Estimated Rules for Monetary Policy

By George A. Kahn

Estimated policy rules describe how monetary policy has responded in the past to key economic indicators. Based on economic conditions and policy objectives, estimated rules can be used to evaluate past policy decisions and the outcomes of those decisions. In conjunction with "optimal" rules that economists derive from economic models and simple rules that approximate optimality in a range of models, estimated rules can help guide policymakers' assessment of the current stance of monetary policy and the appropriate path for policy.

But estimated rules are useful only to the extent they can describe policy choices that, in retrospect, turned out to be good or can help policymakers learn from policy choices that turned out to be bad. For example, if a period of favorable macroeconomic performance can be attributed to good monetary policy, policymakers may benefit from understanding what factors drove policy decisions over that period and by trying to systematically replicate that behavior. In contrast, if monetary policy actions led to unsatisfactory outcomes, policymakers should try to understand what went wrong and fix it.

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This article estimates policy rules over periods of favorable economic performance to derive benchmark rules that might be useful guides for future monetary policy. Section I describes two simple, non-estimated rules that have been proposed as guides for policy and examines how closely they describe the actual setting of policy over various periods. Section II identifies time periods over which macroeconomic performance has generally been favorable and estimates policy rules that describe how monetary policy responded to key indicators over these periods. Section III evaluates past and current policy relative to the estimated rule and gives a number of reasons why policymakers should remain cautious about blindly following any estimated rule.

The article concludes that a rule that puts somewhat greater weight on inflation than output in determining a setting for the federal funds rate has worked well in the past and could be a useful guide in the future. However, some of the unique features of the current economic situation—including a binding zero lower bound on interest rates and a desire to manage downside risk to the outlook for economic activity—may suggest a need for flexibility in following the prescription of any rule based on past performance.

I. SIMPLE RULES THAT HAVE PERFORMED WELL IN THE PAST

Central banks have long relied on rules to help guide monetary policy. However, the use of simple feedback rules that prescribe a setting for the policy interest rate as a function of a few key economic indicators accelerated sharply with the rule that Stanford University economics professor John Taylor formulated in 1992 and published in 1993.[1] Since then, a number of variants have been proposed. Most of these rules recommend a setting for the federal funds rate—the interest rate banks charge each other for overnight loans of reserves and the rate that the Federal Open Market Committee (FOMC) targets—based on inflation relative to a target inflation rate and some measure of real economic activity. The surprising feature of these simple rules is how well many of them match the actual path of the federal funds rate.

The most well-known rule is the Taylor 1993 rule, which sets the federal funds rate as a function of inflation relative to a target of 2 percent and the output gap. The output gap is the difference between

real GDP and potential real GDP expressed as a percentage of potential real GDP. Given Taylor's parameterization, the rule can be written as follows:

$$ffr = 2 + p + .5(p - 2) + .5y \quad \text{1.A}$$
$$= 1 + 1.5p + .5y, \quad \text{1.B}$$

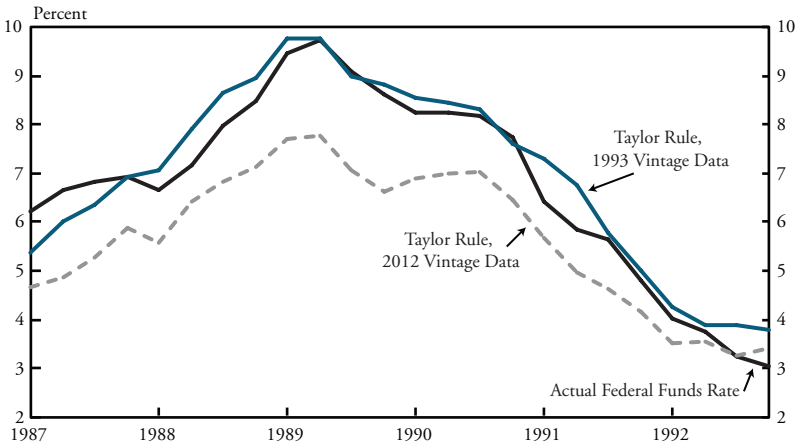
where *ffr* is the nominal federal funds rate, *p* is the inflation rate as measured by the GDP deflator, *y* is the output gap, and $(p - 2)$ represents inflation relative to its assumed 2 percent target. Thus, when inflation is at its target of 2 percent and real GDP is at potential $(y = 0)$, the rule says that the nominal federal funds rate should be set at 4 percent. According to Taylor, the equal weight of one-half for the coefficients on the deviation of inflation from target and output from potential captures "the spirit of the recent research [on interest-rate reaction functions] and … is quite straightforward" (Taylor 1993, p. 202). The equilibrium real federal funds rate—calculated as the nominal rate minus the target rate of inflation—was assumed to be a constant 2 percent.

The Taylor rule gained popularity for a number of reasons. It was simple and transparent. It aligned well with the Fed's dual mandate, balancing the goals of inflation and output stabilization. It anchored inflation over the long run at an assumed 2 percent rate. It approximated the "optimal" policy rule across a number of macroeconomic models. And, it called for an increase in the nominal funds rate by more than one-for-one in response to an increase in inflation, thus ensuring that the real funds rate would rise when inflation rose.[2] Such an increase in the real federal funds rate represents a tightening of monetary policy that puts downward pressure on inflation and over time returns it to its long-run target.

But to a great extent the appeal of the Taylor 1993 rule was also based on how closely it described the actual funds rate from 1987 to 1992—the period of Taylor's original analysis. This "perhaps surprising" result, as Taylor described it, was derived from the early 1990s vintage data available at the time of Taylor's analysis.[3] Based on these data, prescriptions from the 1993 Taylor rule do in fact closely match the actual federal funds rate. As shown in Chart 1, prescriptions of the rule (blue line) move closely in tandem with the actual federal funds rate (black line). This tight correspondence from 1987 to 1992

Chart 1

THE FEDERAL FUNDS RATE AND 1993 TAYLOR RULE PRESCRIPTIONS



Sources: Board of Governors of the Federal Reserve System, Bureau of Economic Analysis, Congressional Budget Office, and author's calculations.

replicates the data in the chart Taylor presented in his analysis. Given a judgment that macroeconomic performance over this period was favorable, economists and policymakers began to use the rule as a normative guide to monetary policy, as well as a description of how policymakers responded in the past to incoming data.

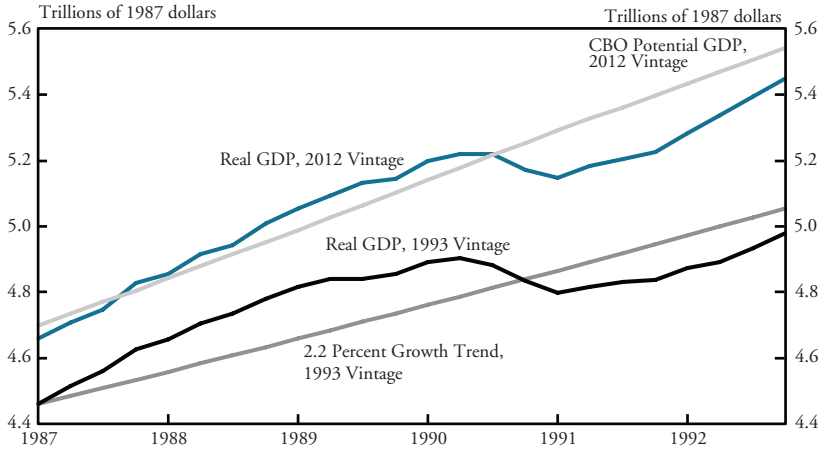
Since 1993, however, the data have undergone significant revision. The top panel of Chart 2 shows that potential real GDP growth is now estimated to have been faster, and the output gap is now estimated to have been somewhat less positive from 1988 to 1990 and somewhat more negative from 1991 to 1993.[4] The bottom panel shows that inflation as measured by the GDP deflator has been revised down from 1987 to 1993.

As a result, when the revised data are plugged into the 1993 Taylor rule, the close fit of its prescriptions to the actual FOMC setting of the federal funds rate target deteriorates. As shown by the dashed line in Chart 1, when 2012 vintage data are substituted for the earlier vintage data, the Taylor rule prescribes a uniformly lower funds rate than the actual funds rate. This finding, in turn, raises questions about whether the 1993 Taylor rule is a good guide for policy today given our current understanding of the data. In particular, if policy in the 1987 to 1992

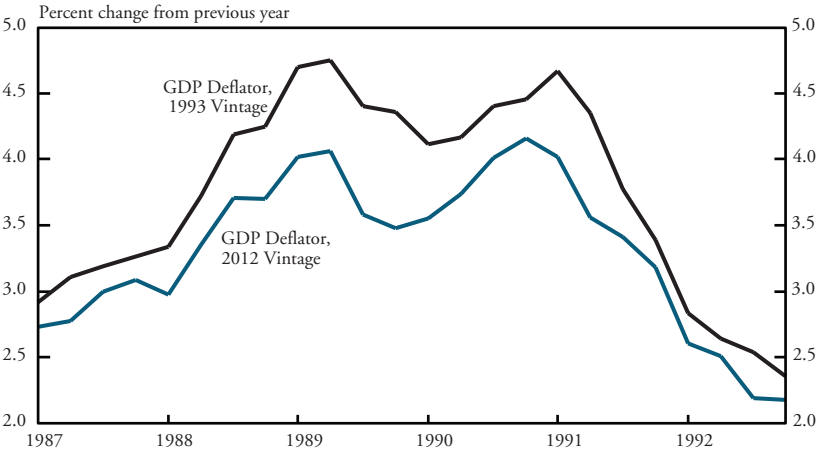
Chart 2

REAL OUTPUT AND INFLATION: DATA REVISIONS MATTER

A. Real GDP as measured in 1993 versus 2012



B. Inflation as measured in 1993 versus 2012



Note: The 2012 vintage of actual and potential real GDP was converted from chained 2005 dollars to 1987 dollars in order to be consistent with the measurement of real GDP in 1993.
Sources: Bureau of Economic Analysis, Congressional Budget Office, and author's calculations.

period is still considered to have been "good," replicating that policy rule today might require adjusting the parameters of the rule to better fit current vintage data.

An alternative to the Taylor 1993 rule—that some analysts have claimed better describes how the FOMC responds to economic conditions—is the so-called "Taylor 1999" rule:[5]

$$ffr = 2 + p + .5(p - 2) + 1.0y \qquad 2.A$$
$$= 1 + 1.5p + 1.0y \qquad 2.B$$

Taylor 1999 puts greater weight on the output gap (the coefficient on the output gap is 1.0 rather than 0.5) but is otherwise the same as Taylor 1993. The Taylor 1999 rule shares many of the characteristics of the Taylor 1993 rule. However, Taylor 1999 has been shown to better stabilize output and inflation in a variety of macroeconomic models than Taylor 1993. For example, Yellen (2012) shows that, in the Federal Reserve's FRB/US model, the Taylor 1999 rule more closely matches the optimal control path for the federal funds rate than the Taylor 1993 rule.[6] On the other hand, the 1993 rule puts less weight on the output gap which is unobservable and difficult to estimate in real time.[7]

Various statistics can be calculated to evaluate the relative fit of Taylor 1993 and 1999 to the data. These statistics measure the deviation of the actual federal funds rate from prescriptions of Taylor 1993 and Taylor 1999 over various sample periods that might be associated with "good" or "bad" monetary policy. The first period is 1987:Q1 to 1992:Q4—roughly the same as in Taylor's original analysis.[8] The second period extends Taylor's sample to 1997:Q4—just before the acceleration of stock prices in the dot-com bubble. The third period extends the sample to 2001:Q4—the trough of the 2001 recession. The fourth sample covers the expansionary period starting in 2002:Q1 and ending in 2007:Q4—a year before the federal funds rate target was lowered to its effective lower bound of zero to 25 basis points.[9] The fifth sample encompasses the complete business cycle from 1990:Q3 to 2001:Q1. The sixth sample runs from 1987:Q1 to 2007:Q4. And, for comparison with an earlier era of high and volatile inflation, a final sample covers the 1970s and early 1980s. All data are current 2012 vintage.

Table 1 shows that deviations of the actual federal funds rate from the prescriptions of the 1993 Taylor rule over these periods are generally

Table 1

DEVIATIONS OF THE FEDERAL FUNDS RATE FROM THE 1993 AND 1999 TAYLOR RULES

	Root Mean Square Error		Average Absolute Deviation		Cumulative Deviation	
	Taylor Rule 1993	Taylor Rule 1999	Taylor Rule 1993	Taylor Rule 1999	Taylor Rule 1993	Taylor Rule 1999
1987:1-1992:4	1.266	1.525	1.142	1.397	26.599	33.519
1987:1-1997:4	1.443	1.774	1.253	1.582	52.050	69.588
1987:1-2001:4	1.404	1.633	1.207	1.415	62.540	66.951
2002:1-2007:4	2.526	2.650	2.215	2.323	-53.162	-55.742
Peak to Peak 1990:3-2001:1	1.379	1.756	1.126	1.506	45.344	54.084
Full Sample 1987:1-2007:4	1.797	1.978	1.495	1.675	9.379	11.209
1970s and Early 1980s 1970:1-1982:4	3.944	4.246	3.477	3.682	-115.574	-86.840

Sources: Board of Governors of the Federal Reserve System, Bureau of Economic Analysis, Congressional Budget Office, and author's calculations.

smaller than deviations from prescriptions of the 1999 rule. For practically all periods and for all three measures of deviation—the root mean square error, average absolute deviation, and cumulative deviation—the 1993 Taylor rule prescriptions produce smaller deviations.[10]

The only exception is the 1970 to 1982 period when the 1999 rule had a smaller cumulative deviation. Under this measure, a rule would be deemed to "fit well" if past deviations are offset by deviations in the opposite direction in a later period. For example, a policy that is too accommodative over a given period, but is then too restrictive during a later period, can have a relatively small cumulative deviation. A large positive cumulative deviation would suggest that policy was persistently too "tight" relative to the rule's prescription, while a large negative cumulative deviation would suggest policy was persistently too "loose." Thus, according to either rule, policy was relatively loose on average in 1970-82 and 2002-07 and relatively tight in the other periods.

Another key finding from Table 1 is that deviations of either rule's prescriptions from the actual federal funds rate were considerably smaller in the late 1980s and throughout the 1990s than they were from 2002 to

2007 and from 1970 to 1982. For example, taking an average of the root mean square errors of the 1993 and 1999 Taylor rules yields a deviation of roughly 1.5 percentage points for the 1987-2001 period compared with a deviation of about 2.6 percentage points for the 2002-07 period. The average of the root mean square errors for the 1970-82 period was more than 4 percentage points. Thus, the actions of the FOMC followed the systematic behavior prescribed by the Taylor rules much more closely from 1987 to 2001 than in either the earlier or later period.

II. ESTIMATED POLICY RULES AND THE GREAT MODERATION

Although the simple rules described so far fit the data surprisingly well over a number of sample periods, *estimating* the parameters of the rules can provide an even better fit. Estimating the parameters over periods of "good" monetary policy has the added potential advantage of providing a better normative guide for monetary policy. Such estimated rules can help policymakers replicate the systematic response of monetary policy to inflation and output that, in the past, resulted in good macroeconomic performance. Under the premise that recent periods of good macroeconomic performance are at least partially attributable to good monetary policy, this section estimates simple rules over these periods and compares parameters from these rules to the parameters of Taylor 1993 and 1999.

Monetary policy in the Great Moderation

Estimating a rule that can serve as a guide to future monetary policy first requires identifying past periods of good monetary policy. The underlying assumption in the analysis is that the Great Moderation represents such a period in which good monetary policy contributed to favorable macroeconomic performance. The Great Moderation was a period of reduced volatility of inflation and economic activity in the United States beginning in the early 1980s. This period includes the three long expansions of 1983-90, 1991-2001, and 2002-2007 that were interrupted by two mild recessions in 1990-91 and 2001. The period may or may not have come to an end in late 2007 with the onset of the recent financial crisis and Great Recession. If the 2007-09 recession was the result of an unusually big and persistent shock with no

fundamental change in the monetary policy reaction function (other than the challenges associated with hitting the zero lower bound on nominal interest rates), the Great Moderation may resume. But this is an open question.[11]

Economists disagree about the causes of the Great Moderation. While some studies have found evidence that the Great Moderation was caused by good luck (Stock; Stock and Watson; Ahmed, Levin, and Wilson), others have argued in favor of structural change (McConnell and Perez-Quiros; Dynan, Elmendorf, and Sichel; Greenspan). Still others have shown that good monetary policy played a significant role (Benati and Surico; Bernanke 2004; Canova; Clarida, Gali, and Gertler; DeLong). Clearly, the U.S. economy experienced lower inflation and more stable output and employment during the Great Moderation than in the 1970s and early 1980s. One episode in particular points to the role of monetary policy in achieving this outcome. It is one of the few successful instances in which the Federal Reserve acted preemptively to staunch a possible buildup of inflationary pressures. Specifically, in 1994-95, the Federal Reserve raised its target for the federal funds rate by 3 percentage points as real economic indicators suggested a likelihood that inflation would begin to rise in the absence of such action. The FOMC's policy action preemptively stopped a rise in inflation and did so without causing a recession (Goodfriend, p. 194).

As shown in the previous section, the Great Moderation was also associated with much smaller deviations in the federal funds rate from simple Taylor rule prescriptions than the 1970s and early 1980s. The large Taylor rule deviations before 1983 were associated with high and volatile inflation and the deep recessions of 1973-75 and 1981-82. To the extent monetary policy contributed to this poor macroeconomic performance, policymakers would not want to repeat the actions that contributed to this outcome. Specifically, they would not want to replicate their 1970s-era responses to output and inflation.

While most economists agree that the Great Moderation continued at least until the start of the financial crisis, they disagree about whether monetary policy remained "good" throughout the period. Despite low and stable inflation and a long continuous expansion, the decade of the 2000s was marked by volatility in commodity prices, a possible buildup of financial imbalances stemming from persistently

low interest rates, and the development of the housing bubble. Some economists, including Taylor, have argued that the Federal Reserve kept interest rates too low for too long in the lead up to the financial crisis, contributing to the housing bubble and subsequent housing bust (Taylor 2007; Kahn 2010). And indeed during this period, as shown by the cumulative deviation column in Table 1, the actual federal funds rate remained persistently below the prescriptions of both Taylor 1993 and 1999. Others, including Federal Reserve Chairman Ben S. Bernanke (2010), disagree that monetary policy was to blame. Given the disagreement and uncertainty about the role of monetary policy in fostering financial imbalances from 2002 to 2007, the analysis omits this period from the samples considered representative of "good" monetary policy.

Three periods of favorable macroeconomic performance are examined under the assumption that they were associated with "good" monetary policy. All begin in 1987:Q1, the beginning of Taylor's sample and safely within the period of the Great Moderation. They end in the fourth quarters of 1992, 1997, and 2001. The 1987-92 period is roughly that of Taylor's original analysis. The 1987-97 period ends before the buildup of the dot-com stock market bubble and the housing boom. The 1987-2001 period includes the dot-com bubble (see Kahn 2010), but excludes the housing boom. In all periods, real output was close to trend. And inflation, which fell through much of the first period, stabilized at a rate close to 2 percent from 1992 to 2001.

Estimated rules

The initial approach to estimating policy rules is to follow Taylor's 1993 specification of variables as closely as possible. Thus, the inflation rate is measured as the 4-quarter percent change in the GDP price deflator, and the output gap is defined as the percent deviation of real GDP from a smooth trend. While Taylor used a 2.2 percent growth trend for real GDP, the analysis here uses the Congressional Budget Office estimate of potential real GDP as the trend.

All rules are estimated using current vintage data as opposed to "real-time" data; that is, data available to policymakers at the time decisions were made. The purpose of the analysis is not to evaluate past policy decisions, which would require the use of real-time data, but rather to examine how policymakers could replicate the outcome of

policy decisions in earlier periods given our understanding of the data today.[12] Again, the underlying assumption is that policy was good during all of the periods considered. Thus, by using the estimated rule to help guide responses to future deviations of inflation from target and real GDP from potential real GDP, policymakers may be able to replicate the good macroeconomic performance of the earlier periods.

Table 2 shows the parameters of a simple policy rule estimated over the three periods and compares them with the parameters of the Taylor 1993 and 1999 rules. The first row of the table gives the implied estimate of the equilibrium real federal funds rate under the assumption that the Fed's implicit inflation target over each period was a constant 2 percent.[13] The equilibrium real rate is the inflation-adjusted nominal federal funds rate associated with an inflation rate of 2 percent and a level of real GDP equal to potential real GDP. It is determined by real economic conditions rather than monetary policy. In contrast to the assumption of a 2 percent equilibrium real rate in the Taylor 1993 and 1999 rules, the equilibrium rates in the estimated rules range from 2.7 percent to 3.5 percent. Thus, based on current vintage data, a higher value of the equilibrium real rate would be required in a simple rule to replicate the policy path of the funds rate from 1987 to 2001.

The second row of the table shows the coefficient on the deviation of inflation from the assumed 2 percent target. In two of the three samples, the estimate is very close to the 1.5 coefficient in the Taylor 1993 and 1999 rules. In the first sample, however, the coefficient is closer to 2 than 1.5. Importantly, in all cases, the estimates are above 1. As a result, when the inflation rate increases, other things equal, all of the estimated rules prescribe that the funds rate be raised by more than the increase in inflation. This response of the funds rate to inflation ensures that policy is tightened—that the real federal funds rate rises—when inflation rises above target.

The third row of the table addresses the question of what weight to place on the output gap in simple rules—the key distinction between Taylor 1993 and Taylor 1999. In the estimated rules, the coefficients fall between the Taylor 1993 and Taylor 1999 coefficients. At the low end, over the period from 1987 to 2001, the coefficient is 0.6—comparable to Taylor 1993. At the high end, from 1987 to 1997, the coefficient is roughly 0.8—closer to, but still below, Taylor 1999.

Table 2

ESTIMATED POLICY RULES VERSUS THE 1993 AND 1999 TAYLOR RULES

	Estimated Policy Rules				
	1987:1-1992:4 (1)	1987:1-1997:4 (2)	1987:1-2001:4 (3)	Taylor Rule 1993 (4)	Taylor Rule 1999 (5)
Equilibrium real federal funds rate ($\hat{r}$)	2.682*** (0.426)	3.497*** (0.298)	3.036*** (0.304)	2.0	2.0
GDP deflator inflation gap ($\hat{\beta}$)	1.907*** (0.247)	1.387*** (0.198)	1.533*** (0.218)	1.5	1.5
GDP output gap ($\hat{\gamma}$)	0.690*** (0.043)	0.792*** (0.105)	0.558*** (0.126)	0.5	1.0
R-square	0.9518	0.8436	0.7067		
Standard Error	0.4433	0.7657	0.9602		
Observations	24	44	60		
Average GDP deflator inflation	3.315	2.724	2.466		

***Significant at 1 percent level.

Notes: The equations were estimated under the assumption that the target inflation rate was 2 percent. This assumption allows the constant term to represent an estimate of the equilibrium real interest rate. Specifically, the regressions took the following form:

$$ffr_t - 2 = \hat{r} + \hat{\beta}(p_t - 2) + \hat{\gamma} y \text{ , which is equivalent to:}$$

$$ffr_t = \hat{r} + p_t + (\hat{\beta} - 1)(p_t - 2) + \hat{\gamma} y.$$

The coefficient on $(p_t\text{-}2)$ gives the response of the nominal federal funds rate to an increase in inflation. Newey-West robust standard errors given in parentheses.

Sources: Board of Governors of the Federal Reserve System, Bureau of Economic Analysis, Congressional Budget Office, and author's calculations.

In general, except for the higher equilibrium real rate—in effect a bigger constant term in the regressions—the parameters of the estimated rules are close to those of Taylor 1993 and 1999. Of course, the estimation procedure (ordinary least squares) chooses parameters to minimize the sum of square differences between the actual funds rate and that predicted by the estimated rules. As a result, the prescriptions from the estimated rules deviate less over the estimation period from the actual funds rate than Taylor 1993 or Taylor 1999.

Using the parameter estimates from the 1987-2001 period and rounding them to the nearest tenth yields a rule that says the funds rate should be set at 3 plus the inflation rate plus 0.5 times the deviation of inflation from its target rate plus 0.6 times the output gap. Equivalently and more simply, the estimated rule suggests the funds rate be set at 2 plus 1.5 times the inflation rate plus 0.6 times the output gap:

$$ffr = 3 + p + .5(p - 2) + .6y \quad 3.A$$
$$= 2 + 1.5p + .6y. \quad 3.B$$

In summary, the simple estimated policy rule is similar to Taylor 1993 but with a higher constant term and a slightly higher coefficient on the output gap.

III. PRESCRIPTIONS AND CAVEATS

The estimated policy rule can be used to evaluate monetary policy since 2001. The evaluation is based on our knowledge of the data today, not on the data available to policymakers at the time. Thus, it is not a critique of past policy decisions that were made in real time. Rather, the actual path of the federal funds rate is compared with a hypothetical path based on a response of the funds rate to output and inflation similar to that from 1987 to 2001, but given current vintage data. In addition, the analysis shows how policymakers would need to respond to incoming information on inflation and output today if they wanted to duplicate the policy responses estimated from 1987 to 2001.

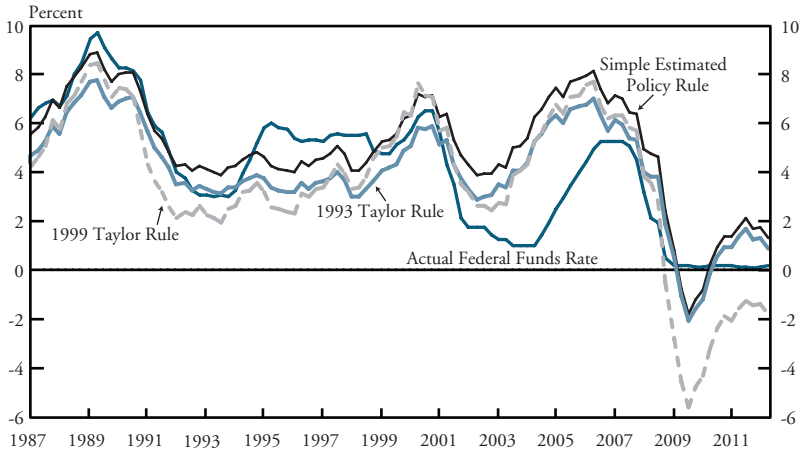
The analysis is subject to a number of important caveats. First, policy prescriptions depend on the specification of the estimated rule and the time period of "good" macroeconomic performance on which the estimates are based. Second, the estimated rule does not account for the zero lower bound on nominal rates. Third, the equilibrium real federal funds rate may not be constant. Fourth, monetary policymakers may want to take other factors besides inflation and output into account in setting monetary policy. These other factors might include financial conditions and risk management.

Policy evaluation

Chart 3 compares the actual path of the federal funds rate with prescriptions from the estimated policy rule (3.B) and the two non-estimated Taylor rules (1.B and 2.B). Not surprisingly, the estimated rule closely follows the actual funds rate over the estimation period from 1987 to 2001. In addition, it prescribes a higher funds rate—a tighter policy—than either Taylor 1993 or Taylor 1999 over the same period. Nevertheless, prescriptions from the estimated rule fell below the actual funds rate from 1995 to 1999 and rose above the actual funds rate after 1999.

Chart 3

COMPARISON OF THE FEDERAL FUNDS RATE AND PRESCRIPTIONS FROM THE SIMPLE ESTIMATED POLICY RULE



Sources: Board of Governors of the Federal Reserve System, Bureau of Economic Analysis, Congressional Budget Office, and author's calculations.

In the post-estimation period, the prescribed federal funds rate deviated much further from the actual funds rate.[14] From 2002 to 2007, prescriptions from the estimated rule rose above the funds rate, reaching a high of roughly 8 percent compared with 5¼ percent for the actual funds rate. Similarly, prescriptions from Taylor 1993 and 1999 also rose above the actual funds rate, reaching a height of roughly 7 percent for Taylor 1993 and nearly 8 percent for Taylor 1999. These deviations suggest that, with 20/20 hindsight and current vintage data, policy may have been too easy over this period.

After 2007, prescriptions from the estimated policy rule, as well as the two Taylor rules, fell sharply and in close alignment with the actual federal funds rate. All three rule-based prescriptions reached zero in late 2008 at roughly the same time as the actual federal funds rate fell to near zero percent. And, all three rules prescribed a negative federal funds rate from 2009 to mid-2010 as the actual funds rate remained at its effective zero lower bound.

Prescriptions from the estimated and non-estimated rules again diverged during the subsequent recovery. As the actual federal funds rate remained near zero percent, the Taylor 1999 rule continued to

recommend a negative nominal funds rate, while the estimated rule and Taylor 1993 recommended tighter policies. Currently, both the Taylor 1993 rule and the estimated policy rule suggest that the federal funds rate should be near 1 percent—down from almost 2 percent in late 2011.

Important caveats

While this analysis suggests that monetary policy may have been too accommodative from 2002 to 2007 and may be too accommodative today, the analysis ignores several key issues. First, the evaluation of policy depends on the period over which the rule is estimated and its particular empirical specification. Periods that were assumed to represent "good" macroeconomic performance may have been due to good luck (smaller shocks) or structural change rather than good monetary policy. If so, rules that describe policy during those periods may not provide good policy prescriptions for other periods.

With respect to specification, the estimated rule used to evaluate policy after 2001 was based on Taylor's 1993 analysis that used the GDP deflator as the measure of inflation and the output gap as the measure of the level of economic activity. In contrast, the Federal Reserve's preferred inflation measure is the personal consumption expenditure (PCE) price index, and the Fed often uses the core PCE price index as a measure of the underlying inflation rate. Also, under its dual mandate for price stability and maximum employment, the Fed often focuses on the unemployment rate as a measure of economic slack rather than the output gap.[15] In addition, policymakers may choose to smooth fluctuations in the target federal funds rate by including a lagged funds rate in their reaction function.[16] Substituting these variables into an estimated rule results in different parameters and different policy prescriptions than the ones reported in Table 2 and Chart 3.

In particular, as shown in Table 3, coefficients on various measures of inflation and economic slack differ considerably depending on which measures are used. For example, when the core PCE inflation rate is substituted for the GDP price deflator, the coefficient on inflation in a rule estimated over the same samples as in Table 2 varies from 0.8 to 1.2—considerably lower than when the GDP price deflator is used to measure inflation. Moreover, in some samples and specifications, the coefficient falls below 1. In addition, the coefficient on the lagged

Table 3

ALTERNATIVE ESTIMATED POLICY RULES

	1987:1-1992:4		1987:1-1997:4		1987:1-2001:4	
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged federal funds rate ($\hat{\rho}$)		0.545*** (0.083)		0.547*** (0.057)		0.665*** (0.095)
Equilibrium real federal funds rate ($\hat{r}$)	3.666*** (0.828)	3.118*** (0.966)	3.497*** (0.185)	3.731*** (0.232)	2.945*** (0.194)	2.794*** (0.418)
Core PCE inflation gap ($\hat{\beta}$)	0.829** (0.349)	1.068** (0.485)	0.915*** (0.117)	0.788*** (0.136)	1.188*** (0.129)	1.245*** (0.244)
Unemployment rate gap ($\hat{\gamma}$)	-1.707*** (0.235)	-1.991*** (0.091)	-1.749*** (0.124)	-2.038*** (0.110)	-1.499*** (0.116)	-1.778*** (0.214)
R-square	0.9278	0.9782	0.9355	0.9810	0.8670	0.9380
Standard Error	0.5426	0.3051	0.4915	0.2699	0.6466	0.4453
Observations	24	24	44	44	60	60
Average unemployment rate	6.146		5.986		5.548	
Average core PCE inflation	3.966		3.139		2.733	

***Significant at 1 percent level. **Significant at 5 percent level.

Notes: The equations were estimated under the assumption that the target inflation rate was 2 percent. This assumption allows the constant term to represent an estimate of the equilibrium real interest rate. Specifically, the regressions took the following forms:

$$\textit{Columns}\ (1),\ (3),\ (5): ffr_t - 2 = \hat{r} + \hat{\beta}(p_t - 2) + \hat{\gamma}(u_t - u_t^*)$$

$$\textit{Columns}\ (2),\ (4),\ (6): \begin{cases} r_t^* = ffr_t - 2 = \hat{r} + \hat{\beta}(p_t - 2) + \hat{\gamma}(u_t - u_t^*) \\ ffr_t - 2 = \hat{\rho}(ffr_{t-1} - 2) + (1 - \hat{\rho}) r_t^* \end{cases}$$

The coefficient on (p_t-2) gives the response of the nominal federal funds rate to an increase in inflation. The unemployment gap, ($u_t - u_t^*$), is the difference between the unemployment rate, u, and the natural rate of unemployment, u*. Newey-West robust standard errors given in parentheses.

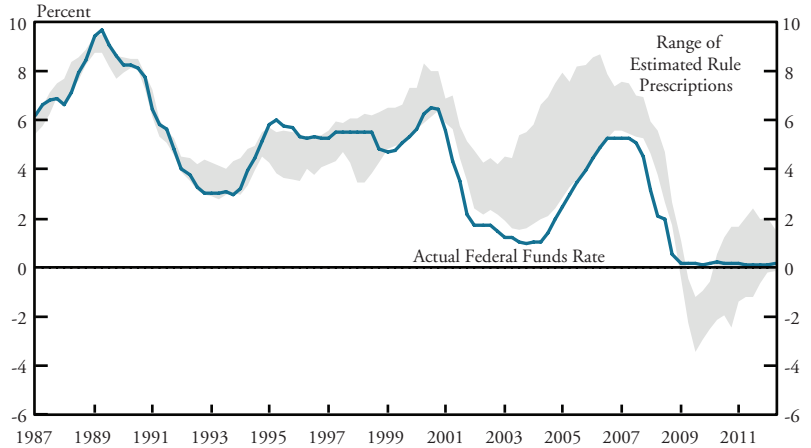
Sources: Board of Governors of the Federal Reserve System, Bureau of Economic Analysis, Bureau of Labor Statistics, Congressional Budget Office, and author's calculations.

federal funds rate is statistically significantly different from zero and its inclusion in the regression improves the fit of the estimated rule as measured by the R-square statistic.

Varying the specification of the estimated rule results in a range of policy prescriptions. As shown by the shaded area in Chart 4—which depicts the envelope of prescriptions from the nine estimated rules in Tables 2 and 3—policy prescriptions cover a relatively large range from 2002 to 2007. Nevertheless, the actual federal funds rate fell slightly below or touched the bottom of the envelope over the entire period. Moreover, the current policy prescription ranges from just below zero to just under 2 percent.

Chart 4

COMPARISON OF THE FEDERAL FUNDS RATE WITH PRESCRIPTIONS FROM ALTERNATIVE ESTIMATED POLICY RULES



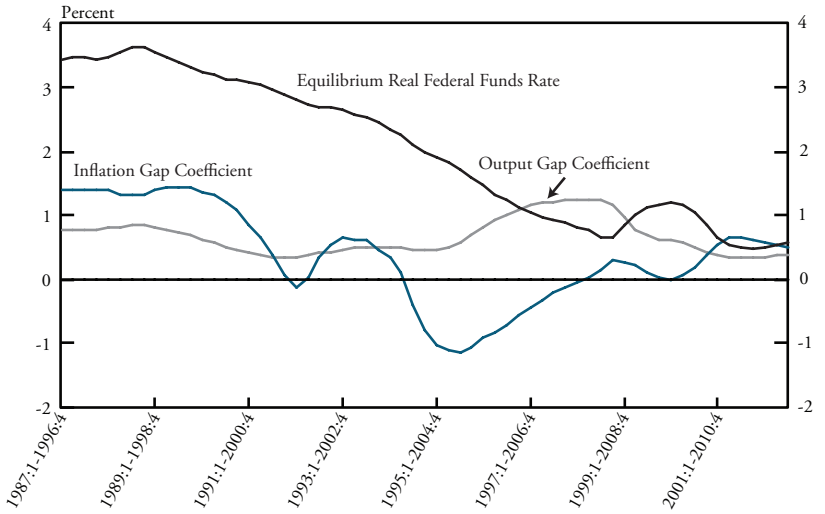
Sources: Board of Governors of the Federal Reserve System, Bureau of Economic Analysis, Bureau of Labor Statistics, Congressional Budget Office, and author's calculations.

A second caveat is that the estimated rules—as well as Taylor 1993 and 1999—disregard the possibility of getting stuck at the zero lower bound.[17] Following such a rule in a world where the zero lower bound is occasionally binding may cause the long-run inflation rate to persistently undershoot the inflation target and real output to undershoot potential. As a result, in the presence of the zero lower bound, prescriptions from a rule that fails to account for the zero bound might need to be adjusted downward or its implicit medium-term inflation target raised slightly.[18] Alternatively, policymakers may choose to lower the federal funds rate more aggressively than suggested by a rule *before* the economy hits the zero lower bound and raise it less aggressively than prescribed *after* hitting the zero lower bound. In this way, a period in which the funds rate is constrained by the zero lower bound can potentially be offset by a period in which the funds rate is kept lower than prescribed by a simple rule after the constraint of the zero bound is lifted (Reifschneider and Williams).[19]

A third caveat is that the equilibrium real interest rate may not be constant. As Yellen suggests, financial headwinds and the deleveraging process may have lowered the equilibrium real funds rate relative to the assumptions in Taylor 1993 and 1999 and relative to estimated

Chart 5

POLICY RULE COEFFICIENTS OVER 40-QUARTER ROLLING WINDOW REGRESSIONS



Sources: Board of Governors of the Federal Reserve System, Bureau of Economic Analysis, Congressional Budget Office, and author's calculations.

policy rules over the period from 1987 to 2001. As shown in Chart 5, the parameters of estimated policy rules vary over time, with the estimated equilibrium real interest rate (assuming a fixed 2 percent inflation target) falling from 3.5 percent in 1987-96 to 1 percent in 1997-2006. These estimates are based on rolling regressions over a 40-quarter window. Note also that the estimated coefficients on the inflation gap vary considerably and fall below 1 in 40-quarter sample periods starting after 1991. They fall below zero in samples starting in the mid-1990s.

A final caveat, pointed out by former Federal Reserve Vice Chairman Donald Kohn, is that policymakers may want to take other factors into account in setting policy in addition to inflation and output.[20] Kohn argues that

> "… the state of a complex economy like that of the United States cannot be fully captured by any small set of summary statistics. Moreover, policy is best made looking forward, that is, on the basis of projections of how inflation and economic

> activity may evolve. Lagged or current values of the small set of variables used in a given simple rule may not provide a sufficient guide to future economic developments, especially in periods of rapid or unusual change" (p. 177).

In a related point, Kohn argues that simple rules—estimated or otherwise—fail to provide a mechanism for policymakers to manage risk.

> "In some circumstances, the risks to the outlook or the perceived costs of missing an objective on a particular side may be sufficiently skewed that policymakers will choose to respond by adjusting policy in a way that would not be justified solely by the current state of the economy or the modal outlook for output and inflation gaps" (p. 178).

Kohn attributes the deviation of policy from the prescriptions of simple Taylor rules after 2002 to four factors. The first factor is the use of a headline inflation measure in the simple policy rule as opposed to a measure of core inflation. The second factor is the use of a particular estimate of the output gap in the simple policy rule as opposed to a measure of slack based on the unemployment rate. The third factor is the failure to recognize other influences on the economy, including "higher uncertainty about the financial health of firms" and a widening of credit spreads. Finally, Kohn argues that data available at the time suggested a risk of deflation. Under those circumstances, a risk management approach to monetary policy called for taking out insurance against the possibility of hitting the zero lower bound and falling into deflation.

IV. CONCLUSIONS

Estimated policy rules can provide a useful guide for monetary policy. The key consideration is to distinguish between episodes of good monetary policy and bad policy. The analysis in this article associates good monetary policy with periods of relative stability in output and inflation that occurred in the late 1980s through 2001. Reaction functions estimated over these periods of good monetary policy can be used to help guide policymakers' responses to incoming data on inflation and output.

A rule that places slightly more weight on inflation than on output closely describes the outcome of past policy decisions during periods

of favorable economic performance. Such a rule may serve as useful guidance again in the future. But current economic conditions are unusual in several ways, featuring a binding zero lower bound on interest rates and a potential need to manage downside risk to the prospects for growth. These circumstances may warrant a flexible approach to using any rule based on past performance. Nevertheless, as the economic recovery gains momentum and economic conditions return to a more normal state, policymakers may want to more closely follow the prescriptions of rules estimated over periods of more favorable macroeconomic performance.

ENDNOTES

[1]See Asso and Leeson for a history of the use of policy rules leading up to the Taylor rule.

[2]In addition, the Taylor rule put the federal funds rate on the left hand side, as opposed to a monetary or reserve aggregate. In doing so, the Taylor rule prescribed a setting for the primary instrument of policy in use at the Federal Reserve. The Taylor rule also addressed the issue of time consistency by defining policy as a systematic response to economic conditions as opposed to a period-by-period optimization problem with expectations taken as given. See Kahn (2012) for a discussion of how and why the Taylor rule came into widespread use in central banking.

[3]Data "vintage" refers to the latest available data at a given point in time. Because data are revised over time, later vintage data may differ from earlier vintage data.

[4]As shown in the chart, Taylor assumed a "steady state" or potential real GDP growth rate of 2.2 percent per year from 1984:Q1 to 1992:Q3. This growth rate was about the same as the Congressional Budget Office's 1993 vintage estimate of the average real potential GDP growth rate over the period.

[5]According to Taylor (1999), the 1999 rule is one that "others have suggested" and not his preferred rule. For example, Laurence Ball suggested a Taylor rule with greater weight on the output gap in a working paper published in 1997. (See Bryant, Hooper, and Mann for an earlier reference.) For ease of exposition, "Taylor 1999" is used here to designate a Taylor rule with greater weight on the output gap than the original Taylor 1993 rule. Yellen calls the Taylor 1999 rule a "balanced-approach" rule, but this terminology can be confusing. When expressed as a setting for the real federal funds rate by subtracting p from both sides of 1.A, Taylor 1993 puts equal weight on the inflation and output gaps. When expressed as in 2.A., Taylor 1999 puts greater weight on the output gap than on the inflation gap and is, therefore, not strictly "balanced."

[6]An optimal control path for the federal funds rate minimizes the policymakers' loss function, which in turn expresses how policymakers balance the cost of having inflation deviate from target with the cost of having real output deviate from potential real output. The optimal control path is computed in the context of a particular macroeconomic model and may not be robust across alternative models.

[7]Other Taylor-type rules base their policy recommendation on different measures of inflation—such as changes in the personal consumption expenditure (PCE) price index or in the core PCE price index—or on different measures of economic activity—such as the unemployment rate relative to the natural rate of unemployment or real GDP growth. Still other rules incorporate forecasts of inflation and economic activity on the right hand side based on the idea

that monetary policy operates with considerable lags and, therefore, needs to be explicitly forward looking. See Nikolsko-Rzhevskyy and Papell for a comparison of the original Taylor rule with various alternative specifications.

[8]Taylor's original sample ended in 1992:Q3.

[9]The sample ends in 2007:Q4 because the business cycle reached a peak in that quarter. The severity of the subsequent recession suggests a possible end to the Great Moderation. (See Clark for a discussion of whether the Great Recession means the Great Moderation is over.) In addition, in December 2008, the federal funds rate fell essentially to zero. Because the zero lower bound on interest rates prevents the funds rate from going negative, Taylor rule prescriptions calling for a negative rate cannot be implemented.

[10]The conclusion that the Taylor 1993 rule produces smaller deviations than the Taylor 1999 rule generally holds for specifications of the Taylor rule that incorporate alternative measures of inflation. For example, when the total Personal Consumption Expenditure (PCE) price index is used as the measure of inflation, Taylor 1993 produces smaller deviations by all measures and in all periods except for the cumulative deviation in the full sample and in the period from 1970 to 1982. When the core PCE price index is used, Taylor 1993 produces smaller deviations except for the average absolute deviation from 2002 to 2007 and the cumulative deviation from 1970 to 1982. When the total Consumer Price Index (CPI) is used as the measure of inflation, Taylor 1993 produces smaller deviations as calculated by the root mean square error and average absolute error in all of the samples. However, it produces larger cumulative deviations for most of the samples. In contrast, when the core CPI is used to measure inflation, deviations from Taylor 1993 are in most cases larger than deviations from Taylor 1999.

[11]Clark analyzes the increase in volatility associated with the beginning of the recession in late 2007. He concludes that "over time, macroeconomic volatility will likely undergo occasional shifts between high and low levels, with low volatility the norm" (p. 6).

[12]One potential problem with this approach is a possible inconsistency with expectations that were formed by the public in real time. An advantage of a credible policy rule is that it allows agents in the economy to form expectations about future policy that fully reflect the decision rules of policymakers. If agents form expectations based on real-time estimates of the parameters of a policy rule but policymakers revise those parameters as data revisions are made, then agents' expectations will no longer be consistent with the policy path. On the other hand, if agents understand that data revisions lead to changes in the parameters of a policy rule, then they may take those changes into account when forming expectations. In particular, they may re-estimate the policy rule that held during the reference period of good macroeconomic performance each time the historical data are revised. Going forward, agents and policymakers might form expectations about the current and future setting of the federal funds rate under the assumption that the current vintage data are unbiased predictors of the final revised data.

[13]Alternatively, the rules could be estimated under the assumption that the equilibrium real federal funds rate was equal to a particular value—say 2 percent as in Taylor 1993. Then, the implied inflation target could be estimated. Of course, neither assumption may be warranted—both the equilibrium real rate and the implicit inflation target could be different than assumed in Taylor 1993 and could vary over time. The regression analysis does not allow the separate estimation of an equilibrium real rate and an implicit inflation target without assuming a value for one of the two parameters.

[14]The analysis is static in the sense that it evaluates policy at each point in time without allowing an alternative setting of policy to affect future output and inflation. A dynamic analysis would allow the real economy to respond endogenously to the policy path.

[15]Whether the unemployment or output gap is used as the measure of slack in the economy, the natural rate of unemployment or the potential level of real GDP must be estimated. Coefficients and prescriptions will differ depending on how these variables are estimated. Because it is difficult to estimate the output gap in real time, some economists have suggested using the growth rate of real GDP as the measure of economic activity.

[16]Smoothing out changes in the target federal funds rate has the advantage of limiting possible policy reversals and the potential to allow changes in the funds rate target to have a larger impact on long-term interest rates through the expectations channel. See Rudebusch for a discussion of the rationale for and empirical evidence on interest rate smoothing.

[17]However, it is worth noting that the zero bound was not encountered until after policy deviated from the estimated policy rule.

[18]See Billi and Kahn for a discussion of the "optimal" inflation rate in the presence of an occasionally binding zero lower bound. They conclude that, in the context of a simple modern macroeconomic model, the optimal inflation rate is above zero but remains below 2 percent as measured by the PCE price index. The finding, though, is based on a number of simplifying assumptions. See also Reifschneider and Williams who conclude that economic performance "would likely deteriorate somewhat if the target rate of inflation were to fall below 1 to 2 percent" (p. 956), and Coenen, Orphanides, and Wieland who conclude that "the consequences of the zero lower bound are negligible for target inflation rates as low as 2 percent" (p. 14).

[19]This analysis ignores the possibility that, when the zero lower bound is encountered, the central bank can engage in unconventional policies such as large-scale asset purchases (also known as quantitative easing). If these tools are effective, they can to some degree offset the inability to ease policy through further reductions in the federal funds rate.

[20]Kohn also points out the issues of the choice of which measure of inflation to use and the need to estimate the equilibrium real interest rate and the level of potential real GDP.

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