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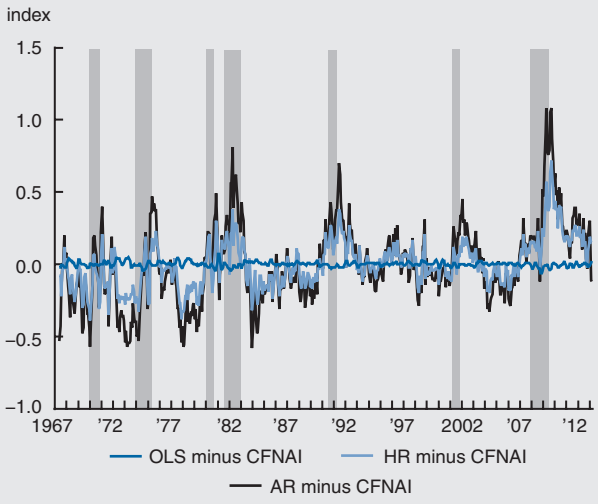
Estimating the trend rate of economic growth using the CFNAI

by Scott A. Brave, senior business economist, and R. Andrew Butters, graduate student, Kellogg School of Management, Northwestern University

This article shows how a new methodology for constructing the Chicago Fed National Activity Index (CFNAI) can be used to identify both the cyclical (medium-run) and trend (long-run) components of real gross domestic product (GDP) growth.

The uneven recovery from the Great Recession has led some observers to question whether the growth potential of the U.S. economy declined in its aftermath. To address this important question, economists need to be able to differentiate between movements in the trend component of economic growth and those in the cyclical component. The cyclical component captures medium-run factors driving economic growth and is generally associated with the business cycle—the periodic fluctuations in economic activity around its long-term historical trend. In contrast, the trend component captures long-run factors, such as potential growth in productivity, capital, and labor. In this *Chicago Fed Letter*, we detail a new way for constructing the CFNAI that makes it possible to simultaneously link the estimation of the monthly CFNAI to quarterly real GDP growth and decompose it into its trend and cyclical components. At least some of the weakness in real GDP growth during the recovery can be attributed to a decline in its trend (or average) rate of growth, although cyclical factors are shown to have played a more dominant role.

1. Differences between DF-CFNAI and CFNAI



NOTES: The figure displays the difference in every month from January 1967 through March 2013 between each of the three DF-CFNAI variants (see the text for details on OLS, HR, and AR) and the CFNAI. All four indexes were standardized (i.e., transformed to have a zero mean and a standard deviation of one) and transformed into three-month moving averages prior to calculating the differences. Shading indicates U.S. recessions as identified by the National Bureau of Economic Research.

SOURCE: Authors' calculations based on data from Haver Analytics.

CFNAI and DF-CFNAI

The CFNAI is a monthly index of U.S. economic activity constructed from 85 data series (or indicators) classified into four groups: production and income; employment, unemployment, and hours; personal consumption and housing; and sales, orders, and inventories.[1] The index is normalized to reflect deviations around a trend rate of economic growth. As such, a zero value for the index indicates that growth in economic activity is proceeding along its long-term historical path, a negative value indicates below-average growth, and a positive value indicates above-average growth.

Essentially, the CFNAI is a weighted average of the 85 data series, with their individual weights representing the relative degree to which each series explains the total variation among all the series. The statistical method used to generate these weights is called principal components analysis, or PCA. The CFNAI is the first principal component of the 85 data series, as it is the single factor common to each data series that explains the most variation across all 85. To construct our alternative CFNAI, we reweight the underlying data series to

2. Fraction of data variance explained

		DF-CFNAI		
	CFNAI	OLS	HR	AR
Total	0.29	0.29	0.28	0.27
Production and income	0.38	0.38	0.46	0.55
Employment, unemployment, and hours	0.36	0.36	0.33	0.27
Personal consumption and housing	0.08	0.08	0.05	0.02
Sales, orders, and inventories	0.17	0.17	0.16	0.15

NOTES: The figure displays the fraction of the variance of the 85 underlying indicators in the CFNAI and the three variants of the DF-CFNAI (see the text for details on OLS, HR, and AR) that is explained by each index (see top row). In addition, it decomposes this fraction into the share explained by each of the four broad categories of indicators listed here. The values for the categories' shares may not sum to one because of rounding.

SOURCE: Authors' calculations based on data from Haver Analytics.

3. RMSE ratios for current quarter GDP growth forecasts

	DF-CFNAI		
	OLS	HR	AR
1967–2012	0.91*	0.93*	0.93*
1985–2012	0.91*	0.92*	0.92*
1967–76	0.89*	0.92*	0.93
1977–86	0.90*	0.94*	0.94*
1987–96	0.92*	0.97	0.97
1997–2006	0.89*	0.90*	0.91*
2007–12	0.95*	0.91*	0.92*

NOTES: The figure displays root mean squared error (RMSE) ratios for current quarter real gross domestic product (GDP) growth forecasts based on the three variants of the DF-CFNAI (see the text for details on OLS, HR, and AR). A value less than one indicates a forecast based on the DF-CFNAI for the sample period labeled in each row is more accurate than a similar forecast based on the CFNAI (more precisely, the lower the value, the more accurate the DF-CFNAI's forecast). All of the forecasts based on the DF-CFNAI include a time-varying mean for real GDP growth, in contrast to those based on the CFNAI, which instead allow for discrete shifts in the mean of real GDP growth as explained in the text. Ratios with * denote statistical significance at the 95% confidence level according to the Diebold–Mariano mean squared error test statistic for equal forecast accuracy.

SOURCE: Authors' calculations based on data from Haver Analytics.

instead isolate the single factor that explains the most variation in the 85 data series and real GDP growth, as well as best describes their historical evolution. This alternative estimation procedure for the underlying series' weights results in the construction of what is referred to as a dynamic factor.[2]

The differences between the CFNAI and the index that results from our alternative estimation procedure—which we call the DF-CFNAI—tend to be very small unless we also relax some of the additional assumptions of PCA. Figure 1 (on front page) plots the differences between the CFNAI and three variants of the DF-CFNAI from January 1967 through March 2013 after each index was transformed into a three-month moving average. With this construction, we get a more consistent picture of national economic growth than that shown by the monthly indexes, which can vary significantly from month to month. The three-month moving average also has the advantage of highlighting the medium-run movements that are typical of the business cycle, captured in figure 1 by the shaded periods corresponding with U.S. recessions as identified by the National Bureau of Economic Research. The differences between the indexes that do exist appear around several business cycle turning points and, most notably, during the recovery from the most recent recession.

The two assumptions of PCA that we relax in figure 1 affect the way the weights are calculated by assigning less of the variance of the individual indicators to the common factor and more to idiosyncratic shocks. The first assumption that we relax—the result of which we refer to as HR in figure 1—is that an individual indicator cannot be subject to idiosyncratic shocks that are more volatile than similar shocks for other indicators.[3] The second assumption that we relax is that idiosyncratic shocks for each indicator are not persistent. The result of relaxing both assumptions is referred to as AR in figure 1. Neither PCA assumption is relaxed for the DF-CFNAI variant referred to as OLS in figure 1. In this case, the small differences between the CFNAI and OLS stem entirely from our alternative estimation procedure.

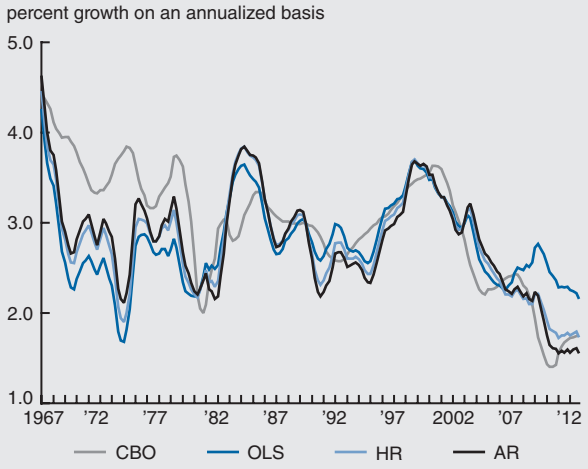
The recent experience of the housing market is inconsistent with both assumptions, in that the protracted recovery of the housing indicators implies that they experienced idiosyncratic shocks that were more volatile and persistent than those experienced by other indicators. The DF-CFNAI puts relatively less weight on the housing indicators than does the CFNAI as a result. However, the housing indicators in the CFNAI are not the only indicators inconsistent with these assumptions—and such inconsistency is not solely confined to the recent period. Similar to what we found in previous work examining potential trends in the CFNAI's 85 underlying indicators, the contributions to the index from two other categories of indicators—the employment, unemployment, and hours category and the sales, orders, and inventories category—are also affected by these assumptions.[4]

Figure 2 decomposes the overall variance explained by the CFNAI and the three variants of the DF-CFNAI into the contributions from their four groups of indicators. Compared with the CFNAI, the HR and AR variants of the DF-CFNAI capture a much larger share of the overall variance in the production and income category at the expense of the other three categories of indicators. It is also the case that these two variants of the DF-CFNAI capture slightly less of the *total* variance of the 85 underlying data series than the CFNAI. The latter finding suggests that the HR and AR variants of the DF-CFNAI are normalized at slightly different average levels than the CFNAI. This finding, then, also has implications for the trend rate of economic growth.

Trend rate of economic growth

In previous work, we documented how the three-month moving average of the CFNAI—the CFNAI-MA3—can be used to generate current quarter forecasts of real GDP growth.[5] Values of the CFNAI-MA3 that were above zero in the recent past have historically been associated with above-average current quarter real GDP growth. This is also true for the three-month moving average of the DF-CFNAI. Because DF-CFNAI values during much of the recent recovery have been systematically higher than CFNAI

4. Estimates of the trend rate of economic growth



NOTES: The figure displays estimates of the time-varying mean of real gross domestic product (GDP) growth based on the three variants of the DF-CFNAI (see the text for details on OLS, HR, and AR) from 1967:Q1 through 2012:Q4. For comparison, the Congressional Budget Office's (CBO) estimate of growth in potential real GDP for the U.S. is also presented.

SOURCE: Authors' calculations based on data from Haver Analytics.

values (shown in figure 1), this suggests real GDP growth that is even further above average. How do we reconcile this with the fact that real GDP growth has been much weaker on average during the recent recovery than during the recoveries from previous deep recessions? One interpretation is that average (or trend) real GDP growth is now much lower and has been declining during the recovery.

Our alternative estimation framework makes it possible to quantify this possibility by decomposing real GDP growth into its cyclical and trend components in the process of estimating the DF-CFNAI. To do so, we use a "nowcasting" equation (similar to the one used in Brave and Butters, 2010), which relates current quarter real GDP growth to current and past values of the three-month moving average of the DF-CFNAI. In this way, we both control for the cyclical dynamics of real GDP growth using the DF-CFNAI and allow current quarter real GDP growth to shape the DF-CFNAI's recent history. Here, however, to capture the trend component we also include a time-varying mean for real GDP growth, which distinguishes this exercise from Brave and Butters (2010) where we instead considered several discrete shifts in the mean of real GDP growth over time.[6]

We use the DF-CFNAI to control for the cyclical component of real GDP growth because, like the CFNAI, it can be shown to be an excellent coincident indicator of the business cycle. Using the method developed by Berge and Jordà[7] to quantify the accuracy of our indexes in capturing U.S. recessions and expansions since 1967, we find that the HR and AR variants of the DF-CFNAI are both 95% accurate, while the OLS variant and CFNAI are 94% accurate. So, by this measure, the HR and AR variants of the DF-CFNAI are only slightly more accurate in identifying U.S. recessions and expansions than the OLS variant and the CFNAI, with the difference not being statistically significant.

Figure 3 presents root mean squared error (RMSE) ratios computed using current quarter forecasts of real GDP growth based on the CFNAI and the three variants of the DF-CFNAI. For the CFNAI's forecasts, we allow for discrete shifts in the mean of real GDP growth over time as in Brave and Butters (2010). In contrast, the DF-CFNAI's forecasts are based on a time-varying mean for real GDP growth. A value less than one in figure 3 indicates in each instance that the DF-CFNAI's forecasts are more accurate than the CFNAI's (more precisely, the lower the value, the more accurate the DF-CFNAI's forecasts).[8] There is some variation in the level of accuracy across the DF-CFNAI variants' forecasts depending on the time period. In general, the OLS variant's forecasts dominate those of the other two. More recently, however, the HR and AR models have produced slightly superior forecasts, but not enough to be statistically significantly different from the OLS model's.

Figure 4 plots the history of our estimates of the time-varying mean of real GDP growth based on the DF-CFNAI over the period 1967:Q1–2012:Q4. For comparison, we also include in figure 4 the Congressional Budget Office's (CBO) estimate of growth in potential real GDP. The CBO's estimate of potential real GDP growth is calculated in a vastly different way than our estimate of the time-varying mean of real GDP growth, but it too aims to capture a similar notion of the long-run growth trend.[9] Our HR and AR estimates of the time-varying mean of real GDP growth are highly correlated with the CBO's estimate of potential growth and have an average absolute deviation of 0.2 percentage points from it in the post-1984 era. That said, all four estimates have very different interpretations of recent history. The HR and AR growth estimates exhibit declines of about 0.5 percentage points and 0.7 percentage points since 2007, respectively; and the OLS growth estimate fell by roughly 0.3 percentage points since then, while the CBO's estimate of potential growth decreased by 0.6 percentage points.

Conclusion

Our estimates of the trend rate of economic growth show that it has fluctuated considerably over time, falling from around 4.5% in 1967:Q1 to 2.25%–2.5% by the end of 2007. Its further decline

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since the Great Recession suggests that at least some of the weakness of the current recovery can be attributed to long-run growth factors. Our estimates of the time-varying mean of real GDP growth range from 1.6% to 2.1% in 2012:Q4. That said, the magnitude of the recent decline in the mean of real GDP growth is entirely consistent with the pace of the decline in average real GDP growth seen over the past decade. Thus, it appears that cyclical factors are more to blame for the current weak recovery.

[1] For more details, see www.chicagofed.org/cfnai.

[2] For more information on this procedure, see Catherine Doz, Domenico Giannone, and Lucrezia Reichlin, 2012, "A quasi-maximum likelihood approach for large, approximate dynamic factor models," *Review of Economics and Statistics*, Vol. 94, No. 4, November, pp. 1014–1024, and B. Jungbacker, S. J. Koopman, and M. van der Wel, 2011, "Maximum likelihood estimation for dynamic factor models with missing data," *Journal of Economic Dynamics and Control*, Vol. 35, No. 8, August, pp. 1358–1368.

[3] In statistical terms, the idiosyncratic disturbances are assumed to be homoskedastic and serially uncorrelated in PCA but allowed to be heteroskedastic for all and to be first-order autocorrelated for some in our dynamic factor method.

[4] See Scott Brave, 2008, "Economic trends and the Chicago Fed National Activity Index," *Chicago Fed Letter*, Federal Reserve Bank of Chicago, No. 250, May, available at www.chicagofed.org/digital_assets/publications/chicago_fed_letter/2008/cflmay2008_250.pdf.

[5] Scott Brave and R. Andrew Butters, 2010, "Chicago Fed National Activity Index turns ten—Analyzing its first decade of performance," *Chicago Fed Letter*, Federal Reserve Bank of Chicago, No. 273, April, available at www.chicagofed.org/digital_assets/publications/chicago_fed_letter/2010/cflapril2010_273.pdf.

[6] Our specification for the time-varying mean of real GDP growth is similar to that considered in James H. Stock and Mark W. Watson, 1998, "Median unbiased estimation of coefficient variance in a time-varying parameter model," *Journal of the American Statistical Association*, Vol. 93, No. 441, March, pp. 349–358. For further details, see the accompanying technical report, available at www.chicagofed.org/digital_assets/others/people/research_resources/brave/brave_butters_cfl_311_technical_report.pdf.

[7] Travis J. Berge and Òscar Jordà, 2011, "Evaluating the classification of economic activity into recessions and expansions," *American Economic Journal: Macroeconomics*, Vol. 3, No. 2, April, pp. 246–277.

[8] Statistical significance is assessed based on the Diebold–Mariano mean squared error test statistic for equal forecast accuracy; see Francis X. Diebold and Robert S. Mariano, 2002, "Comparing predictive accuracy," *Journal of Business & Economic Statistics*, Vol. 20, No. 1, January, pp. 134–144.

[9] For details on the CBO's methodology, see www.cbo.gov/publication/15384.