# From Many Series, One Cycle:
## Improved Estimates of the Business Cycle from a Multivariate Unobserved Components Model

Charles A. Fleischman and John M. Roberts

Federal Reserve Board

March 16, 2012

# Disclaimer

The views expressed in this presentation are those of the authors and do not indicate concurrence by other members of the research staff or the Board of Governors.

# Thanks!

Thanks to the organizers for inviting Charles and me to attend the conference and have the opportunity to present our paper.

# Structural and Cyclical Elements in Macroeconomics

- Title of the conference (see above)
- We view out paper as addressing exactly this topic—namely, how to determine how much of a movement in any of several economic indicators is owing to structure and how much to the cycle.

# Making sense of data

- Decision makers are faced with a vast amount of data.
- How to make sense of it?
- Factor models are one approach to processing a great deal of data.
- But the results are difficult to interpret.
  - Principal components don't necessarily have an economic interpretation.
  - No structural or cyclical elements

# Reduced-form state-space models

- Reduced-form state-space models permit a greater degree of interpretation.
  - For example, trend and cycle decomposition
- Early univariate approaches relied on time-series identification: The trend is nonstationary, cycle stationary.
  - Eg, Watson (1986), Clark (1987)

# Comovement

- Using many series allows an additional source of identification of the cycle, namely, comovement among the series.

- The idea that comovement is a defining feature of the business cycle goes back at least to Burns and Mitchell (1946).

- Examples of using comovement in a formal econometric setting include Stock and Watson (1989), Diebold and Rudebusch (1996), and Basistha and Startz (2008)
  - Comovement also lies behind the factor model approach.

# The natural rate principle

- A third source of identification of the business cycle is the natural rate principle.
  - Inflation is a key cyclical variable
  - Including a (reduced-form) Phillips curve gives a "natural rate" interpretation to the output gap.

# Combining these approaches

- Here, we combine these three principles of business cycle identification:
    1. Permanent/transitory
    2. Comovement
    3. Natural rate
- Basistha and Startz (2008) have also used all three principles to identify the cycle
- We use more data, and decompose trends

# Outline of rest of talk

1. Discuss choice of data
2. Discuss modeling approach
3. Present estimates of cycles and trends
4. Comparative information content of data
5. Addressing the Orphanides-Van Norden critique
6. Updated estimates (through 2011:Q4)
7. Why different from Weidner/Laubach/Williams?
8. Conclusion and future extensions

# Data used

1. GDP
2. Nonfarm business output, product-side
3. Nonfarm business output, income-side
4. NFB hours
5. NFB employment
6. Unemployment rate
7. Labor-force participation rate
8. Core CPI inflation

# Advantages of this choice of data

- Large dataset allows more opportunity to exploit comovement
- Can address important trade-offs:
  - What if household employment and payroll employment are sending different signals?
  - How much weight should we put on income- vs. product-side measures of output?
  - In 2011, the unemployment rate fell a lot while there was tepid GDP growth—what's the most plausible explanation?

# Advantages: Trend components

- Use of this extended dataset allows us to identify a rich accounting of the components of trend output
  - Trend productivity
  - The NAIRU
  - Trend labor-force participation
- Trend components are of interest
  - Trend productivity is, for example, a key driving variable in many macroeconomic models
  - Specificity enhances credibility

# Advantages: Identify measurement error

- Because we include two measures of output—from the product and income sides—we can also identify a third component of movements in these variables, namely, measurement error.

- Work of Nalewaik (2007, 2010) has emphasized the value of income-side measures of output.

# The model

- Observables are decomposed:

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

- Cycle follows an AR(2):

$$cyc_t = \rho_1\ cyc_{t-1} + \rho_2\ cyc_{t-2} + \eta_t$$

- Trends are compound; basic units follow unit-root processes:

$$Z_t^{\ *} = Z_{t-1}^{\ *} + \gamma_{Zt} + \varepsilon_{Zt}$$

$$\gamma_{Zt} = \gamma_{Zt-1} + \nu_{Zt}$$

# Trends

- There is a full accounting of trends:
  - Common GDP/GDI trend ($GDO^*$) is composed of trend nonfarm business-sector output ($NFBO^*$) plus a trend output discrepancy (OSR):
  - $GDO^* = NFBO^* + OSR^*$ (in logs)
  - $NFBO^* = OPH^* + HNFB^*$
  - $HNFB^* = WW^* + ENFB^*$
  - $ENFB^* = ECPS^* + ESR^*$
  - $ECPS^* = ERATE^* + LFPR^*$

# Trends, cont'd

- Fundamental components (which are random walks with drift) are in red:
  - $GDO^* = NFBO^* + $ <span style="color:red">$OSR^*$</span> (in logs)
  - $NFBO^* = $ <span style="color:red">$OPH^*$</span> $ + HNFB^*$
  - $HNFB^* = $ <span style="color:red">$WW^*$</span> $ + ENFB^*$
  - $ENFB^* = ECPS^* + $ <span style="color:red">$ESR^*$</span>
  - $ECPS^* = $ <span style="color:red">$ERATE^*$</span> $ + $ <span style="color:red">$LFPR^*$</span>

# Example of decomposition

- Example: Employment rate

  $ERATE_t = 100 \times log(1 - \text{unemployment rate}/100)$

  $ERATE_t = ERATE_t{}^* + \lambda_0\, cyc_t + \lambda_1\, cyc_{t-1} + \lambda_2\, cyc_{t-2} + u_t$

- *ERATE\** is the natural rate of employment, and follows a random-walk process (no drift)

- Equation amounts to a form of Okun's law

# Key identifying assumption

$$GDP_t = GDO_t^* + cyc_t + u_{ot}$$

- Assume that cycle affects output contemporaneously (no lags)
- Consistent with conventional assumption that GDP/GDI is best aggregate indicator
- Normalize effect to be one (so cycle has units of an output gap).

# Idiosyncratic components

$$X_{it} = \lambda_i(L) \; cyc_t \; + X_{it}^{*} + u_{it}$$

- In most cases, idiosyncratic components are assumed to be *i.i.d.*

- Exceptions are the two output measures of NFB sector output (income and product side).

   $NFBP_t = NFBO_t + u_{1t}$

   $NFBI_t = NFBO_t + u_{2t}$

   $NFBO_t = \gamma \; cyc_t + NFBO_t^{*}$

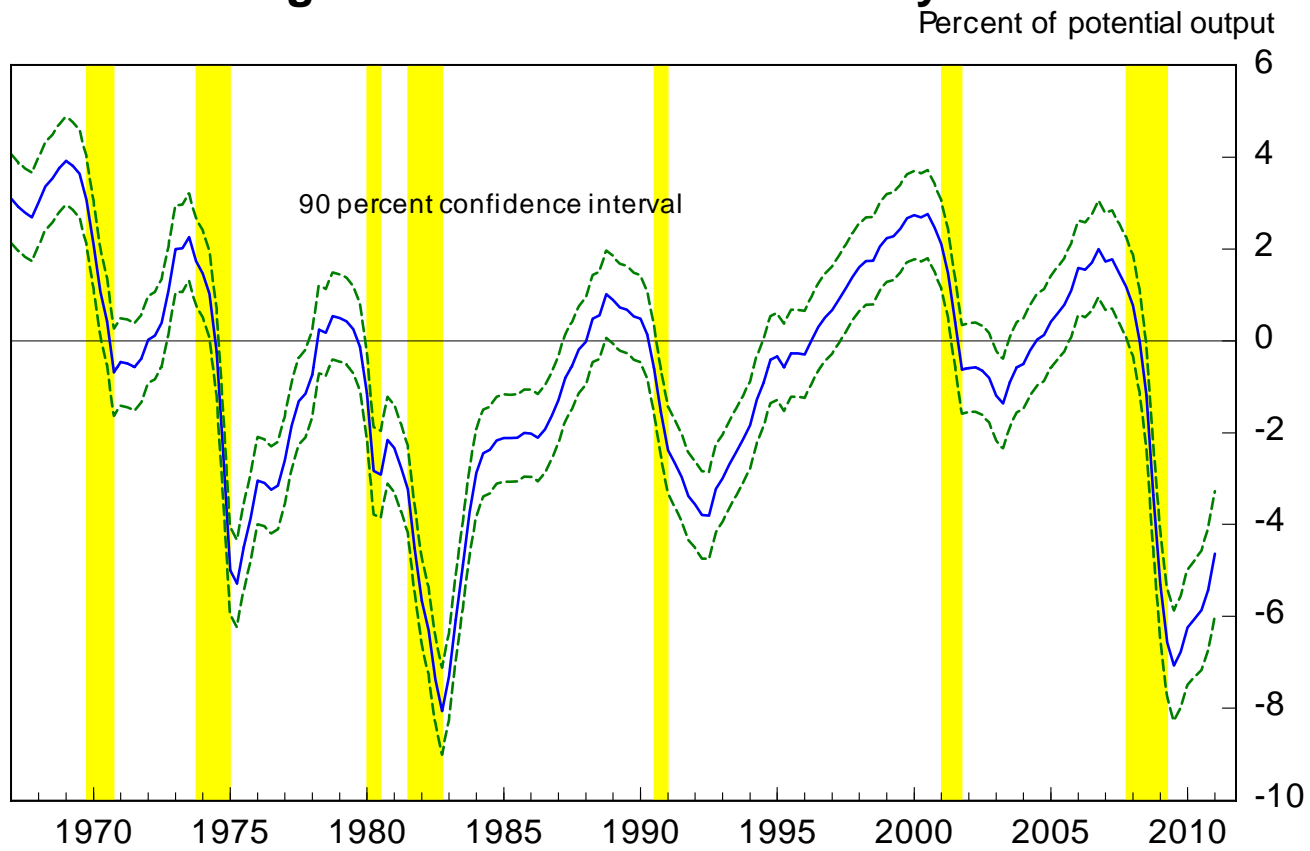- In these cases, measurement error is assumed to be AR(1).

# Phillips curve

- In order to give our trends a natural rate interpretation, we include a Phillips curve in our model:

$$core\ inflation_t = A(L)core\ inflation_{t-1}$$
$$+ \beta_1(L)relative\ energy\ prices_{t-1}$$
$$+ \beta_2(L)relative\ import\ prices_t$$
$$+ \theta\ (\lambda_0\ cyc_t + \lambda_1\ cyc_{t-1} + \lambda_2\ cyc_{t-2}) + u_{9t}$$

- Cyclical pattern corresponds to the cyclical component of the employment rate.
- $A(1) = 1$

# Figure 1:  Model Estimate of Cycle

Percent of potential output

90 percent confidence interval

Shading indicates NBER recessions.

# Estimates of output measurement error



Figure 2: The Cycle and the Gaps

Percent of potential output

Model-based cycle
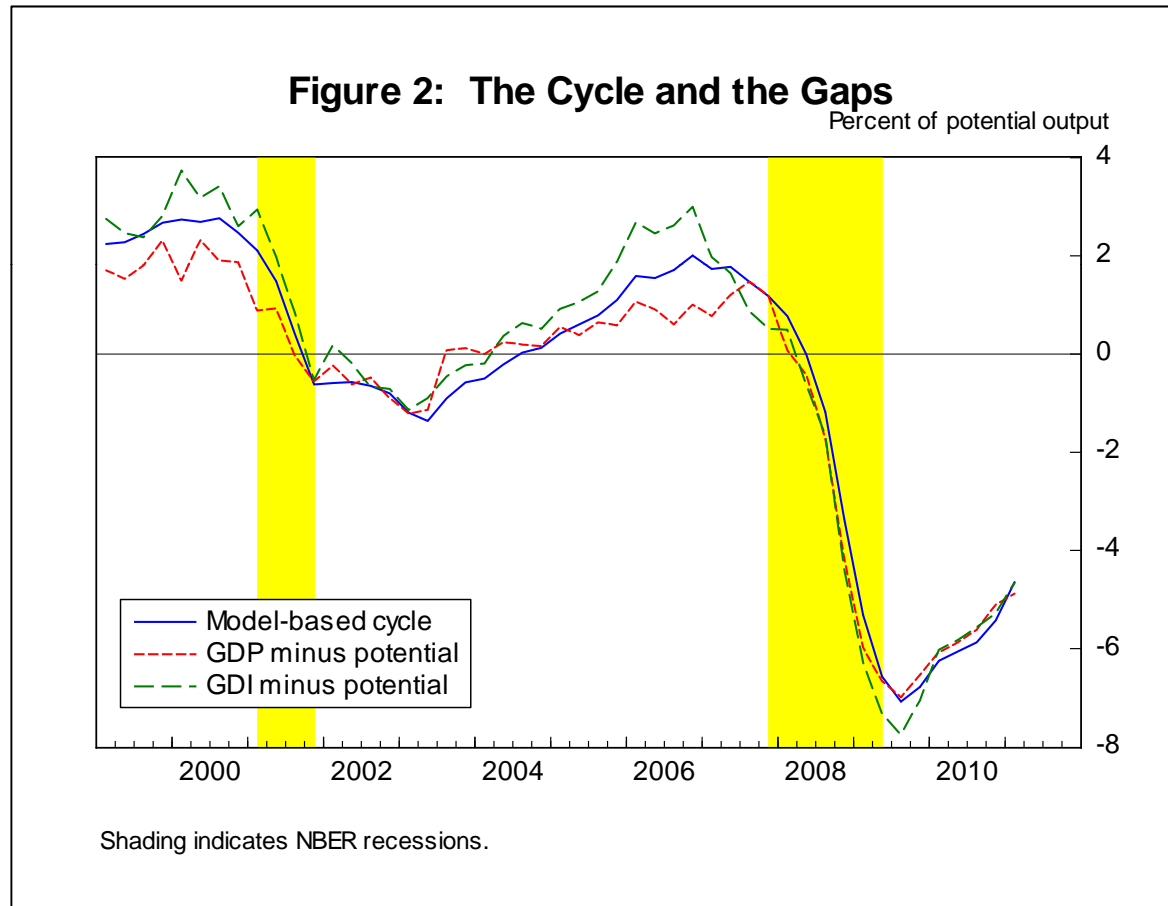GDP minus potential
GDI minus potential
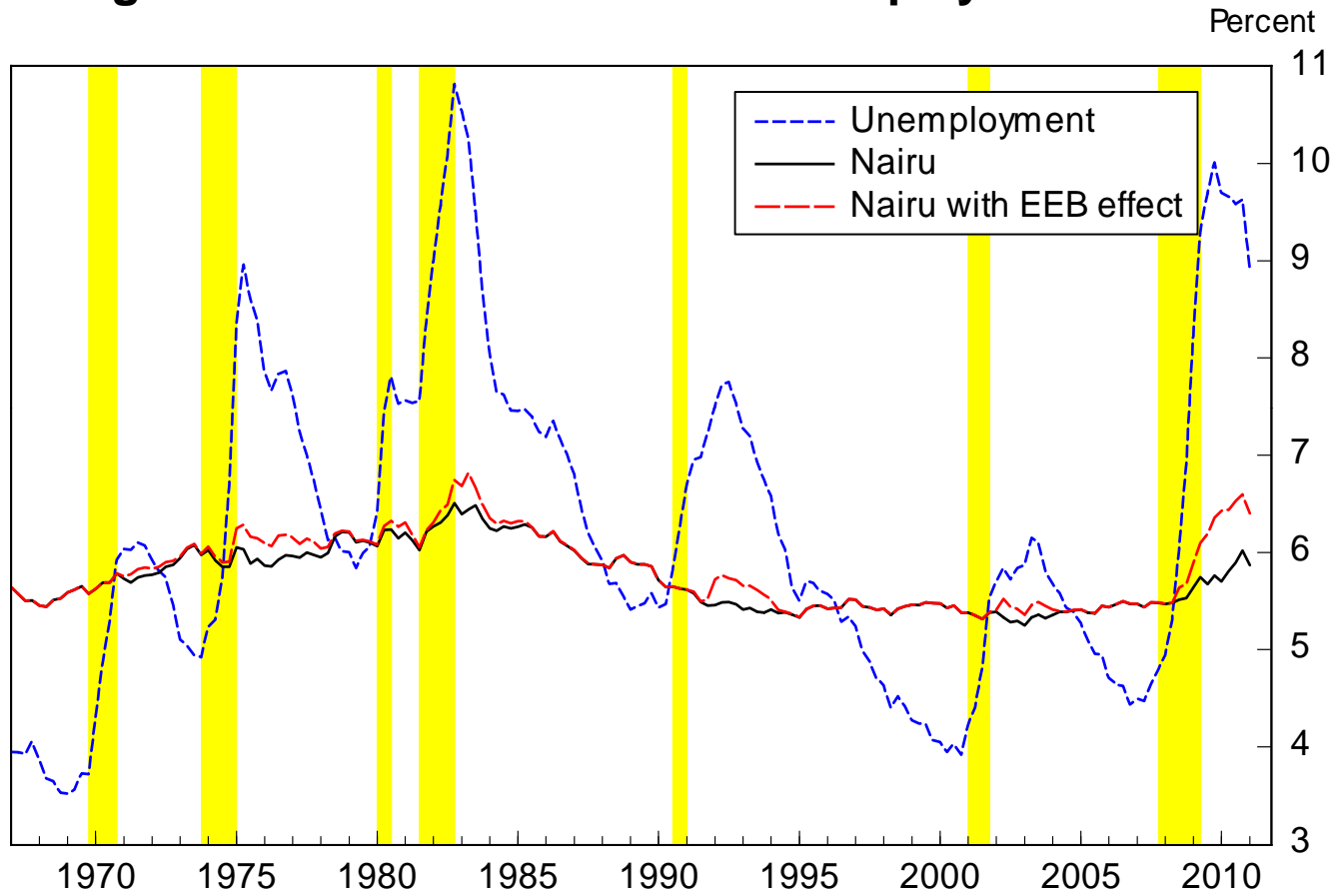
Shading indicates NBER recessions.

# Figure 4: The NAIRU and the Unemployment Rate

Percent



Shading indicates NBER recessions.

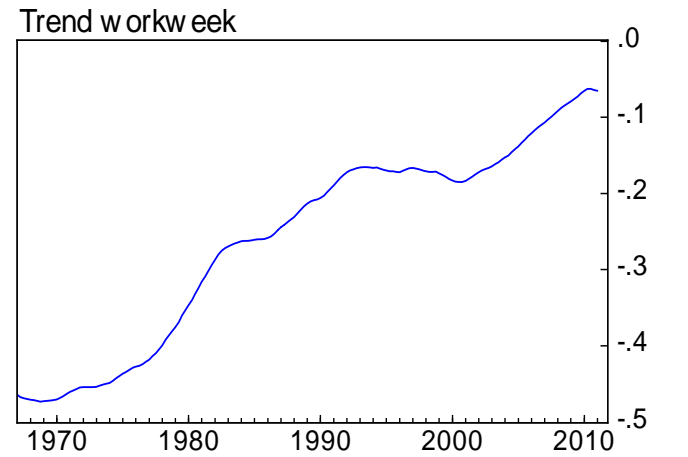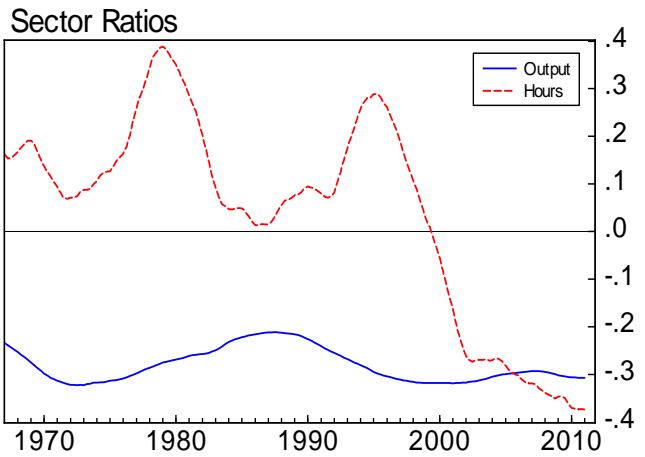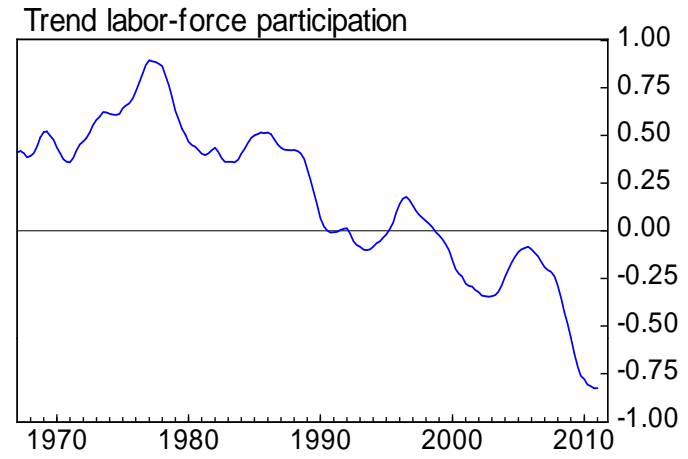| Table 2: Decomposition of Recent Movements in GDP and GDI | | | | | | |
|---|---|---|---|---|---|---|
| Q4/Q4 percent change | | | | | | |
| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
| Actual real GDP | 2.8 | 2.4 | 2.2 | -3.4 | -0.5 | 3.1 |
| Actual real GDI | 3.7 | 3.0 | -0.5 | -2.9 | -0.9 | 3.4 |
| Common components | | | | | | |
|    Potential output | 2.3 | 1.9 | 2.0 | 2.0 | 1.8 | 1.7 |
|    Cycle | 1.0 | 0.9 | -0.8 | -4.5 | -3.4 | 1.4 |
| Measurement errors | | | | | | |
|    GDP | -0.6 | -0.6 | 1.1 | -0.7 | 0.9 | 0.0 |
|    GDI | 0.3 | 0.1 | -1.4 | -0.3 | 0.6 | 0.4 |

| | Table 3: Decomposition of Potential Output, 2005-2010 | | | | | |
|---|---|---|---|---|---|---|
| | Q4/Q4 percent change | | | | | |
| | | | | | | |
| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
| Potential output | 2.3 | 1.9 | 2.0 | 2.0 | 1.8 | 1.7 |
| Total hours | 1.0 | 1.2 | 0.6 | 1.1 | -0.1 | 0.7 |
| Population | 1.2 | 1.1 | 1.1 | 1.1 | 1.0 | 0.9 |
| LFPR | 0.0 | 0.0 | -0.2 | -0.2 | -0.7 | -0.9 |
| Employment rate | 0.0 | 0.0 | 0.0 | -0.1 | -0.2 | -0.3 |
| Workweek | -0.1 | 0.0 | -0.3 | 0.2 | -0.2 | 1.0 |
| NFB labor productivity | 2.1 | 1.4 | 1.4 | 1.5 | 2.5 | 2.1 |
| Sector Ratios | | | | | | |
| GDO to NFBO | -0.2 | -0.3 | 0.1 | 0.0 | -0.7 | -0.5 |
| NFB to total employment | -0.5 | -0.4 | -0.1 | -0.6 | 0.1 | -0.6 |

# Figure 3: I(2) Trend Components



Trend labor productivity

Trend labor-force participation

Sector Ratios

Trend workweek

# Sensitivity analysis

- We explore the sensitivity of our results by examining a number of alternatives
  - Less data
  - Drop the Phillips curve
  - More volatile NAIRU
- By and large, the baseline results hold up

# How informative are the data for the states?

- Incoming data frequently send conflicting signals
  - For example, in 2011, the unemployment rate fell even though measures of output were relatively weak
- The state-space model can provide guidance on how much weight to place on different series
  - The Kalman gain

# Information content: Cycle

- The single most informative variable for the business cycle is the unemployment rate
  - High individual $R^2$
  - Highest (normalized) Kalman gain
- Conditional on unemployment rate, the next most informative variable is inflation
  - Next highest Kalman gain
  - Combined $R^2$ is 0.93

# Information content: Productivity trend

- In contrast to cycle, output measures are quite informative for trend productivity

- As are hours

- Unemployment is not so important:  Hours and output have a combined $R^2$ of 0.94

- Income- and product-side measures of output are about equally informative for trend productivity

# Revisions to cycle estimates

- Orphanides and Van Norden (2002) criticize output gaps based on econometric methods on the grounds that they revise too much:
  - Revisions about as large as cyclical variation
- We undertook a quasi-real-time (QRT) assessment to gauge importance of revisions
  - QRT uses current vintage data, not real-time
  - Okay, because OVN critique methods, not data

# QRT exercise

- Back up to 1988
- Re-estimate model each quarter
- Generate estimates of the output gap
- Compare eight-variable model with univariate models (the focus of Orphanides and Van Norden)

# Results from QRT analysis

- Orphanides and Van Norden computed the ratio of the RMSE of the revision to the cycle estimate to the standard deviation of the cycle itself

- OVN criticize the univariate methods because this ratio exceeds 1 (we find 1.07).

- For our preferred model, it is 0.56—about half as big.
  - Signal-noise ratio > 3

# Update

- We reran our model including (partial) information through 2011:Q4.
  - At the 2009 trough, cycle is still around -7 percent.
  - 2011:Q4 estimate of the cycle is -3¾ percent.
  - 2011:Q4 estimate of the NAIRU is 6¼ percent (not including EEB effects).
  - Potential GDO rose only 0.9 percent in 2011, as trend LFP continued to fall and trend productivity decelerated to about a 1 percent gain.

# Weidner/Laubach/Williams

- Weidner and Williams (2009) find a much smaller estimate of the output gap at the trough than we do—about -3 percent (March 2011 update).

- Why?
  - Original Laubach-Williams (2003) paper focused on estimating natural rate of interest, not output gap.
  - We would point to the virtues of our multivariate approach.

# Limitations of reduced-form state-space approach

- Despite its power, the reduced-form state-space approach has its limitations
- Trend and cycle are typically assumed to be orthogonal
  - But movements in trend MFP lead to short-run fluctuations in many macroeconomic models.
  - And investment is procyclical, and so the capital stock is affected by the cycle
    - *By some conventions, capital stock belongs in the trend.*

# Defense of reduced-form state-space approach

- There has been some testing of the trend/cycle orthogonality assumptions
- Results are mixed; no very strong rejections

# One idea: Use a DSGE model

- DSGE models take theory very seriously
- The techniques used to estimate DSGE models incorporate sate-space methods at their core
  - So they are well-suited to the estimation of latent variables.
- Fit of recent DSGE models is good.
  - Relieving concerns about structural restrictions.
- Would need to modify existing DSGE models to accommodate data and trend choices, for example.

# Conclusions

- We propose a multivariate approach to structural/cyclical identification that includes key macroeconomic variables

- Exploits comovement, permanent/transitory, and "natural rate" principles

- Extensive dataset allows trade-offs to be explored, and a detailed decomposition of trends

- Approach holds up to the Orphanides/Van Norden critique