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S ince Milton Friedman's (1968) presidential address to the American Economic Association, one of the most enduring ideas in macroeconomics has been that inflation will increase when unemployment persists below its natural rate, the so-called NAIRU, or nonaccelerating inflation rate of unemployment. But what is the NAIRU? Is it 5.8 percent as estimated by the CBO (1996)? Is it 5.7 percent as used by the Council of Economic Advisors (1996) or 5.6 percent as estimated by Gordon (this issue)? Or can unemployment safely go much lower, as recently argued by Eisner (1995a,b)? For all of 1995 and the first two quarters of 1996, unemployment hovered around 5.6 percent, while inflation remained in check. This has led to a debate among academics and policymakers over whether there has been a decline in the NAIRU and, more generally, whether economists should continue to rely on unemployment and the NAIRU as indicators of an overheated economy (Weiner, 1993, 1994; Tootell, 1994; Fuhrer, 1995; Council of Economic Advisors, 1996, pp. 51–57; Congressional Budget Office, 1996, pp. 5, 27).

At the heart of this debate lie several empirical questions. Has the NAIRU declined in recent years? What is the current value of the NAIRU? How confident should economists be in these estimates? How useful is knowledge of NAIRU in

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anticipating increases in inflation? This paper summarizes recent research and presents some new evidence on these questions.

We begin by discussing and extending recent attempts to estimate the NAIRU. We find that there is statistical evidence that the NAIRU has changed over the past 30 years and in particular that the NAIRU has fallen by approximately one percentage point from its peak in the early 1980s to a current estimate that ranges from 5.5 percent to 5.9 percent, depending on the details of the specification. However, the most striking feature of these estimates is their lack of precision. For example, the 95 percent confidence interval for the current value of the NAIRU based on the GDP deflator is 4.3 percent to 7.3 percent. In fact, our 95 percent confidence intervals for the NAIRU are commonly so wide that the unemployment rate has only been below them for a few brief periods over the last 20 years.

Faced with this uncertainty about the NAIRU, it is not surprising that forecasts of inflation based on the Phillips curve are insensitive to different assumptions about the NAIRU: we find that forecasters using values of the NAIRU ranging from 4.5 to 6.5 percent would have produced similar forecasts of inflation over the next year. Finally, we find that, although unemployment is a useful predictor of inflation over the next year, other leading indicators of inflation are better, and the relative strength of other indicators increases at longer forecast horizons. It seems to us that, in light of this imprecision, the recent debate over whether the NAIRU is currently 6 percent or 5.5 percent does little to inform monetary policy.

The NAIRU: Estimates and Confidence Intervals

A Preliminary Look at the Data

One difficulty with empirical examinations of the Phillips curve tradeoff between inflation and unemployment is the lack of a perfect measure of inflation. The literature on the Phillips curve uses a variety of measures, from broad ones like the gross domestic product (GDP) deflator to narrow measures of "core inflation," which is usually defined to exclude prices of food and energy goods. For most of this paper, broad inflation will be measured by the percentage growth in the GDP price index, and core inflation will be measured by the percentage growth in the personal consumption expenditure (PCE) price index, excluding expenditures on food and energy. The results for these two series are typical of those for other broad or core price series. The measure of the unemployment rate used throughout is the civilian unemployment rate for all workers, ages 16 and above.

Our main findings are illustrated by the scatterplot in Figure 1. The horizontal axis shows the unemployment rate in the previous year. The vertical axis shows the change in the inflation rate from last year to the current year. The data are from 1962–1995. There is evidently a negative relationship; for example, inflation increased in six of the seven years that unemployment was below 5 percentage points. Also plotted in Figure 1 is the ordinary least squares regression line estimated over this full sample. The intersection of this line with the unemployment axis is the

Figure 1

Year-to-Year Change in GDP Inflation ($\Delta \pi_t$) vs. Total Unemployment in the Previous Year and Regression Line, Annual Data for the United States, 1962–1995

Unemployment$_{t-1}$

ordinary least squares estimate of the value of unemployment for which inflation is predicted to be constant, that is, the NAIRU. Based on this regression line, the estimated NAIRU is 6.2 percent. A wide range of unemployment intercepts are, however, plausibly consistent with these data: historically, values of unemployment ranging from less than 4 percent to 9 percent have been consistent with changes in inflation of less than one-half percentage point in the following year. Thus the NAIRU appears to be imprecisely estimated. Moreover, forecast errors of more than one percentage point in average annual inflation based on this regression are common. A policymaker would understandably hope for a better predictor of inflation than the regression displayed in Figure 1.

Econometric Methodology

The graphical analysis of Figure 1 does not control for other factors that complicate this relationship, such as lagged effects of unemployment and inflation, or supply shocks, such as changes in energy prices or terms of trade. This can be done in a regression that includes the deviation of the unemployment rate from the natural rate in several previous years, together with control variables that include past changes in the inflation rate and measures of supply shocks. For example, a regression with two lags of unemployment is

$$\Delta \pi_t = \beta_1 (u_{t-1} - \bar{u}) + \beta_2 (u_{t-2} - \bar{u}) + \gamma X_t + v_t,$$

where π_t is the rate of price inflation, u_t is the unemployment rate, and X_t denotes additional control variables that include one or more lags of past changes in the

inflation rate and supply shock measures. In this regression, the NAIRU, $\bar{u}$, enters as an unknown parameter.

This version of the model is difficult to estimate because the NAIRU appears twice and because the model is nonlinear in the parameters. However, these problems are readily handled by rewriting this equation to obtain an equivalent expression that can be estimated by ordinary least squares. After separating out and collecting the terms involving the NAIRU, the regression is

$$\Delta\pi_t = \mu + \beta_1 u_{t-1} + \beta_2 u_{t-2} + \gamma X_t + v_t,$$

where $\mu = -(\beta_1 + \beta_2)\bar{u}$. Given ordinary least squares estimates of the constant term μ and coefficients β_1 and β_2, the NAIRU can be estimated as $-\mu/(\beta_1 + \beta_2)$.

The regression line in Figure 1 is a special case of this approach in which neither u_{t-2} nor X_t appear, so that u_{t-1} is the only regressor. The ordinary least squares regression line in Figure 1 is $\Delta\pi_t = 2.73 - 0.44u_{t-1}$, so the estimated value of the NAIRU is 2.73/.44 = 6.2 percent. This technique can be extended to as many lags of unemployment as seems appropriate and is the conventional method for the estimation of the NAIRU as used by Gordon (1982), the Congressional Budget Office (1994), Eisner (1995a), Tootell (1994), Weiner (1993, 1994), Fuhrer (1995) and others.[1]

As mentioned already, this formulation does not allow for time variation in the NAIRU. One approach is to model the natural rate of unemployment as having discrete jumps at certain points in time, an approach used by Gordon (1982), Weiner (1993) and Tootell (1994). However, because "break" models of this sort must be constrained not to jump too often, these models imply that NAIRU is constant over long periods. For investigating whether the NAIRU has declined in recent years, we prefer to use a more flexible approach in which the NAIRU is modeled by a flexible polynomial, a so-called "spline."[2]

Confidence Intervals for the NAIRU

It is impossible to interpret parameters that have been estimated econometrically without having a measure of their precision such as their standard errors. However, until recently no such measures of the precision of the NAIRU have been available. Presumably, the reason for this absence is that the NAIRU is a nonlinear

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[1] Additional recent estimates of the NAIRU or potential GDP appear in Amato (1995); Congressional Budget Office (1994); Cromb (1993); King, Stock and Watson (1995); Kuttner (1994); Layard, Nickell and Jackman (1991); Salemi (1996), Setterfield, Gordon and Osberg (1992); Staiger, Stock and Watson (1996, 1997); and van Norden (1995). Additional recent articles discussing changes in the NAIRU, stability in the Phillips curve and the implications for monetary policy include Cecchetti (1995); Fair (1996); Gordon (1990); Juhn, Murphy and Topel (1991); King and Watson (1994); Krugman (1994, 1995, 1996); and Kuttner (1992).

[2] Specifically, a cubic spline with two knot points is used. Between the knot points, the spline is a third degree polynomial. These polynomials are constrained to be equal, and to have equal first and second derivatives, at the knot points. The knot points used are equally spaced values along the time axis; for the regressions with 138 observations (quarterly, from 1961:III to 1995:IV), the knot points were at observations 46 and 92.

function of regression coefficients (notice that the ß terms appear in the denominator of the expression following the second display equation), and regression packages do not automatically produce standard errors for nonlinear functions. In Staiger, Stock and Watson (1997), we used Monte Carlo simulations to compare two methods for constructing confidence intervals for the NAIRU, the "delta" method,[3] which is a method used by Fuhrer (1995), and an approach that we refer to as Fieller's method. Those simulations indicated that intervals constructed using Fieller's method performed significantly better than intervals based on the delta method.[4] In this article, we therefore focus exclusively on confidence intervals based on Fieller's method.

Fieller's method is an extension of the technique proposed by E. C. Fieller (1954) to construct a confidence interval for the ratio of the means of two dependent normal random variables. A 95 percent confidence interval for, say, a mean can be calculated by performing hypothesis tests on all possible hypothetical values of the true mean; the set of values not rejected at the 5 percent level constitutes a 95 percent confidence interval. To construct a confidence interval for the NAIRU, first select a trial value of NAIRU, say 6.0, and construct the unemployment gap series, $u_t - 6.0$. If the NAIRU is in fact 6.0, then the true intercept in the regression of $\Delta \pi_t$ on this unemployment gap, its lags and the control variables X_t (which include lags of $\Delta \pi_t$) is zero, as in the first display equation. If the estimated intercept in this regression is statistically insignificant at the 5 percent level, then the hypothesis that the NAIRU is 6.0 percent cannot be rejected at the 5 percent level, that is, an estimated NAIRU of 6.0 percent lies in a 95 percent confidence interval. Repeating this for all possible values of the NAIRU produces the 95 percent confidence interval.

Estimates of the NAIRU and its 95 percent Fieller confidence interval are plotted in Figure 2, using data on the quarterly core rate of PCE inflation for 1962–1995. All the specifications reported in this section include four lags of unemployment, four lags of inflation and two supply shock control variables: one to capture the Nixon wage and price controls, and the other to capture supply shocks to food and energy prices.[5] The NAIRU is estimated to have been higher during the 1970s

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[3] The delta method is a general technique for constructing asymptotic standard errors for nonlinear functions of parameters. By using a first-order Taylor series expansion, the nonlinear function is approximated by a linear function that is asymptotically normally distributed. Standard errors are then computed using estimated first derivatives. For example, suppose that θ is a vector of parameters, $\hat{\theta}$ is its estimate, and $g(\theta)$ is the function of interest; then the delta method approximates the distribution of $g(\hat{\theta})$ by a normal distribution with mean $g(\hat{\theta})$ and variance $(\partial g/\partial \theta)' \hat{V} (\partial g/\partial \theta)$, where $\hat{V}$ is the estimated variance-covariance matrix of $\hat{\theta}$ and $(\partial g/\partial \theta)$ is the first derivative of g, evaluated at $\hat{\theta}$; cf. Greene (1990).

[4] This is not surprising. The NAIRU is estimated as the ratio of coefficients, and distributions of ratios of random variables are well known to have nonnormal, even bimodal, distributions. The delta method approximates the distribution of the estimated NAIRU by a normal, but the Fieller method intervals do not. An interesting econometric analogy is to instrumental variables estimation. The two-stage least squares estimator is the ratio of two random variables and, depending on the quality of the instruments, it can have a bimodal distribution; see for example Charles Nelson and Richard Startz (1990).

[5] The wage and price control variable, called NIXON, is the sum of the two wage and price control variables in Gordon (1982); this enters with no lag. The food and energy prices variable, RPFE, is the

Figure 2

Estimate of the NAIRU, 95 percent Confidence Interval and Unemployment, Based on Core PCE Inflation, 1961:III–1995:IV
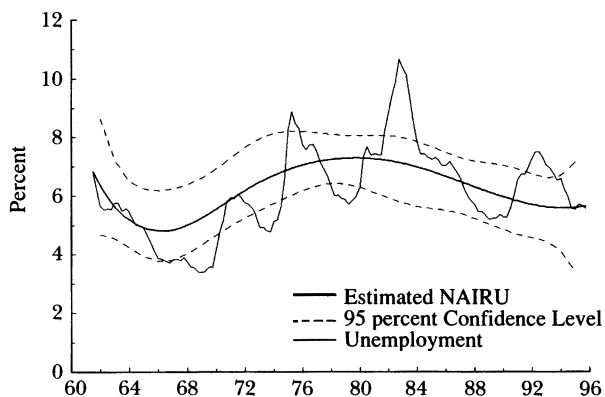
and early 1980s than during the 1960s or 1990s; during most of the 1960s, the NAIRU is estimated to have been below 5.5 percent. This variation over time is statistically significant at the 10 percent level. For these three decades, the 95 percent confidence intervals are wide enough to include most observed values of unemployment, with the exception of some cyclical peaks and troughs.

Estimates of the NAIRU are presented in Table 1. In addition to GDP inflation and core PCE inflation, results are reported for other price indexes: the full chain-weighted personal consumption expenditures (PCE) deflator; the all-items consumer price index (CPI); the CPIR, which is an adjusted version of the CPI in which the CPI for tenants' rent is substituted for the CPI for home ownership between 1967–1983; the core CPI and CPIR, which are recalculated to exclude food and energy; and finally the core CPI-M, which is a weighted median core CPI measure, published by the Federal Reserve Bank of Cleveland. The point estimates of the NAIRU based on these different inflation series are similar. However, there are substantial differences in the precision of the estimates. In general, the tightest estimates are found using core inflation, but the particular measure of core inflation makes a large difference in the confidence intervals. Even the tightest of these intervals for 1994:I, based on core CPIR inflation, is 4.8 percent to 6.6 percent, almost 2 percentage points wide.

Past researchers like Weiner (1993) and Tootell (1994) have found evidence that the NAIRU has changed over the postwar period, and some of the results here are consistent with this view. The point estimates of the NAIRU in Table 1 show a

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log ratio of the wholesale price deflator for food and energy, as defined in King and Watson (1994), to the CPIR, which is the CPI deflator with a rental cost adjustment as defined in the next paragraph; this enters with a single lag.

Table 1

Estimates of and Confidence Intervals for the NAIRU

Inflation Measure	NAIRU and 95 percent Confidence Intervals at Three Dates		
	84:I	*89:I*	*94:I*
GDP deflator (chain)	6.6 (4.5, 7.6)	6.3 (5.0, 7.4)	5.9 (4.3, 7.3)
PCE deflator	6.9 (2.9, 8.3)	6.4 (4.2, 8.5)	5.6 (2.8, 7.7)
CPI	6.8 (4.2, 7.9)	6.4 (4.9, 8.0)	5.9 (3.9, 7.6)
CPIR (with rental equivalency adj.)	6.8 (4.6, 7.9)	6.4 (5.0, 7.8)	5.9 (4.0, 7.4)
Core PCE	7.0 (5.6, 7.9)[a]	6.1 (5.0, 7.1)[a]	5.6 (4.1, 6.7)[a]
Core CPI	6.9 (5.5, 7.8)[a]	6.2 (5.2, 7.2)[a]	5.8 (4.5, 6.9)[a]
Core CPIR	7.0 (6.1, 7.7)[b]	6.1 (5.4, 6.8)[b]	5.8 (4.8, 6.6)[b]
Core CPI-M	6.6 (4.2, 7.7)	6.1 (4.5, 7.3)	5.8 (4.0, 7.3)

[a] The hypothesis of a constant NAIRU is rejected at the 10 percent significance level.
[b] The hypothesis of a constant NAIRU is rejected at the 5 percent significance level.
Notes: Data are quarterly with regressions run over the period 1961:III–1995:IV, with earlier observations used for initial conditions. All regressions include as regressors $u_{t-1}, \ldots, u_{t-4}, \pi_{t-1}, \ldots, \pi_{t-4}$, NIXON$_t$, RPFE$_{t-1}$, s_t, where s_t is a vector of variables defining the cubic spline.

decline of approximately one percentage point between 1984 and 1994, from the high 6s to the high 5s. However, of the eight models reported in Table 1, the hypothesis of a constant NAIRU is rejected at the 10 percent level for only three. For several of the inflation series, the NAIRU is estimated very imprecisely, and it is not surprising that statistically significant historical changes in its value cannot be detected.

Some observers have argued that our recent experience of nearly constant inflation and unemployment hovering near 5.6 percent implies that the NAIRU currently is likely to be in the range of 5.5 to 5.7 percent (for example, Council of Economic Advisors, 1996, p. 53). From an econometric perspective, the problem with this reasoning is that it ignores the effects of the shocks to inflation that are omitted from the Phillips curve specification (that is, the v_t terms in the equations given earlier). Unfortunately, these shocks generally are not observable, at least quantitatively; if they were, they could be entered as additional Xs in the econometric specifications. Without precise quantitative knowledge of all of the shocks, it is impossible to deduce a value of the NAIRU from a single year of data. Indeed, between 1963 and 1995, there were nine years in which GDP inflation changed by no more than 0.3 percentage points. These years were preceded by unemployment rates ranging from 3.8 percent (in 1967) to 7.5 (in 1985). But these values fall outside standard estimates of the NAIRU in the literature. It would have been wrong to conclude that the NAIRU was 3.8 percent in 1968 based on the 1967–68 data, and it is wrong to conclude that it now must be 5.5 percent based on the 1995–96 data.

Although the NAIRU is imprecisely estimated, it should be emphasized that

the empirical estimates confirm a clear, negatively sloped Phillips curve. According to the core PCE equation used to produce Figure 2, for example, the predicted effect of a decrease in the unemployment rate from 5.5 to 4.5 percentage points, relative to a base case of constant 5.5 percent unemployment, is an increase in the inflation rate of 0.9 percentage points over the first year and an increase of 1.5 percentage points cumulatively over the first two years. The slope of this Phillips relation is negative and is estimated fairly precisely (the t-statistic on the sum of the coefficients on lagged unemployment is −4.1). This simply quantifies the basic message of the unemployment/inflation scatterplot in Figure 1: there is a clear negative relationship, but because of the relatively few number of observations and the large errors around the regression line, the "*x*-axis" intercept (the NAIRU) is imprecisely estimated.

Sensitivity to Changes in Specification

We have investigated the robustness of the results in Figure 2 and Table 1 to literally hundreds of changes in the specification. A few of these changes are especially worth highlighting. The interested reader is referred to Staiger, Stock and Watson (1996, 1997) for further details.

One check on the specification is to include contemporaneous values of unemployment, not just lagged values. This specification is more consistent with textbook discussions of the Phillips curve, which often relate current unemployment to changes in inflation. We focus on models with lagged unemployment because of concerns about the exogeneity of contemporaneous unemployment, because the inflationary effect of tight demand plausibly occurs with a lag, and because we wish to interpret the results in terms of forecasts based on past data. When contemporaneous unemployment is included, the basic results in Table 1 do not change, although the time variation in the NAIRU becomes statistically significant using six of the eight inflation series.

A second specification check is to consider alternative models of inflationary expectations. A standard theoretical formulation of the Phillips curve relates "unexpected" inflation to deviations of unemployment from its natural rate. Our econometric specification is consistent with this formulation if the change in inflation equals unexpected inflation. Alternatively, one can proxy expected inflation either by a more complex model of how expectations might depend on past inflation rates or by real time forecasts of inflation published in contemporaneous surveys of economists and forecasters. Because some real-time survey forecasts systematically underestimate inflation, using these alternative series for inflationary expectations sometimes affects the point estimates of the NAIRU. Otherwise, the basic conclusions remain unchanged.

A third check is to consider alternative measures of unemployment. For example, the CBO bases its estimates of the NAIRU on unemployment among married males, which may be a better measure of unemployment because it is less affected by changing demographics of the workforce and because married males have strong attachment to the labor force. When we reestimate Table 1 using married male

unemployment or unemployment among males aged 25–55, our basic conclusions are largely unchanged (except that the NAIRU is estimated to be lower because unemployment is lower for these groups). The one difference is that the hypothesis that NAIRU was constant over the entire sample period typically cannot be rejected for these groups.

A fourth modification is to use alternative models of how the NAIRU can vary over time. The results for break models with three time periods, where each time period has a constant NAIRU, are qualitatively similar to those for the model presented here. When the regime dates are estimated, they tend to detect a regime in the 1960s through the early 1970s, the mid-1970s through the early 1980s, and the early 1980s through the end of the sample. A quite different approach, used in King, Stock and Watson (1995), Staiger, Stock and Watson (1997) and Gordon (this issue) is to model the NAIRU as varying in each period, but to treat that time variation as a stochastic function of time, rather than as a deterministic function as in the models presented here. This approach introduces intrinsic uncertainty into the NAIRU: even if the parameters other than the natural rate were known with certainty, the NAIRU, plausibly, would not be. The result is estimates of the NAIRU that are similar to those in Table 1, but with wider confidence intervals. These confidence intervals are wider because they incorporate an additional source of uncertainty by explicitly treating the NAIRU as evolving over time in a way that cannot be perfectly predicted. We consider this additional source of uncertainty as plausible and in this sense consider the confidence intervals in Table 1 to be too tight.

It is not surprising that among the hundreds of specifications that we have considered, a handful yield relatively tight confidence intervals. Especially if one is willing to assume that the NAIRU has not changed over the last 35 years, then it is possible to obtain apparently precise estimates of the NAIRU for a few combinations of the inflation and unemployment series. However, we would hesitate to rely on such estimates for policy purposes, unless there were strong a priori grounds for believing that the particulars of these specifications are correct. Among the recent papers that have estimated the NAIRU, we are not aware of any that has made such an a priori case. Rather, the approach in this literature is, sensibly, to admit that there is uncertainty across specification and to estimate a variety of specifications. If anything, the published estimates of NAIRU tend to use the broad measures of inflation like the GDP deflator and the unadjusted all-items CPI series that we find provide relatively less precise estimates of NAIRU.

Unemployment as a Leading Indicator of Inflation

If the link between the unemployment rate and future inflation were strong and precisely estimated, then unemployment could be an invaluable tool for predicting the course of inflation and thus for guiding policymakers. But the link is

not precise. With this in mind, we turn to a closer examination of unemployment as a leading indicator for inflation. We first focus on unemployment and consider whether forecasts are heavily dependent on the value of the NAIRU; we find that, on a practical level, they are not. We then consider the broader issue of how unemployment compares with many alternative leading indicators of inflation.

Three Forecasters, Three Values of the NAIRU

Consider three hypothetical forecasters who use the deviation of unemployment from the NAIRU to forecast inflation. The forecasters aim to predict average inflation over the next four quarters; as information arrives each quarter, they reestimate and construct a new forecast. The only difference among these forecasters is that they assume different values for the NAIRU: forecaster 1 uses a NAIRU of 4.5 percent, forecaster 2 uses 5.5 percent, and forecaster 3 uses 6.5 percent. How would these forecasters have performed relative to each other? Would their forecasts suggest significantly different directions for monetary policy?

To explore this question we estimated an equation similar to those presented earlier in the paper. The dependent variable was the change in the annual inflation rate over the next four quarters. The explanatory variables were current and past values of the gap between the natural and actual unemployment rate and the change in the inflation rate in past years.[6] We examined what forecasts would have been made during each quarter from the start of 1984 to the end of 1994, based on quarterly data from 1959 up to the quarter when the forecast was made. For example, in the first quarter of 1984, the model was estimated using data from 1959 through that quarter, and forecasts were computed for average annual inflation over the next four quarters. The forecast and the forecast error were saved. Then the process was repeated for the second quarter of 1984, using data from 1959 up to that date and looking four quarters ahead, so that a new forecast and forecast error were created.

This process is known as recursive least squares. It is a way to gauge real-time forecasting performance because each forecast is out-of-sample. By contrast, a regression based on data from the entire sample period can perform deceptively well because it uses future data that would be unavailable to a forecaster operating in real time. Recursive least squares has the additional advantage that it captures the idea that macroeconomic forecasting relations can (and do) shift over time, while full-sample ordinary least squares assumes a stable relation over the entire sample period.

The track record of these hypothetical forecasters as they made quarterly forecasts from the start of 1984 to the end of 1994—thus predicting annual inflation ending from the first quarter of 1985 to the end of 1995—is summarized in the second column of Table 2. The measure reported there is the root mean squared

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[6] Specifically, for each forecaster the dependent variable is $\pi_{t+4}^{(4)} - \pi_t^{(4)}$, where $\pi_{t+4}^{(4)}$ is the average annual rate of inflation over the four quarters $t + 1, \ldots, t + 4$; that is, $\pi_t^{(4)} = .25\Sigma_{i=0}^{3}\pi_{t-i}$. The regressors are $u_t - \bar{u}, \ldots, u_{t-3} - \bar{u}, \Delta\pi_t, \ldots, \Delta\pi_{t-3}$ (excluding a constant term); the difference among the forecasters is their hypothesized value of the NAIRU, $\bar{u}$.

Table 2

Forecasts of Four-Quarter Inflation Based on Three Different Values of the NAIRU

Assumed NAIRU	One year ahead Recursive RMSE, 1985:I–1995:IV	Forecast of inflation	
		1996	*1997*
A. GDP inflation			
4.5	0.70	2.2%	2.2%
5.5	0.61	2.3	2.4
6.5	0.64	2.6	2.9
B. Core PCE inflation			
4.5	0.53	2.0	2.1
5.5	0.49	2.2	2.2
6.5	0.54	2.5	2.7
C. CPI inflation			
4.5	1.58	2.4	2.4
5.5	1.49	2.5	2.5
6.5	1.45	2.8	2.9

Notes: Forecasts of inflation for 1996 and 1997 are constructed using data through the end of 1995:IV. Inflation values in 1995:IV are 2.5 percent (GDP), 2.4 percent (Core PCE) and 2.6 percent (CPI).

error (RMSE) of their forecasts over this period, which provides a measure of a typical forecast error. The RMSE is the square root of the average squared difference between the forecast and the actual inflation rate; this equals the square root of the sum of the variance and the squared forecast bias, and thus it captures both the spread of the forecast error distribution and any systematic bias in the forecast. The units of the RMSE are the same as the units of inflation. If the forecast errors are normally distributed, an RMSE of 0.6 means that two-thirds of the forecasts fall within ±0.6 percentage points of the actual value of inflation. Over this period, the forecaster who used a NAIRU of 5.5 percent would have done better than the competition for forecasting GDP and core PCE inflation, but the 6.5 percent NAIRU forecast was more accurate for CPI inflation. However, the average forecast accuracy of the different forecasters would have been very similar: the forecasting gain from assuming a 5.5 percent NAIRU, as opposed to a 4.5 percent or 6.5 percent rate, is an order of magnitude smaller than the typical forecast errors produced by any of the methods (as measured by the RMSE).

These three hypothetical forecasters would also produce similar forecasts. The final two columns of Table 2 provide forecasts of average inflation in 1996 and in 1997, based on all the data through the fourth quarter of 1995.[7] The forecasts based

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[7] The forecast of inflation in 1997 was computed using the same recursive procedure as described for the one-year-ahead forecasts, except that the dependent variable was the annual inflation two years hence minus current inflation; that is, the dependent variable was $\pi_{t+8}^{(4)} - \pi_t^{(4)}$.

on assumed NAIRUs of 4.5 percent and 5.5 percent are virtually identical. Forecasts based on NAIRUs as different as 4.5 and 6.5 percent produce forecasts of inflation in 1997 that differ more, by up to 0.7 percentage points. This is, however, arguably a small difference relative to the difference in the assumed value of NAIRU.

Unemployment vs. Other Leading Indicators of Inflation

If the task is to predict inflation using a measure of cyclical tightness, then there are literally dozens of candidate cyclical indicators in addition to the unemployment rate. This section reports the results of a comparison of unemployment with 69 other business cycle indicators as predictors of inflation. The 69 indicators are taken from Stock and Watson (1996) and include data on output and sales, labor markets, new orders, inventories, prices, interest rates and stock prices, money and credit, and miscellaneous series, such as exchange rates and consumer sentiment. Some of these leading indicators are real, and others are nominal. The interested reader should consult Stock and Watson (1996) for definitions and details of series selection and data construction.

For each potential indicator of future inflation, we estimated a regression where the dependent variable was the change in the annual inflation rate over the next four quarters, and the candidate leading indicator was used as an explanatory variable, along with past values of the change in inflation and a constant term. In addition, we estimated an autoregression using lags of inflation only; including the model with unemployment, there were a total of 71 forecasting models. As in the previous section, each equation was estimated recursively, so that we could consider what forecasts would have been made based on this information, both for the 1975–1984 time period and the 1985–1993 time period.[8] Forecasts of this sort were made using different measures of inflation. In addition to these results at the one-year horizon, forecasts were also made for the change in annual inflation over two years (as defined in footnote 7).

The performance of the various cyclical indicators, as measured by the RMSE of their forecast errors, is summarized in Table 3 for forecasts of GDP inflation. The first line presents the model using lagged unemployment as the candidate indicator; this is the NAIRU model in which all parameters (including the NAIRU) are updated in each period as more data become available. Evidently, this unemployment-based model provides one of the better indicators of future inflation over the next year: it was among the top ten indicators in both the 1975–1984 and 1985–1993 periods. However, the relative and absolute performance of the unemployment rate—as measured by its

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[8] Four lags of the change of inflation and the candidate leading indicator were included in each regression. In reality, this exercise is "pseudo" out-of-sample, for two reasons: the obvious one that it was done in the present, and the less obvious but potentially significant one that it was done using the most recent revisions of the data. For some series, such as interest rates, there are few or no revisions, but for others, such as money supply variables, there can be substantial revisions due to changes in survey scope or design, greater data availability, new weighting methods, or revisions of seasonal adjustment factors. Thus the results from this comparison are only a guide to what true out-of-sample performance would have been given then-current information for these series.

Table 3

Unemployment as a Leading Indicator of GDP Inflation

	One year ahead		Two years ahead	
Candidate Leading Indicator	*75:I–84:IV*	*85:I–93:IV*	*75:I–84:IV*	*85:I–93:IV*
Unemployment rate				
(all workers 16+)	1.57 (7)	.70 (10)	2.32 (17)	1.42 (30)
Average initial claims,				
state unempl. insurance	1.85 (36)	.56 (1)	2.71 (38)	.78 (1)
Capacity utilization rate,				
manufacturing	1.46 (3)	.61 (3)	2.16 (9)	1.10 (4)
New orders index, Nat'l Assn.				
of Purchasing Mgrs	1.52 (5)	.74 (20)	1.93 (2)	1.36 (24)
Manufacturers' unfilled				
orders, durable goods	1.61 (13)	.71 (11)	2.70 (35)	1.36 (25)
Federal Funds rate	1.93 (50)	.66 (5)	2.50 (26)	1.08 (3)
M3 money stock (growth rate)	1.93 (49)	.76 (30)	3.29 (64)	1.15 (5)
Lagged inflation only	1.88 (43)	.73 (16)	3.14 (60)	1.16 (6)

Notes: Entries are root mean squared errors (RMSEs) of forecasts of the change in GDP inflation and (in parentheses) their ranks among 71 candidate leading indicator forecasts of inflation over the indicated sample period.

RMSE and its ranking among indicators, respectively—deteriorates when the forecast some indicators of inflation that performed as well as or better than unemployment over the past 20 years. The capacity utilization rate in manufacturing produces more accurate forecasts at both horizons over both sample periods; the National Association of Purchasing Managers' index of new orders outperforms unemployment at both horizons in the 1975–1984 period; and the federal funds rate outperforms unemployment at both horizons in the 1985–1993 period. (Of course, the federal funds rate is not a particularly useful leading indicator for monetary policymakers, because it is largely under their control.) Other labor market variables are also useful indicators of future inflation, but none uniformly dominates the total civilian unemployment rate. For example, average initial claims for state unemployment insurance produced the most accurate forecasts of GDP inflation for the 1985–1993 period, but these forecasts were not as accurate as those using unemployment during the 1975–1984 sample period. It is notable that a forecaster who used only lags of inflation would have produced more accurate two-year-ahead forecasts of inflation over the 1985–1993 period than those based on unemployment.[9]

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[9] It might at first seem counterintuitive that one could do worse using more information; after all, adding more variables will necessarily increase the R^2 in ordinary least squares regression. However, this is not so in a recursive least squares process, because the data set for each regression ends before the forecast period. If there are structural breaks in these forecasting relations, as was found in the broader investigation in Stock and Watson (1996), then the combination of the additional variable and the changing structure can well produce worse recursive forecasts than using only lags of the dependent variable.

These results are robust to using different inflation or unemployment series. For example, forecasts of core PCE inflation based on these leading indicators produces similar results: at the one-year horizon, the unemployment rate ranks twelfth during 1975–1984 and fifth during 1985–1993, but it drops to fifteenth in both subsamples at the two-year horizon. Repeating this forecasting comparison using the prime age or married male unemployment rate also produces results similar to those reported in Table 3. A pattern across all these results is that inflation forecast errors were more accurate during 1985–1993 than during 1975–1984. It is tempting to conclude that inflation forecasting models have improved, but a more reasonable explanation is that the 1975–1984 period was turbulent with several large, essentially unpredictable shocks to inflation; forecasting inflation simply was easier during the quiescent late 1980s.

These results suggest that some other variables are at least as valuable as unemployment for predicting inflation. But do these additional variables provide valuable information beyond that contained in lagged unemployment and inflation? To investigate this, the recursive forecasts were recomputed, except that each recursive forecast was based on a constant, lagged values of the change of inflation, lags of unemployment and lags of the candidate leading indicator (with four lags of all series). Because the forecasts were computed by recursive least squares, in theory these augmented models could all have larger RMSEs than the constant-NAIRU model in the first line of Table 3. In fact, approximately 20 percent of these augmented models improve upon the forecasting performance of the NAIRU model at the one-year horizon, and approximately half of the models improve upon its performance at the two-year forecast horizon. Combining information in other series with the information in unemployment can enhance forecasts of inflation.

In summary, although the unemployment rate is a useful predictor of short-run inflation, it is less useful for predicting longer-run inflation. Despite the usefulness of unemployment as an indicator of future inflation at short horizons, the NAIRU itself plays little role in the forecasting relation. Models utilizing a wide range of values of the NAIRU produce forecasts with similar degrees of accuracy.

Conclusion

This paper has focused on "state-of-the-art" models that allow the NAIRU to change over time. Based on the models examined here, there is evidence that the NAIRU has declined by approximately 1 percentage point over the past 10 years. Estimates of the NAIRU in 1994 range from 5.6 to 5.9, depending on the specification. However, these estimates are imprecise; the tightest of the 95 percent confidence intervals for 1994 is 4.8 to 6.6 percentage points. If one acknowledges that additional uncertainty surrounds model selection and that no one model is necessarily "right," the sampling uncertainty is prudently considered greater than suggested by the best-fitting of these models.

Fortunately, precise knowledge of the NAIRU is not very important from the perspective of forecasting inflation. Forecasts of inflation based on the deviation of unemployment from the NAIRU are similar whether the NAIRU is assumed to be 4.5, 5.5 or 6.5 percent. The difficulty in estimating the NAIRU and its limited role in forecasting inflation are, of course, interrelated; after all, if the NAIRU played a more important role in forecasting inflation, then its value could be pinned down with greater precision from the data.

An extreme conclusion to draw from these results would be that a natural rate does not exist. This argument could either be based on a belief that the NAIRU has shifted, or on the wide confidence intervals surrounding the estimates. A theoretical justification for such a position could be that the hysteresis that has been proposed as a description of European unemployment (Blanchard and Summers, 1986) is present in the U.S. economy as well, so that there is no rate of unemployment that is in general consistent with constant inflation. We do not, however, believe that the evidence supports this view. Although there is evidence that the NAIRU has shifted, the shifts have been relatively minor over the past three decades: using total civilian unemployment and the GDP deflator, the NAIRU moved from a low of 4.9 in 1966 to a high of 7.0 in 1978.

It would also be misguided to conclude that running a loose monetary policy runs no risk of higher inflation, or that running a tighter policy will not reduce inflation. In our regressions, there is a downward-sloping Phillips curve; it simply is difficult to estimate the level of unemployment at which the curve predicts a constant rate of inflation. For some purposes, such as targeting the level of unemployment at which inflation is stable, this is a problem; but for other purposes, such as estimating how much inflation will increase for a one-percentage point drop in unemployment, knowledge of the NAIRU is irrelevant. Policymakers and macroeconomists need to recognize these limitations and advantages of the Phillips curve. Indeed, for the purposes of positive economic analysis, it might suffice to know that there is an empirical regularity, albeit a noisy one, between the unemployment rate and changes in inflation, and that the natural rate probably lies between 4.3 and 7.3 percentage points of unemployment.

Norbert Wiener, the great physicist, is reported once to have said, "Economics is a one or two digit science" (Morgenstern, 1963, p. 116). This observation should be kept in mind when economists enter the public discourse about the value of unemployment at which monetary policy strikes a neutral balance between expansion and contraction. The results reported here do not provide a better estimate of that value of unemployment; rather, they suggest that debating over whether the NAIRU is 4.5, 5.5 or 6.5 percent does little to enlighten monetary policy.

A more useful, if more difficult, task is to focus on the general problem of forecasting inflation. Certainly, the recent history of the unemployment rate helps to predict inflation over the next year, although it is less valuable over the next two years. But other variables are as good or better, including the capacity utilization rate, other labor market variables, interest rates and, at longer horizons, some monetary aggregates. The results presented here are only suggestive; the construction

and use of leading indicators for inflation and other macroeconomic variables constitutes a challenging and important research program. Nonetheless, these results reinforce the commonsense, if unexciting, view that monetary policy should be informed by a wide range of variables, not just unemployment.

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