Chicago Fed Letter

Detecting early signs of financial instability

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

The authors analyze the usefulness of a new measure of nonfinancial leverage as an early warning indicator for financial instability and its consequences for economic growth.

> The NFCI's nonfinancial leverage subindex has performed well as a leading indicator for historical periods of financial stress and their accompanying recessions in the United States.

Following the financial crisis, policy-makers and researchers have sought to identify new indicators that may be useful in gauging the relationship between the financial and nonfinancial sectors of the economy in the hope of detecting early signs of financial instability. The ratio of private credit to gross domestic product (GDP) has received a lot of attention in this regard.[1] This leverage ratio serves as an early warning indicator of financial instability, insofar as it captures instances where the nonfinancial sector's financial obligations form an outsized share of the broader economy's resources.

In this *Chicago Fed Letter*, we propose an alternative early warning indicator to the private-credit-to-GDP ratio. Our measure is constructed as a subindex made up of two nonfinancial leverage measures used in the Chicago Fed's National Financial Conditions Index (NFCI). We show that this subindex has performed well as a leading indicator for historical periods of financial stress and their accompanying recessions in the United States; we also demonstrate that it has been more accurate than the private-credit-to-GDP ratio in predicting both at longer forecast horizons.

The NFCI and financial stability

The NFCI is a coincident indicator of U.S. financial activity, meaning that it describes current financial conditions. The weekly index is constructed as a weighted average of 100 indicators of risk, credit, and leverage in the U.S. financial system. By risk, we mean not only the premium placed on risky assets embedded in their returns, but also the volatility of asset prices. By credit, we refer to the willingness to both borrow and lend at prevailing prices. Measures of leverage provide a reference point for financial debt relative to equity. In other research, we document that known periods of financial stress, or crises, are well captured by the NFCI.[2]

Risk measures tend to receive positive weights in the NFCI, while credit and leverage measures tend to receive negative weights, generally indicating that tight financial conditions (positive NFCI values) are associated with above-average risk and below-average credit and leverage and that loose financial conditions (negative NFCI values) are associated with the opposite. To allow for a more detailed examination of the movements in the NFCI, we also produce three subindexes (risk, credit, and leverage), using subsets of its indicators. Brave and Butters (2012) detail how the NFCI subindexes can be used to assess the degree and timing of periods of financial stress.

Leading indicator of financial instability

Here we focus on a particular combination of indicators in the NFCI that best exemplifies how leverage can serve as an early warning signal for financial stress and its impact on economic growth.[3] We refer to this combination of household

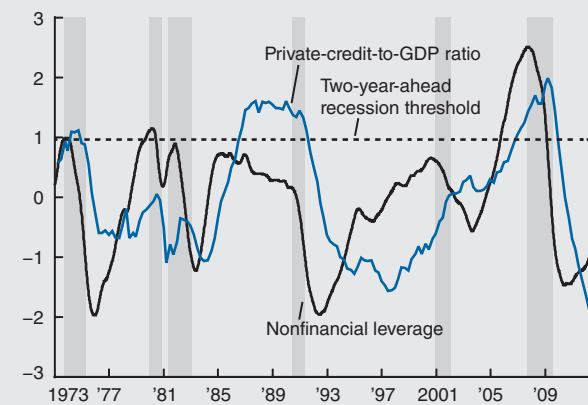**1. Early warning indicators of financial crisis and recession**

A. Indicators of financial crisis

standard deviations
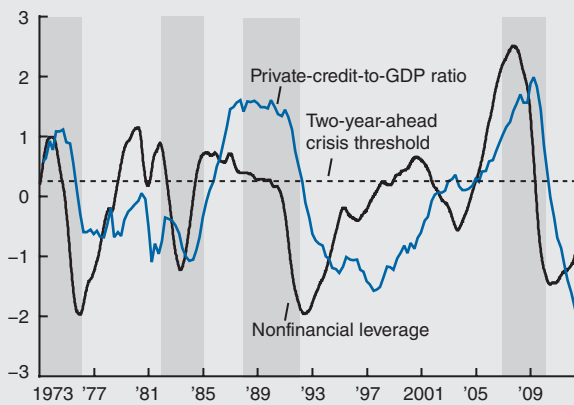
B. Indicators of recession

standard deviations

NOTES: The solid black line is the nonfinancial leverage subindex of the Chicago Fed's National Financial Conditions Index, and the solid blue line is the ratio of private credit to gross domestic product (GDP) detrended as explained in note 4. For ease of comparison, both measures have been scaled to have a mean of zero and a standard deviation of one over the period 1973–2012. The horizontal (time) axis is measured in weeks. We assign the quarterly private-credit-to-GDP ratio to the last week of each quarter to be able to plot it on the same figure panel as the weekly nonfinancial leverage subindex. The shaded regions in panel A correspond with historical periods of financial stress based on the analysis in Brave and Butters (2012). The shaded regions in panel B correspond with U.S. recessions as defined on a quarterly basis by the National Bureau of Economic Research. The dashed black line is the two-year-ahead prediction threshold for a financial crisis (panel A) and a recession (panel B) calculated for the nonfinancial leverage subindex, as explained in the text.

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

and nonfinancial business leverage measures as "nonfinancial leverage" and plot it in figure 1. For comparison, we also plot in figure 1 the detrended ratio of private credit to GDP discussed in Drehmann, Borio, and Tsatsaronis (2011).[4]

The positive weight assigned to both the household and nonfinancial business leverage measures in the NFCI reflects the fact that rising values of each are typically associated with increasingly tighter financial conditions. In the NFCI, household leverage receives roughly 1.3 times the weight that nonfinancial business leverage does, owing to the former's stronger correlation with the index's risk, credit, and other leverage indicators.

These features make our nonfinancial leverage subindex characteristic of the feedback process between the financial and nonfinancial sectors of the economy, which is often referred to as the "financial accelerator."[5] Increasingly tighter financial conditions are associated with rising risk premiums and declining asset values. The net worth of households and nonfinancial firms is, thus, reduced at the same time that credit tightens. This leads to a period of deleveraging (i.e., debt reduction) across the financial and nonfinancial sectors of the economy and ultimately to lower economic activity.

Our nonfinancial leverage subindex offers a picture over time that is highly consistent with the level of financial stress, as well as the depth and length of the recession historically accompanying each instance of a significant tightening of financial conditions. The shaded periods in panel A of figure 1 capture four historical periods of financial stress.[6] Panel B of figure 1 repeats much of the information in panel A but instead displays shaded periods of recession as defined by the National Bureau of Economic Research (NBER). Above-average values of nonfinancial leverage precede most instances of both crises and recessions.

How our measure works

It is not enough for an indicator just to provide a leading signal of the onset of financial stress or recession. It must also clearly delineate periods of stress from periods of nonstress, as well as recessions from expansions, thereby capturing the observed duration of financial crisis or recession at a forecast horizon.[7] To more systematically evaluate the indicators in figure 1 in this regard, we use the methodology described in Brave and Butters (2012).[8]

The receiver operating characteristic (ROC) analysis framework produces a simple summary statistic (the AUROC) with which we can judge the historical accuracy of an indicator in delineating periods of stress from periods of nonstress, as well as recessions from expansions. While a detailed explanation of our methodology is beyond the scope of this article, a brief description follows.

Using the data in figure 1, we can find the fraction of observations of the indicator that fall inside and outside the shaded regions separately for each panel. These fractions are the *unconditional* probabilities associated with periods of stress and nonstress (panel A) and with recessions and expansions (panel B). In order to evaluate the ability of an indicator to separate the shaded and nonshaded regions, we calculate the following probabilities. For each value between the minimum and maximum observations of an indicator, we find the fraction of observations where that value and all subsequently higher values fall inside the shaded regions in each panel x periods later, with x denoting the forecast horizon. We then do the same to find the fraction of observations that fall outside the shaded regions. These two statistics are called the true and false positive rates for separating the shaded periods from the nonshaded periods in each panel at the given forecast horizon.

2. Example of an ROC curve

true positive rate
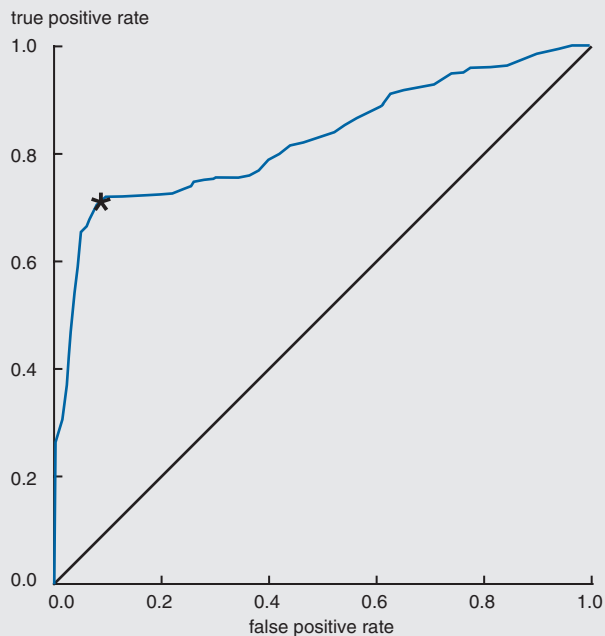
NOTES: The solid blue line is the receiver operating characteristic (ROC) curve at a two-year-ahead forecast horizon for the nonfinancial leverage subindex of the Chicago Fed's National Financial Conditions Index using the shaded periods of financial stress shown in figure 1, panel A. The solid black line is a 45-degree line from the origin with an area under the line equal to 0.5. The starred point on the ROC curve corresponds with the two-year-ahead prediction threshold of nonfinancial leverage for a financial crisis, as explained in the text.

SOURCE: Authors' calculations.

3. Accuracy in predicting financial crises and recessions

	Forecast horizon			
	Six months	One year	Two years	Three years
A. Financial crises				
Nonfinancial leverage	**0.68**	**0.75**	**0.83**	**0.80**
Private-credit-to-GDP ratio	**0.83**	**0.80**	**0.74**	**0.66**
B. Recessions				
Nonfinancial leverage	**0.86**	**0.86**	**0.77**	**0.63**
Private-credit-to-GDP ratio	**0.68**	0.58	0.58	0.37

NOTES: The figure displays the areas under the ROC curve (AUROC) at various forecast horizons for the nonfinancial leverage subindex of the Chicago Fed's National Financial Conditions Index and the ratio of private credit to gross domestic product (GDP) detrended as explained in note 4. Values in bold denote statistical significance from a baseline of 0.5 (or 50% accuracy) at the 95% confidence level. The timing of financial crises and recessions matches the shaded regions shown in figure 1.

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

By plotting the true and false positive rates against each other for every historical value of an indicator, we produce an estimate of what is termed the "ROC curve." For example, figure 2 displays the ROC curve computed at a two-year-ahead forecast horizon for nonfinancial leverage using the shaded periods of financial stress shown in figure 1, panel A. Berge and Jordà (2011) show that

by calculating the area under this curve (AUROC), we arrive at an estimate of the overall ability of an indicator to separate the shaded regions from the nonshaded regions in figure 1 at the given forecast horizon. With the AUROC, we can then evaluate an indicator's ability to delineate periods of stress from periods of nonstress, as well as recessions from expansions, at different forecast horizons.

Figure 2 also depicts a 45-degree line from the origin. By construction, this line has an AUROC equal to 0.5. For an indicator that is positively correlated with the shaded regions in figure 1, the more the ROC curve deviates in total above this 45-degree line, the higher that indicator's AUROC will be. Higher values of the AUROC imply that the indicator can better distinguish true positives from false positives. In addition, for an indicator's AUROC to exceed 0.5, it must have a slope greater than 1 at some point on the ROC curve such that, for a given increase in the true

positive rate, the associated increase in the false positive rate is smaller.

Figure 3 contains all of the AUROC values for nonfinancial leverage and the detrended private-credit-to-GDP ratio. Figure 3's panel A summarizes the accuracy of each indicator in separating the four periods of financial stress from periods of nonstress shown in panel A of figure 1; and its panel B does the

same for the NBER recessions and expansions shown in panel B of figure 1.[9] Each column of figure 3 highlights a different forecast horizon, ranging from six months to three years ahead.

The private-credit-to-GDP ratio performs very favorably as a leading indicator of financial crises at the six-month- and one-year-ahead horizons. However, nonfinancial leverage is significantly more accurate at the two- and three-year-ahead horizons. This feature of nonfinancial leverage is robust to several alternative dating conventions for periods of financial stress, as shown in Brave and Butters (2012). Nonfinancial leverage also aligns much more closely with the timing of the recessions that accompany these periods of stress.

As shown in Berge and Jordà (2011), it is also possible within the ROC framework to identify at a forecast horizon the historical index values, or "thresholds," that equally penalize type I (false positive) and type II (false negative) classification errors for the shaded and nonshaded regions in figure 1. These thresholds mark the point on the ROC curve where it is no longer possible to increase the true positive rate without producing more

Charles L. Evans, *President*; Daniel G. Sullivan, *Executive Vice President and Director of Research*; Spencer Krane, *Senior Vice President and Economic Advisor*; David Marshall, *Senior Vice President, financial markets group*; Daniel Aaronson, *Vice President, microeconomic policy research*; Jonas D. M. Fisher, *Vice President, macroeconomic policy research*; Richard Heckinger, *Vice President, markets team*; Anna L. Paulson, *Vice President, finance team*; William A. Testa, *Vice President, regional programs, and Economics Editor*; Helen O'D. Koshy and Han Y. Choi, *Editors*; Rita Molloy and Julia Baker, *Production Editors*; Sheila A. Mangler, *Editorial Assistant*.

false positives than is consistent with the observed relative frequency of the shaded periods and nonshaded periods.[10] The threshold for panel A of figure 1 is indicated by the black starred point on the ROC curve in figure 2.

The dashed black line in panel A of figure 1 gives the two-year-ahead financial crisis threshold for nonfinancial leverage; the dashed line in panel B of figure 1 gives the two-year-ahead recession threshold. Instances where nonfinancial leverage falls above both thresholds are characteristic of the run-up to many of the most severe crises and deepest recessions (e.g., those in 1973–75, 1980, 1981–82, and 2007–09), while instances where nonfinancial leverage falls in between the two thresholds are generally more consistent with less pronounced periods of financial stress and shallower recessions (e.g., those in 1990–91 and 2001).

Conclusion

Our nonfinancial leverage indicator signals both the onset and duration of financial crises and their accompanying recessions more reliably at longer lead times than the private-credit-to-GDP ratio.

Beginning with the November 15, 2012, NFCI release, we will include the nonfinancial leverage subindex in the publicly available materials for the NFCI at www.chicagofed.org/nfci.

[1] See M. Drehmann, C. Borio, and K. Tsatsaronis, 2011, "Anchoring countercyclical capital buffers: The role of credit aggregates," *International Journal of Central Banking*, Vol. 7, No. 4, December, pp. 189–240.

[2] S. Brave and R. A. Butters, 2012, "Diagnosing the financial system: Financial conditions and financial stress," *International Journal of Central Banking*, Vol. 8, No. 2, June, pp. 191–239; and S. Brave and R. A. Butters, 2011, "Monitoring financial stability: A financial conditions index approach," *Economic Perspectives*, Federal Reserve Bank of Chicago, Vol. 35, First Quarter, pp. 22–43.

[3] The two NFCI indicators are the quarterly growth rate of the ratio of nonfinancial business debt outstanding to GDP and the quarterly growth rate of the ratio of household mortgage and consumer debt outstanding to the sum of residential investment and personal consumption expenditures on durable goods.

[4] We focus on a single method of detrending this series—i.e., the Hodrick–Prescott filter using a smoothing parameter of 400,000—but all of the results discussed here are robust to the alternative choices considered in the referenced article.

[5] See B. S. Bernanke, M. Gertler, and S. Gilchrist, 1999, "The financial accelerator in a quantitative business cycle framework," in *Handbook of Macroeconomics*, J. B. Taylor and M. Woodford (eds.), Vol. 1C, Amsterdam: Elsevier / North-Holland, chapter 21.

[6] The four periods are 1973–75, 1982–84, 1988–91, and 2007–09.

[7] For further discussion, see Ò. Jordà, 2011, "Discussion of 'Anchoring countercyclical capital buffers: The role of credit aggregates,'" *International Journal of Central Banking*, Vol. 7, No. 4, December, pp. 241–259.

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

[9] When performing our ROC calculations at longer forecast horizons, we lose the ability to include much of the 1973–75 period in our analysis because the nonfinancial leverage subindex begins in 1973. Even so, using data going back to 1970 for the private-credit-to-GDP ratio does not significantly alter the AUROC results in figure 3.

[10] In other words, the threshold equates the slope of the ROC curve to the ratio of the unconditional probabilities of the shaded and nonshaded regions. Alternatively, one could achieve a specific trade-off of type I errors for type II errors by scaling up or down this ratio. See Brave and Butters (2012).