How Do Data Revisions Affect the Evaluation and Conduct of Monetary Policy?

By Sharon Kozicki

Many economic data series are revised as more comprehensive information becomes available and as methodologies improve. Even the latest available data are subject to uncertainty, and at some point historical data may be replaced by more accurately measured observations. Because monetary policy decisions are made with an eye to the state of the economy, data uncertainty complicates the evaluation and conduct of monetary policy.

Revisions to data series complicate the evaluation of historical policy actions. Policy actions taken based on data available at the time may differ considerably from recommendations based on revised data (Orphanides 2001). Policy settings that seemed appropriate when they were made may be regarded as mistakes when viewed with the revised data. Thus, to understand the policy concerns of the past, it is important to know the data policymakers were observing at the time (Runkle; Croushore and Stark 2000).

Sharon Kozicki is a vice president and economist at the Federal Reserve Bank of Kansas City. *Matthew Cardillo, an assistant economist at the bank, helped prepare the article. Special thanks go to Bob Arnold at the Congressional Budget Office for providing the real-time CBO estimates of the NAIRU and potential real GDP. Francis Horvath at the Bureau of Labor Statistics provided information on revisions to employment and unemployment statistics. This article and a real-time dataset containing CBO estimates of potential output and the NAIRU are available on the bank's website at **www.kc.frb.org**.*

Editor's Note: Earlier versions of this article that appeared on this website contained editorial errors. This version, like the one published in the first quarter 2004 *Economic Review*, is correct.

A related consequence of data revisions is that policymakers today must make decisions based on data that they know are noisy or imprecise measures of activity. Since different data series are revised to different extents, knowing the justification and properties of historical revisions can help policymakers distinguish important economic signals in data fluctuations from noise. Data subject to smaller revisions might be regarded as less noisy and more reliable. Consequently, when making decisions policymakers might choose to put more weight on such series.

This article focuses on revisions to data that policymakers often examine when assessing monetary policy options. While other studies have looked at the impact of data revisions on monetary policy, this article is the first to examine the policy implications of revisions in two widely used benchmarks of resource utilization—the Congressional Budget Office (CBO) estimates of potential output and the natural rate of unemployment. The article is also the first to consider how data revisions affect policy decisions through changes in estimates of the equilibrium real rate of interest.

The article finds that revisions to data can lead to policy regret—instances when revised data may suggest alternative actions would have been preferable to those taken. Based on this finding and analysis in other studies, the article recommends making policy less sensitive to economic indicators that are subject to large revisions. The first section of the article addresses what data revisions are relevant for monetary policymakers. The second section reviews the timing and magnitude of historical revisions to a key set of policy-relevant indicators. The third section illustrates how data revisions complicate the evaluation and conduct of monetary policy. The fourth section reviews the strengths and weaknesses of proposals on how to minimize the complications of data revisions when setting monetary policy.

I. WHAT REVISIONS MATTER FOR POLICY?

Most macroeconomic data series are revised. Although financial data, such as bilateral exchange rates and security prices, generally are not revised, measures of real economic activity and aggregate prices typically are. This article analyzes measurements of activity and inflation that are representative of the economic variables typically encountered in studies on the conduct of monetary policy.

The choice of series is motivated by recent literature drawing on Taylor (1993) that uses policy rules to recommend a target level for the federal funds rate based on the equilibrium real interest rate, a measure of economic activity, and the deviation of inflation from the policymakers' inflation goal.[1] Such policy rules are convenient for highlighting the implications of data uncertainty but do not capture the complications of the actual policymaking process. Nevertheless, as argued by Taylor (1993) and Svensson, the rules may provide useful benchmarks for thinking about policy in a complex world.

In the framework for monetary policy just described, two types of revisions are important: (1) revisions to "observable" data series, and (2) revisions to estimates of economic concepts made as a consequence of revisions to data, the availability of additional data, or modifications to economic theories. Although analysts tend to think of the latest available data as the truth, in reality, these data are estimates of the true measure of the underlying concept. Many data reporting agencies provide revised estimates of the data series as they obtain more complete source data and improve their techniques to construct the data. Earlier releases of data series thus may be considered noisy or uncertain when compared with the later releases.

In addition, some economic concepts—such as potential output, the natural rate of unemployment, or the equilibrium real rate—are not directly measured but play an important role in the monetary policy process. Estimates of these unobserved economic variables are constructed based on economic theory and published data.[2] Revisions to published data generally lead to revised estimates of the economic concepts. However, revisions also may occur as more recent data become available or in response to new theoretical developments.

This article will consider both types of revisions. Observed data series that will be examined include real gross domestic product (GDP), GDP price index inflation, Consumer Price Index (CPI) inflation, and the unemployment rate.[3] Estimates of other economic concepts that will be examined include the natural rate of unemployment, potential output, and the equilibrium real interest rate. As revisions to both observable data and estimates of economic concepts can affect policy-rule recommendations, revisions to either are important for the evaluation and conduct of monetary policy.

II. HOW LARGE ARE DATA REVISIONS?

To assess the magnitude of revisions that policymakers must face, this section compares different versions of data series. Because data are revised, multiple versions of the historical evolution of an economic variable exist. Careful labeling is needed to track these different versions of history. Thus, this section starts with an introduction to terminology before proceeding to an analysis of the magnitude of revisions.

What does "vintage" mean?

Discussions of data revisions are often awkward because, when data are subject to revisions, multiple versions of each observation of an economic variable exist. The term *vintage* is used to distinguish between different versions of the same data. In particular, the vintage of a data series refers to the date when that version of the data became available.[4]

Because it will be revised, the *latest available* vintage of a data series (2003Q1-vintage data for the purposes of this article) does not accurately represent the information available to policymakers historically.[5] To accurately assess information available to policymakers when they made their decisions, that is, in *real time,* it is important to use the vintages of data to which they had access. Thus, decisions made in the fourth quarter of 1994, for example, should be assumed to depend on 1994Q4-vintage data, while decisions made in the first quarter of 2003 should depend on 2003Q1-vintage data.

This article focuses on 13 different vintages of data: the first quarters of 1991 through 2003.[6] These vintages reflect revisions of potential output and the natural rate of unemployment made by the Congressional Budget Office (CBO). With the exception of the equilibrium real rate, remaining data were obtained from the Real-Time Dataset for Macroeconomists available from the website of the Federal Reserve Bank of Philadelphia.[7]

Table 1
A SUMMARY OF THE TIMING AND REASONS FOR DATA REVISIONS

Data Series (Reporting Agency)	*Timing of Revisions*	*Reason for Revisions*
National Income and Product Accounts Data—includes real GDP and the GDP price index (Bureau of Economic Analysis)	1 month after initial (advance) release	more complete information
	2 months after initial release	more complete information
	every July the prior 3 years of data are revised	better, less timely information becomes available
	all historical data are revised every 5 years or so (benchmark revisions)	new source data, possible changes in definitions of variables or in methodology
Unemployment rate (Bureau of Labor Statistics)	occasional	with changes in census population (usually, but not always, associated with the decennial census)
	for 5 years after initial release	seasonal adjustment factors are revised with the availability of additional data
Consumer price index (Bureau of Labor Statistics)	occasional	to correct reporting errors or software errors
	for 5 years after initial release	seasonal adjustment factors are revised with the availability of additional data

The period to be examined covers the fourth quarter of 1987 through the end of 2001. This sample was chosen because it starts with the appointment of Alan Greenspan as chairman of the Federal Reserve and extends through the last observation for which at least two vintages of data are available. By limiting the sample to a period during which a single person was chairperson of the Federal Reserve, regime change and its effects on the specification of the policy rule are less likely to complicate the analysis.[8] However, extending the sample further back would not qualitatively change the results as no additional vintages of data are available. The sample is sufficiently long to include periods with very different economic experiences, including the 1987 stock market crash, the 1990-91 recession and subsequent recovery, the expansion from 1991-2001 (the longest expansion since 1854), fallout from the 1997 Asian crisis, the NASDAQ correction that started in 2000, and the 2001 recession.

Table 2

A VINTAGE COMPARISON OF THE AVERAGE OVER 1987Q4 THROUGH 1990Q4

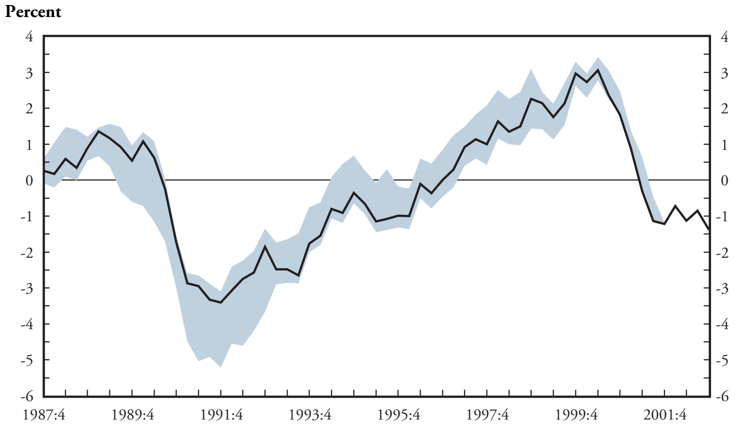
	Measures of Activity							*Inflation*		*Eq real rate*
Data vintage	Output gap	Unemp rate	NAIRU	Unemp gap	Real GDP growth	Potential GDP growth	Real GDP growth – potential growth	GDP price inflation	CPI inflation	Eq real rate
1991	.42	5.46	5.46	.00	2.22	2.60	-.38	3.71	4.82	3.32
1992	.07	5.46	5.62	-.16	1.93	2.66	-.73	4.06	4.82	2.69
1993	.10	5.46	5.62	-.16	1.80	2.40	-.60	4.22	4.82	2.69
1994	-.20	5.46	5.62	-.16	2.01	2.56	-.55	4.21	4.82	2.56
1995	.25	5.46	5.95	-.49	2.01	2.60	-.59	4.21	4.84	2.65
1996	.01	5.46	5.95	-.49	2.17	2.67	-.50	4.04	4.84	2.55
1997	.35	5.48	5.96	-.48	2.17	2.56	-.39	4.07	4.84	2.94
1998	.71	5.48	5.96	-.48	2.16	2.50	-.34	4.07	4.84	3.29
1999	.67	5.48	5.91	-.43	2.16	2.56	-.40	4.07	4.84	3.43
2000	.46	5.48	5.90	-.42	2.59	3.00	-.41	3.69	4.84	3.55
2001	.41	5.48	5.90	-.42	2.58	2.94	-.36	3.69	4.84	3.18
2002	.48	5.48	5.90	-.42	2.58	2.91	-.33	3.69	4.84	2.90
2003	.46	5.48	5.90	-.42	2.58	2.90	-.32	3.69	4.85	2.90

Measures of economic activity

The discussion in this article focuses on three measures of economic activity frequently used in policy rules: the output gap, the unemployment gap, and the deviation of real GDP growth from potential growth.

The output gap. In the policy rule popularized by Taylor (1993), economic activity is typically measured using the output gap, defined as the percent difference between real GDP and potential GDP.[9] Estimates of the output gap are revised with revisions to real GDP, potential GDP, or both and historically have been sizable.[10] Real GDP data are subject to an ongoing process of revision reflecting more complete information, new source data, changes in definitions of variables, and changes in methodology (Table 1). Potential GDP is not directly observable and must be estimated. This article examines the properties of CBO estimates of potential GDP. CBO estimates of potential GDP may be revised, for example, as economic data are revised, as new observations become available, or with new developments in the economic theory underlying their estimates.[11]

Chart 1
RANGE OF OUTPUT GAPS ACROSS VINTAGES



Source: Congressional Budget Office; Federal Reserve Bank of Philadelphia; author's calculations

Table 2 shows the average of the series over 1987Q4 through 1990Q4 for each of the data vintages. This subsample was chosen because it is the longest subsample for which data are available for all 13 vintages. Differences in the average across vintages signal large or persistent data revisions. By using a multiyear sample, revisions that reflect, for example, a shifting of the timing of activity between quarters will be averaged out and revisions that predominantly affect a single quarter will be down-weighted.

The average view of the state of the economy in 1987Q4 through 1990Q4 changed substantially over time as data were revised. In 1994, a retrospective view of this period suggests that on average real GDP was below potential, but by 1998 revisions changed the view of history such that on average real GDP exceeded potential by about 0.7 percent.

A second method to assess the magnitude of revisions is to examine the range across vintages of reported values for each quarter. In general, when comparing revisions to different data series, the series with the larger range across vintages will be the series subject to larger revisions and to more measurement uncertainty. Chart 1 shows a band that spans the 13 vintages of estimates of the output gap with a solid line showing the output gap according to the latest available vintage of data. The band

Table 3
THE RANGE OF DATA ACROSS VINTAGES

	Average	*Minimum*	*Maximum*
Economic Activity			
Output Gap	1.34	.03	2.39
Unemployment Gap	.38	.00	.69
Unemployment rate	.06	.00	.23
NAIRU	.56	.48	.62
Real GDP growth – Potential GDP growth (4-quarter)	.86	.01	2.00
Real GDP growth – Potential GDP growth (1-quarter AR)	1.61	.62	3.27
Real GDP growth (1-quarter AR)	1.54	.48	3.35
Potential GDP growth (1-quarter AR)	1.29	.52	3.04
Nominal GDP growth (1-quarter AR)	1.39	.45	3.00
Inflation			
GDP price inflation (4-quarter)	.44	.04	.88
GDP price inflation (1-quarter)	.71	.04	1.76
CPI inflation (4-quarter AR)	.04	.00	.11
CPI inflation (1-quarter AR)	.31	.00	.93
Equilibrium real rate			
Equilibrium real rate	1.34	.27	2.05

Note: Results are over 1987Q4 – 2001Q4. 4-quarter denotes growth rates over the previous four quarters; 1-quarter AR denotes growth over the previous quarter expressed at an annual rate.

narrows for more recent time periods because, starting in 1991Q4, one less vintage of data is included in the range every four quarters. Thus, for example, over 1991Q4 through 1992Q4, 12 vintages are available, over 1997Q4 through 1998Q4 only six vintages are available, and over 2001Q4 through 2002Q4 only a single vintage is available.

Table 3 provides some summary statistics on the historical range covered by the available data vintages.[12] In each quarter, the range across vintages of the output gap is the height of the shaded area in Chart 1—the difference between the maximum across vintages of the reported value for that quarter and the minimum. This approach to evaluating the size of revisions confirms and strengthens the findings from Table 2. In particular, revisions to estimates of the output gap have been very large. Depending on the vintage of data available, CBO estimates of the output gap differed by as much as 2.39 percentage points.

Although large, the range in Chart 1 and the summary statistics in Tables 2 and 3 may considerably understate uncertainty in the output gap since they reflect relatively recent experience. The chart only shows revisions to data starting in the fourth quarter of 1987 and for vintages starting in 1991. Orphanides (2003) found revisions as large as about ten percentage points to estimates of the output gap in the 1970s when comparing real-time data with 1994-vintage data.[13]

The unemployment gap. The unemployment gap, defined as the difference between the unemployment rate and the natural rate of unemployment, is an alternative measure of economic activity that appears in some policy rule specifications. The notion of the natural rate of unemployment examined in this article is the rate of unemployment that is consistent with stable inflation. It is often referred to as the nonaccelerating inflation rate of unemployment (NAIRU).

Revisions to either the unemployment rate or to estimates of the NAIRU lead to revisions in the unemployment gap. This is important because, although revisions to the unemployment rate are very small, the same is not the case for estimates of the NAIRU.[14] The average CBO NAIRU estimate over 1987Q4 through 1990Q4 differed by as much as almost 0.5 percentage point and ranged from a low of 5.46 for 1991 vintage data to a high of 5.96 for 1997 and 1998 vintages of data (Table 2). The unemployment gap inherits the uncertainty that accompanies NAIRU revisions (Table 3). Nevertheless, uncertainty about the unemployment gap is considerably smaller than uncertainty about the output gap.

Real GDP growth less potential growth. A third measure of economic activity that may be used in policy rules is the deviation of real GDP growth from potential growth.[15] This measure of activity is revised with revisions to either real GDP growth or to potential growth. The largest revisions to average real GDP growth rates shown in Table 2 primarily reflect the effects of benchmark revisions that occurred in 1991, 1995, and 1999. In the table, benchmark revisions contribute to the large jumps between average growth rates that occur between the 1991 and 1992 vintages, the 1995 and 1996 vintages, and the 1999 and 2000 vintages.[16]

When benchmark revisions lead to large changes in real GDP data over multiple quarters or years, estimates of potential output also tend to be revised in the same direction. Moreover, the effect of data revisions on the deviation between the two is attenuated. As shown in Table 2, the average potential GDP growth rate over 1987Q4 through 1990Q4 was revised up by about 0.4 percentage point between 1999 and 2000. This coincided with the benchmark revision to NIPA data that led to an increase in average real GDP growth of about 0.4 percentage point. The largest difference between average real GDP growth rates is 0.79 percent, obtained comparing the 1993 and 2000 vintages of data. The largest difference between average potential growth rates is 0.60 percent, also obtained by comparing the 1993 and 2000 vintages of data. However, the difference between the deviations of real GDP growth from potential growth is only 0.19 percent, when comparing the same two vintages of data—and the minimum difference across vintages is only 0.41 percent, obtained comparing 1992 with 2003 vintage data.

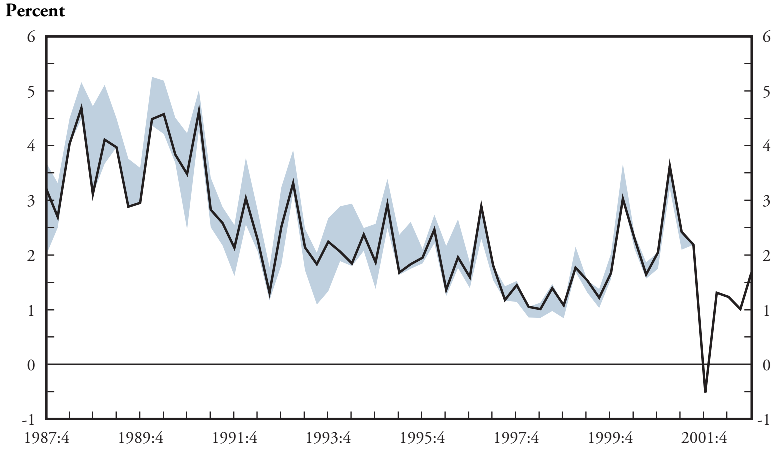
Revisions to one-quarter growth rates (annualized) of real GDP and potential output and the difference between the two growth rates are quite large. This is particularly true when the revisions are compared with revisions to the unemployment rate, the NAIRU, and the unemployment gap (Table 3).[17] However, since real GDP growth can be quite volatile from quarter to quarter, when used as a measure of economic activity in a policy rule, growth rates are usually calculated over four quarters. This is the same convention typically used for inflation (Taylor 1993). While the motivation for this practice is to reduce quarter-to-quarter variation in the inputs to the policy rule and the consequent policy recommendation, this practice also reduces data uncertainty associated with revisions.

Measures of inflation

Revisions to two measures of inflation are examined. Although revisions to GDP price inflation are larger than those to CPI inflation, the latter is not necessarily subject to less uncertainty. Overall, revisions to inflation, particularly when inflation is measured over four quarters, are relatively small compared with revisions to the output gap or the deviation of real GDP growth from potential.

GDP price inflation. The GDP price index is one of the series in the NIPA data.[18] Consequently, GDP price inflation is revised on the same timetable as the real GDP data (Table 1).[19] Chart 2 shows a shaded

Chart 2
RANGE OF GDP PRICE INFLATION ACROSS VINTAGES



Source: Federal Reserve Bank of Philadelphia

band that envelops all 13 vintages of GDP price inflation. The upper border of the band in each quarter is defined by the maximum across all vintages of GDP price inflation for that quarter (annual rate) with the lower border defined by the minimum. For reference, GDP price inflation as reported in the latest available vintage of data is superimposed on the band.

On average, revisions to GDP price inflation are of comparable magnitude, but in the opposite direction of revisions to real GDP growth (Table 2). However, statistics on the range across vintages of reported GDP price inflation rates suggest these revisions are not as large as those to real GDP growth or the output gap (Table 3). In addition, the implications of revisions to GDP price inflation for policy are reduced further by the common practice of using inflation measured over four quarters rather than over one quarter in implementing policy rules.

CPI inflation. For analyzing general price trends in the economy, the seasonally adjusted CPI is usually preferred over the nonseasonally adjusted CPI. Revisions to these data may reflect corrections to the underlying nonseasonally adjusted data as well as updated seasonal adjustment factors (Table 1).

Since revisions to the CPI are largely confined to seasonal factors, they tend to average to zero over a year.[20] As seen in Table 2, unlike the case for GDP price inflation, the mean CPI inflation rate is almost the same across all vintages. In addition to being small on average, the divergence across vintages of CPI inflation is much smaller than the vintage differences for GDP price inflation (Table 3).

Observations of the CPI inflation rate may not be directly comparable over time. Unfortunately, with the exception of changes due to new seasonal factors, historical CPI data are largely unrevised when the methodology used to construct the CPI is revised.[21] New observations may be generated using a new methodology, but historical observations are left unchanged.

In the 1990s, existence of a likely positive bias in reported CPI inflation rates received considerable attention, and the BLS undertook several changes to reduce the size of the bias. Thus, the reported CPI inflation rate could have suggested a decline in inflation, when all that was really happening was an improvement in data construction techniques. To account for such methodological changes, policymakers might want to adjust the implicit target for inflation, or allow their implicit definition of the price stability goal to change with methodological adjustments.

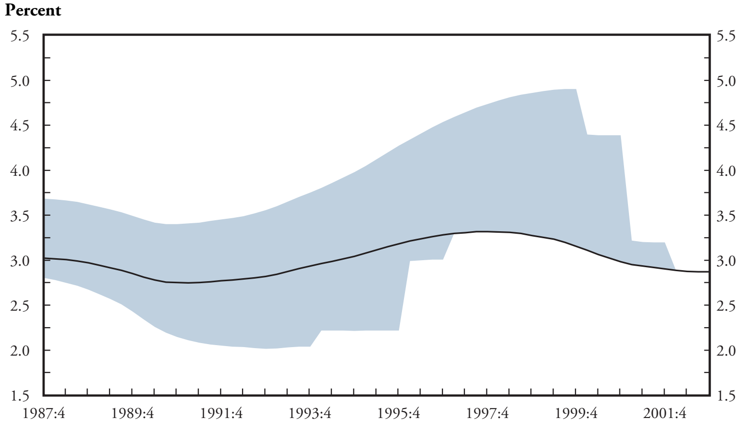
Recent BLS research has found that the measured rate of inflation would have been 0.45 percentage point lower on average between 1978 and 1998 if methods used in calculating the CPI at the end the end of the period had been in place over the entire period (Stewart and Reed). However, since a series of changes were implemented over that period, the yearly differences between the CPI and the 1998-method CPI (the so-called Consumer Price Index research series) varied considerably around the 0.45 percentage point mean.

The equilibrium real rate

The equilibrium real rate, or natural rate of interest, is the real interest rate consistent with a stable rate of inflation and with output equal to its potential. As was the case for the NAIRU and potential GDP, the equilibrium real rate is a concept that is estimated, not observed. This analysis uses real-time, time-varying estimates of the equilibrium real rate following a procedure similar to that of Laubach and Williams. Details

Chart 3

RANGE OF EQUILIBRIUM REAL RATES ACROSS VINTAGES



Source: Author's calculations

of the estimation procedure are provided in the appendix. Since the estimation procedure is held constant across vintages of data, revisions to estimates of the equilibrium real rate reflect revisions to data series used by the estimation procedure and the availability of additional observations in later vintage data.[22] In general, the availability of additional observations tends to be the larger contributing factor to revisions to estimates of the time-varying equilibrium real rate.

Revisions to estimates of the equilibrium real rate can be quite large. The average level of the estimated equilibrium real rate from 1987Q4 to 1990Q4 varies between 2.55 percent and 3.32 percent across the 13 vintages (Table 2). Estimates of the equilibrium real rate for the 13 vintages of data lie within the shaded band shown in Chart 3, with the solid line showing the estimate based on latest available data. The range of estimates is comparable to that for the CBO output gap (Table 3).

Since policy rule recommendations move one-for-one with the equilibrium real rate, large revisions in estimates of the equilibrium real rate imply large changes in policy rule characterizations of appropriate monetary policy. Compared with typical policy actions taken at Federal Open Market Committee (FOMC) meetings—usually 0.25 to 0.50 percentage point—the average range of 1.34 percentage points is very large.

III. WHAT DO DATA REVISIONS IMPLY FOR POLICY? A POLICY RULE VIEW

This section examines how data revisions affect monetary policy decisions. The framework for the discussion is a policy rule in the spirit of Taylor (1993). The policy rule provides a recommendation for the target level of the federal funds rate *(funds rate)* based on an estimate of the equilibrium real rate *(eq real rate)*, the level of economic activity *(activity),* and the deviation of inflation *(inflation)* from the policymakers' inflation target *(target)*:[23]

$$\textit{funds rate} = \textit{eq real rate} + \textit{inflation} + \frac{1}{2} \times (\textit{inflation} - \textit{target}) + \frac{1}{2} \times \textit{activity} \qquad (1)$$

According to this rule, to slow economic activity or reduce inflation, policymakers should set the federal funds rate at a level that exceeds a reference value equal to the sum of the equilibrium real rate and inflation. To stimulate economic activity, policymakers should set the federal funds rate below the reference value.

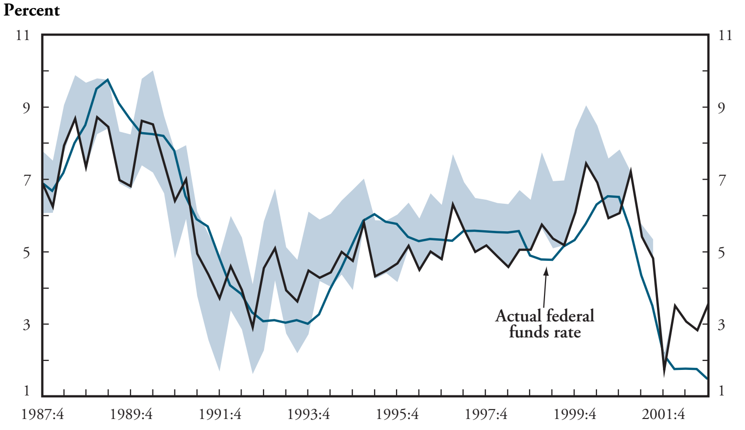
The data revisions discussed in the previous section matter because they complicate the evaluation of historical policy actions and the conduct of policy. A quick glance at the ranges summarized in Table 3 reveals that measures of economic activity and the equilibrium real rate are subject to considerable uncertainty. Thus, rule recommendations for the funds rate in a given quarter will likely differ considerably depending on the vintage of data used.

Why does it matter that rule recommendations are sensitive to data vintage?

Chart 4 provides an example of how vintage effects can lead to divergent policy recommendations. Recommendations in the chart use the output gap to measure economic activity, use GDP price inflation over the previous four quarters to measure inflation, and assume Taylor's original setting of 2 for the inflation target.[24] The range shows how much the recommendations vary across the various vintages of estimates of the equilibrium real rate, GDP price inflation, and the output gap.

Chart 4

RANGE OF TAYLOR RULE RECOMMENDATIONS ACROSS VINTAGES



Source: Author's calculations

The shaded band in Chart 4 helps illustrate how data revisions complicate the evaluation of historical policy actions. Policy rule recommendations based on latest available data are often used as a metric for determining whether past policy actions were mistakes. One interpretation of the band is that it covers the range of policy recommendations that ex post evaluations of economic conditions could have justified assuming policy had been set according to this version of the original Taylor rule. The width of the band signals the likelihood of policy regret—the degree to which a policy action, viewed as appropriate given real-time information, may appear to be too accommodative or too restrictive when evaluated based on subsequently revised data. The larger the band, the more disappointing a revisionist view of historical policy decisions might be. For example, performing a similar exercise for an earlier period, Orphanides (2003) attributed the Great Inflation of the 1970s to real-time mismeasurement of potential GDP in the context of activist monetary policy such as recommended by a Taylor rule.

In addition, data revisions complicate the conduct of policy. The band may be seen as representing uncertainty associated exclusively with data revisions about what the Taylor rule would recommend for policy. A wider band signifies that historically the data on which the policy recommendation is based have been subject to larger revisions. Since large revisions may indicate that future revisions to current data will also be large, the width of the band reflects the degree of noise in the data relative to the underlying economic signal and thus represents uncertainty associated with the policy-rule recommendation.[25]

Are rule recommendations less uncertain for alternative measures of economic activity?

The first section discussed several ways of measuring economic activity—the output gap, the unemployment gap, and the deviation of real GDP growth from potential growth. For which of these alternative measures do data revisions have the smallest effect on policy rule recommendations? To answer this question, Table 4 compares the range of policy recommendations based on the output gap as the measure of economic activity (the baseline case shown in Chart 4) with the range of policy recommendations based on the other measures of activity.

Even though revisions to the unemployment gap are considerably smaller than those to the output gap, only small reductions in uncertainty about policy-rule recommendations are obtained. Uncertainty reductions are smaller because policy responses to unemployment gaps would be larger than those to output gaps. Results for the unemployment gap are for a rule in which the weight on the unemployment gap is three times larger than the weight on the output gap and the opposite sign (-1½ instead of ½). The factor of three comes from an assumption of a coefficient of three in Okun's law that relates the deviation of output growth from potential growth to changes in the unemployment rate (Orphanides 2002). A negative weight is used to reflect the negative business cycle correlation between the output gap and the unemployment gap. In particular, a positive unemployment gap is similar to a negative output gap in that both signal disinflationary pressures, and vice versa.

Table 4
THE RANGE OF RULE RECOMMENDATIONS FOR DIFFERENT MEASURES OF ACTIVITY

Measure of activity	*Average*	*Minimum*	*Maximum*
Panel A: 1987Q4 – 1990Q4			
Output gap	1.86	1.20	2.97
Unemployment gap	1.67	.69	2.53
Real GDP growth – potential growth	1.72	1.04	2.47
Nominal GDP growth with a constant nominal target	1.44	.96	2.34
Panel B: 1987Q4 – 2001Q4			
Output gap	1.85	.02	3.55
Unemployment gap	1.73	.19	3.47
Real GDP growth – potential growth	1.61	.24	2.89
Nominal GDP growth with a constant nominal target	1.55	.31	2.79

The third measure of economic activity examined is the deviation of real GDP growth over the prior four quarters from potential growth over the same period. When the weights on the real GDP growth deviation and inflation are equal, this implementation of the rule corresponds to a nominal growth targeting rule. Because nominal GDP growth is equal to real GDP growth plus GDP price inflation, when the weights in the policy rule on economic activity and inflation are equal as they are here, the policy rule can be rewritten as:

$$\textit{funds rate} = \textit{eq real rate} + \textit{inflation} + \frac{1}{2} \times (\textit{nominal GDP growth} - (\textit{nominal target})), \qquad (2)$$

where the nominal target is equal to the sum of potential real GDP growth and the inflation target. This policy rule implementation exhibits a modest reduction in uncertainty compared with the recommendations based on the output gap (Table 4). If the nominal target is defined as a constant, then additional reductions in uncertainty are obtained.[26]

Recommendations that policy be set according to nominal growth targets are not new. Hall recognized the difficulties of setting policy when the economy is undergoing structural change and potential output is particularly challenging to estimate. He recommended setting monetary policy to keep nominal GDP on a prescribed growth path. A selection of other studies that examine forms of nominal output targeting include Gordon, Tobin, Taylor (1985), McCallum, McCallum and Nelson, and Orphanides (2003).

Overall, while the evidence suggests measurements of economic activity other than the output gap may imply less uncertainty for policy rule recommendations, the improvements are not large. One caveat to the results is that the properties of the uncertainty bands summarized in Table 4 are clearly sensitive to assumed values for parameters of the policy rule and uncertainty associated with other variables in the rule.

How important are revisions to estimates of the equilibrium real rate?

Taylor's original specification assumed that the equilibrium real rate was a constant (equal to 2 percent). In fact, it is not uncommon for policy rules to assume that the equilibrium real rate does not vary over time. However, with empirical evidence that the trend rate of growth of productivity increased in the mid-1990s, policymakers acknowledged that real interest rates would have to increase (Meyer, Greenspan, Poole). Recent empirical analysis supports a close link between the trend growth rate and the equilibrium real rate (Laubach and Williams). Thus, it is important that policy rules account for time variation in the equilibrium real rate.

To assess the economic significance of revisions to time-varying estimates of the equilibrium real rate, policy rule recommendations based on time-varying estimates are compared with recommendations based on constant estimates. Constant estimates are set equal to the average of the real funds rate, defined as the difference between the nominal funds rate and inflation over 1962-90, a sample for which data are available for all vintages. Constant estimates will differ across vintages due to revisions to inflation. Similar results are obtained if the equilibrium real rate is replaced by a constant equal to 2 as in Taylor's original specification. The difference between the range based on time-varying estimates and the range with constant estimates provides an assessment of the marginal sensitivity of funds rate recommendations to equilibrium real rate measurement uncertainty.[27]

Table 5

IMPLICATIONS OF TIME-VARYING ESTIMATES OF THE EQUILIBRIUM REAL RATE FOR THE RANGE OF RULE RECOMMENDATIONS

Estimate of equilibrium real rate	*Average*	*Minimum*	*Maximum*
Panel A: 1987Q4 – 1990Q4			
Time-varying	1.86	1.20	2.97
Constant	1.40	.79	2.30
Panel B: 1987Q4 – 2001Q4			
Time-varying	1.87	.02	3.55
Constant	1.04	.07	2.66

Revisions to estimates of the equilibrium real rate lead to economically important differences in Taylor rule recommendations (Table 5). A comparison of the average range for the time-varying equilibrium real rate to those for the constant estimates reveals that the marginal sensitivity of Taylor rule recommendations is quite sizable—on the order of 45 to 85 basis points. This result is important because many studies that examine how to conduct monetary policy in the presence of data uncertainty focus on difficulties associated with estimating potential output and the output gap and assume the equilibrium real rate is known and constant.

A naïve interpretation of Table 5 might lead an analyst to advocate following a policy based on a constant and unrevised value for the equilibrium real rate. This would be a risky policy, particularly since the constant chosen is unlikely to equal the true unobserved equilibrium real rate. The range of estimates in Table 5 is narrower for a constant equilibrium real-rate implementation of the Taylor rule only because, for illustrative purposes, most of the uncertainty about one of the variables has been excluded.

What do data revisions imply for appropriate weights in the Taylor rule?

Taylor (1999) suggested that policy recommendations from a rule with a higher weight on the output gap would be preferred by a central bank with a stronger aversion to output variability. While Taylor's suggestion was that the weight on the output gap be doubled from 0.5 as

Table 6

IMPLICATIONS OF DIFFERENT WEIGHTS ON ECONOMIC ACTIVITY FOR THE RANGE OF RULE RECOMMENDATIONS

Weight on the output gap	*Average*	*Minimum*	*Maximum*
Panel A: 1987Q4 – 1990Q4			
Weight = 0.5	1.86	1.20	2.97
Weight = 1.0	2.41	1.47	3.88
Panel B: 1987Q4 – 2001Q4			
Weight = 0.5	1.87	.02	3.55
Weight = 1.0	2.27	.27	4.58

in his original 1993 specification to 1, even this larger degree of responsiveness falls short of that suggested by some analysts (Rudebusch and Svensson). Table 6 summarizes the sensitivity of policy rule recommendations to data revisions when the weight on economic activity is doubled (to 1). Results are reported for economic activity measured using the output gap, although similar results would be obtained for other measures of economic activity.

Not surprisingly, Taylor rule recommendations based on a unit weight on the output gap cover a broader range than those based on a weight of 0.5 on the output gap. The larger range obtains because a larger weight is put on a variable measured with considerable uncertainty, in this case, the output gap. The larger range might be interpreted as a warning to policymakers that policy actions that respond more aggressively to economic variables such as the output gap, which are subject to larger degrees of revision, are more likely to be viewed in hindsight as a mistake.

Does gradual adjustment to the policy rule recommendation reduce uncertainty?

Some analysts have argued that gradual adjustment of the federal funds rate may be desirable in the presence of uncertainties about the structure of the economy (English, Nelson, and Sack; Amato and Laubach).[28] To assess the implications of gradual policy in the presence of

Table 7
IMPLICATIONS FOR RULE RECOMMENDATIONS OF GRADUAL ADJUSTMENT

	Average	*Minimum*	*Maximum*
Panel A: 1987Q4 – 1990Q4			
No gradualism	1.86	1.20	2.97
Gradualism	1.06	.43	1.93
Panel B: 1987Q4 – 2001Q4			
No gradualism	1.87	.02	3.55
Gradualism	1.59	.14	2.50

data revisions, policy recommendations are modified so that the funds rate is only adjusted by a fraction of the rate change recommended by the policy rule:

$$\textit{new funds rate} = \textit{old funds rate} + \lambda\ (\textit{policy rule recommendation} - \textit{old funds rate}) \qquad (3)$$

where λ is a fraction between 0 and 1. This specification captures gradualism in policy actions by making adjustments to the federal funds rate in response to changes in economic conditions more sluggish.

Table 7 provides summary statistics on the degree of uncertainty, assuming the funds rate is only adjusted by 25 percent of the recommended change, that is, $\lambda = 0.25$.[29] This weight is in line with empirical estimates (Kozicki; Sack and Wieland). Gradualism reduces the effect of uncertainty on policy recommendations but does not eliminate it. The range of policy recommendations is narrower on average when based on a gradualist policy.

IV. REDUCING POLICY SENSITIVITY TO DATA UNCERTAINTY

The analysis of the previous section revealed that in the face of data revisions, after-the-fact reviews of policy actions may find considerable fault with past decisions, in the sense that policy actions taken based on best available data may be viewed as less appropriate after the data are revised. Furthermore, real-time policy rule recommendations are subject to considerable uncertainty. This section will review the strengths and weaknesses of two proposals that attempt to minimize the complications of data revisions when setting monetary policy.

Let policy be guided by measures of activity that are revised less

While most economic data series are revised, they are revised to different extents. With differences in the size of revisions, policymakers may be better off conditioning their policy decisions on data series that are less subject to revision. Care must be taken in applying this proposal because data that are revised less do not necessarily provide a better measure of the true underlying economic variable, and smaller revisions do not always reduce uncertainty about policy rule recommendations or limit incidents of inappropriate policy action.

The fact that data are not revised does not imply that the initial release of a data point provides the best estimate of the true value. For example, over time, methodological improvements may be developed to bring measurements closer to the true underlying economic concept. Some agencies may want to ensure that all observations are as accurate as possible according to the latest available technology. This requires not just using the new methodologies to produce future observations, but substantial effort to revise historical data according to the new methodology. However, historical revisions can have complicated implications, depending on how the data are used. For instance, if wages or other nominal payments were indexed to a price index subject to historical revisions, then what would be the appropriate response to revisions to the price index that rewrite its history? Would employees be responsible for repaying wages should the price index be revised down? In some cases it may be preferable not to revise data. There is a presumption in BLS policy and practice against revisions to the nonseasonally adjusted CPI that extends back over lengthy periods. However, to satisfy demands for a methodologically consistent price index, the BLS now publishes an estimate of the CPI, known as the CPI research series using current methods, that incorporates most of the improvements made historically.

The size of the revisions also may be misleading because smaller revisions do not always translate into reduced policy rate uncertainty. Average revisions to the unemployment gap are about a third of the size of average revisions to the output gap (Table 3). However, because policy rules generally recommend larger responses to unemployment gaps than to output gaps, the advantages of the smaller revisions associated with the unemployment gap are largely negated (Table 4).

Nevertheless, in some situations policymakers might want to focus their attention on data subject to smaller revisions. Revisions to the deviation of output growth from potential growth tend to be smaller than revisions to estimates of the output gap or the unemployment gap, and this advantage carries over to policy rule recommendations. Uncertainty surrounding policy rule recommendations based on nominal GDP growth tend to be smaller than implementations that use other measures of activity. But, nominal growth targeting does not totally escape difficulties associated with data revisions. As estimates of potential growth change with historical data revisions, nominal growth targeting requires either an adjustment of the real potential growth component of the nominal target or, in the constant-target case, recognition that the implicit price-inflation target must be revised in the opposite direction to balance the change in real potential growth.

The evidence on nominal income growth targeting is mixed. Orphanides (2003) finds that in the presence of data uncertainty, nominal income growth targeting is preferable to an output-gap-based policy rule. Rudebusch generally supports the logic of nominal growth targeting, but he finds that optimized output-gap-based rules tend to be preferable to optimized nominal income growth targeting rules.

Ultimately, no high-quality data series appear to be sufficiently precise and timely to justify not considering data subject to revision. Thus, the relevant question is how policymakers can reduce the implications of data revisions for policy.

Respond less to more uncertain data

Several analysts have used models of the U.S. economy to evaluate how policymakers should respond to data series that are subject to revision. They found that uncertainty in the measurement of the output gap on the order of that found in comparisons of real-time estimates of the output gap to latest available data brings a substantial deterioration in economic performance (Orphanides, Porter, and others; Orphanides 2003). When properly taking account of uncertainty, policy should respond more cautiously to apparent imbalances in economic activity (Swanson; Svensson and Woodford; Smets; Tetlow; Orphanides 2003; Rudebusch; Wieland). In a policy rule framework, this translates to a lower weight on the output gap. In related work, Meyer, Swanson, and Wieland studied policy rules based on unemployment gaps instead of output gaps. They recommend that, during periods of heightened uncertainty about the NAIRU, policymakers should lessen their response to changes in the observed unemployment rate.

While analysts generally agree that policy responses to economic imbalances should be smaller when their measurements are more uncertain, there is less agreement on the absolute size of the appropriate response. In general, most analysts find that, in the absence of uncertainty, policy should respond more aggressively to the output gap and inflation than estimates of historical policy suggest has been the case. Thus, a "less aggressive" response to an uncertain measure could still imply a more aggressive response than historically. For example, Rudebusch finds that, for plausible estimates of the degree of uncertainty in the output gap, optimal monetary policy should respond more aggressively to the output gap (with a weight of 1 to 1½) than in the standard Taylor rule. However, other analysts suggest that problems associated with measuring the level of potential output are sufficiently severe that alternative policies that avoid reacting to the level of the output gap would be preferred (Orphanides 2003). Policy gradualism is an alternative approach to down-weighting new information that may be noisy. By recommending that policy only partially adjust to the new data, the emphasis on the uncertain data is reduced. Rather than reduce the weight on a given variable in the policy rule, policy gradualism implicitly reduces the response weight to all variables on which the policy recommendation depends. Several analysts argue for more gradual responses in the presence of uncertainty (Orphanides, Porter, and others; English, Nelson, and Sack; Amato and Laubach).

Orphanides and Williams find that a simple and effective approach for dealing with ignorance about the degree of uncertainty in estimates of the NAIRU and equilibrium real interest rate is to set policy so that the change in the federal funds rate depends on changes in inflation and changes in the unemployment gap. Walsh argues for a similar set up but with the change in the output gap replacing the change in the unemployment gap. Such rules do not require knowledge of the level of potential output, the NAIRU, or the equilibrium real rate for setting policy and consequently are immune to likely misperceptions in these concepts. However, results tend to be specific to the model used.

In general, rules that provide recommendations for the change in the level of the funds rate tend to perform very poorly in models where expectations depend on recent and past data (adaptive expectations) but relatively well in forward-looking models. Overall, there appear to be economic costs associated with completely ignoring the estimated levels of the output gap or unemployment gap and the equilibrium real interest rate, even when uncertainty regarding these variables is high.

V. CONCLUSIONS

This article highlighted some of the difficulties associated with conducting monetary policy with data uncertainty. When historical policy actions are reexamined using revised data, past decisions may appear to be excessively accommodative or excessively restrictive. When setting current policy, data revisions imply uncertainty about the appropriate target level for the federal funds rate. Unfortunately, while some approaches hold promise for reducing the likelihood of policy regret, it is not possible to totally eliminate the difficulties associated with data uncertainty.

To reduce instances of policy regret, it may be desirable to make policy actions less sensitive to highly uncertain data. Some approaches that hold promise include responding to data averaged over several quarters, setting policy based on measures of activity that are less uncertain, and reducing the responsiveness of policy to noisy information.

APPENDIX
ESTIMATING THE EQUILIBRIUM REAL RATE

The equilibrium real rate is estimated following an empirical framework similar to Laubach and Williams (LW). Output gap dynamics are modeled using a simple reduced-form equation as in Rudebusch and Svensson:

$$\tilde{y}_t = a_{y,1}\tilde{y}_{t-1} + a_{y,2}\tilde{y}_{t-2} + \frac{a_r}{2}\sum_{j=1}^{2}(r_{t-j} - r^*_{t-j}) + \varepsilon_{y,t}$$

where $\tilde{y}_t$ is the output gap, r_t is the real federal funds rate, and $\varepsilon_{y,t}$ is a shock term. For y_t equal to the logarithm of real GDP and y_t^* equal to the logarithm of potential real GDP, the output gap is defined as $\tilde{y}_t = 100 \times (y_t - y_t^*)$. The unobserved equilibrium real rate, r_t^*, is assumed to follow a random walk process:

$$r_t^* = r_{t-1}^* + \varepsilon_{r,t}$$

where $\varepsilon_{r,t}$ is a shock. The terms $\varepsilon_{y,t}$ and $\varepsilon_{r,t}$ are assumed to be serially uncorrelated and contemporaneously uncorrelated innovations with variances σ_y^2 and σ_r^2, respectively. The first equation defines the measurement equation of a state-space model and the second defines the transition equation.

The specification differs from that in LW along several dimensions. One difference is that LW included a Phillips curve equation in which inflation depends on the output gap and a transition equation for potential GDP. The equilibrium real rate process and a series for potential output were jointly estimated. In the analysis of this article, CBO estimates of potential output were used for y_t^*, so the only unobserved state variable to be estimated is r_t^*. Second, LW assumed that the equilibrium real rate is a linear function of potential growth and an unobserved stochastic process, whereas here the link to potential growth is not explicitly modeled. This choice was made because the growth rate of CBO estimates of potential output was much more volatile than the estimated potential growth series of LW, and explicitly modeling the

Table A-1

Data Vintage	$\sum a_y$	a_r	$\sigma(\tilde{y})$
1991Q1	.90 *(.04)*	-.13 *(.03)*	.84
1992Q1	.90 *(.04)*	-.14 *(.04)*	.84
1993Q1	.91 *(.03)*	-.14 *(.03)*	.81
1994Q1	.90 *(.03)*	-.13 *(.03)*	.80
1995Q1	.90 *(.03)*	-.13 *(.03)*	.79
1996Q1	.90 *(.04)*	-.10 *(.03)*	.82
1997Q1	.90 *(.03)*	-.11 *(.03)*	.81
1998Q1	.91 *(.03)*	-.10 *(.03)*	.80
1999Q1	.91 *(.03)*	-.08 *(.03)*	.80
2000Q1	.92 *(.03)*	-.09 *(.03)*	.77
2001Q1	.91 *(.03)*	-.09 *(.02)*	.77
2002Q1	.91 *(.03)*	-.08 *(.02)*	.78
2003Q1	.92 *(.03)*	-.08 *(.02)*	.77

link led to excessively volatile estimates of the equilibrium real rate. Third, LW considered several variations on their specification of the unobserved stochastic process, leading to multiple series of estimates of the equilibrium real rate. Here, one series is estimated and it is calibrated so that shocks to the equilibrium real rate are of the same variance as in the LW baseline random walk specification. Fourth, LW separately included core import price inflation and crude imported oil price inflation. Here, these effects are included in a single term—import price inflation.

Finally, LW used different measures of inflation and the real federal funds rate than were chosen here. In this article, historical estimates of the equilibrium real rate are constructed for different vintages of data. Since revisions to real potential output and the GDP price index tend to be related to revisions to real GDP, it seemed appropriate to use the GDP price index to measure inflation rather than the core CPI as was chosen by LW. To be consistent, the real federal funds rate was also constructed using GDP price inflation rather than core CPI inflation. The analysis in this article defined the real federal funds rate to be the difference between the quarterly average federal funds rate and quarterly inflation. By contrast, LW constructed an estimate of the ex ante real rate using a proxy for expected inflation based on the forecast of the four-quarter-ahead percent change in the price index for personal consumption expenditures excluding food and energy (core PCE prices) from an AR(3) model of inflation estimated over the prior 40 quarters.

Kalman filter techniques are applied to the model. During maximum likelihood estimation, the variance of $\varepsilon_{r,t}$ is restricted to equal $(0.34)^2 = 0.1156$, corresponding to the variance of the shock to the equilibrium rate in the baseline random walk case of LW. Smoothed estimates of the unobserved state variable were taken as estimates of the equilibrium real rate. Although, as shown in Chart 3, estimates of the equilibrium real rate differenced considerably across vintages, other details of the estimation were quite similar. Coefficient estimates are provided in Table A-1 for the 13 data vintages. The output gap exhibits considerable persistence and responds negatively to deviations of the real federal funds rate from the equilibrium real rate.

ENDNOTES

[1]While the Federal Reserve has long-run goals of price stability and sustainable economic growth, it does not have an explicit numerical target for inflation.

[2]The difference between observable data and other economic concepts may seem to be difficult to distinguish—particularly since the estimates of unobservable concepts such as potential output and the natural rate of unemployment are published by a government agency, the Congressional Budget Office (CBO). In this respect, one way to distinguish between observable data and estimates of unobservable concepts is to consider what series analysts use. Analysts tend to use observable data as published by the government. However, some analysts prefer to use their own estimates of unobservables rather than those published by, say, the CBO.

[3]The data series are meant to be a representative, but not exclusive, list of the economic variables typically encountered in studies on the conduct of monetary policy.

[4]For example, real GDP growth for the first quarter of 1977 was first published to be 5.2 percent (seasonally adjusted annual rate) in the advance release of April 1977, but was subsequently revised to 7.5, 7.3, 8.9, 9.6, 8.9, 5.6, 6.0, 5.3, 4.9, and 5.0 percent later in 1977, and then in 1978, 1979, 1980, 1982, 1986, 1991, 1996, 1997, and 2000, respectively (Croushore and Stark 2000). In this example, April 1977 is the vintage of the advance release and the years label ten subsequent vintages of real GDP growth for the first quarter of 1977.

[5]For example, even if all observations after the first quarter of 1977 were excluded, a dataset constructed from the latest available vintage of data would incorporate revisions to historical data for observations before the first quarter of 1977 that would not have been available in April 1977.

[6]For notational simplicity, the vintages will be referred to by the year of the vintage only.

[7]For each vintage of CBO data, remaining data from the Real-Time Dataset for Macroeconomists was taken from the same quarter's vintage dataset. This timing only approximately reconciles the timing of available information from the two data sources. The first-quarter vintage data from the Real-Time Dataset for Macroeconomists includes the advance estimates of the National Income and Products Accounts data for the fourth quarter. However, while both the advance estimates of National Income and Products Accounts data for the fourth quarter and the CBO data are published in the first quarter, the advance release of fourth quarter data is published after the CBO data and would not have been available when the CBO data were constructed.

[8]Judd and Rudebusch estimated Taylor rules for samples distinguished by the chairman of the Federal Reserve and found their framework successfully captured differences in policy regime across chairmen.

[9]The output gap was constructed as $100*\log(GDP(t)/\text{potential } GDP(t))$.

[10]Orphanides (2003) found that revisions to estimates of potential GDP used by staff at the Federal Reserve Board were the major contributor to revisions to Board staff estimates of the output gap.

[11]The CBO estimates potential GDP as part of their budget projection efforts. Details on their estimation methodology are provided in CBO (2001).

[12]The average range may understate the degree of uncertainty because fewer vintages of data are available for recent observations as these data have been subject to fewer revisions. In fact, only two vintages of data are available for 2001. The minimum range may appear very low for the same reason.

[13]Orphanides studied different estimates of the output gap than those examined here. His analysis was based on estimates of potential output used by staff at the Board of Governors of the Federal Reserve.

[14]Starting with the 1995-vintage data, NAIRU estimates derive from an econometric estimate of a Phillips curve that relates the change in inflation to the deviation of the unemployment rate from the NAIRU and other factors such as productivity growth, oil price shocks, and wage and price controls (CBO 1994 and 2001).

[15]1991-vintage data are real GNP rather than real GDP. Annualized values of quarterly growth rates are calculated as *400*log(real GDP (t) / real GDP (t-1))*.

[16]When a longer history of vintages is examined, differences across vintages can be considerably larger than reported in the table (Croushore and Stark 2000 and 2001).

[17]Mankiw and Shapiro provide an analysis of the properties of GNP revisions. Although they find that the magnitude of revisions to GNP growth are quite large, they conclude that at the time of each revision the new figure is generally the best available estimate of the final value.

[18]1991-vintage data are GNP price inflation rather than GDP price inflation.

[19]Annualized values of quarterly inflation rates are calculated as *400*log(price index (t)/price index(t-1))*.

[20]Occasional revisions are made to correct reporting errors or software errors (Bureau of Labor Statistics). In September 2000, the BLS revised nonseasonally adjusted CPI data for the January to August 2000 period to correct the implications of a software error. During the 1990s, revisions were made only seven times, generally to correct reporting errors. However, none of these corrections led to any revision of the All Items index at the U.S. level.

[21]Since there is presumption in BLS policy and practice against revisions to the nonseasonally adjusted CPI that extend back over lengthy periods, changes to correct the errors have to be large enough to warrant republication.

[22]Revisions to estimates of potential output and the NAIRU are also driven by the same two factors. However, more information than a history of vintages of the final estimates is required to determine the sizes of the relative contributions of each factor to these series.

[23]This article focuses on the sensitivities of rule recommendations to data revisions. Kozicki showed that Taylor rule recommendations are sensitive to how inflation and the output gap are measured, to estimates of the equilibrium real rate, and to other details of the rules specification. That article did not discuss issues related to data revisions and only latest available versions of data were examined.

[24]Funds rate recommendations in a given quarter are based on data from the previous quarter to account for time lags in the real-time availability of data.

[25]Uncertainty linked to data revisions is only one source of uncertainty affecting policy decisions. Accounting for other sources of uncertainty, such as what measure of inflation should be the focus of monetary policy, what methodology

should be used to estimate potential GDP and/or the output gap, and what weights should be placed on the output gap and inflation, would lead to a wider range of funds rate recommendations (Kozicki).

[26]In Table 4, entries labeled "Nominal GDP growth with a constant nominal target," the nominal target is defined as the sum of a constant inflation target set to 2 percent and average real GDP growth over 1960-90.

[27]Although revisions to estimates of the equilibrium real rate are mapped one-for-one to funds rate recommendations, the marginal difference may be smaller than the uncertainty summarized in Table 3 if revisions to estimates of the equilibrium real rate are correlated with revisions to the output gap, potential growth, or inflation.

[28]In addition, English, Nelson, and Sack suggest that gradualism may reduce volatility in financial markets and may increase the economic responses to policy actions by magnifying the response of other market interest rates to policy actions.

[29]The results in the table take the funds rate in 1987Q3 as a starting point and then construct policy settings recursively. A different recommendation is obtained than if the funds rate is set as a linear combination of (1-λ) multiplied by the *actual* funds rate in the previous quarter and λ multiplied by the recommendation of the policy rule recommendation.

REFERENCES

Amato, Jeffrey D., and Thomas Laubach. 1999. "The Value of Interest Rate Smoothing: How the Private Sector Helps the Federal Reserve," Federal Reserve Bank of Kansas City, *Economic Review,* Third Quarter, pp. 47-64.

Bureau of Labor Statistics. Department of Labor. 2000. "Revisions in January to August 2000 CPI Data," at *www.bls.gov/cpi/cpirev01.htm.*

Congressional Budget Office, U.S. Congress. 2001. "CBO's Method for Estimating Potential Output: An Update," August.

__________. 1994. "Appendix B: Reestimating the NAIRU," *The Economic and Budget Outlook: An Update,* August, pp. 59-63.

Croushore, Dean, and Tom Stark. 2001. "A Real-Time Data Set for Macroeconomists," *Journal of Econometrics,* vol. 105. pp. 111-30.

__________. 2000. "A Funny Thing Happened on the Way to the Data Bank: A Real-Time Data Set for Macroeconomists," Federal Reserve Bank of Philadelphia, *Business Review,* September/October, pp. 15-27.

English, William B., William R. Nelson, and Brian P. Sack. 2003. "Interpreting the Significance of the Lagged Interest Rate in Estimated Monetary Policy Rules," *Contributions to Macroeconomics,* vol. 3, issue 1, article 5, pp. 1-16.

Gordon, Robert J. 1985. "The Conduct of Domestic Monetary Policy," in A. Ando, E. Eguchi, R. Farmer, and Y. Suzuki, eds., *Monetary Policy in Our Times.* Cambridge, Mass.: The MIT Press.

Greenspan, Alan. 2000. "The Federal Reserve's Semiannual Report on the Economy and Monetary Policy," testimony before the Committee on Banking and Financial Services, U.S. House of Representatives, February 17, 2000.

Hall, Robert E. 1983. "Macroeconomic Policy Under Structural Change," in *Industrial Change and Public Policy,* proceedings of a symposium sponsored by the Federal Reserve Bank of Kansas City.

Judd, John P., and Glenn D. Rudebusch. 1998. "Taylor's Rule and the Fed: 1970-1997," Federal Reserve Bank of San Francisco, *Economic Review,* no. 3, pp. 3-16.

Kozicki, Sharon. 1999. "How Useful Are Taylor Rules for Monetary Policy?" Federal Reserve Bank of Kansas City, *Economic Review,* Second Quarter, pp. 5-33.

Laubach, Thomas, and John C. Williams. 2002. "Measuring the Natural Rate of Interest," mimeo, Board of Governors of the Federal Reserve System, October.

Mankiw, N. Gregory, and Matthew D. Shapiro. 1986. "News Or Noise: An Analysis of GNP Revisions," *Survey of Current Business,* May, no. 66, pp. 20-25.

McCallum, Bennett T. 1988. "Robustness Properties of a Rule for Monetary Policy," *Carnegie-Rochester Conference Series on Public Policy,* no. 29, pp. 173-204.

McCallum, Bennett T., and Edward Nelson. 1999. "Performance of Operational Policy Rules in an Estimated Semi-Classical Structural Model," in John Taylor, ed., *Monetary Policy Rules.* Chicago: University of Chicago Press, pp. 57-119.

Meyer, Laurence H. 1999. "Q&A on the Economic Outlook and the Challenges Facing Monetary Policy," remarks before the Philadelphia Council for Business Economics, Federal Reserve Bank of Philadelphia, September 8.

Meyer, Laurence H., Eric T. Swanson, and Volker W. Wieland. 2001. "NAIRU Uncertainty and Nonlinear Policy Rules," *AEA Papers and Proceedings,* vol. 91, no. 2, May, pp. 226-31.

Orphanides, Athanasios. 2003. "The Quest for Prosperity Without Inflation," *Journal of Monetary Economics,* vol. 50, pp. 633-63.

__________. 2002. "Monetary-Policy Rules and the Great Inflation," American Economic Association, *AEA Papers and Proceedings,* vol. 92, no. 2, May, pp. 115-20.

__________. 2001. "Monetary Policy Rules Based on Real-Time Data," *American Economic Review,* vol. 91, no. 4, September, pp. 964-85.

Orphanides, Athanasios, Richard D. Porter, David Reifschneider, Robert Tetlow, and Frederico Finan. 2000. "Errors in the Measurement of the Output Gap and the Design of Monetary Policy," *Journal of Economics and Business,* vol. 52, pp. 117-41.

Orphanides, Athanasios, and John Williams. 2002. "Robust Monetary Policy Rules with Unknown Natural Rates," *Brookings Papers on Economic Activity,* Issue 2, pp. 63-145.

Poole, William. 2003. "Economic Growth and the Real Rate of Interest," speech at Bryant College, Providence, R.I., October 14.

Rudebusch, Glenn D. 2002. "Assessing Nominal Income Rules for Monetary Policy with Model and Data Uncertainty," *Economic Journal,* vol. 112, April, pp. 402-32.

Rudebusch, Glenn D., and Lars E.O. Svensson. 1999. "Policy Rules for Inflation Targeting," in John B. Taylor, ed., *Monetary Policy Rules.* Chicago: University of Chicago Press.

Runkle, David E. 1998. "Revisionist History: How Data Revisions Distort Economic Policy Research," Federal Reserve Bank of Minneapolis *Quarterly Review,* vol. 22, no. 4, Fall, pp. 3-12.

Sack, Brian, and Volker Wieland. 2000. "Interest-Rate Smoothing and Optimal Monetary Policy: A Review of Recent Empirical Evidence," *Journal of Economics and Business,* 52, pp. 205-28.

Smets, Frank. 1999. "Output Gap Uncertainty: Does It Matter for the Taylor Rule?" in Benjamin Hunt and Adrian Orr, eds., *Monetary Policy under Uncertainty,* Reserve Bank of New Zealand.

Stewart, Kenneth J., and Stephen B. Reed. 1999. "Consumer Price Index Research Series Using Current Methods, 1978-98," *Monthly Labor Review,* June, pp. 29-38.

Svensson, Lars E.O. forthcoming. "What Is Wrong with Taylor Rules? Using Judgment in Monetary Policy Through Targeting Rules," *Journal of Economic Literature.*

Svensson, Lars E.O., and Michael Woodford. forthcoming. "Indicator Variables for Optimal Policy," *Journal of Monetary Economics.*

Swanson, Eric T. forthcoming. "On Signal Extraction and Non-Certainty-Equivalence in Optimal Monetary Policy Rules," *Macroeconomic Dynamics.*

Taylor, John B. 1999. "Introduction," in John B. Taylor, ed., *Monetary Policy Rules.* Chicago: University of Chicago Press.

__________. 1993. "Discretion Versus Policy Rules in Practice," *Carnegie-Rochester Conference Series on Public Policy,* vol. 39, pp. 195-214.

__________. 1985. "What Would Nominal GNP Targeting Do to the Business Cycle?" *Carnegie-Rochester Conference Series on Public Policy,* vol. 22, pp. 61-84.

Tetlow, Robert J. 2000. "Uncertain Potential Output and Monetary Policy in a Forward-Looking Model," mimeo, Board of Governors of the Federal Reserve System.

Tobin, James. 1983. "Monetary Policy: Rules, Targets, and Shocks," *Journal of Money, Credit, and Banking*, vol. 15, November, pp. 506-18.

Walsh, Carl E. 2003. "Implications of a Changing Economic Structure for the Strategy of Monetary Policy," manuscript prepared for "Monetary Policy and Uncertainty: Adapting to a Changing Economy," a symposium sponsored by the Federal Reserve Bank of Kansas City.

Wieland, Volker. 2002. "Monetary Policy and Uncertainty About the Natural Unemployment Rate," Center for Financial Studies Working Paper No. 2003/05.