BOARD OF GOVERNORS OF THE FEDERAL RESERVE SYSTEM

DIVISION OF RESEARCH AND STATISTICS

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To: Dave Stockton

From: Charles Fleischman and John Roberts

Subject: A new state-space model of potential output and the business cycle

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In putting together the Greenbook estimates of resource utilization, potential output, and the NAIRU, the staff routinely decomposes incoming data on output and the labor market into trend and cyclical components. Frequently, however, key indicators of macroeconomic activity send divergent signals about the state of the business cycle and about important macroeconomic trends. Resolving the tensions between the various measures is one of the major challenges of the staff's judgmental approach. For example, the staff has wrestled with the implications for the Greenbook estimates of potential output, the NAIRU, and the output gap from the apparent disparity between movements in real GDP and the unemployment rate. Our attached paper, "A Multivariate Estimate of Trends and Cycles," addresses these issues by producing new estimates of potential output and the output gap using a state-space model that allows for the simultaneous consideration of product- and income-side measures of real output along with many of the key labor market indicators that the staff uses in its analysis of the current economic situation.

Our model exploits a number of identifying assumptions that have been used in the literature. First, our multivariate approach means that we can rely on comovement in important indicators of output and the labor market to help identify the business cycle (as in the early work of Burns and Mitchell and in the factor-model approach of Stock and Watson, 2002, and Giannone, Reichlin, and Small, 2005). Second, we assume that trends are permanent and cycles are transitory, as in many of the early decompositions of output into trend and cycle, such as Clark, 1987, and Watson, 1986. A third idea we

incorporate is that cyclical fluctuations may affect inflation. In particular, we include a Phillips curve in our model, which helps to decompose activity variables into cycle and trend components and which allows us to interpret the "trend" in the unemployment rate as a NAIRU and the trend in real output as potential output.

We believe there are several reasons why our model may be a useful input into the staff's judgmental process:

- The model is able to assess the trade-offs among competing signals from different indicators in an integrated fashion because it treats the major macroeconomic indicators in a single system. For example, our approach relates the output gap and the unemployment gap, and thus includes a form of Okun's law. But it also includes NFB output and hours, and so also yields estimates of trend productivity and the productivity gap.

- Our model includes a decomposition of trends similar to that in the staff's growth-accounting framework. As in the staff's approach, the model's estimates of potential output are built up from estimates of structural labor productivity and trend hours, and the model includes "technical factors" to reconcile aggregate labor market data with the productivity data covering the nonfarm business (NFB) sector.

- The model includes both product- and income-side measures of real output, which allows us to exploit information in both measures about the state of the cycle and about trend productivity.

- The staff frequently consults Phillips curve errors in assessing the degree of economic slack; our model also allows Phillips curve errors to affect the assessment of slack.

Of course, no model is perfect, and this one is no exception. While more data can, in principle, help identify the cycle and lead to more precise estimates, the literature on macroeconomic model is replete with examples of large models that ultimately fail, from the 1970s critiques of large macro models by Sims and others down to the recent failure of factor models during the financial crisis. Moreover, the current version of our model

does not allow for changing cyclical dynamics (such as the possibility that labor productivity has become less procyclical) or other structural changes. In the end, neither this model nor any other can be a substitute for the staff's judgment.

Overview of the Approach

We use nine series in the model: Real GDP, real GDI, the unemployment rate, the labor-force participation rate, aggregate hours for the NFB sector of the economy, a corresponding measure of NFB employment, NFB-sector output (measured both on the product side and on the income side), and inflation as measured by the core CPI. In particular, the inclusion of both income- and product-side data is a key feature of our approach, given that GDP and GDI can present substantially different views of overall macroeconomic activity.[1] In our analysis, we assume that both GDP and GDI are measured with error, but that they share a common trend and cyclical component, and we define the concept of GDO as the common components in GDP and GDI,

$$GDO_t = cyc_t + GDO_t^* \qquad (1)$$

where cyc is the common cyclical component, which we will refer to generally as the output gap or the cycle, and GDO_t^* is the common trend component, which we will refer to as potential output. GDP and GDI are related to GDO by:

$$GDP_t = GDO_t + e_t^1 \qquad (2)$$

and

$$GDI_t = GDO_t + e_t^2 \qquad (3)$$

where e_t^1 and e_t^2 are the GDP and GDI measurement errors, respectively.

In our model, we similarly break the other measures of real output (NFB output) and each of the measures of labor-market activity into the sum of a cyclical component, a trend, and an idiosyncratic residual:

$$X_{it} = \lambda_i(L)\, cyc_t + X_{it}^* + u_{it}. \qquad (4)$$

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[1] Inclusion of these additional income-side indicators is the most notable advance over the models in Basistha and Startz (2008).

The cyclical component *cyc* is common across all the series. By introducing a lag polynominal $\lambda_i(L)$, we allow for the possibility that the cyclical component may have lagged effects on the variable x_i. The trend is X_i^* and the residual is u_i.

Finally, to help identify the cycle—and to allow our measures of trends to have the "natural rate" property, we include a Phillips curve for the CPI excluding food and energy (*DCPIX*) that is very similar to those used in the MCR section, but which also allows for a break in the coefficient on energy prices in the mid-1980s.

As described in the paper, we impose adding-up restrictions on the trends implied by the growth accounting framework to construct the aggregate trend. Specifically, we construct potential GDO as the (log) sum of potential NFB output and the output technical factor; we construct potential NFB output as the sum of structural labor productivity and trend NFB hours; and we construct potential NFB hours as the sum of the population, the trend labor force participation rate, the trend employment rate, the trend workweek, and the hours technical factor. This accounting framework is very similar to the one used by the staff in its judgmental assessment of trends.

Some Key Results

- *Measuring resource utilization and the cycle.* We find that the unemployment rate is the most useful indicator of the state of the business cycle, in the sense that the model chooses to put the largest weight on the unemployment rate in deriving its estimate of the cycle. Neither income- or product-side measures of output are particularly useful cyclical indicators, likely because both are measured with considerable error.

- *Inflation is helpful in identifying the business cycle.* Despite the presumed flatness and instability of the Phillips curve, core inflation is the second most informative variable (after the unemployment rate) for our estimates of the cycle.

- *The output gap.* As of 2009:Q4, the model estimated that the output gap was -7¾ percent of potential output. By way of comparison, the April Greenbook

estimate of the Q4 GDP gap was -7½ percent.[2] The model's estimate of the gap between measured GDP and potential output was -6½ percent in 2009:Q4 and the gap between GDI and potential output was a little more than -8 percent. (See figure 1.) The difference between the GDP and GDI gaps is accounted for by measurement error. Thus, our model suggests that as of 2009:Q4 real GDP overstated the level of real output by nearly 1¼ percent while real GDI understated the level of real activity by about ½ percent. Moreover, since the business cycle peak in 2007:Q4, real GDP has understated the cumulative decline in real activity by 1¼ percentage points, while real GDI has understated the decline by about ¼ percentage point.

Figure 1
Model Estimates of the Output Gaps (2-sided)
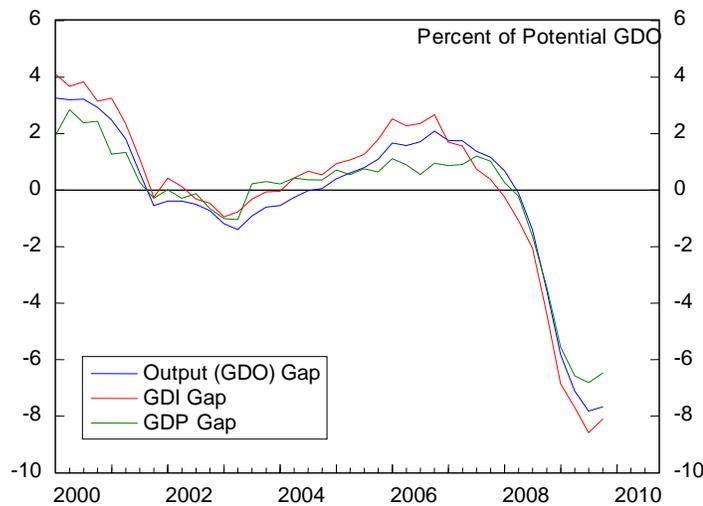
- *The productivity gap.* Inferences about the level of labor productivity relative to structural labor productivity are also sensitive to the discrepancy between the income- and product-side measures. (See figure 2.) Specifically, the product-side measure of labor productivity had moved above the model's estimated level of structural productivity by 2009:Q3, while the income-side measure is still below the structural level.

Figure 2
Labor Productivity (Actual and Trend)

Legend:
Income measure
Product measure
Model Trend (2-sided)

2000   2002   2004   2006   2008   2010
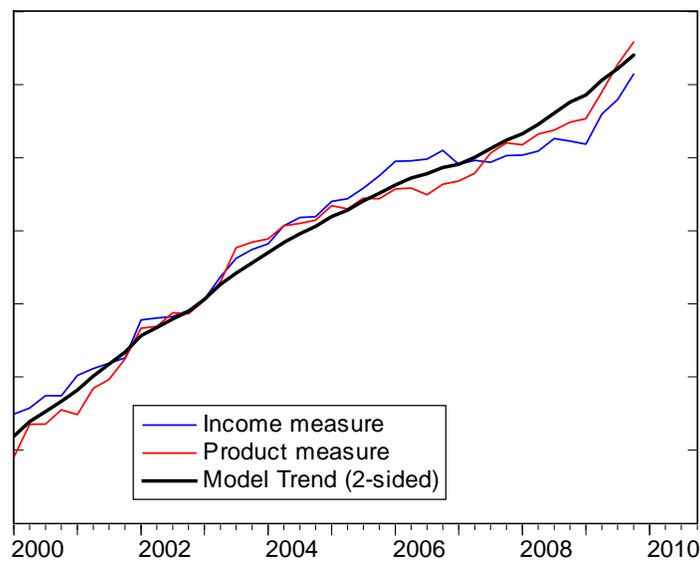
- *The NAIRU.* The model's estimate of the NAIRU was 5¾ percent in 2009:Q4, compared with the Greenbook estimate of 5¼, while the comparable estimates of the structural unemployment rate (which adds in the estimated unemployment-rate effect of emergency and extended UI benefits) were about 6½ percent and 6¼ percent, respectively. (See figure 3.)

Figure 3
Structural Unemployment Rates
(NAIRU and EEB effects)
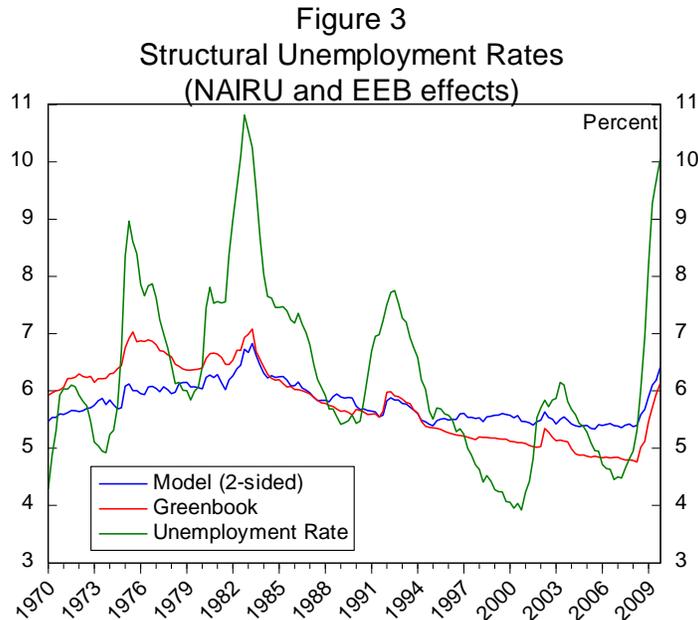
The results we discuss in this memo are based on a version of our model that is slightly different from the one in the paper. In particular, the version discussed here includes the staff's EEB (emergency and extended unemployment benefits) variable, which we use to estimate the effect of the programs on the unemployment rate. The current staff view is that the EEB programs raise the unemployment rate but do not increase labor market slack. With the exception of the estimates of the NAIRU, the estimates of the model parameters and the other state variables are very similar to those reported in the paper.[3]

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[3] Some of the key model estimates are sensitive to including data from 2009, particularly the last three quarters of the year. In particular, the two-sided estimates of the NAIRU are qualitatively different when estimation runs through 2009 than when it ends in earlier recent years. We have two conjectures about the source of this sensitivity. First, the estimated variance of the NAIRU shock is quite low, so when the (one-sided estimate of the) NAIRU increases sharply from 2008Q4 to 2009Q4, the model reinterprets the historical NAIRU; essentially, the model discounts its previously estimated 1 percentage point decline in the NAIRU between 1995 and 2008. Second, the estimated slope of the Phillips curve is appreciably lower when the model is estimated through 2009 (about 0.3) than through 2008 or earlier (nearly 0.4). Given a

Possible Uses in the Staff's Potential Output Deliberations

Because the model encompasses the key macroeconomic relationships that the staff consults in setting the Greenbook assumptions for potential output—the Phillips curve, Okun's Law, and the growth accounting identities—it can be considered to be a more systematic implementation of the staff's eclectic approach. As we discussed earlier, the model simultaneously considers the behavior of several key macroeconomic variables, which allows tensions among variables to be more readily and transparently resolved than using the variable-by-variable approaches currently used by both MCR and MAQS (FRB/US).[4]

- As noted earlier, our results suggest that in estimating the state of the business cycle, a large weight should be placed on labor-market variables, especially the unemployment rate, when labor-market indicators and NIPA-based estimates of real activity diverge. Accordingly, one insight from the model is that the staff should reinterpret "Okun's law errors" largely as errors in measuring real GDP. More broadly, we think the staff should place greater emphasis on trend, cycle, and possible measurement error in different measures of output in our discussions of the medium-run outlook.

- The results suggest that more weight should be given to income-side measures than to product-side measures when these diverge. In particular, the staff should look at both income-side and product-side measures of labor productivity; our results suggest that both are very informative about productivity trends.

- Estimates from the model could be used as a starting point for developing historical estimates of potential output that are consistent with our current methodology.

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shallower Phillips curve, the model requires a more variable unemployment rate gap (less variable NAIRU) to explain the behavior of inflation.

[4] EDO also incorporates measurement error in its estimate of the cycle. But the current version of EDO does not use income-side measures as alternative indicators of production, and hence does not touch upon many of the issues we highlight.