Joshua V. Rosenberg and Samuel Maurer

Signal or Noise? Implications of the Term Premium for Recession Forecasting

- Since the 1970s, an inverted yield curve has been a reliable signal of an imminent recession.
- Some have argued that the yield curve inversion in August 2006 did not signal a recession because it was driven by an unusually low level of the term premium rather than by changes in interest rate expectations.
- If the predictive power of the yield curve signal comes from interest rate expectations, then a forecasting model that separates this component from the term premium may be more accurate than the standard model.
- A comparison of forecasting performance finds that a model without the term premium provided recession signals similar to those of the standard model since the 1970s, but recently the two models' signals have diverged.

1. Introduction

Ongoing efforts to find the best method for predicting recessions leave many questions unresolved. Existing papers propose a variety of indicators and modeling techniques, yet overall forecast accuracy has been mixed (see, for example, Stock and Watson [2003]). One approach with an excellent track record is the term spread model of Estrella and Hardouvelis (1991).[1] When the yield on a three-month Treasury bill rises higher than the yield on a ten-year Treasury note, the model forecasts that a recession will begin twelve months in the future.

Why should a negative term spread predict a recession? The expectations hypothesis posits that long-term interest rates are determined by expected future short-term rates. Because short-term rates are governed by monetary policy, investors should expect declines as a phase of monetary tightening transitions to monetary easing. As expected future short-term rates fall below current short-term rates, the yield curve inverts. Estrella and Adrian (forthcoming) show that the yield-curve inversion that comes at the end of a tightening cycle has historically been followed by a decline in real activity, which provides a compelling link between yield-curve inversion and an imminent recession.

[1] This approach is developed further in Estrella and Mishkin (1998), Estrella (2005a, b), and Estrella and Trubin (2006).

Joshua V. Rosenberg is a research officer and Samuel Maurer an assistant economist at the Federal Reserve Bank of New York.
Correspondence: <joshua.rosenberg@ny.frb.org>

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However, a large body of literature (such as Dai and Singleton [2002]) shows that the expectations hypothesis does not provide a complete explanation of yield-curve behavior. In particular, yields also depend on the maturity of securities: Longer term Treasury securities are riskier and require a premium to compensate for this extra risk. These term premia vary over time as interest rate risk and investors' risk tolerance fluctuate.

Normally, the term premium provides a buffer that prevents minor variations in interest rate expectations from inverting the yield curve. But when the term premium is small and the yield curve is relatively flat, this buffer disappears. Previous research does not find a strong link between low term premia and recessions (see, for instance, Hamilton and Kim [2002] and Rudebusch, Sack, and Swanson [2007]), so this occasional sensitivity to small changes in expectations may reduce the accuracy of recession forecasts.

This article investigates whether changes in the term premium tend to distort the term spread's recession signals.

In August 2006, the yield curve inverted and the Estrella and Hardouvelis (1991) model predicted that a recession would begin in August 2007.[2] This event drew renewed attention to the term spread recession forecasting approach. However, the term premium had also fallen to an unusually low level, which raised concerns that the observed yield-curve inversion might not in fact indicate an impending recession (see, for example, Dudley [2006]).

This article investigates whether changes in the term premium tend to distort the term spread's recession signals.[3] We begin by decomposing the term spread into an expectations component and a term premium component, based on the Kim and Wright (2005) term premium estimates. Next, we construct recession forecasting models based on these components, following the approach of Estrella and Hardouvelis.

We find that the expectations component model is similar to the standard term spread model: Both models accurately predict all six recessions since 1961 when the signal threshold is set to a twelve-month recession probability of 25 percent. The term spread model passes this threshold again from August 2006 to May 2007, giving recession probabilities of up to 37 percent, while the expectations component model gives probabilities below 18 percent.

Our analysis provides some evidence that the expectations component model is the more accurate of the two. However, we do not have enough historical data to reach a definitive conclusion about which model is superior. Furthermore, measurements of the term premium are imprecise, a factor that adds uncertainty to forecast models that exclude this component from the term spread.

2. Decomposing the Term Spread

The *term spread*—the observed difference between the yield on a long-term and a short-term bond—reflects a combination of underlying factors. Its largest component is investors' expectations about future short-term interest rates. We refer to the difference between average expected short-term rates over the lives of the two bonds as the *expectations component* of the term spread. The remaining difference in yield compensates investors for the risks associated with holding long-term rather than short-term investments. We call this the *term premium component*. Neither component is directly observable, so we measure term premia using a statistical model and attribute the balance of the term spread to the expectations component. The relationship between the term spread and its components is given in equation 1:

1) *term spread = expectations component + term premium component.*

In turn, each component includes both inflation-related and real factors:

2) *expectations component = inflation expectations + real rate expectations*

3) *term premium component = inflation risk premium + real rate risk premium.*[4]

Thus, the expectations component of the term spread measures the difference in anticipated average inflation over

[2]The Wright (2006) model also signaled an imminent recession. According to Fernald and Trehan (2006), that model estimated a 47 percent chance of recession over the next four quarters based on data from November 8, 2006.

[3]Recent papers document significant differences in the cyclical properties of the term spread's expectations component and its term premium component. Most of this work focuses on predicting real activity using GDP growth (such as Ang, Piazzesi, and Wei [2006]), but little consideration has been given to the effect of the term premium in forecasting recessions. One exception is Wright (2006), who includes the Cochrane and Piazzesi (2005) excess bond return factor with the term spread to forecast National Bureau of Economic Research (NBER) recessions. However, Wright's model does not explicitly decompose the term spread.

[4]Durham (2006) decomposes nominal rates into the expected real rate, expected inflation, the real term premium, and the inflation risk premium. Longstaff and Schwartz (1992), Engle, Lilien, and Robins (1987), and Wachter (2006) develop models in which the term premium depends on interest rate risk and risk aversion.

long and short horizons, plus the difference in anticipated average real rates over long and short horizons. Changes in the expectations component are likely to be dominated by variation in short-term expectations. Changes in the term premium component, however, are expected to be driven primarily by the long-term risk outlook, since relatively little compensation is needed for short-term risk. We would thus expect the term premium component to decline as investor uncertainty about long-term productivity improves (indicating reduced real rate risk) and as inflation expectations become more stable.[5]

3. Measuring Term Spread Components

A standard measure of the term spread is the difference between ten-year and three-month Treasury yields. We follow this convention in our empirical analysis. Our ten-year constant-maturity rate and three-month secondary-market rate are taken from the Federal Reserve's H.15 Statistical Release.[6]

While term premia cannot be observed, there are a variety of estimation approaches that incorporate both macroeconomic and financial market data. Although current models are far from perfect, Rudebusch, Sack, and Swanson (2007) find that different techniques generate remarkably similar results.[7] The five models they compare produce ten-year term premium estimates that are highly correlated. They report that the Kim and Wright (2005) measure is the most representative,[8] so we use estimates from this model in our analysis.

Kim and Wright isolate the term premium component from the expectations component using a term structure model that requires all bonds to be priced fairly (see, for example, Duffee [2002]). According to this approach, each bond's price is equal to its expected future value minus a discount to compensate investors for that particular bond's risk. Additional restrictions on the behavior of bond values and risk premia over time allow these components to be estimated using historical interest rate data.

More specifically, in the Kim and Wright model, three unobserved factors drive interest rate changes. Tang and Xia (2007) show that these three factors are correlated with the current interest rate level, the slope of the yield curve, and the curvature of the yield curve.[9] In turn, Dewachter and Lyrio (2006) show that the level factor can be interpreted as the long-run inflation expectations of investors. The slope and curvature factors capture the current economic outlook and the stance of monetary policy, respectively.

The Federal Reserve Board provides data from the Kim and Wright model at a daily frequency. We measure the term spread's term premium component by calculating the difference between the Kim and Wright ten-year par term premium and three-month instantaneous term premium estimates.

These data begin in 1980, but we would like to go back farther to include more recessions in our analysis. Cochrane and Piazzesi (2005) show that the term premium can be estimated as a linear function of forward Treasury rates. We use a similar technique to identify the relationship between forward rates and the Kim and Wright term premium component. We assume that the post-1980 relationship holds before 1980 as well and estimate the term premium from forward rates over the entire period in which they are available.

While term premia cannot be observed, there are a variety of estimation approaches that incorporate both macroeconomic and financial market data.

Specifically, we regress the Kim and Wright term premium component on daily one- to seven-year instantaneous forward rates from January 1980 to July 2007, using data from the yield-curve model produced by Gurkaynak, Sack, and Wright (2006). Our model has an excellent fit, with an adjusted R^2 of 99.0 percent and a root mean squared error of less than 7 basis points.[10] Forward rate data are available since July 1961, so we use fitted values from our model to represent the term

[5]Vasicek (1977) shows that the term premium depends on interest rate volatility and the maturity of the bond. Several empirical papers confirm this relationship. Hamilton and Kim (2002) find that the term premium is closely linked to long-term interest rate volatility, while Orphanides and Kim (2007) identify a strong relationship between the term premium and the dispersion of inflation forecasts. Beechey (2007) shows that most of the response of ten-year forward rates to macroeconomic news comes from changes in the term premium rather than expected future short-term rates.

[6]We are grateful to Arturo Estrella for providing the term spread data. Estrella converts the three-month rate from a discount rate to a bond-equivalent rate, as described in Estrella and Trubin (2006).

[7]Rudebusch, Swanson, and Wu (2006) present evidence that a decline in the term premium (using estimates from macro-finance models) is unable to fully explain the behavior of yields during the 2004-05 period. See also Swanson (2007).

[8]The Kim and Wright (2005) term premium estimate has a 99 percent correlation to the first principal component of the five measures that Rudebusch, Sack, and Swanson (2007) compare. The first principal component represents the most important common variation among models.

[9]Litterman and Scheinkman (1991) identify these factors as the ones that effectively characterize the shape of the yield curve.

[10]The equation for the fitted term premium component is $-0.85 - 0.78 f_1 + 4.32 f_2 - 15.62 f_3 + 33.71 f_4 - 41.01 f_5 + 26.68 f_6 - 7.06 f_7$, where f_t is an instantaneous forward rate at year t.

premium component from 1961 to 2007.[11] We subtract these values from the term spread to obtain the estimated expectations component. Finally, we take monthly averages of the term spread and its two components.

4. Relating Term Spread Components to Recessions

Chart 1 shows monthly averages of the term spread, its expectations component, and its term premium component from 1961 to 2007. During this period, there were six recessions as defined by the NBER.

The term spread and the expectations component generally range from 0 percent to 3 percent during periods of economic expansion, but decline to especially low levels immediately before each recession. Preceding a recession, the term spread consistently falls below 0 percent and the expectations component falls below -1 percent. Furthermore, the two measures reach these low levels *only* in the months preceding recessions.[12] Low levels of the term spread or expectations component seem to provide reliable predictions of upcoming recessions.[13]

In contrast, the term premium component follows a longer trend. It usually ranges from 0 percent to 1.5 percent, rising above 2 percent in the 1980s and generally declining thereafter. There is no clear pattern linking its level to the business cycle.

To quantify the recession likelihood indicated by the term spread and its components, we estimate probit models following the approach of Estrella and Hardouvelis (1991).[14] First, we represent the state of the economy as a variable equal to 0 during economic expansion and 1 during recession (which we define as the month following an NBER business-cycle peak through the month of the trough). Then, we map the level of the term spread at time t to the state of the economy twelve months later by calibrating the equation

$$4)\qquad (\textit{recession indicator})_{t+12} = \Phi\,(\alpha + \beta * \textit{spread}_t),$$

where $spread_t$ is the term spread at time t, $(\textit{recession indicator})_{t+12}$ is the state of the economy twelve months after t, and α and β are estimated coefficients. Φ is the cumulative normal distribution function, which maps its contents to a value between 0 and 1.

After estimating the model's coefficients, we can use equation 4 to calculate from the level of the term spread the probability of economic recession in twelve months. We also produce similar models using the expectations component, the term premium component, or a combination of the two in place of the term spread.

In their empirical analysis using data from 1955 to 1988, Estrella and Hardouvelis report that the coefficient on the term spread (β) is negative. So, as the long-term rate falls relative to the short-term rate, the predicted recession probability rises. They find that the model fits recessions well, with a pseudo-R^2 of 30 percent.

Table 1 presents estimation results for the equation 4 specification using the term spread alone (column 1), each term spread component separately (columns 2 and 3), and the two components together (column 4). The sample period is July 1961 to July 2006.[15] Our estimated term spread model is quite similar to that of Estrella and Hardouvelis. We obtain a negative and highly significant term spread coefficient, and the model fit is good, with a pseudo-R^2 of 25.5 percent.

The expectations component results are very close to those of the term spread. The estimated expectations component coefficient is negative and highly significant, and the model's pseudo-R^2 (27.4 percent) is higher than that of the term spread model. However, the term premium component model performs poorly: The coefficient on the term premium component is not statistically significant, and the model has no explanatory power. When we use both term spread components together, the expectations component remains significant, the term premium component remains insignificant, and the model fit shows a slight improvement.

5. Predicting Recessions

Chart 2 gives the probability forecasts produced by the term spread and expectations component probit models. As expected, they reach their highest values in the year-and-a-half before a recession. The two forecasts generally track each other closely. However, the expectations component model produces higher recession probabilities than the term spread model does in the mid-1980s and lower probabilities during the 1960s, the late 1990s, and the current cycle.

[11]This procedure treats the forward rates as instrumental variables, correcting for bias due to estimation error in the Kim and Wright term premium data from which our independent variables are derived.

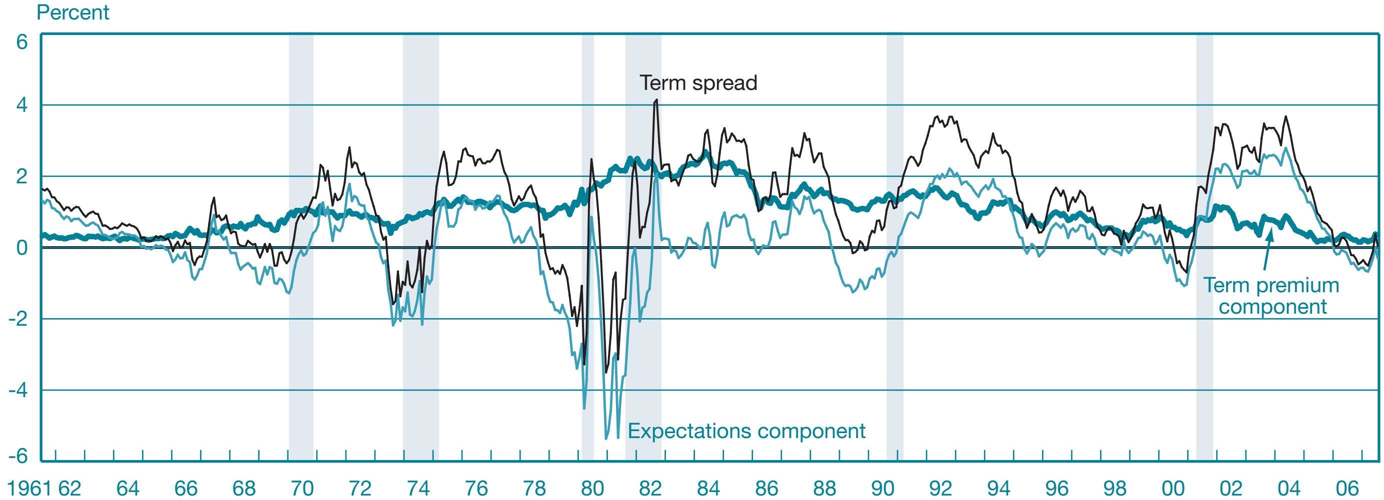
[12]There are two possible exceptions to this rule: the term spread declines below 0 percent in 1966 and in 2006-07, as we discuss in the next section.

[13]We use this observation to motivate our statistical models, but we do not focus on the threshold at which the expectations component would signal a recession. The expectations component is always less than the term spread because the term premium is positive, so this threshold is likely to be lower than zero. In other words, a negative level of the expectations component is not expected to be sufficient to generate a recession signal.

[14]In a probit model, the variable to be explained is equal to either 0 or 1. The probability of state 1 occurring is given by a linear combination of explanatory variables inserted into a cumulative normal distribution function.

[15]When we extend the sample period through November 2006, the estimation results are essentially the same, but the model fit is slightly weaker.

Chart 1
Term Spread and Components



Sources: Board of Governors of the Federal Reserve System; authors' calculations.

Note: The shaded areas indicate periods designated national recessions by the National Bureau of Economic Research.

Table 1
Recession Forecasting Model Estimation Results

	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-0.73***	-1.44***	-1.31***	-1.21***	-1.62***	-1.19***
Term spread	-0.78***				-0.57***	
Expectations component		-0.77***		-0.81***		-0.87***
Term premium component			-0.13	-0.26		
Fed funds effective rate					0.11***	-0.04
Number of observations	541	541	541	541	541	541
Estrella pseudo-R^2 (percent)	25.5	27.4	0.2	27.9	28.3	27.5
Log likelihood	-133	-128	-198	-127	-126	-128

Source: Authors' calculations.

Note: The dependent variable is the National Bureau of Economic Research recession indicator twelve months ahead, from July 1961 to July 2006.

***Statistically significant at the 1 percent level.
**Statistically significant at the 5 percent level.
*Statistically significant at the 10 percent level.

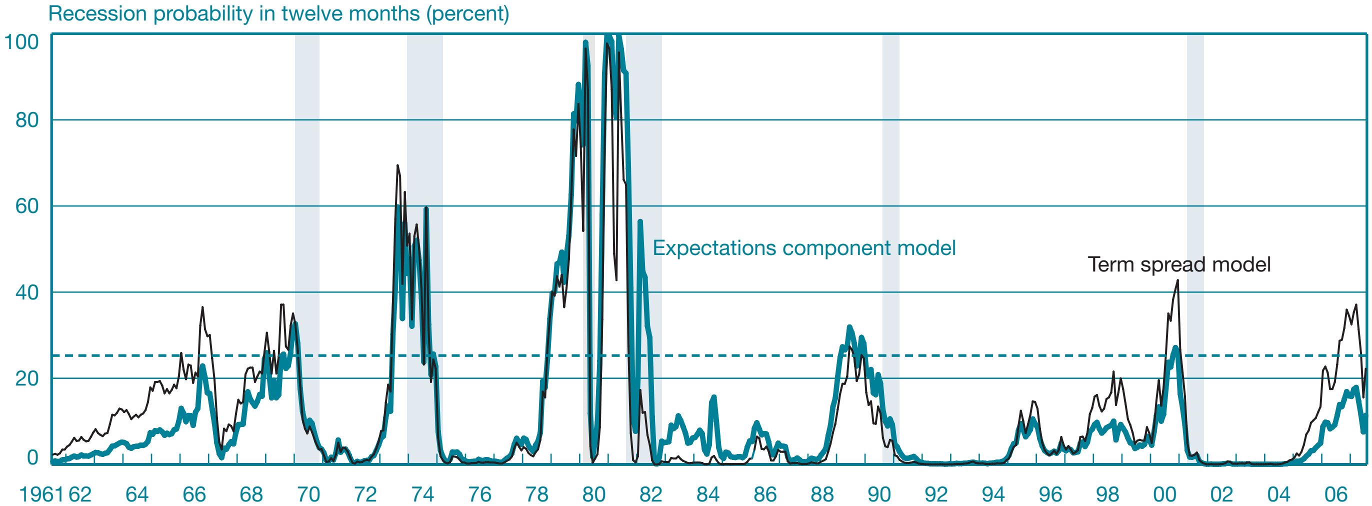
A look at the forecasts that precede the six recessions in our sample helps to interpret these model-based probabilities. We first find the minimum probability level indicated by both models before all recessions. This threshold, 25 percent, can be interpreted as the most conservative recession indicator that would not have missed any recessions in the past.[16]

Both models tend to breach the 25 percent threshold (the dashed line in Chart 2) at the same time. One exception is that

[16]The term spread model's forecast rises above 25 percent for three months prior to the 1990-91 recession, peaking at 27 percent. The expectations component forecast rises above 25 percent for three months prior to the 2001 recession, also peaking at 27 percent. All other recessions are preceded by higher and longer forecasts from both models. A 25 percent forecast occurs when the term spread declines just past 0 percent or when the expectations component declines to about -1.0 percent. Similarly, Estrella (2005b) finds that a reliable recession signal is generated when the term spread falls below about 0 percent, which is equivalent to a 30 percent recession probability from his probit model.

Chart 2

Recession Probability Forecasts



Source: Authors' calculations.

Notes: The shaded areas indicate periods designated national recessions by the National Bureau of Economic Research. The dashed line denotes the historical recession prediction threshold. Model estimates are reported in Table 1, columns 1 and 2.

Table 2

Recession Forecasting Signals

NBER Recessions		Term Spread Signals			Expectations Component Signals		
Beginning	Length	Beginning	Lead	Length	Beginning	Lead	Length
Jan. 1970	11	Dec. 1968	13	15[a]	Jan. 1969	12	14[a]
Dec. 1973	16	June 1973	6	16[a]	June 1973	6	18[a]
Feb. 1980	6	Nov. 1978	15	18	Dec. 1978	14	17
Aug. 1981	16	Oct. 1980	10	12	Oct. 1980	10	21[a]
Aug. 1990	8	June 1989	14	6[a]	Mar. 1989	17	10[a]
Apr. 2001	8	July 2000	9	7	Oct. 2000	6	3
Average	10.8		11.2	12.3		10.8	13.8

Sources: National Bureau of Economic Research; authors' calculations.

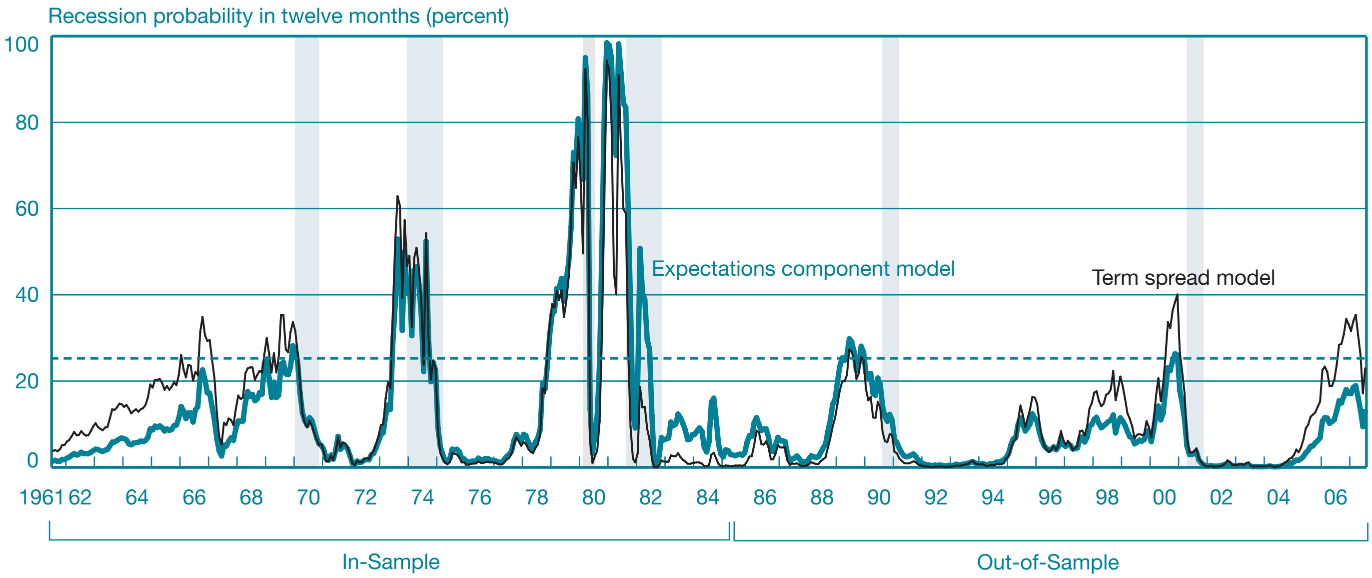
Notes: A recession signal is a forecast probability greater than 25 percent. Lead times and lengths are in months.

[a]Denotes a noncontinuous signal.

the term spread model produces a recession forecast of 37 percent in 1966, while the expectations component model reaches only 23 percent. This result precedes a brief economic downturn that is commonly identified as a "credit crunch" episode (see Burger [1969]) but is not classified as a recession by the NBER. The only other exception occurs in the last two years. From August 2006 to May 2007, the term spread model predicts a recession probability of between 26 percent and 37 percent, while the expectations component model never rises above 18 percent. As of December 2007, the subsequent period has not been classified as a recession by the NBER.

Table 2 compares the warning signals given before each recession as the two model forecasts rise above 25 percent. Signals begin six to seventeen months before a recession, with an average lead time of eleven months. Signals last from three to eighteen months, with an average duration of thirteen months. The overall timing and duration of signals from the two models are similar.

Chart 3
Out-of-Sample Recession Probability Forecasts



Source: Authors' calculations.

Notes: The shaded areas indicate periods designated national recessions by the National Bureau of Economic Research. The dashed line denotes the historical recession prediction threshold. Model estimates are reported in Table 1, columns 1 and 2.

Estrella and Mishkin (1998) show that this type of model may forecast recessions that occur within the regression sample period (in-sample) without being able to forecast recessions that occur after the model estimation period (out-of-sample). We conduct a split-sample test to determine whether this affects our models, estimating each one over the 1961-84 period and then measuring its forecast accuracy from 1985 to 2007.[17] Because the out-of-sample period contains only two recessions, small-sample bias may affect our results (Gart and Zweifel 1967).

Estimation results based on the 1961-84 sample (Table 3, columns 1 and 2) are very similar to those based on the full 1961-2006 sample (Table 1, columns 1 and 2). The term spread and expectations component coefficients are somewhat smaller, but remain negative and highly significant. The short-sample models have in-sample fits that are similar to their full-sample fits. Their out-of-sample fits are only a few percentage points lower (22.3 percent for the expectations component model and 22.4 percent for the term spread model), indicating that these models' forecasting ability remains strong after the sample period ends. Chart 3 shows that the out-of-sample recession probability forecasts of the short-sample models are close to the full-sample forecasts.

Table 3
In-Sample and Out-of-Sample Estimation Results

	(1)	(2)	(3)	(4)
Constant	-0.71***	-1.33***	-1.67***	-1.38***
Term spread	-0.65***		-0.45***	
Expectations component		-0.65***		-0.63***
Fed funds effective rate			0.11***	0.01
Number of observations	282	282	282	282
In-sample Estrella pseudo-R^2 (percent)	25.2	28.1	29.7	28.1
Out-of-sample Estrella pseudo-R^2 (percent)	22.4	22.3	23.0	22.1
In-sample log likelihood	-95.1	-91.1	-88.9	-91.0

Source: Authors' calculations.

Note: The dependent variable is the National Bureau of Economic Research recession indicator twelve months ahead, from July 1961 to December 1984. The in-sample estimation period is July 1961 to December 1984. The out-of-sample forecast period is January 1985 to July 2006; we use a full-sample July 1961 to July 2006 fitted constant model as a performance baseline. The sample period for estimating the term premium component from forward rates is January 1981 to December 1984.

[17] We extrapolate the term premium component using parameters from a regression of the Kim-Wright measure on forward rates from 1981 to 1984. This model's adjusted R^2 is 87 percent and its root mean squared error is 12 basis points. Thus, the expectations component data used in our split-sample model may be less accurate than those used in our full-sample model.

6. Alternative Recession Forecasting Models

We next consider two modifications to our model specifications. Wright (2006) uses the federal funds rate in addition to the term spread (and several other variables) to predict NBER recessions.[18] In Table 1, columns 5 and 6, we augment the models in columns 1 and 2 by adding the federal funds rate.[19] This new term is significant along with the term spread, but not along with the expectations component. Table 3 shows similar results for the short-sample estimations (columns 3 and 4). The addition of the federal funds rate improves the fit of the term spread model, raising its pseudo-R^2 from 25.5 percent to 28.3 percent in the full sample and from 25.2 percent to 29.7 percent in the short sample. However, it improves the term spread model's out-of-sample performance only marginally. These results suggest that the federal funds rate and the expectations component of the term spread contain similar information, which is consistent with the link between the monetary policy cycle and expectations of short-term interest rates.

[Our] results suggest that the federal funds rate and the expectations component of the term spread contain similar information, which is consistent with the link between the monetary policy cycle and expectations of short-term interest rates.

Rudebusch, Sack, and Swanson (2007) use spread changes rather than spread levels to predict GDP growth. We adapt their approach to investigate the explanatory power of spread changes for NBER recessions (see also Estrella and Trubin [2006]). We find that both the term spread change and the expectations component change are statistically significant recession predictors (Table 4). However, the levels models have substantially better in-sample fit and out-of-sample forecasting performance than do the changes models. For example, the full-sample pseudo-R^2 for the term spread levels model is 25.5 percent compared with only 8.7 percent for the changes model. The out-of-sample pseudo-R^2 for both changes models is negative (Table 5), indicating that their performance is worse than the performance of a model with only a constant term.

[18] Wright (2006) finds that the federal funds rate coefficient is positive and highly significant in his recession forecasting model. He uses a somewhat different recession measure than we do, forecasting the likelihood that there will be a recession at any point in the upcoming six quarters rather than a recession in exactly twelve months.

[19] We use the average effective federal funds rate reported in the Federal Reserve's H.15 Statistical Release.

Table 4
Estimation Results Using Changes

	(1)	(2)	(3)
Constant	-1.31***	-1.37***	-1.17***
Twelve-month change in term spread	-0.36***		
Twelve-month change in expectations component		-0.50***	
Twelve-month change in term premium component			0.34
Number of observations	529	529	529
Estrella pseudo-R^2 (percent)	8.7	12.3	0.5
Log likelihood	-174	-165	-196

Source: Authors' calculations.

Note: The dependent variable is the National Bureau of Economic Research recession indicator twelve months ahead, from July 1962 to July 2006.

Table 5
In-Sample and Out-of-Sample Estimation Results Using Changes

	(1)	(2)
Constant	-1.03***	-1.11***
Twelve-month change in term spread	-0.41***	
Twelve-month change in expectations component		-0.51***
Number of observations	270	270
In-sample Estrella pseudo-R^2 (percent)	14.6	17.8
Out-of-sample Estrella pseudo-R^2 (percent)	-7.6	-1.9
In-sample log likelihood	-108	-104

Source: Authors' calculations.

Note: The dependent variable is the National Bureau of Economic Research recession indicator twelve months ahead. The in-sample estimation period is July 1962 to December 1984. The out-of-sample forecast period is January 1985 to July 2006; we use a full-sample sample July 1962 to July 2006 fitted constant model as a performance baseline. The sample period for estimating the term premium component from forward rates is January 1981 to December 1984.

7. Conclusion

Since the 1970s, an inverted yield curve has been a reliable signal of an imminent recession. One interpretation of this signal is that it reflects market expectations that current monetary policy is tighter than it will be in the future, owing to an upcoming deterioration in the economic outlook. If the yield-curve signal comes from interest rate expectations, then a model using only the expectations component of the term spread (removing the term premium component) should produce more accurate forecasts.

Our empirical analysis finds that the expectations component is indeed a leading indicator of recession, while the term premium component is not. When we compare the historical recession forecasting performance of the term spread and its expectations component, we find some evidence that a model based on the expectations component is more accurate. Our results should be interpreted with caution, however, because they rely on imprecise estimates of the term premium and on a sample period that includes only six recessions.

More recently, from August 2006 to May 2007, the term spread model signaled an imminent recession, but the expectations component model did not. The near future will likely shed light on the relative accuracy of these models.

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