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Economic Research Note

Where is the NAIRU?

- **We estimate the NAIRU using several models based on prior work by policymakers and academics**
- **We favor an estimate of 5%, but stress the wide confidence intervals around it**
- **We are more confident that a transitory drop below NAIRU would produce only modest inflation**

The NAIRU—the "non-accelerating inflation rate of unemployment," or the unemployment rate below which inflationary pressures start to build—is a key parameter determining the appropriate stance of monetary policy. As the Fed debates the pace of policy tightening in the coming months and years, debate over the level of the NAIRU will be front and center.

Estimating the NAIRU is never easy, and recent moves in oil prices and the dollar will make distinguishing among sources of inflationary pressure even more difficult than usual. In this note, we develop several models to filter an estimate of the NAIRU from recent data on unemployment and inflation. We settle on a NAIRU estimate of 5%, but confidence intervals are wide and perfectly plausible models can produce both higher and lower estimates. However, our models generally agree that the relationship between unemployment and inflation is weak in recent data, suggesting that a transitory undershooting of the NAIRU would produce only modest inflationary pressure.

Setting the stage

As shown in the chart to the right, estimates of the natural rate of unemployment (a concept closely related to the NAIRU) from the Congressional Budget Office and the FOMC were near 5% as the recession ended. As we have written before, however, the severity of the recession may have changed the labor market in ways that could either raise or lower the NAIRU. For example, high levels of long-term unemployment suggest some workers may have experienced lasting damage to their employability, and a rightward shift in the Beveridge curve suggests a mismatch between workers' skills and available jobs. While these factors suggest that the NAIRU may have risen, increases in nonparticipation and involuntary part-time work suggest it may have fallen.

Early on, arguments for a higher NAIRU won the day. As the chart shows, outside estimates of the NAIRU followed the unemployment rate upward early in the recovery, with the CBO's current estimate of the short-run natural rate peaking at 6% in early 2012. We, however, were skeptical of

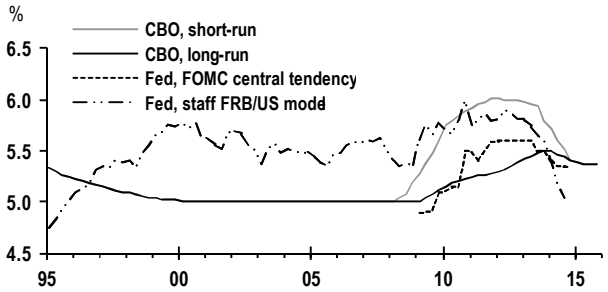
NAIRU Dashboard

Current unemployment rate:	5.6
Outside estimates of the natural rate:	
Congressional Budget Office, Long-run	5.4
Congressional Budget Office, Short-run	5.4
Federal Reserve, FOMC longer-run central tendency	5.4
Federal Reserve, staff FRB/US model	5.0

J.P. Morgan model estimates:	Current NAIRU	Phillips Slope
Linear Phillips curve in last 20 years of core PCE data	5.0	0.04
with core CPI instead of PCE	4.9	0.05
with headline PCE instead of core	5.6	0.09
with ECI instead of PCE	5.3	0.09
with U6 in estimation instead of U3	4.4	0.05
with time-varying NAIRU	5.5	0.05
with supply shocks	4.8	0.04
with survey expectations	4.6	0.16
with kink in curve	5.0	0.09
with correction for downward rigidity (Tobit)	4.4	0.07
with supply shocks and survey expectations	4.6	0.18
and with time-varying NAIRU: 5-yr MA	4.2	0.18
and with time-varying NAIRU: Kalman filter	4.3	0.19

Source: BLS, CBO, Federal Reserve, BEA, J.P. Morgar

Outside estimates of the natural rate of unemployment



Source: CBO, Federal Reserve, J.P. Morgan.
Note: CBO and FRB/US are current estimates of historical path.

arguments that the NAIRU had risen this much and left our estimate at 5.5%. Indeed, as the unemployment rate has fallen rapidly, the CBO has revised down its estimates of the natural rate. Monday's release of the CBO Budget and Economic Outlook trimmed the current short-run natural rate from 5.7% to 5.4%, as shown in the "NAIRU Dashboard" above.

Notably, there have also been substantial declines in the natural rate estimate from a sophisticated statistical model maintained by the staff economists at the Federal Reserve Board. While this model's estimate was near 5.7% for much of the recovery, it has fallen to 5.0% over the last year.

Of course, the most closely watched estimates come from the FOMC. At the December meeting, the midpoint of the central tendency of the participants' estimates was 5.35%, down from 5.5% at the end of 2013. (Technically, participants provide the level of the unemployment rate that they expect in the

"longer run" under the assumptions of appropriate monetary policy and no additional economic shocks.)

As we describe in the rest of this note, many of our model estimates of the NAIRU are below this level, and we settle on a preferred estimate of 5%. We expect the FOMC's projections to move further in this direction as unemployment keeps falling, as the Fed staff's model estimates already have.

A first cut

Many NAIRU estimates are based on an estimate of the "Phillips curve" or the relationship between inflation and unemployment. Recent macroeconomic models are usually based on "accelerationist" Phillips curves, where the change in the rate of inflation (the acceleration of the price level) is related to the gap between the unemployment rate and the NAIRU:

$$\pi_t - \pi_{t-1} = -\beta(U_t - U^*) + \varepsilon_t,$$

where π_t is the rate of inflation in year t, U_t is the unemployment rate, and $U^*$is the NAIRU. β is the parameter measuring the slope of the Phillips curve, and ε_t is an error term capturing other factors that might affect inflation, like import price shocks, productivity gains, or random noise.

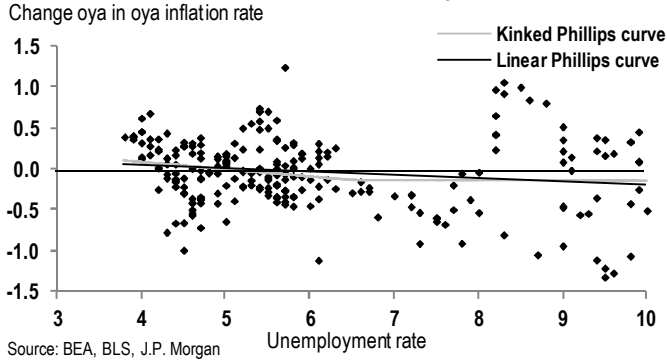
The chart on this page plots an estimate of this equation for core PCE inflation. The y-axis shows the change from one year to the next in the over-year-ago rate of inflation, using overlapping monthly data from the last 20 years. For example, the last observation is the November 2014 rate of oya core PCE inflation (1.41) minus the rate of oya core PCE inflation from November 2013 (1.31), or 0.1. The x-axis shows the level of unemployment at the end of the second year (5.8% in November 2014).

The point on the x-axis where the regression line goes through zero on the y-axis represents the unemployment rate where inflation neither increases nor decreases on average—the NAIRU. This simple model produces a NAIRU estimate of 5.0%.

The first line of the model estimates section of the NAIRU Dashboard above also shows the estimate of the slope of the Phillips curve regression line from the chart. The Phillips curve is extremely flat in recent data: an additional 1%-pt decline in the unemployment rate is associated with only an extra 4bp of inflation.

With only 20 years of data in this specification, however, the standard "delta method" of computing a standard error around the NAIRU produces an estimate of 1. That is, a 95% confidence interval including about two standard errors in each direction would run from about 3% to 7%. In fact, a 1997 paper by Douglas Staiger, James Stock, and Mark

Phillips curve for core PCE inflation in last 20 years of data
Change oya in oya inflation rate



Source: BEA, BLS, J.P. Morgan

Watson argues that standard errors computed in this way are too small, and true confidence intervals are even wider. Although wide bands of uncertainty like this will plague all estimates of the NAIRU, the Fed must still attempt to infer its level in order to choose the appropriate path of policy, and so we forge ahead with our investigation.

We first test robustness to using alternative measures of inflation. The next three lines of the dashboard show that using core CPI in place of PCE brings the NAIRU estimate down a tick to 4.9%, while using headline PCE and the employment cost index nudge it up to 5.6% and 5.3%, respectively. Because the ECI and core CPI produce estimates similar to core PCE, and because the FOMC has clearly indicated its focus on core rather than headline inflation, we focus on core PCE in the rest of our results.

Bells and whistles

More elaborate models of the NAIRU are often built around a Phillips curve like this, but with alternative specifications that might include lags of past inflation and the unemployment rate, along with additional bells and whistles. We focus on understanding the importance of four factors that could shift our NAIRU estimate: variation in the NAIRU over the last 20 years, supply shocks like oil and import prices, the tendency for inflation to return toward long-run expectations, and possible downward rigidities in wage and price setting.

One argument for a changing NAIRU holds that additional labor market slack not captured in the headline "U-3" unemployment rate will restrain wage and price pressures, causing a lower-than-normal level of U-3 unemployment to be consistent with stable prices. The fifth model in the dashboard captures this possibility by fitting a Phillips curve to the U-6 unemployment rate, which produces a NAIRU-6 estimate of 8.9. To compare this estimate to our other models in U-3 terms, we scale it by the current ratio of U-3 to U-6 to arrive at a NAIRU-3 of 4.4%.

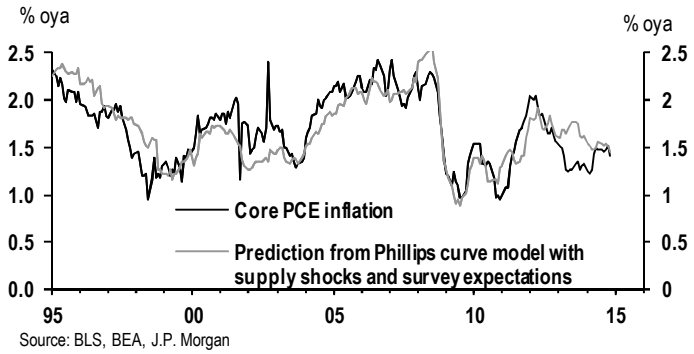
To allow the NAIRU estimate to vary over time more flexibly, the sixth model fits a Phillips curve relationship to the same data from the first chart, but allowing variation in the NAIRU using a statistical technique known as the Kalman filter. This model finds that the NAIRU has risen above its average level in recent years and currently stands at 5.5. This estimate would be consistent with claims that mismatch and long-term unemployment have pushed the NAIRU up.

However, this model still leaves out important factors that can drive inflation. The next two models include variables that control for supply shocks and the tendency of inflation to return toward long-run expectations. Including these two sets of variables separately pushes the NAIRU estimates down a bit, to 4.8% and 4.6%. Notably, the slope of the Phillips curve rises substantially in the model including survey expectations, to 0.16. (The supply shock variables take the form of three lags of annual relative import price inflation. These are highly correlated with relative energy price inflation, so including additional energy-related terms added little to the model. Labor productivity variables also added little, so we leave them out. We measure inflation expectations using data from the Survey of Professional Forecasters, with an adjustment to convert CPI expectations into PCE terms before 2007.)

We worry, however, that models like these could be misled by downward rigidities in wage and price-setting. As we have written before, we think that employers' reluctance to make outright cuts in nominal wages caused a flattening of the relationship between wage growth and unemployment in recent years. With downward moves in wages constrained by these rigidities, price inflation might have fallen less than it otherwise would have when unemployment was far above the NAIRU. Simple Phillips curve models, however, could observe that inflation did not fall dramatically when the unemployment rate was high and conclude that the Phillips curve is flat and the NAIRU high.

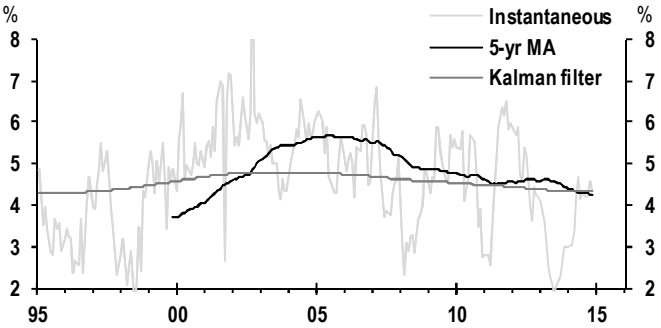
The next two models in the dashboard allow for this possibility. The first allows the Phillips curve to be kinked, with a flatter slope at high levels of unemployment, just as in our prior work on wage inflation. The next one uses a "Tobit" procedure that models the inflation rate as constrained from falling below a certain level even if the Phillips curve is steep. These models do find a steeper slope on the Phillips curve than the simple linear model, but these corrections matter less than including the survey expectations terms. Although we found strong evidence that downward rigidities were important for wages, these results suggest that the link between wages and prices is weak enough that these rigidities are not that important for predicting price inflation.

Core PCE inflation and model prediction



Source: BLS, BEA, J.P. Morgan

Estimates of time-varying NAIRU



Source: BLS, BEA, J.P. Morgan

We thus focus on a linear Phillips curve model including both supply shocks and survey expectations, like many models often used in academic and policy research. The first chart on this page shows predicted inflation from such a model alongside the actual inflation data. They line up nicely, and the model's R-squared is 0.6. This model produces a NAIRU estimate of 4.6%.

We then extend this model to allow the NAIRU to vary over the last 20 years. Inspired by a 2002 paper by Laurence Ball and Gregory Mankiw, we construct an "instantaneous" NAIRU estimate implied by actual inflation and our estimate of β in the model above (essentially equal to $(\pi_t - \pi_{t-1})/\beta - U_t$), with additional terms for supply shocks and expectations). When actual inflation is higher than predicted by the model with a constant NAIRU, the instantaneous NAIRU estimate is higher. When actual inflation is lower than predicted, the instantaneous NAIRU estimate is lower. Essentially, different methods for smoothing this time series produce different time-varying NAIRU estimators that have appeared in the academic literature; two of these are shown in the next chart.

As a first pass, a simple five-year moving average of the instantaneous NAIRU produces a current NAIRU estimate of 4.2. The more sophisticated Kalman filter used by Robert Gordon in a series of papers produces an estimate of 4.3. (The Hodrick-Prescott filter used by Ball and Mankiw comes in at

3.8, and the cubic spline favored by Staiger, Stock, and Watson at 3.9, but we prefer the Kalman filter estimates.)

The model finds low estimates of the current NAIRU because inflation has been lower than the model would otherwise have expected during much of the last five years. This result is driven largely by the model's survey expectation term. The model finds a strong tendency for inflation to return toward long-run expectations. Because inflation has run well below expectations for several years, the model assumes that the expectations were exerting a significant amount of upward pressure on inflation. Because inflation still failed to rise, the model infers that there was a great deal of slack and that the NAIRU must be low.

Although these low numbers remind us that any estimate of the NAIRU is highly uncertain, we suspect they will prove transitory. Inflation ran far below the model's prediction throughout 2013, pulling down the time-varying NAIRU estimates. However, the data have actually been roughly in line with the model since April 2014, as inflation increased and dollar and oil moves pushed the model prediction down. The instantaneous NAIRU estimate has moved back into the range of 4 to 5, and the time-varying estimates will tend to drift up as 2013 fades into the past.

Summing up

Weighing these alternative approaches, we favor a NAIRU estimate of 5%. The lower estimates from some of our models are driven by a strong estimated tendency of inflation to return toward expectations and its failure to do so during the last few years. These results are unfortunately quite sensitive to small changes in the specification of the expectations term, and we also question how much we can learn about the NAIRU using data from recent years when it was very far away. Thus we discount these estimates somewhat and place more weight on results from our other models, which are centered on 5%.

We also highlight three more conclusions from our investigation:

First, there is a great deal of uncertainty around the NAIRU. The variety of estimation approaches in the dashboard produce a range of estimates, each of which has a wide statistical confidence interval around it. Plus, many of these estimates are disappointingly sensitive to seemingly minor changes in model specification. Although any parameter estimate is subject to uncertainty, we think it is exacerbated in this case by the severity of the recession and the slow pace of recovery. For most of the last six years, the unemployment rate has been so far away from normal that we have gained little information about the level of the NAIRU.

Second, despite this uncertainty, the estimates show a clear tendency to decline when we allow for a time-varying NAIRU in a model including survey measures of inflation expectations. Inflation has remained well below long-run expectations for most of the last five years, despite the model's conclusion that they should exert a strong gravitational pull upward. As a result, the model concludes that a large amount of slack has held inflation back, implying that the NAIRU is low. Although we hesitate to take the implications of these results fully on board, we will watch the data carefully for more evidence in this direction.

Finally, we note one fact that is quite robust across estimation approaches—the slope of the Phillips curve is low in recent data. Where research using data from before the 1990s often found a slope of 0.6 or more, none of the slope estimates in the rightmost column of our dashboard is above 0.2. This would suggest, for example, that if the NAIRU is actually 5% but a policy mistake by the Fed allows unemployment to fall temporarily to 4%, we would only see an additional 20bp of inflationary pressure. (Of course, if labor market pressure is allowed to build for too long, expectations could lose their anchoring and the Phillips curve could steepen.)

Overall, we think that considerable uncertainty around the NAIRU raises the odds that the Fed (and everyone else) will misjudge its level in real time. But given the flat slope of the Phillips curve in recent data, the implications of a transitory policy mistake for the inflation outlook would be relatively modest.

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