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The Yield Curve as a Leading Indicator: Some Practical Issues

Arturo Estrella and Mary R. Trubin

Since the 1980s, economists have argued that the slope of the yield curve—the spread between long- and short-term interest rates—is a good predictor of future economic activity. While much of the existing research has documented how consistently movements in the curve have signaled past recessions, considerably less attention has been paid to the use of the yield curve as a forecasting tool in real time. This analysis seeks to fill that gap by offering practical guidelines on how best to construct the yield curve indicator and to interpret the measure in real time.

Before each of the last six recessions, short-term interest rates rose above long-term rates, reversing the customary pattern and producing what economists call a *yield curve inversion*. Thus, it is not surprising that the recent flattening of the yield curve has attracted the attention of the media and financial markets and prompted speculation about the possibility of a new downturn. Since the 1980s, an extensive literature has developed in support of the yield curve as a reliable predictor of recessions and future economic activity more generally. Indeed, studies have linked the slope of the yield curve to subsequent changes in GDP, consumption, industrial production, and investment.

Whereas most earlier analysis has focused on documenting historical relationships, the use of the yield curve as a forecasting device in real time raises a number of practical issues that have not been clearly settled in the scholarly literature. First, the lack of a single accepted explanation for the relationship between the yield curve and recessions has led some observers to question whether the yield curve can function practically as a leading indicator. If economists cannot agree on why the relationship exists, confidence in this indicator may be weakened. Second, the literature lacks a standard approach to constructing forecasts based on movements in the yield curve. How should the slope of the yield curve be defined? What measure of economic activity should be used to assess the yield curve's predictive power? The current variety of approaches to producing and interpreting yield curve forecasts may lead to misreadings of the signal in real time.

This edition of *Current Issues* undertakes to shed light on some of the practical problems arising from the use of the yield curve as a forecasting tool. We begin by considering whether there are explanations of the yield curve's predictive power that would justify the operational use of this signal. We then discuss how best to construct the yield curve indicator and subsequently interpret the measure in real time. Our analysis offers specific guidelines on the choice of interest rates used to calculate the spread, the definition of recessions used in the forecasts, and the strength and duration required of the yield curve signals.

Conceptual Considerations

The literature on the use of the yield curve to predict recessions has been predominantly empirical, documenting correlations rather than building theories to explain such correlations. This focus on the empirical may have created the unfortunate impression that no good explanation for the relationship exists—in other words, that the relationship is a fluke. In fact, there is no shortage of reasonable explanations, many of which date back to the early literature on this topic and have now been extended in various directions. For the most part, these explanations are mutually compatible and, viewed in their totality, suggest that the relationships between the yield curve and recessions are likely to be very robust indeed. We give two examples that emphasize monetary policy and investor expectations, respectively.[1]

Monetary policy can influence the slope of the yield curve. A tightening of monetary policy usually means a rise in short-term interest rates, typically intended to lead to a reduction in inflationary pressures. When those pressures subside, it is expected that a policy easing—lower rates—will follow. Whereas short-term interest rates are relatively high as a result of the tightening, long-term rates tend to reflect longer term expectations and rise by less than short-term rates. The monetary tightening both slows down the economy and flattens (or even inverts) the yield curve.

Changes in investor expectations can also change the slope of the yield curve. Consider that expectations of future short-term interest rates are related to future real demand for credit and to future inflation. A rise in short-term interest rates induced by monetary policy could be expected to lead to a future slowdown in real economic activity and demand for credit, putting downward pressure on future real interest rates. At the same time, slowing activity may result in lower expected inflation, increasing the likelihood of a future easing in monetary policy. The expected declines in short-term rates would tend to reduce current long-term rates and flatten the yield curve. Clearly, this scenario is consistent with the observed correlation between the yield curve and recessions.

The multiplicity of channels through which the predictive power of the yield curve may manifest itself makes it difficult to give one simple explanation for that power. However, it also suggests a certain robustness to the relationship between the yield curve and economic activity: if one channel is not in play at any one time, other channels may take up the slack.

The conceptual relationships outlined here also have implications for the signals provided by the yield curve indicator. First, the fact that long-term investor expectations figure so importantly in these relationships means that the yield curve may be more forward-looking than other leading indicators. In other words, the recession signals produced by the yield curve may come significantly in advance of those produced by other indicators.[2]

Second, the signals provided by the yield curve may be very sensitive to changes in financial market conditions. The precise effect of these changes on the yield curve will depend on whether they stem from technical factors or economic fundamentals. For example, because different maturities of fixed-income securities appeal to different clienteles, a permanent shift in the relative importance of clienteles could produce permanent shifts in the slope of the yield curve. Alternatively, a temporary change in the demand for assets of a given maturity—say, a change resulting from hedging activities—could affect the slope of the yield curve for a short time before the yield curve returns to values determined by economic fundamentals. These considerations suggest that the signals produced by the yield curve must show some degree of persistence if they are to be meaningful, an issue to which we return below.

Empirical Considerations

To make the best possible use of the predictive power of the yield curve, it is important to validate the predictive procedure historically and to apply it consistently in real time. In this section, we consider the elements of one such approach, a model in which a measure of the steepness of the yield curve is used to predict subsequent recessions.

The Probability Model

Empirically, we would like to construct a model that translates the steepness of the yield curve at the present time into a likelihood of a recession some time in the future. Thus, we need to identify three components: a measure of steepness, a definition of recession, and a model that connects the two. The approach we employ is a "probit" equation, which uses the normal distribution to convert—in our application—the value of a measure of yield curve steepness into a probability of recession one year ahead. Details of this calculation are given in the box.

The input to this calculation is the value of the term spread, that is, the difference between long- and short-term interest rates in month t. The output is the probability of a recession occurring in month $t+12$ from the viewpoint of information available in month t. Both of these variables, however, need to be defined more precisely—that is, we need to specify what we mean by a recession and which long- and short-term interest rates we will use to produce the spread that constitutes our measure of steepness.

Defining Recessions

The standard dating of U.S. recessions derives from the cyclical peaks and troughs identified by the National Bureau of Economic Research (NBER). To convert the NBER monthly dates into a monthly recession indicator, we classify as a recession every month between the peak and the subsequent trough, as well as the trough itself. The peak is not classified as a recession month because the economy would have grown from the previous month. A similar rule may be applied to the NBER quarterly dates to derive a quarterly recession indicator. These conventions, while

[1]For more detailed explanations and theoretical models, see Harvey (1988), Estrella and Hardouvelis (1991), Eijffinger, Schaling, and Verhagen (2000), Rendu de Lint and Stolin (2003), Hardouvelis and Malliaropulos (2004), and Estrella (2005).

[2]See, for example, Estrella and Mishkin (1996).

The Probability Model

Our probability model consists of a probit equation of the form

$$Recessm_{t+12} = F(\alpha + \beta sprd_t),$$

where $sprd_t$ is the difference between long- and short-term interest rates in month t, α and β are constants, F is the cumulative normal distribution function

$$F(z) = \int_{-\infty}^{z} 1/\sqrt{2\pi}\, exp(-x^2/2)dx,$$

and $Recessm_{t+12}$ is the probability of a recession occurring in month $t+12$ from the viewpoint of information available in month t. The values of α = -0.6045 and β = -0.7374 were estimated using data from January 1959 to December 2005 so as to match the probabilities with the actual values of the recession indicator as closely as possible.

The probability of a recession for a specific value of the term spread is easy to compute with standard spreadsheet programs. For instance, in Excel®, the probability is computed using the formula =NORMSDIST(-0.6045-0.7374*A1), where A1 indicates the cell that contains the value of the spread (in percentage points). Alternatively, the value of the spread consistent with a given probability is given by the formula =(NORMSINV(B1)+0.6045)/(-0.7374), where B1 indicates the cell that contains the probability (number between zero and one).

not the only possible ones, are the most frequently used in research on U.S. recessions.[3]

Measuring the Spread

The interest rates used to compute the spread between long-term and short-term rates vary across the literature on the yield curve's predictive power. For example, market analysts often choose to focus on the difference between the ten-year and two-year Treasury rates, while some academic researchers have favored the spread between the ten-year Treasury rate and the federal funds rate. Other rates explored in the literature vary as to maturity, obligor, and computational basis. In choosing the most appropriate rates, one should consider a number of criteria, including the ready availability of historical data and consistency in the computation of rates over time. It is also important to consider the role of risk premiums and coupons, although at present there is no standard way of dealing with these issues.

The criteria cited allow us to rule out some interest rates as a measure of yield curve steepness. While a yield curve may be constructed from Eurodollar, swap, or corporate rates, all three have important drawbacks: comprehensive historical data on the rates are lacking and the number of points they provide along the yield curve is limited.

By contrast, Treasury rates readily meet our criteria for the yield curve indicator. Data since the 1950s are available for several maturities, and are consistently computed over the entire period. Treasury securities are also useful because they are not subject to significant credit risk premiums that, at least in principle, may change with maturity and over time. Pairing the long-term Treasury rate with the federal funds rate as the short-term rate is a possibility, but while the spread between ten-year Treasuries and fed funds has been a very accurate predictor of U.S. recessions during some time periods, it has been less so in others.

If Treasury rates are the best choice for our yield curve indicator, then we must next determine what maturity combination works most effectively. In forecasts of real activity, the most accurate results are obtained by taking the difference between two Treasury yields whose maturities are far apart. At the long end of the curve, the clear choice seems to be a ten-year rate, the longest maturity available in the United States on a consistent basis over a long sample period. We use the ten-year constant maturity rate from the H.15 statistical release ("Selected Interest Rates") issued by the Board of Governors of the Federal Reserve System.

With regard to the short-term rate, earlier research suggests that the three-month Treasury rate, when used in conjunction with the ten-year Treasury rate, provides a reasonable combination of accuracy and robustness in predicting U.S. recessions over long periods. Maximum accuracy and predictive power are obtained with the secondary market three-month rate expressed on a bond-equivalent basis,[4] rather than the constant maturity rate, which is interpolated from the daily yield curve for Treasury securities.[5]

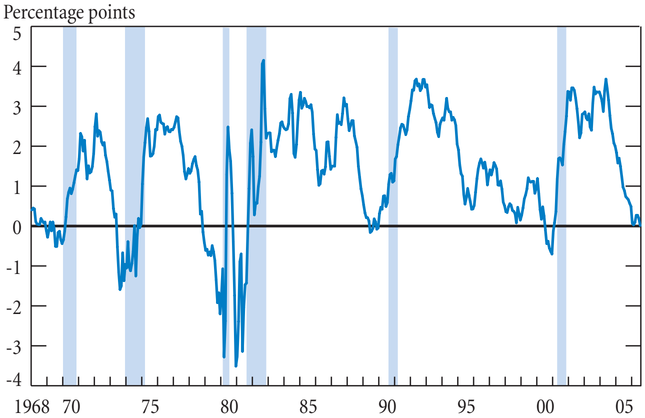
Spreads based on any of the rates mentioned are highly correlated with one another and may be used to predict recessions. Note, however, that the spreads may turn negative—that is, the yield curve may invert—at different points and with different frequencies. For instance, the ten-year minus two-year spread

[3]Other conventions may lead to different results. For example, Estrella, Rodrigues, and Schich (2003) and Wright (2006) use a "cumulative" recession indicator that identifies a recession occurring in any of the following several quarters, and Wright (2006) classifies peaks as recession periods.

[4]The H.15 release provides the secondary market rate on a discount basis. To convert the three-month discount rate to a bond-equivalent basis, we apply the transformation: bond-equivalent = 100*(365*discount/100)/(360-91*discount/100), where "discount" is the discount yield expressed in percentage points.

[5]A drawback of the three-month constant maturity rate is that data are available only back to January 1982.

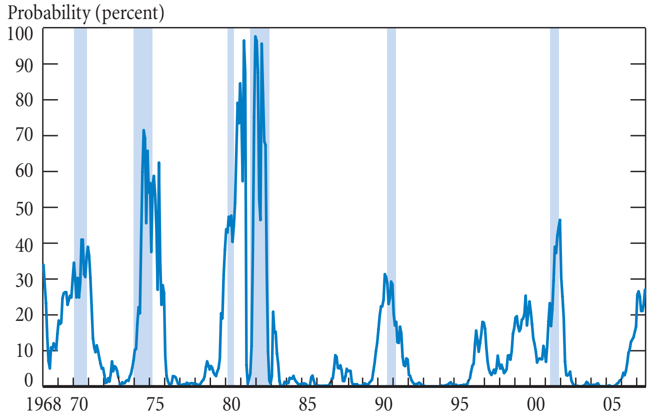
Chart 1
Treasury Spread: Ten-Year Bond Rate minus Three-Month Bill Rate
Monthly Average



Source: Authors' calculations, based on data from the H.15 statistical release of the Board of Governors of the Federal Reserve System.

Notes: The term spread in July 2006 was 0.01 percentage point. The shaded areas indicate periods designated national recessions by the National Bureau of Economic Research.

Chart 2
Probability of U.S. Recession Twelve Months Ahead, as Predicted by the Treasury Spread
Monthly Average



Source: Authors' calculations, based on data from the H.15 statistical release of the Board of Governors of the Federal Reserve System.

Notes: The probabilities are estimated using data from January 1959 to December 2005. The estimated probability of recession in July 2007 is 27 percent. The shaded areas indicate periods designated national recessions by the National Bureau of Economic Research.

tends to turn negative earlier and more frequently than the ten-year minus three-month spread, which is usually larger.[6]

Our preferred combination of Treasury rates proves very successful in predicting the recessions of recent decades. The monthly average spread between the ten-year constant maturity rate and the three-month secondary market rate on a bond-equivalent basis has turned negative before each recession in the period from January 1968 to July 2006 (Chart 1). If we convert this spread into a probability of recession twelve months ahead using the probit model described earlier (estimated with Treasury data from January 1959 to December 2005), we can match the probabilities with the recessions (Chart 2). The chart shows that the estimated probability of recession exceeded 30 percent in the case of each recession and ranged as high as 98 percent in the 1981-82 recession.

Level versus Change

In addition to choosing the type and maturity of the rates used in the model, we must consider whether the probability of recession in twelve months' time is best modeled in terms of interest rate levels or changes. The NBER defines a recession as "a significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales." The focus on a "decline" may suggest that we should look at changes in leading indicators—rather than levels—to assess the health of the economy. In the case of the yield curve indicator, however, the level of the term spread provides the most accurate signal of a forthcoming recession. One reason for the superiority of this measure is that, conceptually, the level of the spread already corresponds to a forward-looking expected change in interest rates.

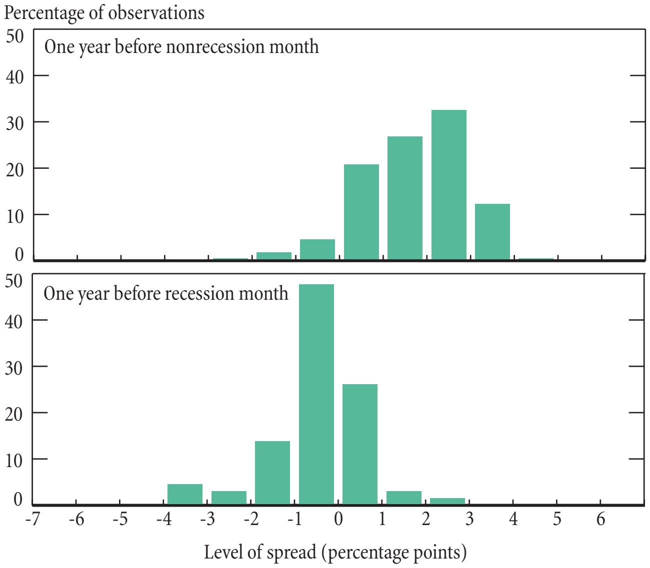
Charts 3 and 4 allow us to compare the strength of the recession signals produced by the level of the term spread and the change in the term spread. The charts show the statistical distribution of monthly observations of the two measures in 1968-2005, broken out by those observations that were followed by a recession month twelve months later (bottom panel) and those that were not (top panel).

Consider first the distribution of the level of the spread (Chart 3). In the top panel—monthly observations that were not followed by a recession twelve months later—the tallest bar shows that the value of the spread was between 2 and 3 percentage points in about 30 percent of the cases. In the bottom panel, the tallest bar shows that when a recession did follow in twelve months, the level of the spread was between -1 and 0 percentage points in almost 50 percent of the cases. The noticeable difference between the distributions in the two panels provides clear visual evidence that the level of the spread may be helpful in distinguishing instances in which a recession follows from instances in which a recession does not follow in twelve months.

Now consider the distribution of the six-month change in the Treasury rate spread (Chart 4). We note at once that the distributions of monthly observations in the top and bottom panels are much more similar here than in Chart 3. To be sure, the

[6]On average, the three-month spread (secondary market bond-equivalent basis) is about 21 basis points when the two-year spread (constant maturity) is zero.

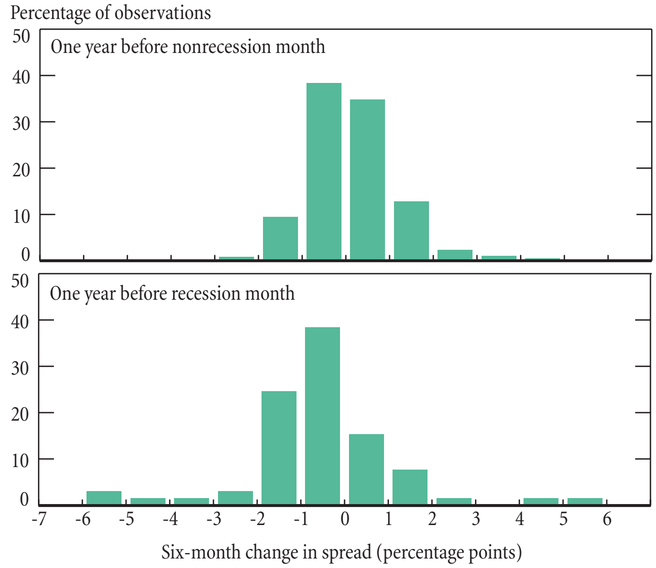
Chart 3
Frequency Distribution of Level of Spread



Source: Authors' calculations, based on data from the H.15 statistical release of the Board of Governors of the Federal Reserve System.

Note: The frequency distribution is estimated using data from 1968 to 2005.

Chart 4
Frequency Distribution of Six-Month Change in Spread



Source: Authors' calculations, based on data from the H.15 statistical release of the Board of Governors of the Federal Reserve System.

Note: The frequency distribution is estimated using data from 1968 to 2005.

observations in the top panel are skewed to the right while observations in the bottom panel are slightly skewed toward more negative levels—a qualitative pattern similar to that found in Chart 3. Nevertheless, it is clear that the ability to discriminate between recessionary and nonrecessionary instances is much more limited with changes than with levels.

A simple example provides further evidence of the weakness of the change in the spread as an indicator. In May 1990, the average spread was 76 basis points. In June, it decreased by 27 basis points to 49. This decline resulted in an increase of 7.1 percentage points in the implied probability of recession. By contrast, when the average spread decreased 27 basis points between January and February of 1993, from 3.54 to 3.27 percentage points, the implied probability of recession declined by less than 0.1 percentage point. These contrasting episodes suggest that the change in the spread may provide an arbitrary signal, one that varies greatly with the steepness of the yield curve: in general, the steeper the yield curve, the smaller the impact of a given change on the implied probability of recession. Hence, the change in the spread by itself is not very informative.

Interpreting the Signal

Having established that tracking the level of the ten-year to three-month Treasury spread is useful in predicting recessions, we now consider how best to interpret the signal sent by this measure. The lower panel of Chart 3 suggests that, of the observations followed by a recession twelve months later, 69 percent (the sum of the bars to the left of zero) are negative. Thus, one could look to an inversion of the yield curve as a signal. However, there still may be some question regarding the strength of the signal. Does the signal have to be persistent? How strong must it be? Does it matter if the inversion is driven by changes in the long end or short end of the yield curve? The next two sections reveal that persistent negative signals, no matter how slight, are reliable predictors and that the model does not depend on particular movements at the long end of the curve.

Persistence and Strength

Market chatter tends to pick up at the slightest sign of a yield curve inversion, regardless of size or duration, even intraday. However, inversions in daily or intraday data often prove to be false signals. Inversions observed over longer periods—at a monthly or quarterly average frequency—provide more reliable signals.

Consider, for example, that all six NBER recessions since 1968 have been preceded by at least three negative monthly average observations in the twelve months before the start of the recession (see table). Moreover, when inversion on a monthly average basis is used as an indicator, there have been no false signals over this period. By contrast, negative spreads occurred on 100 days between January 1, 1968, and December 31, 2005, in months that did not turn out to have negative average monthly spreads.

Although inversion has been a dependable recession signal in recent decades, the precise level of the negative spread has varied

Magnitude of Term Spread Signals Twelve Months before Each Recession since 1968

NBER Recession	Number of Months with Negative Monthly Spreads	Minimum Level of Spread
January 1970 – November 1970	10	-0.51
December 1973 – March 1975	6	-1.59
February 1980 – July 1980	12	-2.20
August 1981 – November 1982	10	-3.51
August 1990 – March 1991[a]	3	-0.08
April 2001 – November 2001	7	-0.70

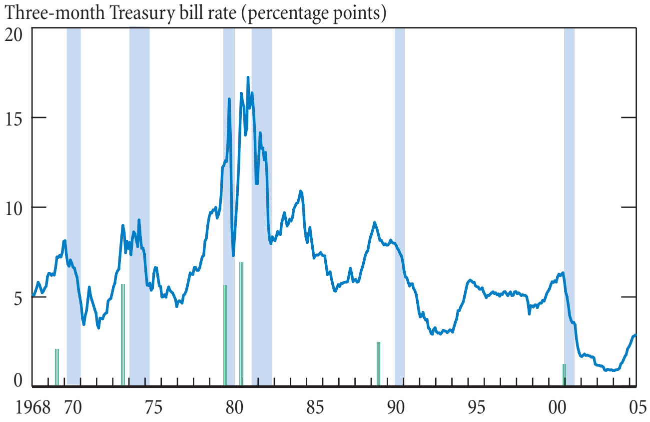
Source: Authors' calculations, based on data from the H.15 statistical release of the Board of Governors of the Federal Reserve System.

[a]Note that the value of the term spread was -0.16 in June 1989, fourteen months before the recession.

Chart 5

Short-Term Rate around Peak Recession Signals

Level of Rate and Eighteen-Month Change in Rate at Peak Signal from Spread



Source: Authors' calculations, based on data from the H.15 statistical release of the Board of Governors of the Federal Reserve System.

Notes: The green bars represent the change in the three-month Treasury bill rate over the eighteen months leading to peak recession signals since 1968. The shaded areas indicate periods designated national recessions by the National Bureau of Economic Research.

with each recession.[7] The table shows the lowest monthly average level of the spread between ten-year and three-month Treasury rates in the twelve months preceding each recession since 1968. In this case, we look at the lowest level of the spread because it provides the strongest signal. Two clear features emerge from the table: the spread has always been negative (the yield curve has inverted at these maturities), and the level at which the spread has bottomed out differs considerably across recessions—from a low value of -3.51 to a slightly negative value of -0.08. We note, however, that while we focus here on predicting the occurrence and not the severity of recessions, there is evidence that more pronounced inversions—as in the early 1980s—have generally been associated with deeper subsequent recessions.[8]

In sum, it seems most appropriate to look at the spread as a recession indicator on at least a monthly average basis. If the spread is calculated from ten-year and three-month bond-equivalent rates, an inversion—even a slight one—is a simple and historically reliable benchmark.

Short-End versus Long-End Changes

Just as the strength of the inversion has no bearing on the ability of the model to predict a recession, so it is also immaterial how the inversion is influenced by changes at the long end of the yield curve. The performance of the yield spread as an indicator does not seem to depend on the particular behavior of the long-term rate in isolation.

Monetary policy most directly influences the short end of the yield curve, although it may affect the level of long-term rates through expectations. An increase in short-term policy rates frequently results in higher longer term rates as well, though the rise at the long end is typically smaller. At times, the long rates move in the opposite direction. Either case, if persistent, may result in an inversion of the yield curve. On occasion, long-term rates decline without a clear simultaneous movement in short-term rates, a pattern that may also result in an inversion.

Chart 5 displays the level of the three-month Treasury rate (blue line) and the change in this rate over the eighteen months leading to peak recession signals since 1968 (green bars). The timing of the peak signals corresponds to the low monthly average spread levels reported in the table. We observe that the green bars in the chart are all positive, indicating that a rise in the three-month rate preceded each recession during this period. In that sense, we could think of every yield curve inversion as resulting at least partly from a rise at the short end.

Chart 6 performs the same analysis for the ten-year Treasury rate, and we see that its behavior is not as consistent as that of the short rate. Prior to the first four recessions, the long end of the yield curve rose as the yield spread signal was unfolding. Prior to the last two recessions, the long rate actually declined, contributing more directly to the yield curve inversion.

The evidence from Chart 6 suggests that the performance of the yield curve as an indicator does not depend on the movements of the long-term rate. The inversion in 1981 was the most pronounced in this period. Contrary to what one might expect, the long rate did not decline but instead experienced its largest rise in

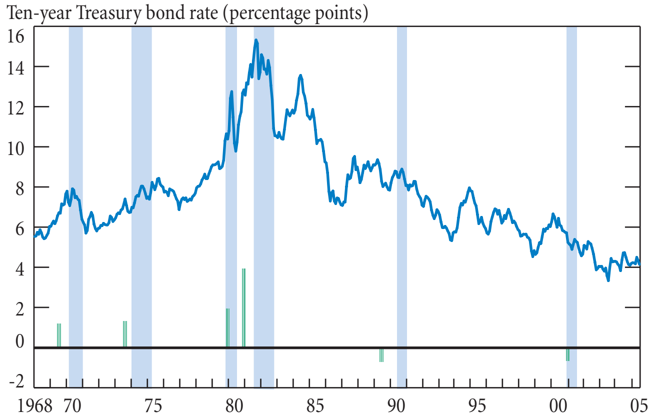
[7]In the 1950s and early 1960s, there were cases in which the yield curve was almost flat, but did not invert in anticipation of recessions. Since 1968, however, the signal from the spread between the Treasury ten-year and three-month rates has always been negative before recessions, and very low positive spreads have not been followed by recessions. See Arturo Estrella, "The Yield Curve as a Leading Indicator: Frequently Asked Questions," <http://www.newyorkfed.org/research/capital_markets/ycfaq.html>.

[8]See, for example, Estrella and Hardouvelis (1991).

Chart 6

Long-Term Rate around Peak Recession Signals

Level of Rate and Eighteen-Month Change in Rate at Peak Signal from Spread



Source: Authors' calculations, based on data from the H.15 statistical release of the Board of Governors of the Federal Reserve System.

Notes: The green bars represent the change in the ten-year Treasury bond rate over the eighteen months leading to peak recession signals since 1968. The shaded areas indicate periods designated national recessions by the National Bureau of Economic Research.

anticipation of the recession. Conversely, the last two inversions were accompanied by declines in the long rate but were not particularly large in magnitude.

Conclusions

Our analysis suggests a number of practical guidelines for the use of the yield curve to predict recessions in real time:

- Defining recessions as the periods between NBER peaks and troughs—counting the troughs but not the peaks—produces clear results.
- Treasury rates are most likely to produce accurate forecasts.
- The best maturity combination may be three months and ten years. Other choices lead to results that are highly correlated with our own, but whatever combination is selected should be used consistently in both analysis and prediction.
- The three-month rate is best represented by the secondary market rate, expressed on a bond-equivalent basis to match the ten-year rate.
- The ten-year constant maturity rate produces good results.
- Levels of the spread are more informative than changes.

As for *why* the yield curve is such a good predictor of recessions, we have reviewed a number of possible reasons, each of which may play an important role at different times. The consistency with which these explanations relate a yield curve flattening to slower real activity provides some assurance that the indicator is valid. Nevertheless, in the end, we must remind ourselves that the evidence of the yield curve's predictive power is statistical and that, however accurate past signals have been, it is impossible to guarantee future results.

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