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The Term Structure as a Predictor of Real Economic Activity

ARTURO ESTRELLA and GIKAS A. HARDOUVELIS*

ABSTRACT

A positive slope of the yield curve is associated with a future increase in real economic activity: consumption (nondurables plus services), consumer durables, and investment. It has extra predictive power over the index of leading indicators, real short-term interest rates, lagged growth in economic activity, and lagged rates of inflation. It outperforms survey forecasts, both in-sample and out-of-sample. Historically, the information in the slope reflected, *inter alia*, factors that were independent of monetary policy, and thus the slope could have provided useful information both to private investors and to policy makers.

THE FLATTENING OF THE yield curve in 1988 and its inversion in early 1989 have been interpreted by many business economists and financial analysts as evidence that a recession is imminent. Implicit in this interpretation is the presumption that a flattening of the yield curve predicts a drop in future spot interest rates and that these lower rates are associated with a lower level of real GNP. Recent empirical work on the term structure of interest rates confirms that changes in the slope of the yield curve predict the correct direction of future changes in spot rates, yet there is little empirical work on the predictability of changes in real economic activity.¹ Indeed, given the near-random-walk empirical behavior of real GNP, a finding that the yield curve can predict future changes in real output would be very impressive.²

Predictability of changes in real output is associated with other equally important questions: How much extra information is there in the term

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¹Fama (1986) and Stambaugh (1988) present graphs showing that increases in forward rates precede economic expansions and decreases in forward rates precede recessions. Neither author performs a detailed statistical analysis. Laurent (1988) looks at the relationship between real GNP and a distributed lag of the spread between the 20-year bond yield and the federal funds rate. Harvey (1988) examines the real term structure as a predictor of changes in consumption.

²For an interesting and thorough analysis of the permanent and transitory components in the growth rate of real GNP, see Cochrane (1988).

structure that is not readily available in other published statistics? Should the term structure be included in the list of leading indicators? Should monetary policy use the term structure to extract information about future output, or is it the case that the yield curve reflects expected monetary actions alone? These are concerns that currently preoccupy the Federal Reserve, for in the latter case the slope of the yield curve would have no extra useful information for the conduct of monetary policy.

Our paper is organized as follows: Section I reviews the recent evidence on the predictive power of the term structure. Section II describes the data and the econometric methods and provides the basic evidence on the predictability of future changes in output. Section III explores the usefulness of the information in the term structure to the monetary authorities. Section IV evaluates the information in the yield curve by comparing its predictive power with survey forecasts, the index of leading indicators, and other available information. Section V summarizes our main conclusions.

I. Previous Evidence

A number of investigators provide evidence that the term structure has predictive power. Fama (1984) examines one- to 6-month Treasury bill rates from 1959 through 1982 and finds that forward rates predict the correct direction of subsequent changes in short-term rates. Mankiw and Miron (1986) find strong predictive ability prior to the establishment of the Federal Reserve using 3- and 6-month rates. They attribute the predictive ability to the presence of a forecastable seasonal pattern in interest rates, which was ironed out after the Fed began intervening in the marketplace. Hardouvelis (1988) examines the predictive power of forward rates across recent monetary regimes using weekly data on T-bill rates with maturities that span one to 26 weeks. He finds no necessary connection between the degree to which the Fed adheres to interest rate targeting and the predictability of interest rates but reports that the predictive power of the term structure has increased dramatically after October 1979. Mishkin (1988) corroborates the evidence of Fama (1984) and Hardouvelis (1988) using more powerful estimation methods. Fama and Bliss (1987) find that long-maturity forward rates also have predictive power 2 to 4 years ahead. They attribute the predictive power to the presence of mean reversion in interest rates over multiperiod horizons. Similarly, Campbell and Shiller (1987) find evidence consistent with the hypothesis that there is useful information in the term structure about the future evolution of interest rates.

There is evidence that the prediction in forward rates represent a composite prediction about both future real rates and future rates of inflation. Mishkin (1990) examines rates with maturities that range from one to 12 months and finds that most of the information in forward rates is about future real rates of interest. However, there is some information about the future rate of inflation at the end of his maturity spectrum. Fama (1990) finds that an increase in the spread between the 5-year and one-year bond

yields predicts an increase in the rate of inflation for the following 5 years and a *decrease* in the real rate of interest one, 2, and 3 years ahead. Overall, the evidence is consistent with the hypothesis that the slope of the yield curve has predictive power about the real rate of interest in the short- and intermediate-run and about the rate of inflation in the intermediate- and long-run (2 to 5 years into the future).

The term structure appears to predict real economic activity as well. Kessel (1956) mentions this empirical regularity, and Fama (1986) discusses it but does not provide any detailed statistical evidence. Laurent (1988) regresses the growth in real GNP on lags of the spread between the 20-year bond rate and the federal funds rate. The sum of all lagged spreads is positive but insignificant. Harvey (1988) examines the term structure of *ex ante* real rates of interest as predictors of future real consumption in the context of the Consumption Capital Asset Pricing model (CCAPM). Harvey focuses on testing the CCAPM and provides evidence on predictability only up to 3 quarters into the future. His evidence on the CCAPM and the predictability of the real term structure is mixed, although he does find that the slope is a better predictor of future real consumption growth than lagged consumption growth or lagged stock returns.³

II. Does the Term Structure Predict Real Economic Activity?

We begin by documenting the empirical relation between future rates of growth in real GNP and its components with the current slope of the yield curve. We postpone the discussion of the theoretical basis for the empirical relations to the following section.

A. Data and Definitions

Real GNP is observed quarterly, and thus our sample is quarterly from 1955 through the end of 1988. The dependent variable in our basic regression is the annualized cumulative percentage change in the seasonally adjusted finally revised real GNP number based on 1982 dollars:

$$Y_{t, t+k} \equiv (400/k) [\log(y_{t+k}/y_t)], \quad (1)$$

where k denotes the forecasting horizon in quarters, and y_{t+k} denotes the level of real GNP during quarter $t+k$, and $Y_{t, t+k}$ denotes the percentage

³After completing this study, we have come across three other simultaneous and independent studies by Chen (1989), Harvey (1989), and Stock and Watson (1989). Those studies overlap with ours, but none explores the predictive ability of the slope in the same detail as we do in this paper. Harvey regresses the growth in real GNP from the next quarter to 5 quarters into the future on the contemporaneous spread between the 5-year Treasury bond rate and 3-month Treasury bill rate. Stock and Watson use the slope of the yield curve among many other variables to predict a new monthly measure of coincident indicators that they construct. Chen's work is closer to our paper, but his emphasis is different. He examines the simultaneous predictability of excess stock returns and tries to relate it to the predictability of real GNP.

change from current quarter t to future quarter $t + k$. We also examine the predictability of the annualized marginal percentage change in real GNP from future quarter $t + k - j$ to future quarter $t + k$, defined as:

$$Y_{t+k-j, t+k} \equiv (400/j) [\log(y_{t+k}/y_{t+k-j})]. \quad (2)$$

Observe that the cumulative percentage change $Y_{t, t+k}$ is the average of consecutive marginal percentage changes $Y_{t+i-1, t+i}$ for $i = 1, 2, 3, \dots, k$. Hence, each $Y_{t+i-1, t+i}$ provides more precise information on how far into the future the term structure can predict.

For simplicity, we use only two interest rates to construct the slope of the yield curve, the 10-year government bond rate R^L , and the 3-month T-bill rate R^S . Both R^L and R^S are annualized bond equivalent yields. A richer array of interest rate maturities would provide finer information on the predictive accuracy of the term structure, but our purpose here is to find simple qualitative evidence on the predictive ability of the slope of the yield curve, and these two rates suffice.⁴ Our measure of the slope of the yield curve is the difference between the two rates.⁵

$$SPREAD_t \equiv R_t^L - R_t^S. \quad (3)$$

In computing the two rates, we use average quarterly data as opposed to point-in-time data. Previous investigators have used beginning-of-period data primarily because the implicit forward interest rates match a future spot rate exactly. For example, in Hardouvelis (1988), Thursday 26-week and 24-week T-bill rates were used to construct forward rates that would match 2-week T-bills of a Thursday 24 weeks into the future. However, here our concern is predicting real GNP, and point-in-time data are not essential. On the contrary, it seems that GNP would be more closely associated with average interest rates over the quarter. Furthermore, averaged data provide an opportunity to check the robustness of previous results on the predictive power of the term structure that used only point-in-time data. There is evidence (for Treasury bills) that point-in-time data at the turn of the calendar month contain systematic biases (Park and Reinganum (1986)).

⁴Recent factor analysis of the term structure by Litterman and Scheinkman (1988) and by Litterman, Scheinkman, and Weiss (1988) shows that the information in the term structure is captured by three factors. The authors identify these factors as the levels of short rates, long rates, and interest rate volatility. In our following analysis we will use short rates, and the spread between R^L and R^S as well as other information (we do not use volatility). Thus, although data on additional maturities would give us more spreads, the independent information in these spreads would be minimal. Stambaugh (1988) performs a factor analysis on T-bills alone and also concludes that at most three factors can explain the variation of interest rates with different maturities.

⁵Observe that $R_t^L - R_t^S$ is proportional to the difference between the forward rate calculated from the 10-year and 3-month yields, f_t , and R_t^S . The forward rate is defined as in Shiller, Campbell, and Schoenholtz (1983): $f_t \equiv (D_L R_t^L - D_S R_t^S)/(D_L - D_S)$, where D_L is the duration of the 10-year bond and D_S is the duration of the 3-month T-bill. The difference $f_t - R_t^S$ is the correct measure of the slope of the yield curve, but it is proportional to $R_t^L - R_t^S$: $f_t - R_t^S = [D_L/(D_L - D_S)](R_t^L - R_t^S)$.

B. Econometric Issues

Our basic regression equations have the following general form:

$$Y_{t,t+k} = \alpha_0 + \alpha_1 SPREAD_t + \sum_{i=1}^N \beta_i X_{it} + \epsilon_t, \quad (4)$$

where $Y_{t,t+k}$ and $SPREAD_t$ are defined by equations (1) and (3) above, and X_{it} represents other information variables available during quarter t . Our sampling period is quarterly, but the forecasting horizon k varies from one to 20 quarters ahead. The overlapping of forecasting horizons creates special econometric problems that are by now familiar from the work of Hansen and Hodrick (1980). The data overlapping generates a moving average error term of order $k - 1$, where k is the forecasting horizon. The moving average does not affect the consistency of the OLS regression coefficients but does affect the consistency of the OLS standard errors. For correct inferences, the OLS standard errors have to be adjusted. We use the Newey and West (1987) method of adjustment. Given that the non-overlapping data may have autocorrelated errors, we allow for a moving average of order length longer than $k - 1$. We choose the lag length of each Newey and West correction after observing the estimated autocorrelation function of the OLS residuals, but the corrected standard errors are not very sensitive to the choice of the lag length.

C. Regression Evidence

Table I presents the basic regression results on the predictive power of the slope of the yield curve. Consistent with current thinking, a steeper (flatter) slope implies faster (slower) future growth in real output. For example, if the current quarter's spread between the 10-year T-bond rate and the 3-month T-bill rate is 100 basis points or one percent, then the Cumulative Change Panel of the fourth row of Table I shows that over the course of one full year from current quarter t to quarter $t + 4$, real GNP is predicted to grow by three percent ($1.70\% + (1.30)(1\%) = 3\%$). Observe that all constant terms α_0 and β_0 are positive. The positive constant terms imply that a negative slope does not necessarily predict negative future real GNP growth. In our previous example of cumulative growth from current quarter t to future quarter $t + 4$, a prediction of a negative real GNP growth would have occurred only if the slope were less than minus 1.31 percent ($-1.31\% = -1.70\%/1.30$).

As expected, cumulative changes in real output are more predictable than marginal changes. The predictive power for cumulative changes lasts for about 4 years, while the predictive power of consecutive marginal changes in real output lasts for about 6 to 7 quarters. The marginal predictive power results indicate that financial market participants are able to predict events that will occur 6 to 7 quarters ahead. Such predictive ability is impressive.⁶

⁶Chen (1989) also presents cumulative and marginal regressions for up to 8 quarters into the future. His results are similar to the results in Table I.

Table I
Predicting Future Changes in Real Output Using the Slope of the Yield Curve

The sample is quarterly from 1955:2 through 1988:4. The estimated models are as follows:

$$\text{Cumulative Change: } (400/k)(\log y_{t+k} - \log y_t) = \alpha_0 + \alpha_1 \text{ SPREAD}_t + \epsilon_t$$

$$\text{Marginal Change: } (400/j)(\log y_{t+k} - \log y_{t+k-j}) = \beta_0 + \beta_1 \text{ SPREAD}_t + u_t, j = 1 \text{ or } 4.$$

y_{t+k} is the level of real GNP of quarter $t+k$. k represents the forecasting horizon. For marginal changes, $j=1$ for forecasting horizons 1 through 8, and $j=4$ for forecasting horizons 12, 16, and 20. SPREAD_t is the difference between the 10-year T-bond and 3-month T-bill rates of quarter t . The interest rates are annualized quarterly average bond equivalent yields. Inside the parentheses are Newey and West (1987) corrected standard errors that take into account the moving average created by the overlapping of forecasting horizons as well as conditional heteroskedasticity. Nobs. denotes the number of quarterly observations, $\bar{R}^2$ the coefficient of determination adjusted for degrees of freedom, and SEE the regression standard error.

Forecasting Horizon; k Quarters Ahead	Nobs.	Cumulative Change				Marginal Change			
		α_0	α_1	$\bar{R}^2$	SEE	β_0	β_1	$\bar{R}^2$	SEE
1	135	1.74* (0.64)	1.23* (0.29)	0.13	3.75	1.74* (0.64)	1.23* (0.29)	0.13	3.75
2	134	1.63* (0.56)	1.35* (0.28)	0.24	2.82	1.51* (0.58)	1.46* (0.31)	0.18	3.64
3	133	1.64* (0.54)	1.35* (0.28)	0.31	2.39	1.67* (0.54)	1.30* (0.30)	0.14	3.75
4	132	1.70* (0.52)	1.30* (0.27)	0.35	2.08	1.89* (0.53)	1.09* (0.30)	0.09	3.86
5	131	1.79* (0.50)	1.24* (0.24)	0.38	1.86	2.18* (0.50)	0.84* (0.75)	0.05	3.95
6	130	1.89* (0.48)	1.15* (0.22)	0.38	1.70	2.42* (0.47)	0.60* (0.20)	0.02	4.02
7	129	1.99* (0.46)	1.05* (0.19)	0.37	1.59	2.60* (0.47)	0.44* (0.20)	0.01	4.06
8	128	2.11* (0.44)	0.93* (0.16)	0.33	1.54	2.98* (0.52)	0.02 (0.26)	-0.01	4.11
12	124	2.50* (0.37)	0.53* (0.14)	0.18	1.34	3.28* (0.56)	-0.25 (0.34)	0.00	2.63
16	120	2.75* (0.30)	0.33* (0.11)	0.09	1.16	3.53* (0.35)	-0.42 (0.28)	0.03	2.51
20	116	2.86* (0.24)	0.23 (0.14)	0.05	1.00	3.28* (0.45)	-0.24 (0.45)	0.00	2.53

*Significantly different from zero at the 5% level in a two-tailed test.

The results for marginal changes in Table I can be used to calculate how low the slope of the yield curve would have to be in order to predict a future recession. For example, if we use the standard definition of a recession as 2 consecutive quarters of negative growth, a spread of minus 1.29 percent would predict a recession in quarters $t+2$ and $t+3$.⁷

⁷A spread of $-1.41\% = (-1.74\%)/1.23$ suffices for a prediction of a negative growth from quarter t to quarter $t+1$. For $t+1$ through $t+2$ the sufficient spread is -1.04% , for $t+2$ through $t+3$ -1.29% , for $t+3$ through $t+4$ -1.74% , and for $t+4$ through $t+5$ -2.60% .

In Table I, the coefficient of determination, R^2 , provides a measure of in-sample forecasting accuracy, while the statistical significance of the *SPREAD* coefficient provides information on the reliability of the equation in predicting the direction of a future change in output. Observe that the forecasting accuracy in predicting cumulative changes is highest 5 to 7 quarters ahead: *SPREAD* explains more than one-third of the variation in future output changes. This is very impressive, especially because, as we show later, the lagged value of real GNP growth has very little predictive power.

Figure 1 provides a visual representation of the predictive power of the slope of the yield curve. The figure plots the annualized rate of growth of real GNP from quarter $t - 4$ to quarter t and the slope of the yield curve during quarter $t - 4$. The slope of the yield curve tracks the future realization in output growth impressively well, especially in the 1970's and early 1980's. Notice, however, that from 1985 through 1988 the association between the two variables is not very precise. This may be due to errors in the most recent GNP numbers that have not been corrected yet.⁸ It may also reflect changes in the relation between the true GNP and the slope of the yield curve, which should serve as a reminder that any historical statistical

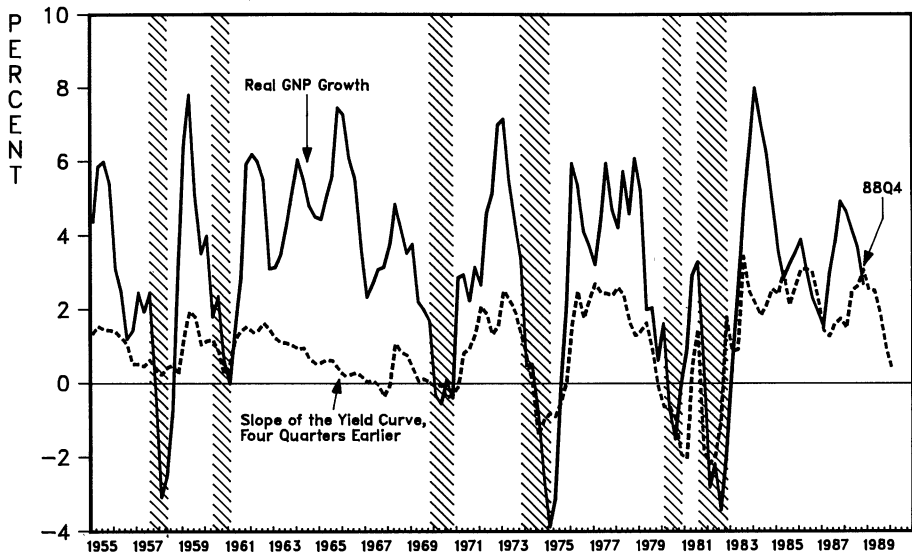


Figure 1. The current growth in real GNP and the slope of the yield curve 4 quarters earlier. The shaded areas denote current NBER-dated recessions. Real GNP growth is the annual rate of growth from quarter $t - 4$ to current quarter t . The slope of the yield curve is the difference between the 10-year Treasury bond rate and the 3-month Treasury bill rate 4 quarters earlier, at $t - 4$. Both rates are quarterly averages of annualized bond equivalent yields.

⁸Our GNP series represents the finally revised numbers. Thus, the most recent GNP numbers have not been as thoroughly revised as the earlier ones. In Estrella and Hardouvelis (1989), we show that the slope of the yield curve is more successful at predicting the final revised numbers.

relationship not based on precise economic principles may easily disintegrate in the future. The slope predicts a drop in the growth rate of real GNP through early 1990.

Table II examines the predictability of cumulative changes in individual real GNP components. The table shows that the predictive power of the yield curve is not confined to any specific component of real GNP. The yield curve has predictive power for all private sector components of real GNP—consumption, consumer durables, and investment—but it cannot predict government spending. As we see later, the individual GNP component results are useful in discriminating between alternative theories of the predictive power of the yield curve. Observe also that the yield curve predicts consumer durables and investment better than consumption, although consumption is a less volatile series.

D. The Probability of a Recession

The short periods that exhibit a lower correlation in Figure 1, such as the 1985–1988 period, may reflect the possibility that the yield curve predicts more accurately when drastic changes in output take place. Put differently, the yield curve may be a better predictor of, say, a binary variable X_t that simply indicates the presence ($X_t = 1$) or absence ($X_t = 0$) of a recession. In order to explore this question, we estimate a model that relates the indicator variable X_t to the slope of the yield curve 4 quarters earlier, $SPREAD_{t-4}$.

The model is nonlinear and relates the probability of a recession as dated by the National Bureau of Economic Research (NBER) during current quarter t to the slope of the yield curve of quarter $t - 4$:

$$Pr[X_t = 1 | SPREAD_{t-4}] = F(\alpha + \beta SPREAD_{t-4}), \quad (5)$$

where Pr denotes probability, F is the cumulative normal distribution, and X_t equals unity during those quarters considered as official recessions by NBER. The NBER definition of a recession corresponds essentially to two consecutive quarters of negative real GNP growth. The model above is the usual probit model, and its log-likelihood function is as follows:

$$\begin{aligned} \log L = \sum_{X_t=1} \log F(\alpha + \beta SPREAD_{t-4}) \\ + \sum_{X_t=0} \log F(1 - \alpha - \beta SPREAD_{t-4}) \end{aligned} \quad (6)$$

Maximizing the log-likelihood function (6) with respect to the unknown parameters α and β over the quarterly sample period from 1956:1 through 1988:4 leads to:

$$\begin{aligned} Pr[X_t = 1 | SPREAD_{t-4}] \\ = F(-0.56^* - 0.78^* SPREAD_{t-4}); \text{ Pseudo-}R^2 = 0.297, \end{aligned} \quad (7)$$

(0.16) (0.16)

where an asterisk denotes statistical significance at the 5 percent level, and

Table II
Predicting Future Cumulative Changes of Real GNP Components Using the Slope of the Yield Curve

The sample is quarterly from 1955:2 through 1988:4. The estimated models are as follows:

$$\text{Cumulative Change: } (400/k)(\log x_{t+k} - \log x_t) = \alpha_0 + \alpha_1 \text{ SPREAD}_t + \epsilon_t$$

x_{t+k} is the quarter $t+k$ value at constant prices of: consumption (consumer nondurables plus services), consumer durables, gross private domestic investment, and government spending. k is the forecasting horizon. SPREAD_t is the difference between the 10-year T-bond and 3-month T-bill rates of quarter t . The interest rates are annualized quarterly average bond equivalent yields. Inside the parentheses are Newey and West (1987) corrected standard errors that take into account the moving average created by the overlapping of forecasting horizons as well as conditional heteroskedasticity. $\bar{R}^2$ is the coefficient of determination adjusted for degrees of freedom, and SEE is the regression standard error.

k Quarters Ahead	Consumption				Consumer Durables				Investment				Government Spending			
	α_0	α_1	$\bar{R}^2$	SEE	α_0	α_1	$\bar{R}^2$	SEE	α_0	α_1	$\bar{R}^2$	SEE	α_0	α_1	$\bar{R}^2$	SEE
1	2.57* (0.45)	0.57* (0.21)	0.10	1.94	0.28 (1.44)	4.16* (0.96)	0.12	12.96	-2.15 (1.60)	5.27* (1.55)	0.08	20.14	2.23* (0.63)	0.06 (0.28)	-0.01	5.06
2	2.60* (0.43)	0.54* (0.19)	0.16	1.47	0.46 (1.35)	3.93* (0.86)	0.23	8.51	-3.24* (1.59)	6.34* (1.40)	0.20	14.81	2.28* (0.65)	0.02 (0.26)	-0.01	3.83
3	2.61* (0.41)	0.53* (0.17)	0.20	1.24	0.68 (1.19)	3.73* (0.65)	0.29	6.84	-3.19* (1.57)	6.33* (1.38)	0.28	12.00	2.26* (0.65)	0.06 (0.27)	-0.01	3.26
4	2.64* (0.39)	0.50* (0.15)	0.21	1.14	1.01 (1.12)	3.42* (0.51)	0.33	5.81	-2.77 (1.48)	5.98* (1.30)	0.32	10.29	2.24* (0.66)	0.10 (0.27)	-0.01	2.97
5	2.68* (0.38)	0.46* (0.13)	0.20	1.08	1.47 (1.03)	3.02* (0.40)	0.30	5.37	-2.27 (1.35)	5.57* (1.11)	0.35	8.93	2.25* (0.66)	0.12 (0.27)	0.00	2.78
6	2.73* (0.38)	0.41* (0.12)	0.18	1.01	1.98* (0.96)	2.58* (0.25)	0.26	5.11	-1.72 (1.24)	5.06* (0.98)	0.36	7.82	2.23* (0.66)	0.15 (0.28)	-0.00	2.66
7	2.78* (0.37)	0.37* (0.11)	0.16	0.96	2.44* (0.89)	2.17* (0.18)	0.20	4.98	-1.12 (1.09)	4.48* (0.83)	0.35	7.08	2.21* (0.65)	0.19 (0.26)	0.00	2.56
8	2.84* (0.36)	0.30* (0.11)	0.12	0.94	2.91* (0.84)	1.69* (0.17)	0.14	4.85	-0.44 (0.98)	3.78* (0.65)	0.30	6.63	2.18* (0.64)	0.23 (0.23)	0.00	2.46
12	3.01* (0.33)	0.14 (0.11)	0.03	0.83	4.17* (0.68)	0.51 (0.30)	0.01	3.96	1.75* (0.73)	1.56* (0.32)	0.11	5.22	2.12* (0.58)	0.29* (0.14)	0.02	2.12
16	3.10* (0.28)	0.06 (0.08)	0.00	0.74	4.71* (0.49)	0.06 (0.33)	-0.01	3.14	2.75* (1.44)	0.70* (0.33)	0.03	4.00	2.17* (0.52)	0.23* (0.12)	0.01	1.88
20	3.12* (0.23)	0.03 (0.07)	-0.01	0.67	4.84* (0.38)	-0.10 (0.33)	-0.01	2.65	3.02* (0.24)	0.45 (0.39)	0.02	3.06	2.24* (0.50)	0.11 (0.18)	-0.00	1.72

*Significantly different from zero at the 5% level in a two-tailed test.

standard errors appear in parentheses below the coefficients.⁹ The pseudo- R^2 is a measure of the overall fit of the equation. Like the R^2 in an OLS regression, it lies between 0 and 1 and corresponds roughly to the hypothesis that all the coefficients except for the constant term are zero.¹⁰ Equation (7) states that an increase in the spread between the long- and short-term interest rates implies a decrease in the probability of a recession 4 quarters later.¹¹ In equation (7), the relation between the probability of a recession and the spread is statistically significant, but because the relation is nonlinear it is difficult to assess the quantitative significance of the association. Figure 2 provides clearer information on the economic importance of the forecasting ability of the slope of the yield curve.

Figure 2 plots the estimated probability of a recession derived from the historical data on *SPREAD* lagged 4 quarters, the parameter estimates of equations (7), and the cumulative normal distribution. In Figure 2, the cross-hatched areas denote periods of actual NBER-dated recessions. Observe that all peaks in the estimated probability were associated with a recession except for the peak of 40 percent in 1966–1967 when a slowdown occurred instead of a recession. Notice that in the recent 1985–1988 period the estimated probability of a recession was close to zero. Also, the yield curve of the last quarter of 1988 does not predict a recession, but the yield curve of the first quarter of 1989 produces a probability of 20 percent.¹² While this probability exceeds the levels observed in most nonrecessionary quarters, it is still substantially lower than the recession predictions of 70 and 90 percent of the last three recessions and is far from a firm prediction.¹³ The low

⁹As in the linear equation with $Y_{t,t+k}$, $k > 1$ as the dependent variable, the overlap of the 4-quarter “forecast horizons” creates a dependence in the residuals, so the standard errors reported above are not exactly correct. Nevertheless, experimentation with a linear equation with a dummy dependent variable for recessionary quarters, with or without a Newey and West (1987) correction, produces very similar results. In fact, compared to the Newey and West linear estimates, the probit standard error for the spread appears conservatively high.

¹⁰The pseudo- R^2 is proposed as a measure of goodness-of-fit by Judge, Griffiths, Hill, and Lee (1980). It is defined as $1 - \log L(\text{unrestricted})/\log L(\text{restricted})$, where $\log L$ is the log-likelihood of the estimated equation, the unrestricted equation includes all the regressors plus a constant term, and the restricted equation includes only a constant term. In comparing several equations with different regressors estimated over the same time period (same number of observations), the pseudo- R^2 produces the same ordering as the log-likelihood and the average likelihood.

¹¹Stock and Watson (1989) have independently found predictive power in the slope of the yield curve using a logit model of the NBER-dated recessions.

¹²Furlong (1989) uses survey data on inflationary expectations and claims that the flat yield curve of the last quarter of 1988 reflects an increase in short-run (one year) inflationary expectations together with a downward trend in long-run (10 years) inflationary expectations, and therefore does not predict a lower growth in real output. It remains to be seen whether or not this represents, as Furlong claims, a change in conditions that may reduce the predictive power of the slope of the yield curve for real economic activity. The downward trend in inflationary expectations was apparent long before the beginning of the last recession, yet, as Figure 2 shows, that recession was accurately predicted by the slope of the yield curve.

¹³All our estimation results use a sample period that ends at the last quarter of 1988. In Figure 2 we added the slope of the yield curve for 1989:1. We have also reestimated the probit model recursively, adding one sample observation at a time and making an out-of-sample probability prediction. These estimated probabilities are very similar to the probabilities in Figure 2 and can be found in Estrella and Hardouvelis (1989).

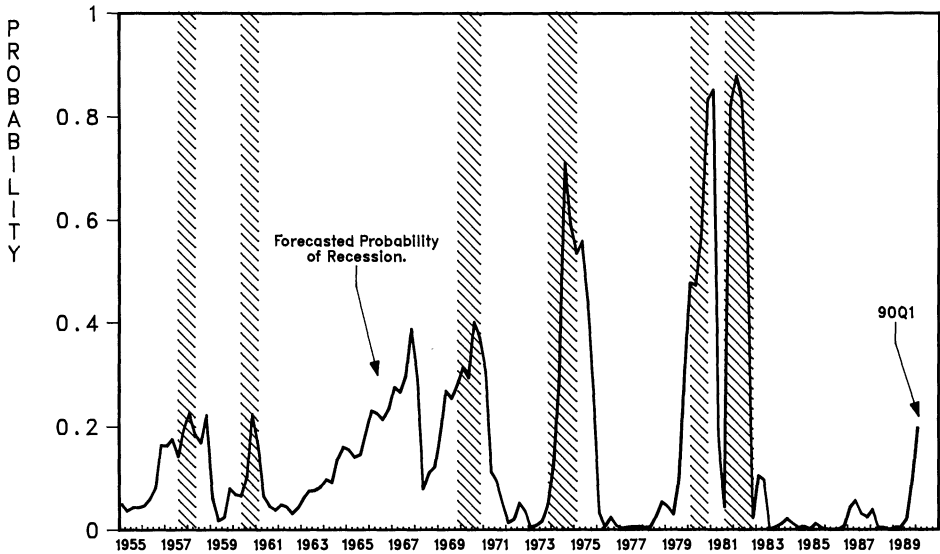


Figure 2. Forecasted probability of recession for current quarter based on the slope of the yield curve 4 quarters earlier. The shaded areas denote current NBER-dated recessions. The forecasted probability of recession denotes the within-sample fit of a probit model, estimated over the quarterly sample period from 1956:1 through 1988:4, in which the dependent variable is a binary variable denoting the current presence or absence of an NBER-dated recession, and the only explanatory variable is the slope of the yield curve observed 4 quarters earlier. The slope of the yield curve is the difference between the 10-year Treasury bond rate and the 3-month Treasury bill rate. Both rates are quarterly averages of annualized bond equivalent yields.

forecasted probability of a recession for the first quarter of 1990 is also consistent with the predictions of Table I. In the first quarter of 1989, the difference between the 10-year and 3-month bond equivalent yields on Treasury securities was 0.35 percent. This spread predicted that the growth in real GNP from 1989:1 to 1990:1 would be 2.15 percent, a percentage that is economically very different from a negative rate of growth.

III. Interpreting the Evidence: How Useful Is the Information in the Term Structure?

In this section we assess the usefulness of the slope of the yield curve to private investors and to the monetary authority in its conduct of monetary policy. We ask: Does the yield curve reflect the effects of current or expected future monetary actions alone? Or does it also reflect the influence of factors other than monetary policy? Furthermore, if the yield curve contained useful information for private investors and for the monetary authorities in the past, would it continue being a useful indicator in the future? Readers who are more interested in an evaluation of the predictive power of the yield curve rather than the source of that predictive power may skip directly to Section IV without any loss of continuity.

A. Is Monetary Policy Responsible for the Predictive Power of the Yield Curve?

We begin by examining the possibility that current monetary policy may cause the slope of the yield curve and future real output to move in the same direction and, hence, result in the observed positive association between those two variables. We then examine whether expected future monetary policy—instead of current policy—may account for the results.

Some may argue that the information in the slope of the yield curve reflects for the most part *current* monetary policy actions. The argument runs as follows: A current short-lived monetary contraction would increase the level of nominal and, in the presence of price rigidities, real short-term interest rates leaving long-term interest rates relatively intact, thus causing the slope of the yield curve to flatten. At the same time, the high real rates today imply low current investment opportunities and, hence, lower output in the immediate future. Both today's slope of the yield curve and future growth in output decline, resulting in a positive association between the two variables.

Undoubtedly, current monetary policy influences the slope of the yield curve. The interesting question, however, is whether or not there is extra information in the slope of the yield curve about future exogenous developments over and above the information which the slope carries about current policy actions. The question can be easily addressed simply by adding to the regressions of Table I the current level of a short-term interest rate and checking to see if the slope of the yield curve continues to have statistically significant regression coefficients at the various forecasting horizons. In Table III, we include an interest rate that is most closely associated with Fed policy, the real federal funds rate (RFF), but the results are similar when the nominal federal funds rate or the nominal 3-month Treasury bill rate are used in its place. The real federal funds rate is the nominal federal funds rate minus an empirical proxy for the expected rate of inflation. Expected inflation is a one-quarter ahead out-of-sample forecast of the growth in the GNP deflator based on a recursively estimated autoregressive model with twelve lags.

Table III confirms that a higher real federal funds rate today is associated with a lower growth in future real output. This negative correlation can be interpreted in a causal fashion: Higher real rates today imply low current investment opportunities and lower output in the future. The more interesting information in Table III, however, is that the predictive power of the slope remains almost intact. The slope continues to have cumulative predictive power for about 4 years and marginal predictive power for about 6 quarters. These results indicate that the information in the slope of the yield curve is mostly about variables other than current monetary policy.

Others may argue that the causal variable behind the predictive power of the yield curve is *expected future* monetary policy. The argument appeals to the rigidity of prices in the short run but flexibility in the long run and goes as follows: An expected future expansion in the growth rate of the money

Table III

Predicting Future Changes in Real Output Using the Slope of the Yield Curve and the Real Federal Funds Rate

The sample is quarterly from 1955:2 through 1988:4. The estimated models are as follows:

$$\text{Cumulative Change} = (400/k) \log(y_{t+k}/y_t) = \alpha_0 + \alpha_1 \text{SPREAD}_t + \alpha_2 \text{RFF}_t + \epsilon_t$$

$$\text{Marginal Change} = (400/j) \log(y_{t+k}/y_{t+k-j}) = \beta_0 + \beta_1 \text{SPREAD}_t + \beta_2 \text{RFF}_t + u_t, j = 1 \text{ or } 4$$

y_{t+k} is real GNP of quarter $t+k$; k represents the forecasting horizon. For marginal changes, $j=1$ for forecasting horizons 1 through 8, and $j=4$ for horizons 12, 16, and 20. SPREAD_t equals the 10-year T-bond rate minus the 3-month T-bill rate of quarter t . RFF_t is the ex ante real federal funds rate of quarter t (nominal rate minus expected inflation; the expected inflation is an out-of-sample one-quarter ahead forecast of inflation based on a 12th order autoregressive model). All interest rates are annualized quarterly average bond equivalent yields. Inside the parentheses are Newey and West (1987) corrected standard errors that take into account the moving average created by the overlapping of forecasting horizons as well as conditional heteroskedasticity. $\bar{R}^2$ is the coefficient of determination adjusted for degrees of freedom and SEE the regression standard error.

Forecasting Horizon; k Quarters Ahead	Cumulative Change					Marginal Change				
	α_0	α_1	α_2	$\bar{R}^2$	SEE	β_0	β_1	β_2	$\bar{R}^2$	SEE
1	2.74* (0.81)	0.93* (0.26)	-0.36* (0.06)	0.17	3.65	2.74* (0.81)	0.93* (0.26)	-0.36* (0.06)	0.17	3.65
2	2.69* (0.67)	1.02* (0.25)	-0.38* (0.08)	0.33	2.66	2.65* (0.67)	1.10* (0.26)	-0.41* (0.09)	0.24	3.50
3	2.54* (0.66)	1.06* (0.24)	-0.32* (0.08)	0.38	2.26	2.28* (0.72)	1.10* (0.30)	-0.22* (0.10)	0.15	3.72
4	2.49* (0.64)	1.04* (0.23)	-0.28* (0.08)	0.42	1.96	2.38* (0.69)	0.92* (0.29)	-0.18 (0.11)	0.10	3.85
5	2.46* (0.62)	1.00* (0.21)	-0.24* (0.07)	0.44	1.76	2.48* (0.62)	0.73* (0.27)	-0.11 (0.08)	0.05	3.95
6	2.45* (0.62)	0.94* (0.20)	-0.20* (0.07)	0.43	1.63	2.47* (0.69)	0.58* (0.26)	-0.02 (0.11)	0.02	4.04
7	2.45* (0.60)	0.88* (0.19)	-0.17* (0.07)	0.41	1.54	2.52* (0.66)	0.47 (0.24)	0.03 (0.11)	0.00	4.08
8	2.53* (0.58)	0.77* (0.17)	-0.15* (0.07)	0.36	1.50	3.04* (0.68)	0.00 (0.29)	-0.02 (0.13)	-0.02	4.12
12	2.63* (0.50)	0.48* (0.15)	-0.05 (0.02)	0.18	1.35	2.82* (0.78)	-0.07 (0.32)	0.17 (0.13)	0.02	2.61
16	2.78* (0.48)	0.31* (0.13)	-0.01 (0.07)	0.08	1.16	3.41* (0.60)	-0.36 (0.24)	0.04 (0.12)	0.02	2.52
20	2.48* (0.45)	0.24 (0.15)	0.01 (0.08)	0.04	1.01	3.23* (0.57)	-0.21 (0.31)	0.02 (0.16)	-0.01	2.54

*Significantly different from zero at the 5% level in a two-tailed test.

supply is expected to decrease the real rate of interest and expand output in the future, but at the same time it may be expected to increase the current nominal long-term rate of interest if the inflation premium is expected to rise by more than the future real rate is expected to decline, hence causing the slope of the yield curve to steepen. This scenario can, therefore, explain the positive association between the slope of the yield curve and future changes in real output.

The foregoing interpretation is consistent with the evidence presented by Fama (1990). Fama found that an increase in today's spread is associated with a future increase in the inflation premium and a future decrease in the real rate of interest. However, the overall plausibility of a scenario based on expected future monetary policy actions is questionable. The scenario described in the previous paragraph implies that real output growth and inflation are positively correlated, especially in the 1970's and 1980's when the association between the slope of the yield curve and future real output growth is stronger (see Figures 1 and 2). Yet, the correlation between those two variables in the 1970's and 1980's has been negative. For example, during the sample period 1970–1988, the contemporaneous correlation between the growth in real output and inflation was -0.3 , and the correlations of the growth in real output with the lags and leads of inflation were also consistently negative. Thus, the hypothesis that the causal variable behind the predictive power of the yield curve is expected future monetary policy appears to be in conflict with very basic sample correlations in the data.

B. The Usefulness of the Information in the Yield Curve

If current or expected future monetary policy actions alone cannot explain the historical predictive ability of the slope of the yield curve, one can conclude that historically the information in the slope of the yield curve could have been useful not only to private forecasters but to the Federal Reserve as well. Of course, as Lucas (1976) has forcefully argued in a more general context, the historical predictive power of the yield curve does not imply that the yield curve would continue to be useful in the future, especially if the monetary authorities begin using the term structure as an indicator of future economic activity. This is because the historical correlations are not necessarily policy invariant. Only if monetary policy is neutral with respect to real output and the historical correlations reflect "deep" parameters in the optimal plans of private agents would the yield curve continue to be a useful indicator after the monetary authorities become aware of its historical usefulness. We are, therefore, led to the question: Can a model that assumes that monetary policy is neutral explain the historical correlations?

Harvey (1988) claims that the consumption capital asset pricing model (CCAPM) is consistent with the observed predictability of consumption growth. The CCAPM describes a relationship between real interest rates and real consumption growth in equilibrium that is independent of the role of monetary policy. Although the CCAPM provides—in its multiperiod setting

—an elegant explanation of the relationship between the slope of the yield curve and future consumption growth, it cannot provide a full explanation of the empirical evidence. Table II showed that the slope of the yield curve is able to predict GNP components other than consumption, such as consumer durables and investment. To explain those correlations one has to construct more general models than the CCAPM.

Kydland and Prescott (1988) have constructed a real business cycle model that generates a positive correlation between the real rate of interest (at leads and lags) and real output. The intuition behind the correlations generated by a real business cycle model is the same as in the CCAPM, namely consumption smoothing. Real business cycle models are simply more general (general equilibrium) models that also allow for productivity shocks to affect asset prices. For example, an expected positive future productivity shock is expected to increase future output, which leads to a higher real rate of interest as economic agents substitute current for future consumption. It is unclear, however, how the Kydland and Prescott model relates to the slope of the yield curve. Furthermore, the negative correlation between the contemporaneous real rate of interest and future output growth of Table III seems to contradict the basic prediction of the Kydland and Prescott model.

Chen (1989) argues that the evidence is consistent with a real business cycle model—specifically, that it is consistent with the intuition in Abel's (1988) model of stock prices. However, it is unclear how Abel's model can be applied to the bond market. Furthermore, as in the case of the Kydland and Prescott model, Abel's model does not accommodate the observed negative correlation between current real rates of interest and future real GNP growth. Clearly, more research is required in this direction.

Of course, even if a model in which monetary policy is neutral could satisfactorily explain the historical correlations reported in Tables I, II, and III, some would argue that the same correlations could also be explained by a model in which money is not neutral; hence, one cannot be sure that the information in the yield curve would not deteriorate in the future. For example, the correlations in Tables I and II could be generated within the context of the textbook IS-LM model if it is assumed that the predominant expected future shock to the macroeconomy originates in the real sector. Put differently, the IS-LM framework can provide a consistent explanation of the evidence if market participants perceive that in the future the IS curve is likely to shift (more than LM curve), causing future output and interest rates to move in the same direction. The expectation, say, of a future increase in interest rates widens the difference between current long and short rates and generates a positive correlation between the slope of the yield curve today and the future change in output.

But is the IS-LM story plausible? There is one piece of evidence in Table II that casts some doubt on its plausibility. According to the IS-LM story, the slope of the yield curve should be a better predictor of the most exogenous of the components of aggregate demand because it is expected exogenous shocks to the IS curve that rationalize the story. In Table II, the most exogenous

component of aggregate demand is government spending. Unfortunately, future government spending is the least predictable component of GNP. Consumption and investment, the interest-sensitive and thus least exogenous components of aggregate demand, show the highest predictability.

We conclude that in order to assess the future usefulness of the yield curve to the monetary authorities and private forecasters, it is important to examine whether or not the historical correlations reported in Tables I and II are simply an artifact of the sample period or reflect more fundamental parameters in agents' intertemporal decision process.

IV. Evaluating the Information in the Term Structure

In this section we examine more closely the comparative value of the information in the yield curve. We have already shown that there is extra information in the slope of the yield curve over and above the information in the level of the real federal funds rate. Here we add to the basic regression equation a number of information variables that are widely thought to predict future real economic activity and examine whether or not the slope of the yield curve continues to have extra predictive power. We also examine whether the slope of the yield curve outperforms survey evidence on real GNP growth.

A. Supplementary Information Variables

The information variables that we choose are the recent growth in the index of leading indicators, the lagged growth in real output, and the lagged rate of inflation. The index of leading indicators is the first obvious choice and consists of twelve macroeconomic variables. These variables are denoted as leading indicators exactly because they are presumed to have predictive power. The index provides a convenient way of summarizing their aggregate information without forcing us to enter each one of them separately in the regression equation. Some of the components of the index do not become known until a month or more after the statement month. Since we want to add regressors that are known during the current quarter t , when constructing the rate of growth of the index of leading indicators we do not use average quarterly data; instead, we use the rate of growth from the first month of the previous quarter to the first month of the current quarter. Next, we include the lagged growth in output and the lagged rate of inflation, primarily because these are the two most important variables that describe the evolution of the macroeconomy.¹⁴

Table IV presents the regression results. First, $SPREAD_t$ continues to have explanatory power over the entire forecasting horizon. Its regression

¹⁴The GNP deflator and the level of real GNP of the current quarter are announced during the following quarter, yet in the regressions we assume that these two variables are known during the current quarter t . Thus, we bias the results against finding extra predictive power in the slope of the yield curve.

Table IV

Predicting Future Cumulative Changes in Real Output Using the Slope of the Yield Curve and Other Information

The sample is quarterly from 1955:2 through 1988:4. The estimated models are as follows:

$$(400/k)(\log y_{t+k} - \log y_t) = \alpha_0 + \alpha_1 SPREAD_t + \alpha_2 RFF_t + \alpha_3 GLI_t + \alpha_4 LDEP_{t-k} + \alpha_5 \pi_{t-k,t} + \epsilon_t$$

y_{t+k} is real output of quarter $t+k$. k is the forecasting horizon. $SPREAD_t$ equals the 10-year T-bond rate minus the 3-month T-bill rate. RFF_t is the real federal funds rate (nominal minus expected inflation). All interest rates are annualized quarterly average bond equivalent yields. GLI_t is the annualized growth in the index of leading indicators from the first month of quarter $t-1$ to the first month of quarter t . In each regression, $LDEP_{t-k} = (400/k)(\log y_t - \log y_{t-k})$ is a lagged dependent variable. $\pi_{t-k,t}$ is the annualized rate of inflation of the GNP deflator from quarter $t-k$ through quarter t . Inside the parentheses are Newey and West (1987) corrected standard errors that take into account the moving average created by the overlapping of forecasting horizons as well as conditional heteroskedasticity. $\bar{R}^2$ is the coefficient of determination adjusted for degrees of freedom and SEE the regression standard error.

Forecasting horizon; k Quarters Ahead	α_0	α_1	α_2	α_3	α_4	α_5	$\bar{R}^2$	SEE
1	3.04* (0.88)	0.55* (0.26)	-0.24* (0.11)	0.16* (0.04)	-0.03 (0.10)	-0.14 (0.11)	0.28	3.40
2	3.39* (0.98)	0.73* (0.24)	-0.31* (0.07)	0.10* (0.03)	-0.04 (0.07)	-0.17 (0.12)	0.40	2.51
3	4.08* (1.04)	0.78* (0.26)	-0.27* (0.07)	0.07* (0.03)	-0.15* (0.07)	-0.26* (0.12)	0.46	2.12
4	4.32* (1.03)	0.81* (0.26)	-0.24* (0.07)	0.04 (0.024)	-0.18* (0.05)	-0.29* (0.12)	0.49	1.84
5	4.55* (1.06)	0.82* (0.24)	-0.20* (0.06)	0.02 (0.02)	-0.21* (0.08)	-0.31* (0.12)	0.52	1.63
6	4.42* (1.05)	0.82* (0.22)	-0.17* (0.07)	0.00 (0.01)	-0.21 (0.11)	-0.29* (0.12)	0.50	1.52
7	4.37* (1.04)	0.79* (0.20)	-0.12 (0.07)	-0.00 (0.01)	-0.22 (0.13)	-0.27* (0.11)	0.48	1.45
8	4.52* (0.93)	0.71* (0.17)	-0.10 (0.07)	-0.01 (0.01)	-0.26 (0.13)	-0.27* (0.11)	0.44	1.41
12	4.84* (1.36)	0.38* (0.15)	-0.00 (0.07)	-0.01 (0.02)	-0.33 (0.21)	-0.26 (0.15)	0.29	1.25
16	5.11* (1.22)	0.27 (0.19)	0.05 (0.04)	-0.01 (0.01)	-0.36 (0.27)	-0.29* (0.08)	0.29	1.02
20	5.81* (0.61)	0.16 (0.09)	0.09 (0.05)	0.01 (0.01)	-0.54* (0.09)	-0.32* (0.05)	0.44	0.77

*Significantly different from zero at the 5% level in a two-tailed test.

coefficients are statistically significant up to 3 years into the future. Second, an increase in the real federal funds rate predicts a drop in real GNP for about 6 quarters into the future. Third, an increase in the index of leading indicators predicts a future increase in real GNP. However, the predictive power lasts for only up to 3 quarters ahead. This is very weak predictive

power when compared to the predictive power of the slope of the yield curve. Fourth, the lagged growth in output has a negative coefficient showing a slight mean reversion. Fifth, the lagged rate of inflation also shows a negative coefficient, which is statistically significant at all horizons beyond two quarters.¹⁵

In the case of the probit equation for predicting recessions, the supplementary information variables are strikingly devoid of additional explanatory power—singly or jointly—in the presence of *SPREAD*. The estimated equation for the 1956–1988 period is as follows:

$$\begin{aligned}
 &Pr[X_t = 1 \mid \text{Information}] \\
 &= N[-1.28^* - 0.61^* \text{SPREAD}_{t-4} + 0.08 \text{RFFY}_{t-4} \\
 &\quad (0.62) \quad (0.19) \quad (0.09) \\
 &\quad - 0.02 \text{GLI}_{t-4} + 0.08 Y_{t-4} + 0.04 \pi_{t-4}], \\
 &\quad (0.02) \quad (0.08) \quad (0.08) \quad (8) \\
 &\text{Psuedo-}R^2 = 0.321,
 \end{aligned}$$

where *RFFY* is the real federal funds rate, *GLI* is the growth in the index of leading indicators, *Y* is the growth in real output, and π is the rate of inflation. All these variables are identical to the variables in Table IV for a forecasting horizon of 4 quarters ahead. Recall that the *pseudo- R^2* in equation (7) with *SPREAD* as the only explanatory variable is 0.297, a number only slightly smaller than the *pseudo- R^2* of 0.321 of the above equation. Note, however, that although the four supplementary variables have little extra explanatory power, their total explanatory power is not zero. In a probit equation with the four supplementary variables as the only explanatory variables, the *pseudo- R^2* is 0.205, a number larger than zero but smaller than the *pseudo- R^2* of 0.297 when *SPREAD* alone is used in the probit equation.

B. The Yield Curve versus Survey Evidence

Another way to assess the quality of the information in the slope of the yield curve is to compare its forecasting performance with the forecasting performance of survey evidence. We use data from midquarter surveys conducted by the American Statistical Association and the NBER since the beginning of 1970. The data are median forecasts of current real GNP and the real GNP of the next 2 quarters. We also have data for the median forecast of 3 quarters ahead since 1981.

Panel A of Table V presents regression results which show that *SPREAD* is a better predictor of future output growth than the median survey forecast.

¹⁵Chen (1989) presents tables similar to Table IV. Two of his additional information variables are similar to ours: The lagged annual growth in the industrial production index, and the one-month nominal T-bill rate. He also uses the dividend price ratio of the NYSE stocks and a quality spread of corporate bond yields, but he does not use lagged inflation or the index of leading indicators.

Table V
Survey Forecasts versus Term Structure Forecasts

Panel A. Regression Results

The regression models are as follows:

$$Y_{t+k} = (400/k)(\log y_{t+k} - \log y_t) = \alpha_0 + \alpha_1 SPREAD_t + \beta_1 SURVEYF_{t,k} + e_t.$$

y_{t+k} is the annualized cumulative growth rate of real GNP from quarter t to quarter $t+k$. $SPREAD_t$ is the difference between the 10-year T-bond and 3-month T-bill yield. Both interest rates are annualized average quarterly bond equivalent yields. $SURVEYF_{t,k}$ is the ASA/NBER survey forecast of Y_{t+k} . Numbers in brackets are significance levels. Numbers in parentheses are Newey and West (1987) corrected standard errors that take into account the moving average created by the overlapping of forecasting horizons as well as conditional heteroskedasticity. $\bar{R}^2$ is the coefficient of determination adjusted for degrees of freedom, and SEE is the regression standard error.

k Quarters Ahead	Sample Period	α_0	α_1	β_1	$\bar{R}^2$	SEE	Chi-Squared (2) ($\alpha_0 = 0, \beta_1 = 1$)
1	70:2-88:4	0.56 (0.59)		0.67* (0.10)	0.08	4.08	16.5* [0.000]
		1.08* (0.45)	1.30* (0.27)		0.19	3.83	
		0.46 (0.54)	1.13* (0.28)	0.26* (0.09)	0.19	3.84	
2	70:3-88:4	-0.32 (0.74)		0.88* (0.17)	0.15	3.11	5.83 [0.054]
		0.96* (0.36)	1.42* (0.22)		0.37	2.68	
		0.21 (0.93)	1.28* (0.24)	0.27 (0.26)	0.38	2.67	
3	82:1-88:4	2.28 (3.44)		0.22 (1.25)	-0.04	3.01	0.51 [0.777]
		-0.13 (0.82)	1.59* (0.28)		0.39	2.33	
		-3.88 (2.58)	1.72* (0.26)	1.04 (0.82)	0.41	2.26	

Panel B. Root Mean Squared Error in Out-of-Sample Forecasts

RMSE's were calculated using the parameters of recursive OLS regressions estimated from 1955 to quarter $t-1$. Two models were estimated: the first uses $SPREAD$ as the only information variable; the second uses all the information variables of Table IV. r^2 is the squared correlation between y_{t+k} and its forecast from either a regression model or the ASA/NBER survey.

k Quarters Ahead	Forecast Period	Regression Model with $SPREAD$		Regression Model with all Information Variables of Table IV		ASA/NBER Survey		St. Deviation of Y_{t+k}
		RMSE	r^2	RMSE	r^2	RMSE	r^2	
1	70:2-88:4	3.99	0.19	3.60	0.29	4.11	0.10	4.26
2	70:3-88:4	2.93	0.37	2.67	0.37	3.17	0.17	3.39
3	82:1-88:4	2.85	0.40	2.42	0.32	2.95	0.00	2.95

*Significantly different from zero at the 5% level in a two-tailed test.

We regress the realized percentage change in real GNP on the predicted change by the survey and on the slope of the yield curve. The survey forecasts have predictive power for one and 2 quarters ahead but not for 3 quarters ahead, as evidenced by the size of the R^2 's and the significance of the regression coefficient β_1 . In the one-quarter ahead prediction, the survey forecasts are biased: the hypothesis of unbiasedness, i.e., that $\alpha_0 = 0$ and $\beta_1 = 1$, is rejected. Observe also that the predictive ability of the slope of the yield curve is better than that of the median survey forecast as evidenced by its uniformly larger R^2 's. Furthermore, adding the survey forecast as an additional regressor in the $SPREAD_t$ regressions does not increase the R^2 .

Panel B of Table V presents the results of out-of-sample forecasts. Here we compare the out-of-sample predictive ability of $SPREAD_t$ with the out-of-sample predictive ability of the expanded set of information variables of Table IV and with the predictive ability of the survey forecasts. Out-of-sample forecasts are generated using the data available at the time of the forecast. Since output is only available with a one-quarter lag, regression based forecasts in period t are based on recursive estimates that use data up to period $t - 1$.

The out-of-sample forecasting results are interesting. For all three forecasting horizons, the root mean squared error (RMSE) of the forecast based on all the information variables of Table IV is the smallest, followed by the RMSE of the forecasts based on the slope of the yield curve alone. Thus, simple econometric models that include more variables in addition to $SPREAD$ outperform $SPREAD$ alone as a forecasting tool. Both predictors perform better than the median forecast of the survey. For the forecasting horizon of 3 quarters, the econometric model that includes only the slope of the yield curve produces a higher correlation (r^2) with the actual values than the econometric model that includes additional information variables. However, the higher correlation of the former model is offset by a larger bias over the sample period 1982–1988.

Although the relative forecasting ability of the slope of the yield curve is good, one should not lose sight of the fact that the absolute forecasting ability is not great. A comparison of the RMSE of $SPREAD$ with the standard deviation of the actual growth in real GNP provides a rough idea of the out-of-sample forecasting accuracy of the slope of the yield curve. For example, the standard deviation of the actual one-quarter ahead growth rate of real GNP is 4.26 percent, and the RMSE of the forecast based on $SPREAD$ is almost as high, 3.99 percent. The forecasting accuracy of $SPREAD$ does improve at longer forecasting horizons and over longer periods, as suggested by the results of Table I.

V. Conclusions

We present evidence that the slope of the yield curve can predict cumulative changes in real output for up to 4 years into the future and successive marginal changes in real output up to a year and a half into the future. The

slope of the yield curve has extra predictive power over and above the predictive power of lagged output growth, lagged inflation, the index of leading indicators, and the level of real short-term interest rates. The slope outperforms survey forecasts both in-sample and out-of-sample, and it predicts all the private sector components of real GNP: consumption, consumer durables, and investment. Of course, the slope of the yield curve is not an unequivocal indicator of future economic activity. Although the slope of the yield curve outperforms all the other predictors we examined, the absolute size of the out-of-sample root mean squared errors of its forecasts is fairly large compared with the standard deviation of the real GNP growth rate.

The observed correlations do show that historically the information in the yield curve could have been useful not only to private investors but also to the Federal Reserve because it reflected, *inter alia*, factors that were not under the control of the monetary authorities. However, it is not clear that the slope will continue to predict well in the future, especially if the Federal Reserve were to adopt the slope as an information variable in its decision rules. The estimated historical correlations are not necessarily policy invariant. The policy invariance of the predictive power of the term structure is an important question for future research.

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