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Measuring the Taylor Rule's Performance

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The Taylor rule has proven a reasonable guide to how the federal funds rate adjusts to economic developments.

In the Full Employment and Balanced Growth Act of 1978, Congress gave the Federal Reserve two goals: Keep inflation low and stable while promoting economic growth.[1] Financial markets, businesses, economic analysts and others expend considerable effort trying to fathom how the Fed attempts to meet its dual mandate.

One tool for understanding Fed policy is the Taylor rule, with its many variations. The brainchild of Stanford University's John B. Taylor, it relates output and inflation to the historical behavior of the federal funds rate—the Fed's most important policy lever—to show the general way the central bank responds to changing economic circumstances. The Taylor rule recognizes the Fed's two monetary policy goals, with rates rising to control inflation when it gets too high and falling to stimulate output and employment when the economy turns sluggish.

The Fed doesn't explicitly follow the Taylor rule or any other formula in making decisions. Instead, the Federal Open Market Committee studies a wide range of information to determine the best course of action. Nonetheless, the rule has proven a reasonable guide to how the federal funds rate adjusts to economic developments.

The Fed has taken steps in recent years to increase the transparency of its decisionmaking, hoping that clearer communication will improve the public's comprehension of its actions, thereby enhancing the economy's performance. In a similar way, the Taylor rule has contributed to better understanding of monetary policy by providing a general guide to how the Fed operates.

What makes a good Taylor rule? We addressed this issue by using a recently developed econometric technique to determine how the original rule and subsequent variations perform using different measures of inflation, output and unemployment. We found that the rule remains relevant today, despite the changes wrought by globalization, financial market innovations and technological advances.

Applying the Taylor Rule

A policy rule is just a predictable pattern of behavior, a characterization of how policy either does, or should, respond to changes in the economy.

The Taylor rule describes how a central bank tries to keep the economy in equilibrium—with inflation at the desired level and output at sustainable potential. If output is below the long-run trend, the rule calls for the Fed to cut interest rates. Cheaper credit would increase investment and purchases of consumer durables, bolstering output and eventually bringing the economy back to equilibrium. Similarly, if inflation rises beyond the desired level, the rule calls for an increase in interest rates, which would reduce investment and purchases of consumer durables. As aggregate demand weakens, inflation would fall, eventually returning the economy to equilibrium.

The Taylor rule operates by focusing on gaps between desired and actual levels of inflation and output. Weights measure the federal funds rate's sensitivity to changes in each of them (*see box*).

Since Taylor's initial formulation in 1993, economists have modified the rule in a number of ways, while preserving its essence. The original Taylor rule is backward looking in that it calls for federal funds rate changes to reflect past changes in inflation and output. In recent years, studies have found that the Fed also responds to *expected* inflation and output, so

A Formal Description of the Taylor Rule

The Taylor rule uses inflation and gross domestic product to predict changes in the federal funds rate. It's typically expressed as

$$i_t = r^* + \pi_t + \delta(\pi_t - \pi^*) + \omega(y_t - y_t^*),$$

where i_t is the federal funds rate at time t, r^* is the equilibrium real interest rate (usually treated as a constant 2 percent), π_t is the inflation rate, $(\pi_t - \pi^*)$ is the deviation of the inflation rate from its target level π^* (also usually 2 percent), and $(y_t - y_t^*)$ is the deviation of output (y_t) from its full-employment level, y_t^*.

The weights δ and ω indicate the sensitivity of federal funds rate changes to each of the two gaps—inflation and output.

The Taylor rule predicts that central banks will increase interest rates when inflation rises above the target level or output moves above its full-employment level, and vice versa.

Short-term interest rate: $i_t =$

Nominal interest rate component: $r^* + \pi_t$

The sum of the equilibrium real interest rate and the current inflation rate, this component defines the level at which the federal funds rate would settle were inflation stable at its target rate and output maintaining its full-employment level.

+

Inflation gap: $\delta(\pi_t - \pi^*)$

When inflation rises above its target level, the Fed raises the funds rate by a multiple of the difference. This action slows money growth, which reduces future inflation.

+

Output gap: $\omega(y_t - y_t^*)$

When output falls short of its full-employment potential, the Fed lowers the funds rate. This action stimulates economic growth, raising output toward its potential.

NOTE: Both y_t and y_t^* are typically converted to natural logs, so that $(y_t - y_t^*)$ represents the percentage by which output deviates from its full-employment level at time t.

newer, forward-looking versions of the Taylor rule have emerged.[2]

In addition to being backward looking, the original Taylor rule implies the Fed immediately adjusts interest rates to target levels, an unwarranted assumption. Gradualism allows the Fed to change rates in a series of small steps in the same direction, a process called interest rate smoothing. Some Taylor rule models account for this gradualism by including lagged values of the federal funds rate.[3]

Gradualism provides a way to exercise caution in policymaking because it allows central banks to assess their tactics and make necessary adjustments. By contrast, wholesale changes in the federal funds rate—an approach Fed Chairman Ben S. Bernanke once described as "cold turkey"—would only add to analytical and forecasting uncertainties.[4]

Even after incorporating gradualism into the Taylor rule, decisions remain about what inflation and output data to use.

Measurement isn't always straightforward. Different price gauges, for example, sometimes send different signals about how much inflation is heating up. In the second half of 2000 and early 2001, for example, the Consumer Price Index (CPI) ran 3–3.5 percent, while the Personal Consumption Expenditures index fell from 3 percent to 2 percent.

A similar imprecision plagues measures of slack—the gap between the economy's actual and potential output. Quarterly GDP figures are routinely revised, sometimes substantially, and potential output estimates depend on occasionally unreliable calculations about the capital stock, labor supply and productivity.[5]

Ambiguity can also be found in alternative slack measures, such as the non-accelerating inflation rate of unemployment, or NAIRU. By one estimate, we can be 95 percent sure the NAIRU was between 5.1 and 7.7 percent in 1990, a wide range that suggests the measure should be used with caution.[6] Economist Robert M. Solow calculated that in 1995, 1 percentage point of unemployment corresponded to about 1.25 million jobs, or about 2 percent of GDP. Small measurement errors can have serious policy implications, he concluded.[7]

Data revisions present a particular problem for the Taylor rule.[8] More complete information often leads to changes in inflation and output figures long after monetary policy actions have been taken. The new data may produce a different relationship between inflation, output and the historical federal funds rate.

Revisions' shifting signals can distort models' explanatory power, creating problems with evaluating their performance. For accurate comparisons, it's essential to use real-time data—information that would have been available to policymakers when they made their decisions.[9] Real-time data might be used more commonly in Taylor rule models if it weren't so difficult to find unrevised data sets.

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Modeling the Taylor Rule

To see what makes a good Taylor rule, we looked at six versions, each of which uses different data to determine the optimal federal funds rate (*Table 1*). The models included four early efforts—three by Taylor himself and one by Richard Clarida, Jordi Galí and Mark Gertler. Two others were of more recent vintage—a 2004 model from Dallas Fed economist Evan Koenig and a 2007 effort by Christian J. Murray, David H. Papell and Alex Nikolsko-Rzhevskyy.

Economists have developed other Taylor rule variations, but these were chosen as representative of the scope of the rule's evolution: from backward to forward looking, from cold turkey to gradualism, and from simple measures of inflation, output and unemployment to more complex ones.

Inflation measures used in Taylor rule models include:

- The GDP deflator, which tracks the month-to-month percentage change in prices of all new domestic goods and services.
- The Blue Chip forecast, an average of the inflation forecasts issued by 52 business economists.
- The CPI, which measures the monthly percentage change in prices of a fixed market basket of goods and services.

The output-gap measures are:

- The percentage by which GDP deviates from a straight-line growth path that's based on historical data.
- The difference between trend and actual GDP growth, using estimates from the Blue Chip forecast.
- The percentage by which industrial production deviates from a nonlinear growth path that's based on historical data.
- The current unemployment rate minus the natural rate, expressed as a five-year average of data from the Philadelphia Fed's real-time data set.

We used real-time data in assessing the models. Initial data are released with a one-quarter lag, which means we used the previous quarter's

Table 1

The Original and Five Variations on the Taylor Rule

Model	Input variables	Other characteristics
Taylor 1993	• GDP deflator • Output deviation from linear trend	Backward looking No interest rate smoothing Fixed weights
Taylor A	• GDP deflator • Output deviation from linear trend • Federal funds rate in previous period	Backward looking Uses interest rate smoothing Fixed weights
Taylor B	• GDP deflator • Output deviation from linear trend	Backward looking No interest rate smoothing Variable weights
Clarida, Galí and Gertler (CGG)	• Blue Chip inflation forecast • Deviation of log of industrial production from quadratic trend • Federal funds rate in previous period • Federal funds rate two periods earlier	Forward looking Uses interest rate smoothing Variable weights
Koenig	• Blue Chip inflation forecast • Current minus five-year moving average unemployment rate • Difference between trend and actual GDP growth as approximated by the Blue Chip GDP growth forecast • Federal funds rate in previous period	Forward looking Uses interest rate smoothing Variable weights
Murray, Papell & Nikolsko-Rzhevskyy (MPNR)	• GDP deflator • Deviation of GDP from quadratic trend • Federal funds rate in previous period	Backward looking Uses interest rate smoothing Variable weights

signals to predict each quarter's federal funds rate.

To evaluate the models, we first conducted a crude goodness-of-fit test to determine how close each of them came to predicting the actual federal funds rate—with 1 denoting a perfect fit and 0 a total failure.

To focus on recent trends, we used a recursive test, with quarterly data from the beginning of 1988 to the beginning of 2006. The procedure involved calculating how well each model depicts actual federal funds rate behavior for the initial 32 quarters, from the beginning of 1988 through the end of 1995—the first point in the graph for each model. We added first quarter 1996 to arrive at the second point and so on. We repeated the procedure until we reached first quarter 1988 to first quarter 2006—the last point.

Four of the models have goodness-of-fit values greater than 0.9 for all periods, suggesting they're reasonable guides to monetary policy (*Chart 1*). The Taylor 1993 and Taylor B versions perform well at the beginning of the period but then deteriorate, most likely because of the absence of a smoothing factor to allow for gradual interest rate changes.

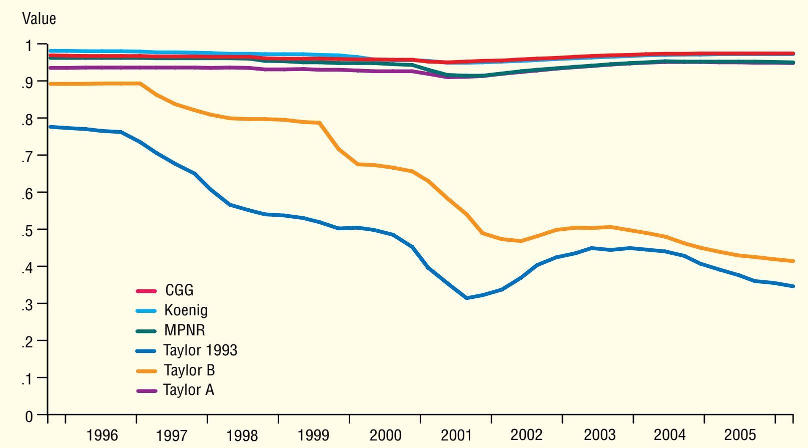
Goodness-of-fit tests evaluate each model on its own but don't compare them. Just as important, the technique implicitly assumes the models accurately specify—on an ongoing basis—the true relationship between the federal funds rate and measures of inflation, output and unemployment. We used a new econometric tool that allows us to relax this assumption and see whether some models perform better than others.

Side-by-Side Tests

In a 2007 paper, Raffaella Giacomini and Barbara Rossi outline an innovative analytical technique that recognizes models may not perfectly describe the economy and input data may have weaknesses.[10] The procedure eases the traditional requirement of calculating Taylor rule weights on inflation and output gaps over the whole sample. Failing to consider variations in the weights may prevent us from seeing relative changes in models' performance over time.

The Giacomini–Rossi test resolves this issue by using results from previous periods to calculate the optimal weights in each quarter, selecting the best model at every point in time.[11] Allowing the weights to vary might enhance—or detract from—any model's performance relative to the others. The Giacomini–Rossi test only allowed us to evaluate two models at a time.[12] For simplicity, we dropped Taylor's original 1993 model, the worst performer on the goodness-of-fit test.

Chart 1
How Well Taylor Rule Models Gauge the Federal Funds Rate



NOTES: In the goodness-of-fit test, 1 is a perfect match and 0 is total failure. Data are quarterly.

We conducted recursive Giacomini–Rossi tests to make our comparisons, which showed that Koenig's Taylor rule formulation performs best in all cases (*Chart 2*).[13] For graphical representation, we designated Koenig as the base model and compared it with four others from first quarter 1988 to first quarter 2006.

Following Giacomini and Rossi, we constructed upper and lower bands to tell us when we can be 90 percent sure one model outperforms another. The bands allow us to visually track the models' relative performance. Values above the upper band mean Koenig performs better than the competing model. Values within the bands mean the models perform equally well. And values below the lower band mean the competing model outperforms Koenig's version.

When it comes to predicting the federal funds rate, Koenig does a better job than Taylor A and Taylor B at every point. The Koenig model outperforms the Murray, Papell and Nikolsko-Rzhevskyy model most of the time, the exception coming in the second through fourth quarters of 2000, when the models perform equally well. The Clarida, Galí and Gertler model has the second-best results, being inferior to Koenig's through 1999 but performing equally well from 2000 onward.

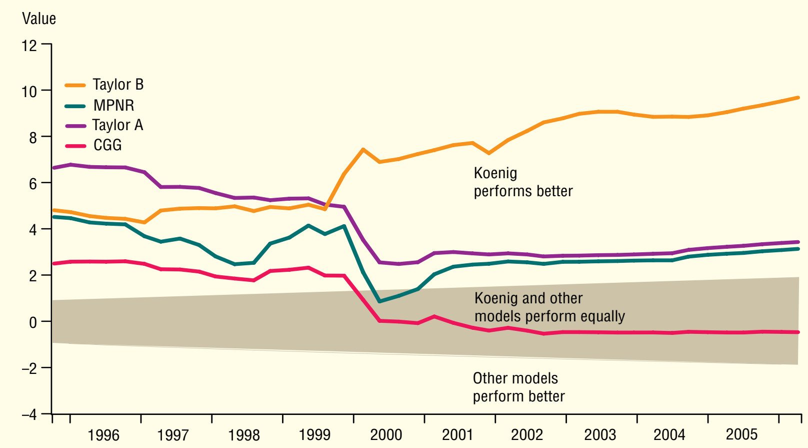
Koenig's model incorporates elements that do a better job of capturing the federal funds rate's history. But we can't be certain his model—or any other—accurately represents the behavior of the federal funds rate.

We know that Taylor rule performance can vary dramatically with different inflation and output gap measures. Comparing various input data in the same way we evaluated the six models may further explain why Koenig's Taylor rule outperforms the others.

For inflation, we looked at the GDP deflator, Blue Chip forecast and CPI. For a more complete analysis, we also included M1 and M2 money growth measures. We tested them because the Fed can influence interest rates through the money supply. M1 includes currency and checking account deposits. M2 broadens M1 by adding funds in savings, money market and similar accounts.

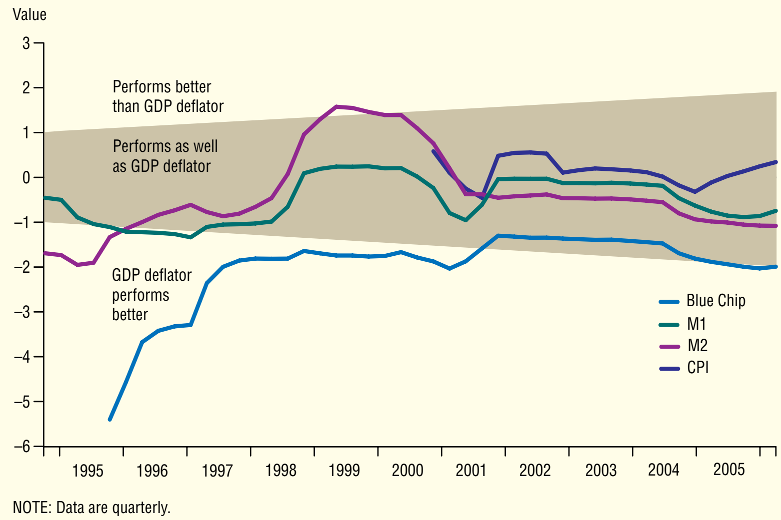
For this round of Giacomini–Rossi recursive tests, the base we chose wasn't the best performer but the GDP deflator—a widely used inflation measure.

Chart 2
Comparing Taylor Rules



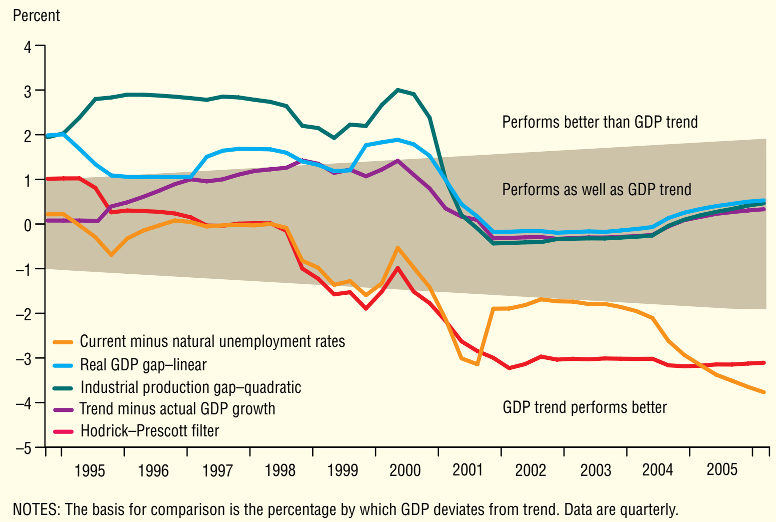
NOTE: Data are quarterly.

Chart 3
Comparing Inflation Measures



NOTE: Data are quarterly.

Chart 4
Comparing Output Gap Measures



NOTES: The basis for comparison is the percentage by which GDP deviates from trend. Data are quarterly.

The Blue Chip forecast lies below the 90 percent bands until 2001 and after 2005, and it does as well as the other models in the interim (*Chart 3*). The results give it an edge over the other inflation indicators in predicting the federal funds rate. In many periods, however, its superiority is only marginally significant.

Which output gap measure works best? In addition to the four concepts our selected Taylor rule models use, we considered two other approaches—the percentage by which GDP deviates from a path that varies over time and GDP growth filtered to remove large fluctuations.[14] The former served as our base (*Chart 4*).

Three output gap measures perform well on the recursive tests—the filtered GDP, the difference between the current and five-year moving average unemployment rates, and the spread between trend and actual growth in real GDP.

Koenig's Taylor rule model uses two of the output gaps that did best on the Giacomini–Rossi tests. It also employs the Blue Chip forecast, the superior performer for the inflation gap. These data no doubt contribute to its success tracking the federal funds rate over two decades. We concluded the Koenig model's superior performance stems both from its design and its choice of input variables.

Indeed, this model shows the power of the Taylor rule (*Chart 5*). Three data sets with little apparent relation to the federal funds rate, when combined with appropriate weights, have a remarkably good record tracking the Fed's policy decisions.

Our findings shouldn't be considered an endorsement of rules to determine monetary policy. The Fed operates with wide discretion, which provides greater freedom and flexibility in policymaking. Even so, the Taylor rule's predictive value should allow observers to better understand the forces that shape Fed actions. As a general guide, the Taylor rule diminishes the overall level of uncertainty in the economy and enhances the transparency of open market operations.

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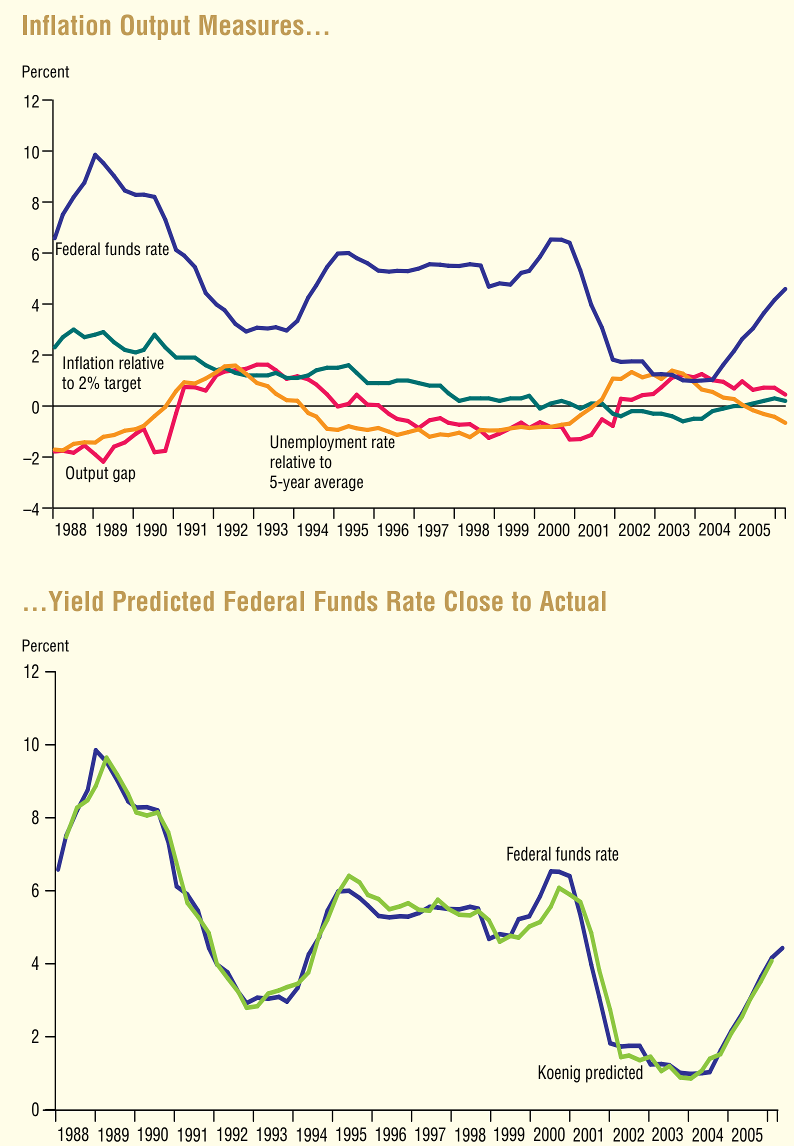
Chart 5
Koenig's Taylor Rule



NOTE: Data are quarterly.

Notes

The authors thank Amber Obermeyer for her research assistance. They will publish details on their methods and findings in an upcoming issue of the Dallas Fed's *Staff Papers*.

[1] While achieving maximum sustainable output over the long run requires keeping prices stable, occasional short-run conflicts between growth and inflation may arise.

[2] A number of papers have drawn attention to the importance of including expectations in interest rate rules. Among them are "Inflation Dynamics: A Structural Econometric Analysis," by Jordi Galí and Mark Gertler, National Bureau of Economic Research Working Paper no. 7551, February 2000; "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory," by Richard Clarida, Galí and Gertler, *Quarterly Journal of Economics*, vol. 115, February 2000, pp. 147–80; and "European Inflation Dynamics," by Galí, Gertler and J. David López-Salido, *European Economic Review*, vol. 45, no. 7, 2001, pp. 1237–70.

[3] The degree of smoothing indicates how gradually interest rates adjust. If we assume the value of this parameter is 0.8, as evidence in Clarida, Galí and Gertler (1998) suggests, the first move of the Fed to go from a rate of 5.25 percent to a target of 5.75 percent would be 5.35 percent. See "Monetary Policy Rules in Practice: Some International Evidence," by Clarida, Galí and Gertler, *European Economic Review,* vol. 42, June 1998, pp. 1033–67 .

[4] See "Gradualism," speech by Ben S. Bernanke at a luncheon co-sponsored by the Federal Reserve Bank of San Francisco–Seattle Branch, May 20, 2004, www.federalreserve.gov.

[5] "Obstacles to Measuring Global Output Gaps," by Mark A. Wynne and Genevieve R. Solomon, Federal Reserve Bank of Dallas *Economic Letter,* vol. 2, March 2007.

[6] "The NAIRU, Unemployment and Monetary Policy," by Douglas Staiger, James H. Stock and Mark W. Watson, *Journal of Economic Perspectives*, vol. 11, Winter 1997, pp. 33–49.

[7] Increases in the unemployment rate are associated with declines in real GDP. This well-studied inverse relationship is called Okun's law. See *Inflation, Unemployment, and Monetary Policy*, by Robert M. Solow and John B. Taylor, Boston: MIT Press, 1998.

[8] "Through a Glass, Darkly: How Data Revisions Complicate Monetary Policy," by Evan F. Koenig, Federal Reserve Bank of Dallas *Economic Letter*, vol. 1, December 2006.

[9] For details on using real-time data, see "A Real-Time Data Set for Macroeconomists," by Dean Croushore and Tom Stark, *Journal of Econometrics*, vol. 105, November 2001, pp. 111–30; "Monetary Rules Based on Real-Time Data," by Athanasios Orphanides, *American*

Economic Review, vol. 91, September 2001, pp. 964–85; and Federal Reserve Bank of Philadelphia, "Notes on the Philadelphia Fed's Real-Time Data Set for Macroeconomists (RTDSM)," www.phil.frb.org/files/forecast/qvqd.pdf.

[10] For details on the Giacomini–Rossi test, see "Model Selection and Forecast Comparison in Unstable Environments," by Raffaella Giacomini and Barbara Rossi, January 2007, http://econ.lse.ac.uk/events/papers/emetrics-110107.pdf.

[11] The parameters are allowed to change and are not based on overall averages, as in typical tests.

[12] As with the calculations for Chart 1, we do a recursive estimation. We estimate the parameters that minimize error for all the models for the initial 32 quarters, from first quarter 1988 to fourth quarter 1995. Then we calculate them from first quarter 1988 to first quarter 1996 and so on, ending with first quarter 1988 to first quarter 2006.

[13] In addition to the recursive test, we employed a rolling Giacomini–Rossi test with eight-year windows that examined the first 32 quarters, then the second through 33rd quarters, the third through 34th and so on. The rolling test, like the recursive one, found no model significantly outperforms the Koenig version in any period.

[14] For this measure, we use the Hodrick–Prescott 1600 filter, which is more sensitive to long-term fluctuations than to short-term deviations.

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