions had been influenced by strength in the foreign exchange value of the dollar.[51] Then in 1988, Chairman Greenspan noted, "the stock market crash of late October [1987] shifted the balance of risks, and the Federal Reserve modified its approach to monetary policy accordingly. In particular, [the Federal Reserve] took steps to ensure adequate liquidity in the financial system during the period of serious turmoil, and … encouraged some decline in short-term interest rates." (Greenspan, March 1988). Congressional testimony by Chairman Greenspan suggests that policy decisions during the 1989-93 period were driven, at least partially, by discretionary responses to financial strains.[52] More recently, Governor Meyer suggested that the three 25-basis-point reductions in the federal funds rate target made in the second half of 1998 were not justified by typical Taylor rule prescriptions (Meyer 1999). Rather, he claimed these changes in policy were in response to dramatic financial market turbulence following the Russian default and devaluation and reduced confidence of some in the traditional model of inflation dynamics.

Additionally, comments by Governor Meyer in 1996 on opportunistic monetary policy may be taken as suggesting that the inflation target may not have been constant (Meyer 1996). And, Vice Chairman Blinder has suggested that the equilibrium real rate is not a fixed number (Blinder).

As the Taylor-type rules examined in the previous section do not account for these aspects of policy, it is likely that the estimated policy rules may misrepresent the decision-making process. In particular, statements by policymakers suggest that often information and events outside the scope of Taylor-type rule specifications influence policy actions. Consequently, the reliability of Taylor-type rules is questionable.

IV. CONCLUSIONS

This article has focused on the usefulness of policy rules to policymakers as they decide how to adjust the federal funds rate. The article presents evidence to suggest that the usefulness of Taylor-type rule recommendations to policymakers faced with real-time policy decisions is limited. Rule recommendations are not robust to reasonable minor variations in assumptions, and their reliability is questionable.

Although recommendations from Taylor-type rules are likely to be of limited use to policymakers facing real-time policy decisions, Taylor-type rules may be useful to policymakers in other ways. One, because Taylor-type rules retain a simple structure and embed crucial aspects of monetary policy, they serve as a simple and easily understood starting point for thinking about monetary policy (Meyer 1999, October 1998, and 1997; Blinder). Two, they may provide a convenient communication tool for focusing policy discussions and for educating the public about some of the issues of concern to the Federal Reserve. And three, most forecasting models require analysts to specify a policy rule.[53] But, the simple structure of Taylor rules clearly has disadvantages, hiding the fact that many aspects of rule specification are subject to considerable uncertainty and ignoring the potential for discretionary responses to special circumstances.

APPENDIX A

This appendix provides more information on each of the six measures of the output gap considered in the article. In all cases, the output gap is expressed as a percent of potential real GDP, calculated by multiplying 100 times the natural logarithm of the ratio of real GDP to an estimate of potential real GDP:

output gap = 100 × Ln (real GDP/estimate of potential real GDP).

Real GDP is measured using the version of 1992 chained dollar real GDP available in December 1998. Differences in estimates of potential real GDP account for differences in the six measures of the output gap.

The *CBO* output gap was constructed using the Congressional Budget Office's estimate of potential output. CBO uses a production function approach to estimate historical values of potential output. The production function approach uses a neoclassical production function, combined with assumptions about the growth of the labor force and the rate of saving to determine how potential output will grow over the long term (Arnold).

The *OECD* output gap was estimated using an interpolated series for potential output. This potential output series was interpolated from a semiannual potential output series constructed from semiannual OECD estimates of the U.S. output gap and real GDP data. The semiannual output gap series obtained from the OECD is based on a potential output series estimated using a production function approach. Giorno, Richardson, Roseveare, and van den Noord (1995) provide more information on the OECD approach to estimating potential output. More information on the interpolation procedure is available from the author on request.

The IMF output gap also was estimated using an interpolated series for potential output. This potential output series was interpolated from an annual potential output series constructed from annual IMF estimates of the U.S. output gap and real GDP data. The original annual output gap series obtained from the IMF is based on a potential output series estimated using a segmented trend approach. This approach assumes that the rate of growth of potential output changes at specific structural points, but is constant between these points. De Masi (1997) provides more information on IMF estimates of potential output. More information on the interpolation procedure is available from the author on request.

The *DRI* output gap was constructed using Standard & Poor's DRI estimate of potential output. DRI also uses a production function approach to estimate historical values of potential output.

The *Taylor* output gap was constructed using a linear-trend estimate of potential output. The fitted value obtained in a regression of the natural logarithm of real GDP on a constant and linear time trend was used as the linear-trend estimate of potential output. The estimation used 25 years of data, extending from the first quarter of 1973 through the fourth quarter of 1997. This approach assumes that the rate of growth of potential output is constant over the estimation sample. This measure of the output gap is similar to that used by Taylor as he used a linear-trend estimate of potential output.

APPENDIX A - continued

However, because Taylor used a shorter sample and an earlier version of real GDP data, his estimates of the output gap would have differed from the so-called Taylor output gap series constructed for this article.

The *Recursive* output gap was constructed using a recursive linear-trend estimate of potential output. Recursive linear-trend estimates of potential output were based on a series of regressions. The estimate of potential output for a given quarter was the fitted value obtained in a regression of the natural logarithm of real GDP on a constant and linear time trend, using data over the 25 years ending in that quarter. For instance, the estimate of potential output in the second quarter of 1994 was obtained from the regression estimated using data from the third quarter of 1969 through the second quarter of 1994. Consequently, the Recursive and Taylor estimates of potential output are the same in the fourth quarter of 1997.

ENDNOTES

[1] The results of this article provide empirical support for the view, voiced by Taylor (1993), that operating monetary policy by mechanically following a specific policy rule is not practical.

[2] The Federal Reserve sets a target for the federal funds rate. However, the actual funds rate may differ from this rate on a day-to-day basis. Institutional details are provided in Meulendyke (1998), pages 42-48, and 52-56. See also Rudebusch (1995) and Bonser-Neal, Roley, and Sellon (1997). To simplify exposition, this article does not distinguish between the target of the funds rate and the actual funds rate.

[3] In general, a monetary policy rule describes a systematic process by which the central bank adjusts a variable it controls (or targets) as the economy fluctuates. This definition admits a huge array of possible policy rules given the multiple possible variables targeted or controlled by monetary policy and the preponderance of possible descriptors of the state of the economy. A list of variables that might be targeted or controlled by monetary policy may include the many measures of money and reserves, the discount rate, the federal funds rate, exchange rates, and monetary conditions indexes. The gold standard may be seen as an early example of a policy rule in which countries sought to maintain a fixed price of their national money in terms of gold. Friedman's (1967) prescription that the monetary authority adopt a policy of achieving a constant rate of money growth is another example of a policy rule. McCallum (1988) proposes a rule which would target the growth rate of the monetary base at the sum of 3 percent less the average growth rate of base velocity plus a fraction of the deviations of nominal GNP from the target path. Bryant, Hooper, and Mann (1993) examine four monetary policy regimes: a version of money targeting, nominal-income targeting, a regime that targets the sum of real GNP and the inflation rate, and a particular form of exchange-rate targeting. The short-term rate of interest rate was specified as the primary instrument for monetary policy in each regime. Meltzer (1996) proposes an adaptive rule for money growth to achieve zero expected inflation.

[4] The Federal Reserve does not have a specific numerical target for a particular measure of inflation. Rather, the Federal Reserve states its inflation goal as "achieving price stability."

[5] Then-Vice Chairman Blinder discussed four crucial aspects of the Taylor rule in remarks on January 10, 1996. The aspects of policy discussed in the text draw on this speech and on Meyer (1996, 1997, October 1998).

[6] To simplify the exposition, the label "Taylor" will henceforth refer to the original Taylor rule. The label "Taylor-type" will refer to rule specifications that are similar to the Taylor rule but that may include different assumptions.

[7] The Taylor rule recommends federal funds rate settings based on recent inflation and the output gap. For example, if inflation over the previous four quarters equaled 4 per-

cent and the output gap equaled 1 percent then the Taylor rule would recommend setting the federal funds rate at 7.5 percent. The federal funds rate is targeted to equal inflation over the previous four quarters (4 percent) plus the equilibrium real rate (2 percent) plus one-half of the inflation gap (0.5 times (4 percent-2 percent)) plus one-half of the output gap (0.5 times 1percent). Thus, in this example, the funds rate is targeted at 7.5 percent (4+2+0.5(4-2)+0.5(1)=7.5).

[8] The Bureau of Economic Analysis revises previously published estimates of the National Income and Product Accounts data annually. These revisions reflect source data that are more complete, more detailed, and otherwise more appropriate than data that were previously incorporated and may also incorporate methodological improvements and redefinitions of variables. Comprehensive revisions differ from annual NIPA revisions because of the scope of the changes and the number of years subject to revision. Comprehensive revisions incorporate: (1) definitional and classificational changes that more accurately portray the evolving U.S. economy, (2) statistical changes that reflect new and improved methodologies and incorporate new and revised source data, and (3) presentational changes. Some recent discussions of annual and comprehensive revisions can be found in the Donahoe (1996), Parker (1997), Seskin (1998), and Grimm and Parker (1998).

[9] Another approach is to use a forecast of the contemporaneous quarter data.

[10] Orphanides (1997) estimated Taylor-type rules over 1987-92 using ex post revised data and real-time data. Using Federal Reserve staff forecasts, he also investigated whether forward-looking specifications describe policy better than backward-looking specifications. Rudebusch and Svensson (1998) compare the properties of a collection of rules with varying weights in a small macroeconometric model of the U.S. economy. Judd and Rudebusch (1998) estimate Taylor-type rules for samples delineated by the terms of recent Fed Chairmen. Clarida, Gali, and Gertler (1998b) estimate forward-looking Taylor-type rules.

[11] Minutes from meetings held in early 1994 suggest that changes in the funds rate may have been smoothed in response to concerns of members of the FOMC about the impact of policy changes on financial markets. For example, the minutes of the FOMC meeting held on February 3-4, 1994, note: "In the course of the Committee's discussion, a number of members endorsed a policy move that would involve only a slight adjustment toward a less accommodative degree of reserve pressure. These members recognized that evolving economic conditions might well justify a somewhat greater policy adjustment. They believed, however, that even a slight move at this time was likely to have a particularly strong impact on financial markets because it would be the first policy change after a long hiatus and indeed the first tightening action in about five years." The minutes of the FOMC meeting held on March 22, 1994, note: "Many members noted that money market interest rates would have to rise by a relatively sizable amount from current levels, given underlying economic conditions, but a majority indicated a preference for another small move at this time. Many were concerned about a possible overreaction in financial markets that had become quite sensitive and volatile since early February."

[12] The differences between GDP price inflation measured using the GDP deflator and the GDP chain price index are small—less than 0.1 percentage point in any quarter during 1983-97.

[13] The output gap adjustment factor provides an indirect method to introduce forward-looking policy. As discussed earlier, because the output gap may signal future inflationary pressures, the output gap adjustment factor may be interpreted as representing forward-looking policy.

[14] Chairman Greenspan testified on May 27, 1994: "The challenge of monetary policy is to interpret current data on the economy and financial markets with an eye to anticipating future inflationary or contractionary forces and to countering them by taking action in advance." Governor Meyer (April 24, 1997) noted that he is "inclined to believe in the forward-looking approach and therefore in preemptive policy." Moreover, he justified forward-looking policy in his comments on March 16, 1998, that "[a] good reason for responding to forecasts of inflation is that the effects of monetary policy on the economy mostly occur about a year from now." In a discussion of monetary policy in Canada, Duguay and Poloz (1994) noted that a key implication of the interaction between policy objectives and mainstream views of how the economy works is that policy formulation must be forward-looking. Using Federal Reserve forecasts and preliminary data available at the time policy choices were made, McNees (1986) found evidence that monetary policymaking has been forward-looking as well as backward-looking. Orphanides (1997) used Federal Reserve forecasts of inflation to estimate forward-looking policy rules. Clarida, Gali, and Gertler (1998b) estimate forward-looking policy rules for pre- and post-1979. Clarida, Gali, and Gertler (1998a) report that Germany, Japan and the U.S. have pursued forward-looking monetary policy. Batini and Haldane (1999) use the Bank of England forecasting model to show that inflation-forecast-based rules confer some real benefits.

[15] Chairman Greenspan (1995) testified that "one factor in judging the inflationary risks in the economy is the potential for expansion of our productive capacity. If "potential GDP is growing rapidly, actual output can also continue to grow rapidly without intensifying pressures on resources. … Knowing in advance our true growth potential obvi-

ously would be useful in setting policy." Governor Gramlich (1998) commented: "For the Fed to lean against the wind of output gaps, it has to know what the output gaps are, and that too can become quite tricky as unemployment approaches its desired level." Governor Meyer, in remarks on April 9, 1998 noted that "there is some question about whether or not or, at least, to what degree the economy is operating beyond the point of sustainable capacity." Governor Ferguson (1998) discussed difficulties in assessing the amount of slack in the economy.

[16] The analysis does not include a forecast of the real output gap for several reasons. The main reason is that forecasts of the output gap are not readily available. For instance, forecast surveys, such as the Survey of Professional Forecasters, generally do not ask survey participants for their forecasts of either potential output or of the output gap. Orphanides (1997) constructed real-time forecasts of the output gap combining Federal Reserve staff forecasts of real GNP or real GDP and estimates of potential output.

[17] Taylor (1993) also suggested examining ranges of rule recommendations across different variants of a policy rule.

[18] Rather than setting the equilibrium real rate and inflation target to 2.0 percent, it may be more appropriate to choose settings that depend on the chosen measure of inflation, for instance. If settings for the equilibrium real rate and inflation target are allowed to vary with the chosen measure of inflation, then a narrower range of rule recommendations may be obtained.

[19] Taylor rule recommendations may differ somewhat from those in Taylor (1993). Rule recommendations in the chart are based on the version of data available in December 1998. Whereas Taylor use the GDP deflator to construct GDP price inflation, in the chart, rule recommendations used GDP price inflation constructed using the GDP chain price index. And, while the Taylor output gap used in the rule recommendations in the chart is constructed in a similar fashion to the output gap used by Taylor, the underlying real GDP data is different. This article uses a longer sample and a more recent version of real GDP data.

[20] Taylor examined the performance of the Taylor rule during the 1987-92 period.

[21] Kuttner (1992) comments that uncertainty in estimates of the output gap may mean that situations requiring policy action may not be recognizable until later on. He further suggests that frequently the best response to uncertainty is to adopt a wait-and-see attitude until more information becomes available.

[22] The average, maximum, and minimum widths of the range are not sensitive to the chosen measure of price inflation.

[23] The average, maximum, and minimum widths of the range are not sensitive to the chosen measure of the output gap.

[24] An alternative approach is to assume that the policy decisions were made according to the recommendations of a Taylor-type rule and estimate the equilibrium real rate as the value that would minimize the squared deviations of the actual funds rate from the rule recommendations. This approach would yield estimates that would differ according to sample period, inflation measure, inflation target, and output gap measure.

[25] All of the GDP-price-inflation estimates of the equilibrium real rate exceed the 2.0 percent setting chosen by Taylor. However, GDP and GDP price indexes have been revised considerably since Taylor wrote his article. Such revisions may have contributed to the difference between Taylor's setting and the estimates shown in Table 1.

[26] The ranges of rule recommendations shown in Charts 3 and 5 might narrow if rule recommendations use estimates of the equilibrium real rate based on the same measure of inflation as used in the rule rather than using the setting of 2.0 percent for all inflation measures.

[27] This difference obtains because the highest GDP-price-inflation estimate of the equilibrium real rate, at 3.44 percent, is roughly one percentage point higher than the lowest GDP-price-inflation based estimate of 2.40 percent.

[28] This difference obtains because the highest GDP-price-inflation estimate of the equilibrium real rate, 3.44 percent, is roughly 1½ percentage points higher than the Taylor setting of 2.00 percent.

[29] A more aggressive response of policy to the output gap is recommended by, for example, Ball (1997). More aggressive responses of policy to the inflation gap are considered by, for example, Batini and Haldane (1999) and Henderson and McKibbin (1993).

[30] Because different weights should be expected to prescribe different interest rate settings, the analysis in this section might be better described as an analysis of the *sensitivity* of rule recommendations to different weights.

[31] As in Taylor (1993), the real rate and inflation targets are set to 2.0 percent.

[32] Also reported are the minimum and maximum ranges.

[33] This is the average of the averages reported in Table 2.

[34] Lists of federal funds rate targets are given in Rudebusch (1995) and Bonser-Neal, Roley, and Sellon (1997).

[35] Also, for reference, Chairman Greenspan referred to the cumulative 2.5-percentage-point increase in the fed funds target in 1994 as a *very substantial* tightening of monetary conditions (May 8, 1997).

[36] Difficulties associated with the choice of inflation measure, estimates of the output gap, and estimates of the equilibrium real rate complicate policy decisions outside the framework provided by Taylor-type rules as well.

[37] This approach to evaluating reliability is based on comments by Taylor (1993): "If the policy rule comes so close to describing actual Federal Reserve behavior in recent years and if FOMC members believe that such performance was good and should be replicated in the future even under a different set of circumstances, then a policy rule could provide some guide to future decisions." Another approach would be to analyze the stabilizing properties of the rules in a model of the U.S. economy. The stabilizing properties of a collection of Taylor-type rules have been documented for a large collection of macroeconomic models of the U.S. economy (Levin, Wieland, and Williams 1998; Taylor 1999). But models are not reality. And typically, the relative performance of different rules changes across macroeconomic models.

[38] Of course, even if an estimated rule fits historical funds rate settings well, it might not provide "good" policy recommendations going forward.

[39] This article interprets a preference for flexibility as a willingness by policymakers to respond to information not encompassed by the output gap, the inflation rate, or the lagged federal funds rate when setting the federal funds rate. Other interpretations may exist.

[40] In this expression, the coefficient in front of inflation is equal to $(1+\alpha)$. To see why, note that the general Taylor-type rule, *funds rate(t) = inflation(t-1) + equilibrium real rate* $+ \alpha \times$ *(inflation(t-1) – target)* $+ \beta \times$ *output gap(t-1)*, can be rewritten as *funds rate(t) = equilibrium real rate* $- \alpha \times$ *target + inflation(t-1)* $+ \alpha \times$ *inflation(t-1)* $+ \beta \times$ *output gap(t-1),* or *funds rate(t) = constant* $+ (1 + \alpha) \times$ *inflation(t-1)* $+ \beta \times$ *(output gap(t-1)),* in which *constant = equilibrium real rate* $- \alpha \times$ *target.*

[41] It is impossible to identify estimates of both the equilibrium real rate and the inflation target from this specification. The constant equals the equilibrium real rate less the product of α multiplied by the inflation target.

[42] For reference, the mean absolute deviation of the actual funds rate from the Taylor rule recommendation as shown in Chart 3 is 1.26 percentage points.

[43] This result is somewhat sensitive to the estimation sample. For the 1987-97 sample and considering only those specifications where the estimated weight on inflation is positive, fit is better with expected inflation when the DRI output gap was used, but fit was comparable to that obtained using core CPI when the CBO output gap was used.

[44] McNees (1986) found evidence confirming that prior to 1987, policy was forward-looking with respect to inflation. Orphanides (1997) also found evidence suggesting that over 1987-92, simple forward-looking specifications described policy better than some alternative Taylor-type specifications.

[45] Because estimated weights are sensitive to the estimation period, so are rule recommendations. Consider, for instance, a comparison of rule recommendations for specifications that use the CBO output gap and expected inflation. Recommendations from rules estimated over the two estimation periods differ by between 1 and 4 percentage points in 1983-84 and by roughly a percentage point in 1990-91 and in 1997, although they are generally closer over most of the remaining years examined.

[46] Orphanides (1997), Clarida, Gali, and Gertler (1998b), and Sack (1998) model smoothing in a similar fashion. Judd and Rudebusch (1998) suggest a slightly different specification.

[47] The specification of the Taylor-type rule with smoothing can be interpreted as suggesting that the funds rate be changed from the previous funds rate by a fraction $1-\rho$ of the difference between the unsmoothed target and the previous funds rate. For values of ρ between zero and one, this interpretation implies that the funds rate will be partially adjusted in the direction recommended by the unsmoothed target.

[48] Results for other measures of inflation were not included for several reasons. First, interpretation of Taylor-type rules with smoothing is less obvious for values of ρ greater than one, and estimates of ρ were greater than one for core CPI inflation. Second, for values of ρ less than one but close to one, policy recommendations are dominated by the previous funds rate setting and it is difficult to estimate the weights in the inflation and output gaps with any precision. In fact, estimates of ρ were between 0.96 and 0.99 for CPI inflation and GDP price inflation, and, in these cases, standard errors on the estimates of the weights were huge (the smallest roughly 2, and the largest over 100). Finally, similar difficulties were obtained with other samples.

[49] Simulations of a funds rate shock in Brayton and Tinsley (1996) can be interpreted as suggesting that if the nominal funds rate is held roughly 0.6 percentage point higher for a year then, by the end of that year, the level of real GDP will

be roughly 0.5 percentage point lower. For rules without smoothing, persistent deviations of rule recommendations tend to be considerably larger than 0.6 percentage points and last at least twice as long.

[50] An example may help clarify why a rule that appears to fit well may not capture the process by which policy decisions are made, and may not be reliable in the future. Consider the policy rule in (5) with ρ set to one. The mean absolute deviation of the recommendations of this rule from historical policy is 0.4 percentage point—only a slightly worse fit than obtained using the estimated rules with smoothing. However, the rule would not be very useful to policymakers as it never recommends changing the federal funds rate from its current setting. The apparent "good fit" of the rule obtains because funds rate movements have tended to be gradual. As this rule allocates all past decisions to change the funds rate into an "unexplained" residual, the rule is not very reliable.

[51] In a statement on July 17, 1985, then-Chairman Volcker noted that "the potential effects of interest rates and decisions with respect to monetary policy on exchange rates and the external sector of the economy have necessarily been a significant ingredient in FOMC deliberations." Furthermore, he commented that "[FOMC] decisions with respect to providing reserves and reducing the discount rate have been influenced to some extent by a desire to curb excessive and ultimately unsustainable strength in the foreign exchange value of the dollar."

[52] On June 22, 1994, Chairman Greenspan testified that: "In the spring of 1989, we began to ease monetary conditions as we observed the consequence of balance-sheet strains resulting from increased debt, along with significant weakness in the collateral underlying that debt. Households and businesses became much more reluctant to borrow and spend, and lenders to extend credit—a phenomenon often referred to as the 'credit crunch.' In an endeavor to defuse these financial strains, we moved short-term rates lower in a long series of steps that ended in the late summer of 1992, and we held them at unusually low levels through the end of 1993—both absolutely and, importantly, relative to inflation."

[53] Because the evolution of the economy depends on past and expected future monetary policy decisions, most forecasting models require analysts to specify a policy rule. Many of the real world difficulties with Taylor-type rules disappear within a modeling framework. Because models are a simplification of reality, many models incorporate only a single measure of inflation. Furthermore, variables such as potential output and the equilibrium real rate, which are unobservable in the real world, are usually well-defined in models. Also, special circumstances that may have led policymakers to diverge from rule-type behavior in the past are usually outside the scope of model specification. Thus, many aspects of rule specification are less complicated when rules are to be used in models.

Although rule specification is simplified, interpretation of model forecasts or of model simulations based on those rules should be made cautiously. If rule specification deviates too much from the historical policy decision-making process, then economic responses to policy built into the model may be misspecified if these responses are estimated using responses to the historical policy process (Lucas 1976). Model forecasts are also likely to be inaccurate if, over the forecast horizon, policy is expected to diverge from rule recommendations, perhaps due to discretionary responses to special circumstances.

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