THE TERM STRUCTURE
AS A PREDICTOR OF REAL ECONOMIC ACTIVITY

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The Term Structure

As a Predictor of Real Economic Activity

Abstract

A positive slope of the yield curve is associated with a future increase in real economic activity: consumption (non-durables plus services), consumer durables, and investment. It has extra predictive power over and above the predictive power of the index of leading indicators, the level of 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. The information in the slope has so far been potentially useful both to private investors and to the Federal Reserve in its conduct of monetary policy because it reflects, inter alia, expectations of how future shocks to real output will affect future interest rates (expected shifts of the textbook IS curve), rather than expectations of how future changes in interest rates will affect future real output (expected shifts of the textbook LM curve).

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THE TERM STRUCTURE AS A PREDICTOR OF REAL ECONOMIC ACTIVITY

The flattening of the yield curve in 1988 and its inversion in early 1989 have been interpreted by many 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 predit future changes in real output would be very impressive.

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

Despite the policy importance of the subject, to our knowledge, this study is the first one to address these issues directly. The 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 possible explanations of the predictive power of the yield curve. 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. An appendix examines whether or not the predictive ability of the term structure is consistent with the predictions of the consumption Capital Asset Pricing Model (CAPM). The appendix also compares the predictability of the finally revised real GNP with the predictability of the originally released number.

I. Previous Evidence

A number of investigators have recently provided evidence that the term structure has predictive power. Fama (1984) examines one- to six-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 three-and six-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 twenty-six 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 and Hardouvelis using more powerful estimation methods. Fama and Bliss (1987) find that long-maturity forward rates also have predictive power two to four years ahead. They attribute the predictive power to the presence of mean reversion in interest rates over multi-period 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 represents a composite prediction about both future real rates and future rates of inflation. Mishkin (1987) examines rates with maturities that range from one to twelve 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 (1988) finds that the prediction in long-maturity forward rates is about future rates of inflation. 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-run and about the rate of inflation in the long-run (two to five 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. He finds that an increase in the real spread predicts an increase in real consumption two and three quarters ahead and claims that the results are consistent with the consumption CAPM. This claim is at odds with the frequent rejections of consumption CAPM by many other investigators. We discuss this issue in the appendix.

II. Does the Term Structure Predict Real Economic Activity?

Economic theory does not provide a precise connection between a future spot rate and the level of real economic activity. Theoretically, an inverted yield curve could predict either a decrease or an increase in real GNP. The current majority thinking that the inverted yield curve of early 1989 predicts a recession is implicitly based on the presumption that future nominal rates are expected to fall because of a fall in real economic activity (an inward shift of the textbook IS curve). However, this need not be the case. For example, the expected lower rate of interest may be due to, say, the expectation of a future expansionary monetary policy (an expected future outward shift of the textbook LM curve as opposed to an inward shift of the textbook IS curve), in which case the implicit prediction in the term structure is that real output would expand. Alternatively, the inverted yield curve may reflect an expected decrease in the rate of inflation caused by the expectation of an expansion in aggregate supply that would also be expected to increase output. Given the theoretical ambiguity on the connection between future interest rates and real economic activity, the belief that the slope of the yield curve predicts future changes in real economic activity in a specific direction can only be judged on empirical grounds. We now turn to the empirical evidence.

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:

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

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

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

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 = 2, 3, ... , 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 ten-year government bond rate, R^L, and the three-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.[2] Our measure of the slope of the yield curve is the difference between the two rates:[3]

$$(3) \qquad SPREAD_t \equiv R^L_t - R^S_t \, .$$

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)).

B. Econometric Issues.

Our basic regression equations have the following general form:

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

where $Y_{t,t+k}$ and $SPREAD_t$ are defined by equations (1) and (3) above, and X_{it} represent other information variables available during quarter t. Our sampling period is quarterly but the forecasting horizon, k, varies from one to twenty 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 forecasing 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-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-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. Evidence.

Table 1 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. Also, as expected, cumulative changes in real output are more predictable than marginal changes. The predictive power for cumulative changes lasts for about four years, while the predictive power of consecutive marginal changes in real output lasts for about six to seven quarters. 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 five to seven 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 1970s and early 1980s. 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 number that have not been corrected yet.[4] 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 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 in the coming quarters.

The short periods that exhibit a lower correlation, such as the 1985-88 period, may reflect the possibility that the yield curve predicts better when drastic changes in output take place. Figure 2 shows the periods when an NBER-dated recession occurred, together with the probability of a recession based on a probit model that uses the SPREAD of four quarters earlier as the only explanatory variable. The dependent variable in the equation has a value of one in quarters within a recession and zero otherwise. The results, using quarterly data from 1956 through 1988, are:

$$\text{Probability(recession)} = N[\underset{(.16)}{-.56^*} \quad \underset{(.16)}{-.78^*}\, \text{SPREAD}_{t-4}] ,$$

where N denotes the standard normal cumulative distribution function, asterisk denotes statistical significance at the 5 percent level, and standard errors appear in parentheses. The only time that the yield curve gave a wrong signal was 1966-67, when a slowdown occurred instead of a recession. Also observe that 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. While this probability exceeds the levels observed in most non-recessionary 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.[5]

Figure 3 is similar to Figure 2 but represents out-of-sample forecasts. A probit model is estimated recursively with SPREAD lagged four quarters as the only independent variable. The model is reestimated with each new sample observation and a single four-quarter ahead forecast is made at a time. The predictive performance is quite comparable to the within-sample results of Figure 2.[6]

Table 2 examines the predictability of 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. Observe that the yield curve predicts consumer durables and investment better than consumption, although consumption is a less volatile series.

III. Interpretation

In this section we explore possible explanations of the observed positive association between the slope of the yield curve and future changes in real economic activity. Our primary aim is to assess the usefulness of the slope of the yield curve to the monetary authority in its conduct of monetary policy. We ask: does the yield curve reflect the effects of expected future monetary actions? Does it reflect the expected influence of factors other than monetary policy? To facilitate the discussion we adopt the Keynesian IS-LM-Aggregate Supply framework that assumes price rigidity in the short-run and price flexibility in the long-run. A real business cycle model is not very useful for this discussion because real business cycle models do not allow monetary policy to have real effects by construction.[7]

Figure 4 shows that the correlation between the slope of the yield curve and changes in future output is consistent with expected shifts of the IS curve within the IS-LM framework of fixed output prices. Current output and interest rates are denoted by y_t and i_t, and expected future output and interest rates by $E_t y_{t+k}$ and $E_t i_{t+k}$. Consistent with the evidence, expected shifts in the IS curve generate movements along the LM curve and, hence, a positive correlation between $E_t i_{t+k} - i_t$ and $E_t y_{t+k} - y_t$. However, expected shifts of the LM curve generate the opposite correlation. Thus it appears that in a Keynesian model with fixed prices the information in the term structure is about the expected future effects of the economy on interest rates rather than vice versa. Hence the information in the term structure is useful not only to private market participants but to the monetary authority as well.

There are two potential major objections to the above interpretation. The first objection appeals to the flexibility of prices. If prices are flexible enough, one can explain the evidence of Table 1 within the context of expected future monetary actions alone. The argument runs as follows: An expected future expansion in the growth rate of the money supply is expected to decrease the real rate of interest and expand output, but at the same time it may be expected to increase the nominal rate of interest if the inflation premium is expected to rise by more than the real rate is expected to decline. This scenario can, therefore, explain the positive association between the slope of the yield curve and future changes in output. However, this interpretation is contradicted by the available evidence on the predictability of future inflation. Mishkin (1987) examined horizons up to one year and found that the information in the slope of the yield curve is about changes in the real rate of interest and not about changes in the inflation premium. In Panel A of Table 3 we show that, indeed, changes in the rate of inflation are predictable by the slope of the yield curve only for horizons beyond seven quarters into the future. Fama (1988) provides similar evidence. Since most of the predictability of future changes in output is for horizons of one to seven quarters ahead, the rigid-price IS-LM framework is an adequate model for our purposes.[8]

The second objection claims that although expectations of future monetary policy alone cannot explain the positive association between the slope of the yield curve and future changes in output, *current* monetary policy actions can. According to the argument, current monetary policy is the primary determinant of the slope of the yield curve simply because long-term interest rates vary very little, and hence the level of short-term rates determines the slope of the yield curve. The monetary authority can affect current short-term rates, and thus it can affect the slope of the yield curve. For example, a current contractionary policy that drives short-term interest rates up makes the slope of the yield curve negative. Since the negative output effects of the contractionary policy come with a lag, the data will show that the current negative slope of the yield curve correctly predicts a decline in future output. Figure 5 presents a visual interpretation of the above argument. The LM curve shifts in contemporaneously, but output is rigid, interest rates overshoot upwards to point B, and the economy is in a disequilibrium. As time passes, the economy contracts gradually towards its equilibrium at point C and interest rates decrease towards their new equilibrium value.

Undoudtedly, 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 that the slope carries about current policy actions. To sort out the different pieces of information in the slope of the yield curve, we regress $Y_{t,t+k}$, the realized future cumulative change in real output, on the contemporaneous level of short rates alone, the contemporaneous level of long rates alone, and on both rates together. Panels B, C, and D of Table 3 present the results.

Panel B of Table 3 shows that future changes in real output are negatively associated with the current level of the three-month T-bill rate. This negative association simply reflects the influence current (real) short-term rates have on future output. Panel C shows that in contrast to short-term rates, current long-term rates exhibit a very weak relation to future output. This is an expected result. Long-term rates are weighted averages of short-term rates, expectations about future short-term rates, and various risk factors. Hence the correlation between current long-term rates and future output does not only reflect a causal link from current interest rates to future output, but also reflects the effects of expectations of future output on current rates. This argument becomes very clear once we add current long-term rates in the regression of future output on current short-term rates. Panel D presents the results. Comparing panel D with panel B shows that the addition of long-term rates dramatically increases the regression fit. The coefficient of long-term rates is positive and statistically significant. Hence, long-term rates have *extra* information about the evolution of future output that is not incorporated into the level of current short-term rates.

To clarify matters further, panel D of Table 3 includes the results of regressing future changes in output on the current short-rate and the current spread between the long- and short-rate. This is the same regression as the earlier one in panel D, but the independent variables enter with a different linear combination. The coefficient of SPREAD is identical to the coefficient of TB10Y, the 10-year rate, in the earlier regression. The new regression clarifies that there is extra information in SPREAD that is not reflected in the current level of short-term rates.

Table 4 sharpens the results of panel D in Table 3. The Federal Reserve influences the three-month T-bill rate but does not control it. The Fed does control the real federal funds rate, however. Thus Table 4 regresses the future cumulative and marginal change in real output on SPREAD and the level of the real federal funds rate. 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 univariate autoregressive - AR(12) - model. The question of interest is whether SPREAD has extra explanatory power when the Fed's instrument, the real federal funds rate, is included in the regression. The table shows that SPREAD continues to predict both cumulative and marginal changes in future output. The cumulative predictive power lasts for approximately four years into the future and the marginal predictive power for approximately a year and a half.[9]

We may interpret the foregoing results in the context of Figure 5. Recall that Figure 5 provides an example where a current restrictive monetary policy increases the real federal funds rate and creates both an inverted yield curve and market expectations of lower future output. Figure 5 warns that one should not ignore the level of the current real federal funds rate when analyzing the relation between future output and the slope of the yield curve. The regressions of Table 4 include the real federal funds rate and corroborate the negative effect of the real federal funds rate on future output that Figure 5 illustrates. However, Table 4 also shows that the slope of the yield curve has predictive power even after controlling for the level of the real federal funds rate. Clearly, factors other than current monetary policy account for the information in the slope of the yield curve in Table 4.

Our interpretation of the information in the slope of the yield curve as information primarily about expected future exogenous shocks to the real economy (shifts of the IS curve) is consistent with the individual predictability of consumption, consumer durables, and investment, as indicated in Table 2. The results for these three components are qualitatively the same as those using output as a whole. Government spending, which is not very cyclical, exhibits no significant correlation with SPREAD. The only exceptions are forecasts of three and four years ahead, which is consistent with the predictability of policy shifts over Presidential terms of office.

We conclude by noting that although current and expected future monetary policy may play a role in determining the slope of the yield curve, the slope contains substantially extra information about the future evolution of real output. Hence, the slope of the yield curve is useful both to the monetary authorities and to private investors.

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 or the level of the nominal three-month T-bill 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 if 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 quartery 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 both variables describe the state of the economy and are likely to have predictive power.[10]

Table 5 presents the regression results. First, $SPREAD_t$ continues to have explanatory power over the entire forecasting horizon. Its regression coefficients are statistically significant up to three years into the future. Second, an increase in the real federal funds rate predicts a drop in real GNP for about six 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 three 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. Observe that the presence of lagged output in the estimated equation implies that the remaining variables Granger cause the growth in real output in an autoregressive model of order one. Fifth, the lagged rate of inflation also shows a negative coefficient, which is statistically significant at all horizons beyond two quarters.

In the case of the probit equation for predicting recessions, the supplementary information variables are strikingly devoid of statistical significance - singly or jointly - in the presence of SPREAD. The estimated equation for the 1956-88 period is as follows:

$$\text{Prob(recession)} = N[\underset{(.62)}{-\ 1.28^{*}}\ \underset{(.19)}{-\ .61^{*}}\ \text{SPREAD}_{t-4} \underset{(.09)}{+\ .08}\ \text{RFFY}_{t-4} \underset{(.02)}{-\ .02}\ \text{GLI}_{t-4} \underset{(.08)}{+\ .08}\ \text{Y}_{t-4} \underset{(.08)}{+\ .04}\ \pi_{t-4}]$$

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 5 for a forecasting horizon of four quarters ahead. The joint likelihood ratio test for excluding the four supplementary variables (all but SPREAD) is distributed as $\chi^2(4)$ and has a value of 2.84, which is insignificant.

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 mid-quarter surveys conducted by the American Statistical Association and the National Bureau of Economic Research since the beginning of 1970. The data are median forecasts of current real GNP, and the real GNP of the next two quarters. Since 1981, we also have data for the median forecast of three quarters ahead.

Panel A of Table 6 presents regression results, which show that SPREAD is a better predictor of future output growth than the median survey forecast. 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 two quarters ahead but not for three quarters ahead, as evidenced by the size of the R^2s 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 foreast as evidenced by its uniformly larger R^2s. Furthermore, adding the survey forecast as an additional regressor in the $SPREAD_t$ regressions does not increase the R^2.

Panel B of Table 6 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 5, 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 5 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 three 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 1982-88.

Although the relative forecasting ability of the slope of the yield curve is very good, one should not loose 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 1.

V. Conclusions

We present evidence that the slope of the yield curve can predict cumulative changes in real output up to four 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.

It appears that the evidence is not very favorable to equilibrium models of business cycles. For example, the consumption CAPM is unable to explain the predictability of real consumption (see Appendix A). The evidence does appear to be consistent with the Keynesian textbook model in which expected shifts of the IS curve dominate the time series. We interpret the positive association of the slope of the yield curve and future real output as evidence that market participants typically expect future output will affect interest rates, and do not expect that future interest rates (say, through expected actions of monetary policy) will affect future output. Hence, we conclude that, historically, the slope of the yield curve contains information useful both to the private sector and to the Federal Reserve in its conduct of monetary policy.

The slope of the yield curve is certainly 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 failry large compared with the standard deviation of the real GNP growth rate. In addition, our evidence may be sample specific. Historical relationships that depend on the relative frequencies of particular types of shocks cannot be trusted to remain intact in the future. Since the predictive ability of the slope of the yield curve cannot be explained by a behavioral model with stable and "deep" parameters, we cannot argue that the predictability of real economic activity will persist indefinitely. Thus, we suggest that the information in the slope of the yield curve be interpreted with caution, and that it be used in conjuction with other variables that have also demonstrated predictive ability for future economic activity.

Appendix A

Is the Consumption CAPM Consistent with the Predictive Power of the Slope of the Yield Curve ?

In this appendix we turn to neoclassical interpretations of the predictive power of the term structure. We examine the consumption CAPM of Merton (1973), Lucas (1978), Breeden (1979), and others. This model was used by Harvey (1988), who claims that it is consistent with the data, but does not show test statistics of his null hypothesis.

Let $U'(C_{t+j})$ denote the marginal utility of real consumption at quarter t+j, δ the rate of time preference, and r_{jt} the continuously compounded real rate of interest linking quarters t and t+j. According to the consumption CAPM, the loss in utility from giving up one unit of consumption at quarter t in order to buy a security, should equal the discounted gain in utility from consuming the expected proceeds from selling the security in future quarter t+j:

$$\text{(A1)} \qquad E_t \left[\delta^j \frac{U'(C_{t+j})}{U'(C_t)} \exp\{j\, r_{jt}\}\right] = 1 ,$$

where E_t denotes conditional expectation based on information available at time t, and exp{ } is the exponential function. For simplicity, let us assume that utility is characterized by constant relative risk aversion:

$$\text{(A2)} \qquad U(C) = \frac{C^{1-\gamma} - 1}{1 - \gamma} \qquad \text{if } \gamma > 0,\ \gamma \neq 1,$$

$$= \log(C) \qquad \text{if } \gamma = 1.$$

Substituting equation (A2) into (A1) we get:

$$\text{(A3)} \qquad E_t \left[\delta^j (C_t/C_{t+j})^{\gamma} \exp\{j\, r_{jt}\}\right] = 1.$$

Following Hansen and Singleton (1983), let us also assume that C_t/C_{t+j} and real rates of return are lognormally distributed, which implies that:

$$\text{(A4)} \qquad 0 \equiv \log E_t[\delta^j (C_t/C_{t+j})^\gamma \exp\{j\ r_{jt}\}] =$$
$$E_t\{\log[\delta^j (C_t/C_{t+j})^\gamma \exp\{j\ r_{jt}\}]\} + 0.5\ \text{var}_t\{\log[\delta^j (C_t/C_{t+j})^\gamma \exp\{j\ r_{jt}\}]\},$$

where var_t denotes the conditional variance. Rearranging (A4) we get:

$$\text{(A5)} \qquad E_t[\log(C_{t+j}) - \log(C_t)] = [(j/\gamma) \log(\delta) + V_j/2\gamma] + (1/\gamma)\ j\ E_t r_{jt},$$

where V_j denotes the conditional variance component in (A4). We assume that V_j remains constant.

Equation (A5) shows that there is a proportional relationship between the growth rate in real consumption from quarter t to quarter t+j and the expected real rate of interest that links quarters t and t+j. This is a fundamentally different relationship than the relationship assumed by the IS-LM model. In the IS-LM model it is consumption levels that are associated with interest rate levels, not consumption growth rates. Consistent with the IS-LM intuition, in the text we regressed consumption growth on the expected change in interest rate levels, but not on the level of ex-ante real interest rates as the consumption CAPM implies. To see whether or not our previous results are consistent with the consumption CAPM, we can rearrange equation (A5) so that the slope of the yield curve appears on the right-hand-side. Moving forward one quarter in equation (A5), letting j = k-1, letting α_{k-1} denote all the constant terms, and taking expectations conditional on information available at quarter t, we get:

$$\text{(A6)} \qquad E_t[\log(C_{t+k}) - \log(C_{t+1})] = \alpha_{k-1} + (1/\gamma)\ (k-1)\ E_t\, r_{k-1,t+1}\ ,$$

where $(k-1)\ r_{k-1,t+1}$ is the real interest rate that links quarters t+1 and t+k. Adding and subtracting $1/\gamma$ $(k-1)\ E_t r_{1t}$ in equation (A6), we get:

(A7) $$E_t[\log(C_{t+k}) - \log(C_{t+1})] = \alpha_{k-1} + (1/\gamma)(k-1) E_t[r_{k-1,t+1} - r_{1t}] + (1/\gamma)(k-1) E_t r_{1t} ,$$

where $(k-1) E_t [r_{k-1,t+1} - r_{1t}]$ is the slope of the real term structure, and $(k-1) E_t r_{1t}$ is the ex-ante three-month real rate of interest. Thus in a regression of the consumption growth on the ex-ante real slope of the yield curve and the ex-ante real three-month rate,

(A8) $$\log(C_{t+k}) - \log(C_{t+1}) = \alpha_0 + \alpha_1 (k-1) E_t [r_{k-1,t+1} - r_{1t}] + \beta_1 (k-1) E_t r_{1t} + \varepsilon_{t+k} ,$$

the consumption CAPM imposes the restrictions that:

$$\alpha_1 = \beta_1 .$$

A natural empirical proxy for $E_t [r_{k-1,t+1} - r_{1t}]$ is the observed difference between the nominal forward rate embodied in the term structure, ${}_t f_{1,k-1}$, and the nominal three-month interest rate, R_{1t}. Let us denote this difference by $FSPREAD_t$.[11] Although $FSPREAD_t$ is a spread of nominal as opposed to real interest rates, it does not contain information about the inflation rate differential for the relevant forecasting horizons of one to seven quarters ahead. This was shown earlier in panel A of Table 3. Thus $FSPREAD_t$ is a goood proxy for $E_t [r_{k-1,t+1} - r_{1t}]$ for forecasting horizons up to seven quarters. Next, in order to construct an empirical proxy for $E_t r_{1t}$ we subtracted the anticipated rate of inflation from the three-month Treasury bill yield. We based the anticipated rate of inflation on the consumption deflator, which is available quarterly since 1947. We used recursive regressions to construct the anticipated rate of inflation. The regression equation contained twelve lags of the actual rate of inflation and a constant. We added one sample observation at a time, reestimated the equation and forecasted one quarter ahead. Thus the construction of the expected rate of inflation did not involve ex-post data.

Table A1 presents the regression results together with a test of the hypothesis that $\alpha_1 = \beta_1$. The coefficient of the real short-term interest rate is actually negative, although insignificant. A test of the equality of the yield slope coefficient with the coefficient of the real short-term rate rejects the null at horizons up to eight quarters. We conclude that the consumption CAPM cannot explain the predictability of consumption.

Appendix B

Original versus Final GNP Release.

Another way of assessing the information in the slope of the yield curve is to compare its predictive power about the final and original real GNP releases. Presumably the last GNP release represents a closer approximation to the true GNP than the original release does. One would hope that the slope of the yield curve is a better predictor of the final GNP release, especially if interest rates embody private information that is not readily available in public statistics.

Table A2 shows the results of regressing two alternative measures of the growth rate of real GNP on the slope of the yield curve. For a particular quarter t, the last release refers to the GNP number that appears in the Citibase data bank as of February 1989; the first release refers to the first number reported in the *Survey of Current Business* adjusted by a multiplicative factor to bring it up to 1982 base prices. The sample period begins in 1959, the first date that first release numbers were available. The interesting statistics in Table A2 are the R^2s. Since both types of regressions have identical regressors, a constant and $SPREAD_t$, and since they refer to the same sample period, their R^2s provide a measure of their comparative predictive accuracy. In all forecasting horizons except the last one, the R^2 of the last release is larger than the R^2 of the first release, which shows that the slope of the yield curve is a better predictor of the better GNP number.

Footnotes

1. Fama (1986) and Stambaugh (1988) present graphs showing that increases in forward rates precede 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 betwen the twenty-year bond yield and the federal funds rate. Finally, Harvey (1988) examines the real term structure as a predictor of changes in consumption.

2. Recent 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 level of short rates, long rates, and interest rate volatility. In our following analysis we will use short rates, and the spread 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.

3. Observe that R^L_t - R^S_t is proportional to the difference between the forward rate calculated from the 10-year and 3-month yields, f_t, and R^S_t. The forward rate is defined as in Shiller, Campbell and Schoenholtz (1983):

$$f_t \equiv (7.59\ R^L_t - 0.25\ R^S_t) \ / \ (7.59 - 0.25),$$

where 7.59 years is the duration of the 10-year bond (estimated over our sample), and 0.25 years is the duration of the 3-month T-bill. The difference f_t - R^S_t is the correct measure of the slope of the yield curve, but it is proportional to R^L_t - R^S_t : $f_t - R^S_t = (7.59/7.34)\ (R^L_t - R^S_t)$.

4. Our GNP series represents the finally revised numbers. Thus the most recent GNP numbers

have not been as thoroughly revised as the earlier ones. We show later in appendix B that the slope of the yield curve is more successful at predicting the finally revised numbers.

5. All 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.

6. Stock and Watson (1989) have independently found predictive power in the slope of the yield curve. They use the slope to predict a new monthly measure of coincident indicators that they construct. In addition, they find the slope is useful in predicting NBER-dated recessions using a logit model.

7. Our eventual interpretation of the evidence is not contradicted by a real business cycle model. However, it is hard to imagine a real business cycle model that can successfully imitate our reported partial correlations. 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. This correlation is consistent with the positive association between the slope of the yield curve and future output. However, we show later in Table 4 that contemporaneous real rates of interest are negatively associated with future output, not positively as the model of Kydland and Prescott predicts. Furthermore, it is an open question whether or not a real business cycle model can successfully replicate the predictive power of the yield curve for each GNP component of Table 2. For example, in appendix A we show that the consumption CAPM cannot explain the predictive power for consumption.

8. Furlong (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 (ten years) inflationary expectations. 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 start of the last recession, which was accurately predicted by the slope of the yield curve (see, for example, Figures 2 and 3).

9. The qualitative results do not change if we use the nominal federal funds rate or the change in the nominal federal funds rate instead of the real federal funds rate. In the probit estimations of the probability of a recession, the real federal funds rate is not statistically significant when SPREAD is present. For the 1956-88 sample period, the estimated equation is as follows:

$$\text{Prob(recession)} = N[\underset{(.29)}{-.83^{*}} - \underset{(.18)}{.66^{*}}\ \text{SPREAD}_{t-4} + \underset{(.08)}{.09}\ \text{RFFY}_{t-4}]\ ,$$

where RFFY denotes the real federal funds rate.

10. The 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.

11. Notice that FSPREAD_t is slightly different from SPREAD_t, which was used in the tables of the text. FSPREAD_t utilizes the forward interest rate defined in footnote 3.

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Table 1

Predicting Future Change in Real Output Using the Slope of the Yield Curve

Sample: Quarterly, 1955:2-1988:4

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

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

k Quarters Ahead	Nobs	Cumulative Change α_1	$\bar{R}^2$	SEE	Marginal Change β_1	$\bar{R}^2$	SEE
1	135	1.23* (.29)	.13	3.75	1.23* (.29)	.13	3.75
2	134	1.35* (.28)	.24	2.82	1.46* (.31)	.18	3.64
3	133	1.35* (.28)	.31	2.39	1.30* (.30)	.14	3.75
4	132	1.30* (.27)	.35	2.08	1.09* (.30)	.09	3.86
5	131	1.24* (.24)	.38	1.86	0.84* (.75)	.05	3.95
6	130	1.15* (.22)	.38	1.70	0.60* (.20)	.02	4.02
7	129	1.05* (.19)	.37	1.59	0.44* (.20)	.01	4.06
8	128	0.93* (.16)	.33	1.54	0.02 (.26)	-.01	4.11
12	124	0.53* (.14)	.18	1.34	-.25 (.34)	.00	2.63
16	120	0.33* (.11)	.09	1.16	-.42 (.28)	.03	2.51
20	116	0.23 (.14)	.05	1.00	-.24 (.45)	.00	2.53

Notes: y_t is the level of real GNP of quarter t. 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. The interest rates are annualized quarterly average bond equivalent yields. Asterisk, *, denotes statistical significace at the 5% level. Inside the parentheses are Newey-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.

Table 2

Predicting Future Cumulative Change of Real GNP Components Using the Slope of the Yield Curve

Sample:1955-1988

Quarters Ahead	Consumption			Consumer Durables			Investment			Government Spending		
	SPREAD	$\bar{R}^2$	SEE	SPREAD	$\bar{R}^2$	SEE	SPREAD	$\bar{R}^2$	SEE	SPREAD	$\bar{R}^2$	SEE
1	.57*	.10	1.94	4.16*	.12	12.96	5.27*	.08	20.14	.06	-.01	5.06
	(.21)			(.96)			(1.55)			(.28)		
2	.54*	.16	1.47	3.93*	.23	8.51	6.34*	.20	14.81	.02	-.01	3.83
	(.19)			(.86)			(1.40)			(.26)		
3	.53*	.20	1.24	3.73*	.29	6.84	6.33*	.28	12.00	.06	-.01	3.26
	(.17)			(.65)			(1.38)			(.27)		
4	.50*	.21	1.14	3.42*	.33	5.81	5.98*	.32	10.29	.10	-.01	2.97
	(.15)			(.51)			(1.30)			(.27)		
5	.46*	.20	1.08	3.02*	.30	5.37	5.57*	.35	8.93	.12	-.00	2.78
	(.13)			(.40)			(1.11)			(.27)		
6	.41*	.18	1.01	2.58*	.26	5.11	5.06*	.36	7.82	.15	-.00	2.66
	(.12)			(.25)			(.98)			(.28)		
7	.37*	.16	0.96	2.17*	.20	4.98	4.48*	.35	7.08	.19	.00	2.56
	(.11)			(.18)			(.83)			(.26)		
8	.30*	.12	0.94	1.69*	.14	4.85	3.78*	.30	6.63	.23	.00	2.46
	(.11)			(.17)			(.65)			(.23)		
12	.14	.03	0.83	.51	.01	3.96	1.56*	.11	5.22	.29*	.02	2.12
	(.11)			(.30)			(.32)			(.14)		
16	.06	.00	0.74	.06	-.01	3.14	.70*	.03	4.00	.23*	.01	1.88
	(.08)			(.33)			(.33)			(.12)		
20	.03	-.01	0.67	-.10	-.01	2.65	.45	.02	3.06	.11	-.00	1.72
	(.07)			(.33)			(.39)			(.18)		

Notes: Consumption refers to consumer non-durables plus services. Investment is gross private domestic investment. Each dependent variable is expressed as an annualized percentage change and is regressed on a constant and SPREAD. SPREAD equals the 10-year minus the 3-month T-bill yield. All interest rates are annualized quarterly averages. Newey-West (1987) corrected standard errors are in parentheses. Asterisk, *, denotes significance at the 5% level.

Table 3

The Information in the Slope of the Yield Curve

Sample: 1955-1988

Dependent Variable: $\pi_{t,t+k} - \pi_{t-1,t}$ in Panel A; $(400/k)\log(y_{t+k}/y_t)$ in Panels B, C, and D.

k Quarters Ahead	Panel A			Panel B			Panel C			Panel D					
	SPREAD	$\bar{R}^2$	SEE	TB3M	$\bar{R}^2$	SEE	TB10Y	$\bar{R}^2$	SEE	TB3M	TB10Y	$\bar{R}^2$	SEE	TB3M	SPREAD
1	-.01	-.01	1.93	-.38*	.08	3.84	-.22	.02	3.97	-1.31*	1.03*	.16	3.67	-.27*	1.03*
	(.06)			(.13)			(.16)			(.29)	(.33)			(.11)	(.33)
2	.04	-.01	1.75	-.40*	.15	3.00	-.22	.04	3.18	-1.42*	1.15*	.31	2.70	-.28*	1.15*
	(.07)			(.12)			(.16)			(.25)	(.29)			(.10)	(.29)
3	.07	-.01	1.72	-.38*	.17	2.63	-.20	.04	2.82	-1.41*	1.16*	.37	2.28	-.25*	1.16*
	(.07)			(.12)			(.15)			(.24)	(.28)			(.10)	(.28)
4	.07	-.01	1.69	-.35*	.18	2.34	-.18	.04	2.53	-1.35*	1.12*	.42	1.97	-.23*	1.12*
	(.08)			(.12)			(.14)			(.22)	(.27)			(.10)	(.27)
5	.09	-.00	1.71	-.32*	.18	2.13	-.17	.04	2.31	-1.28*	1.07*	.44	1.76	-.20*	1.07*
	(.06)			(.11)			(.14)			(.19)	(.24)			(.10)	(.24)
6	.14*	.00	1.75	-.28*	.17	1.96	-.14	.04	2.12	-1.18*	1.00*	.44	1.61	-.18	1.00*
	(.06)			(.11)			(.13)			(.16)	(.22)			(.10)	(.22)
7	.19*	.01	1.80	-.25*	.16	1.84	-.13	.03	1.98	-1.08*	0.93*	.42	1.52	-.15	0.93*
	(.07)			(.11)			(.12)			(.12)	(.19)			(.10)	(.19)
8	.25*	.02	1.82	-.22*	.14	1.75	-.11	.02	1.86	-.95*	.82*	.37	1.49	-.13	.82*
	(.09)			(.11)			(.12)			(.82)	(.17)			(.09)	(.17)
12	.46*	.07	1.93	-.13	.07	1.43	-.06	.01	1.47	-.55*	.47*	.20	1.33	-.08	.47*
	(.13)			(.10)			(.11)			(.12)	(.13)			(.09)	(.13)
16	.65*	.12	2.00	-.10	.07	1.17	-.07	.02	1.20	-.33*	.26*	.11	1.14	-.07	.26*
	(.12)			(.08)			(.09)			(.10)	(.13)			(.08)	(.13)
20	.75*	.13	2.09	-.10	.09	0.98	-.09	.05	1.00	-.20	.13	.09	0.98	-.08	.13
	(.14)			(.07)			(.09)			(.14)	(.18)			(.09)	(.18)

Notes: $\pi_{t,t+k}$ is the annualized rate of inflation of the GNP deflator from quarter t through quarter t+k. y_{t+k} is the level of real GNP of quarter t+k. TB3M is the 3-month T-bill yield. TB10Y is the 10-year T-bond yield SPREAD = TB10Y - TB3M. All interest rates are annualized bond equivalent yields, quarterly averages. Asterisk, *, denotes statistical significance at the 5% level. Newey-West (1987) corrected standard errors are in parentheses. In Panel D, the second set of regressions share the same $\bar{R}^2$ and SEE with the first set.

Table 4

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

Sample: 1955 -1988

Cumulative Change: $(400/k)\log(y_{t+k}/y_t) = \alpha_0+\alpha_1\ SPREAD_t+\alpha_2\ RFF_t+\epsilon_t$

Marginal Change: $(400/j)\log(y_{t+k}/y_{t+k-j}) = \beta_0+\beta_1\ SPREAD_t+\beta_2\ RFF_t+u_t$, j=1 or 4

K Quarters Ahead	Cumulative Change				Marginal Change			
	α_1	α_2	$\bar{R}^2$	SEE	β_1	β_2	$\bar{R}^2$	SEE
1	.93*	-.36*	.17	3.65	.93*	-.36*	.17	3.65
	(.26)	(.06)			(.26)	(.06)		
2	1.02*	-.38*	.33	2.66	1.10*	-.41*	.24	3.50
	(.25)	(.08)			(.26)	(.09)		
3	1.06*	-.32*	.38	2.26	1.10*	-.22*	.15	3.72
	(.24)	(.08)			(.30)	(.10)		
4	1.04*	-.28*	.42	1.96	.92*	-.18	.10	3.85
	(.23)	(.08)			(.29)	(.11)		
5	1.00*	-.24*	.44	1.76	.73*	-.11	.05	3.95
	(.21)	(.07)			(.27)	(.08)		
6	.94*	-.20*	.43	1.63	.58*	-.02	.02	4.04
	(.20)	(.07)			(.26)	(.11)		
7	.88*	-.17*	.41	1.54	.47	.03	.00	4.08
	(.19)	(.07)			(.24)	(.11)		
8	.77*	-.15*	.36	1.50	.00	-.02	-.02	4.12
	(.17)	(.07)			(.29)	(.13)		
12	.48*	-.05	.18	1.35	-.07	.17	.02	2.61
	(.15)	(.02)			(.32)	(.13)		
16	.31*	-.01	.08	1.16	-.36	.04	.02	2.52
	(.13)	(.07)			(.24)	(.12)		
20	.24	.01	.04	1.01	-.21	.02	-.01	2.54
	(.15)	(.08)			(.31)	(.16)		

Notes: y_t is real GNP of quarter t; 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. 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 averages. Asterisk, *, denotes statistical significance at the 5% level. Newey-West (1987) corrected standard errors are in parentheses.

Table 5

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

Sample: 1955-1988

$$(400/k)(\log y_{t+k} - \log y_t) = \alpha_0 + \alpha_1 \text{ SPREAD}_t + \alpha_2 \text{ RFF}_t + \alpha_3 \text{ GLI}_t + \alpha_4 \text{ LDEP}_{t-k} + \alpha_5 \pi_{t-k,t} + \epsilon_t$$

k Quarters Ahead	α_1	α_2	α_3	α_4	α_5	$\bar{R}^2$	SEE
1	.55* (.26)	-.24* (.11)	.16* (.04)	-.03 (.10)	-.14 (.11)	.28	3.40
2	.73* (.24)	-.31* (.07)	.10* (.03)	-.04 (.07)	-.17 (.12)	.40	2.51
3	.78* (.26)	-.27* (.07)	.07* (.03)	-.15* (.07)	-.26* (.12)	.46	2.12
4	.81* (.26)	-.24* (.07)	.04 (.024)	-.18* (.05)	-.29* (.12)	.49	1.84
5	.82* (.24)	-.20* (.06)	.02 (.02)	-.21* (.08)	-.31* (.12)	.52	1.63
6	.82* (.22)	-.17* (.07)	.00 (.01)	-.21 (.11)	-.29* (.12)	.50	1.52
7	.79* (.20)	-.12 (.07)	-.00 (.01)	-.22 (.13)	-.27* (.11)	.48	1.45
8	.71* (.17)	-.10 (.07)	-.01 (.01)	-.26 (.13)	-.27* (.11)	.44	1.41
12	.38* (.15)	-.00 (.07)	-.01 (.02)	-.33 (.21)	-.26 (.15)	.29	1.25
16	.27 (.19)	.05 (.04)	-.01 (.01)	-.36 (.27)	-.29* (.08)	.29	1.02
20	.16 (.09)	.09 (.05)	.01 (.01)	-.54* (.09)	-.32* (.05)	.44	0.77

Notes: y_t is real output of quarter t. 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 as in Table 4). All interest rates are annualized quarterly averages. 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. $\text{LDEP}_{t-k} = (400/k)(\log y_t - \log y_{t-k})$ 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. Asterisk, *, denotes statistical significance a the 5% level. Newey-West (1987) corrected standard errors are in parentheses.

Table 6
Survey Forecasts versus Term Structure Forecasts

Panel A: Regression Results

$$Y_{t+k} \equiv (400/k)(\log y_{t+k} - \log y_t) = \alpha_0 + \alpha_1 \text{ SPREAD}_t + \beta_1 \text{ SURVEYF}_{t,k} + e_t$$

k Quarters Ahead	Sample Period	α_0	α_1	β_1	$\bar{R}^2$	SEE	Chi-Squared(2) (α_0=0, β_1=1)
1	70:2-88:4	.56		.67*	.08	4.08	16.5*
		(.59)		(.10)			[.000]
		1.08*	1.30*		.19	3.83	
		(.45)	(.27)				
		.46	1.13*	.26*	.19	3.84	
		(.54)	(.28)	(.09)			
2	70:3-88:4	-.32		.88*	.15	3.11	5.83
		(.74)		(.17)			[.054]
		.96*	1.42*		.37	2.68	
		(.36)	(.22)				
		.21	1.28*	.27	.38	2.67	
		(.93)	(.24)	(.26)			
3	82:1-88:4	2.28		.22	-.04	3.01	0.51
		(3.44)		(1.25)			[.777]
		-.13	1.59*		.39	2.33	
		(.82)	(.28)				
		-3.88	1.72*	1.04	.41	2.26	
		(2.58)	(.26)	(.82)			

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

Quarters Ahead	Forecast Period	SPREAD		Information Variables of Table 5		Survey		St. Deviation of Y_{t+k}
		RMSE	r^2	RMSE	r^2	RMSE	r^2	
1	70:2-88:4	3.99	.19	3.60	.29	4.11	.10	4.26
2	70:3-88:4	2.93	.37	2.67	.37	3.17	.17	3.39
3	82:1-88:4	2.85	.40	2.42	.32	2.95	.00	2.95

Notes: 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. $\text{SURVEYF}_{t,k}$ is the ASA/NBER forecast of Y_{t+k}. Numbers in brackets are significance levels. Numbers in parentheses are Newey-West (1987) corrected standard errors. In panel B, the model RMSEs were calculated using the parameters of recursive OLS regressions estimated from 1955 to quarter t-1. r^2 is the squared correlation between Y_{t+k} and its forecast.

Table A-1

The Consumption CAPM and the Predictive Power of the Slope of the Yield Curve

Sample: 1955-1988

$$(400/k)\ \log(C_{t+k+1}/C_{t+1}) = \alpha_0 + \alpha_1\ FSPREAD_t + \alpha_2\ RTB3M_t + u_t$$

(k+1) Quarters Ahead	Nobs	α_0	α_1	α_2	$\bar{R}^2$	SEE	t-statistic ($\alpha_1 = \alpha_2$)
2	134	2.86*	.53*	.03	.10	1.94	4.02*
		(.25)	(.14)	(.05)			[.000]
3	133	2.94*	.51*	-.01	.18	1.46	5.27*
		(.25)	(.10)	(.04)			[.000]
4	132	2.95*	.46*	-.01	.20	1.23	5.41*
		(.24)	(.09)	(.04)			[.000]
5	131	2.93*	.43*	-.01	.19	1.15	5.32*
		(.25)	(.10)	(.04)			[.000]
6	130	2.95*	.38*	-.01	.16	1.10	4.77*
		(.25)	(.10)	(.05)			[.000]
7	129	2.98*	.33*	-.01	.14	1.04	4.42*
		(.27)	(.10)	(.05)			[.000]
8	128	2.99*	.28*	.02	.10	1.00	3.23*
		(.27)	(.11)	(.05)			[.001]
9	127	3.00*	.23*	.03	.07	0.97	2.30*
		(.27)	(.11)	(.05)			[.022]
13	123	3.03*	.13	.05	.03	0.83	0.86
		(.27)	(.11)	(.04)			[.389]
17	119	3.06*	.09	.05	.01	0.74	0.45
		(.26)	(.09)	(.04)			[.655]
21	115	3.03*	.10	.08*	.03	0.66	0.28
		(.24)	(.10)	(.04)			[.780]

Notes: C_{t+k+1} refers to the real level of consumer non-durables and services of quarter t+k+1. $FSPREAD_t$ equals the forward rate embodied in the 10-year T-bond and 3-month T-bill yields minus the 3-month T-bill yield of quarter t. $RTB3M_t$ is the ex-ante real rate of interest on a 3-month T-bill of quarter t (nominal rate minus an out-of-sample one-quarter ahead forecast of inflation based on a 12th order autoregressive model). Numbers in brackets are significance levels. Numbers in parentheses are Newey-West (1987) corrected standard errors. Asterisk, *, denotes statistical significance at the 5% level. Nobs denotes the number of obervations, $\bar{R}^2$ the coefficient of determination adjusted for degrees of freedom, and SEE the regression standard error.

Table A-2

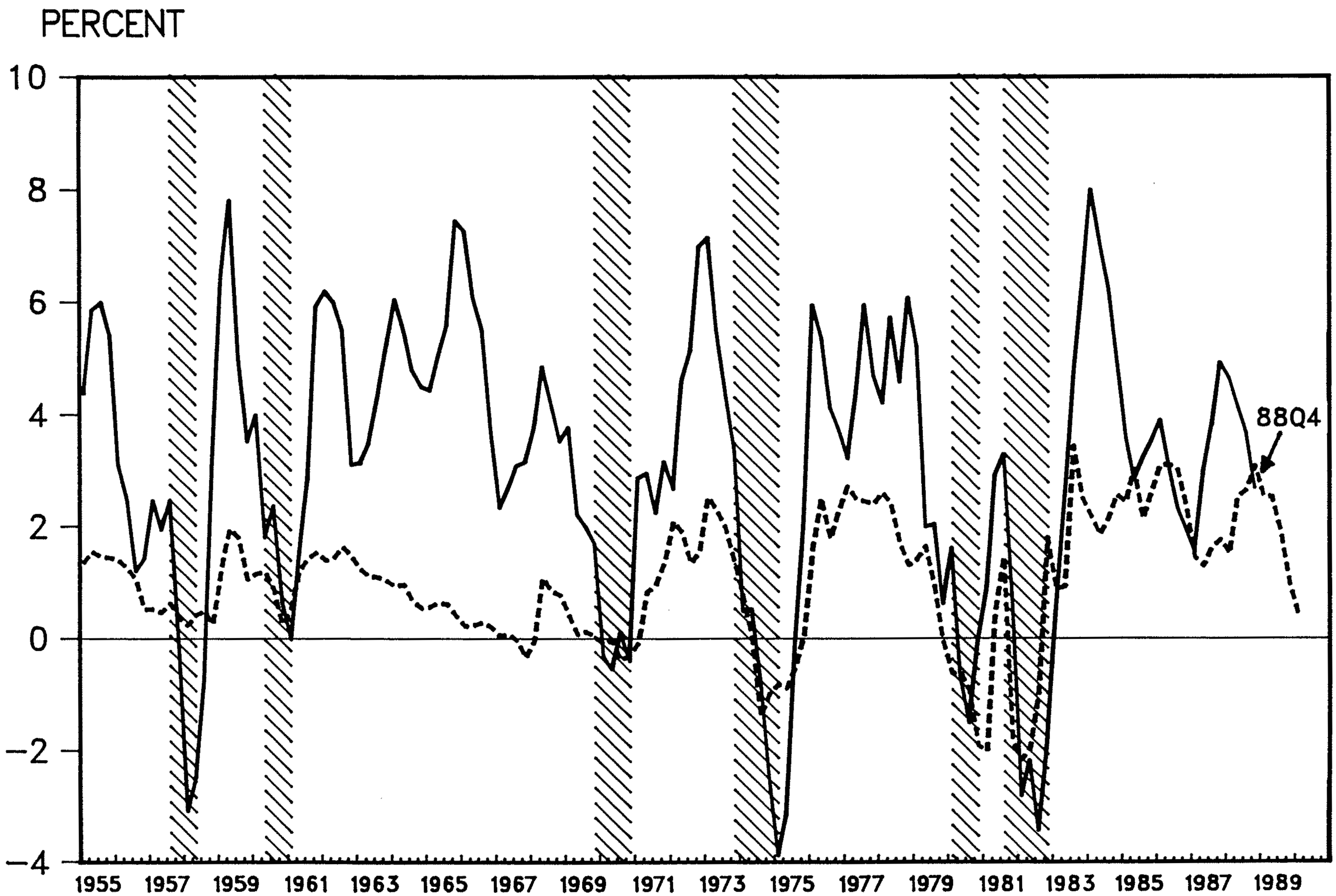
Predicting Cumulative Change in Alternative Measures of Real Output Using the Slope of the Yield Curve

Sample: Quarterly, 1959:1-1988:3

Quarters Ahead	Nobs	First Release SPREAD	First Release $\bar{R}^2$	Last Release SPREAD	Last Release $\bar{R}^2$
1	119	1.29* (.32)	.113	1.11* (.29)	.117
2	118	1.46* (.47)	.226	1.26* (.27)	.246
3	117	1.39* (.48)	.282	1.27* (.28)	.319
4	116	1.30* (.46)	.303	1.26* (.27)	.373
5	115	1.21* (.43)	.317	1.20* (.25)	.392
6	114	1.11* (.37)	.314	1.11* (.22)	.393
7	113	0.96* (.30)	.280	1.02* (.20)	.376
8	112	0.80* (.23)	.231	0.90* (.17)	.334
12	108	0.38* (.11)	.105	0.54* (.13)	.189
16	104	0.23* (.06)	.054	0.31* (.07)	.080
20	100	0.23* (.07)	.070	0.21* (.11)	.043

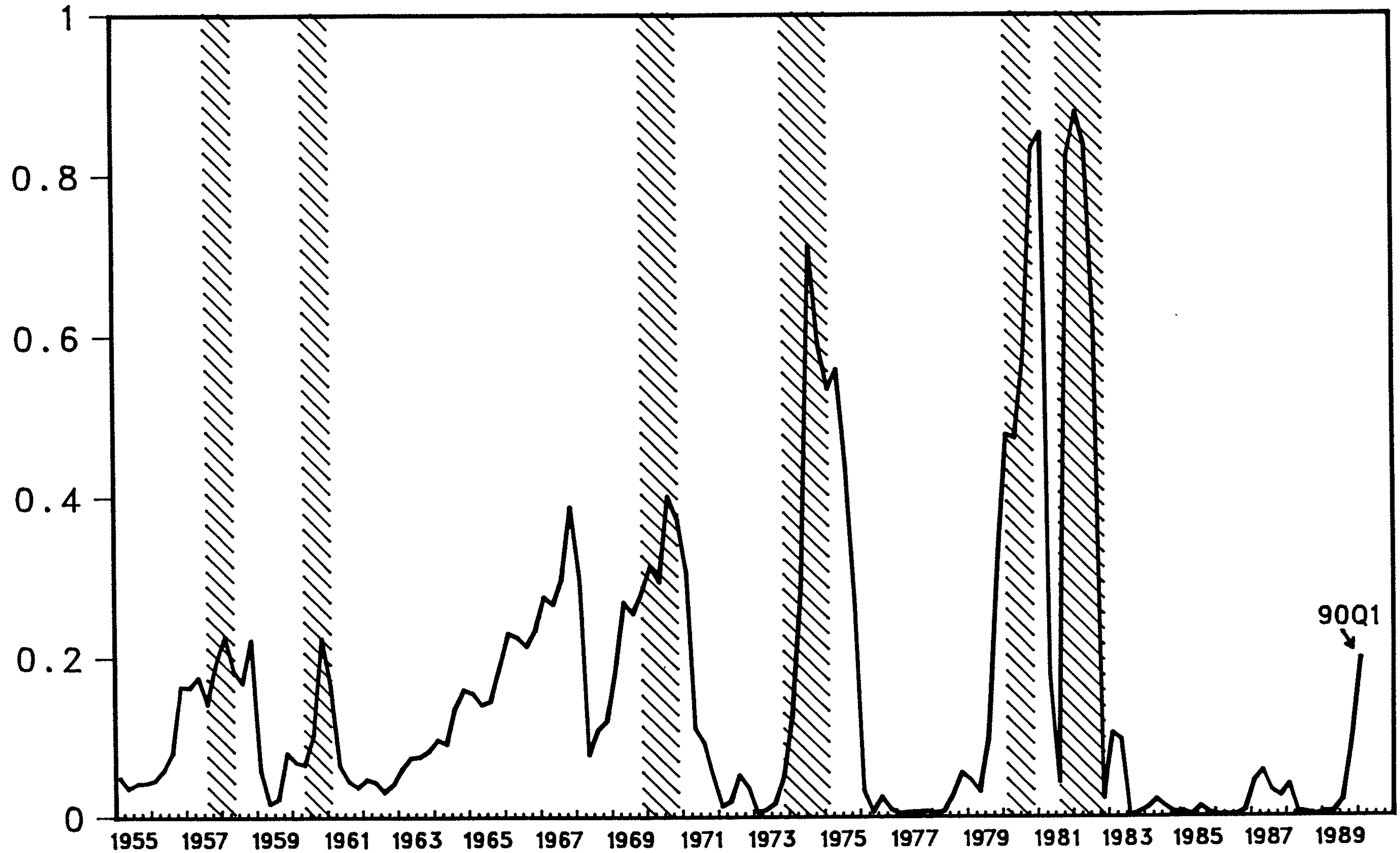
Notes: See the notes of Table 1. The regression equations include a constant term and SPREAD. First Release of GNP is as it appears in the Survey of Current Business adjusted to 1982 base prices. Last Release of GNP is as in previous tables (as it appears in the Citibase data banks as of February 1989).

FIGURE 1
GROWTH OF REAL GNP AND THE SLOPE OF THE YIELD CURVE



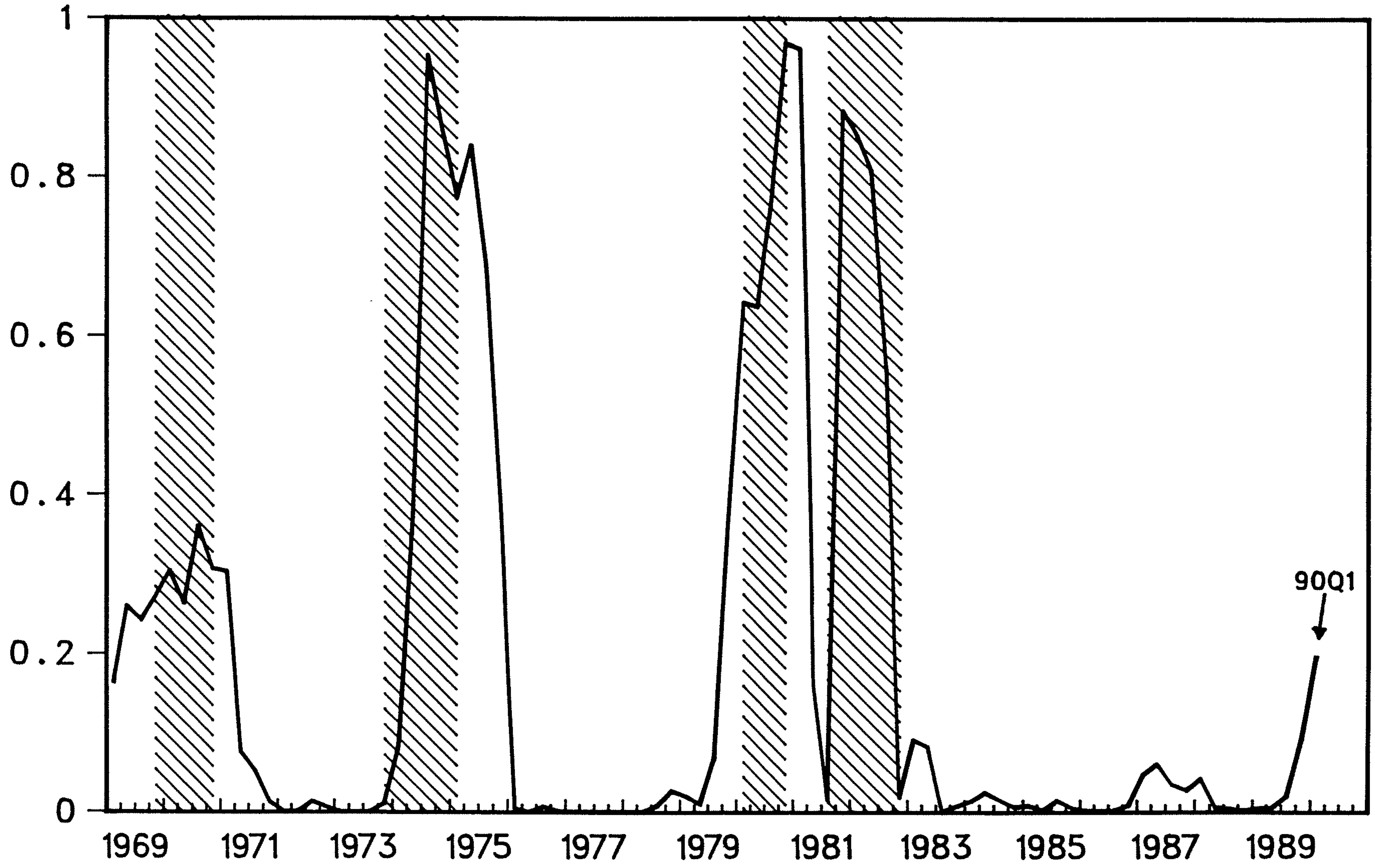
— ANNUALIZED REAL GNP GROWTH FROM QUARTER T−4 TO CURRENT QUARTER T
-- SLOPE OF YIELD CURVE AT QUARTER T−4
SHADED INTERVALS DENOTE RECESSIONS.

FIGURE 2
PROBABILITY OF RECESSION (WITHIN SAMPLE)
BASED ON YIELD CURVE SLOPE FOR QUARTER T-4



SHADED INTERVALS DENOTE RECESSIONS.

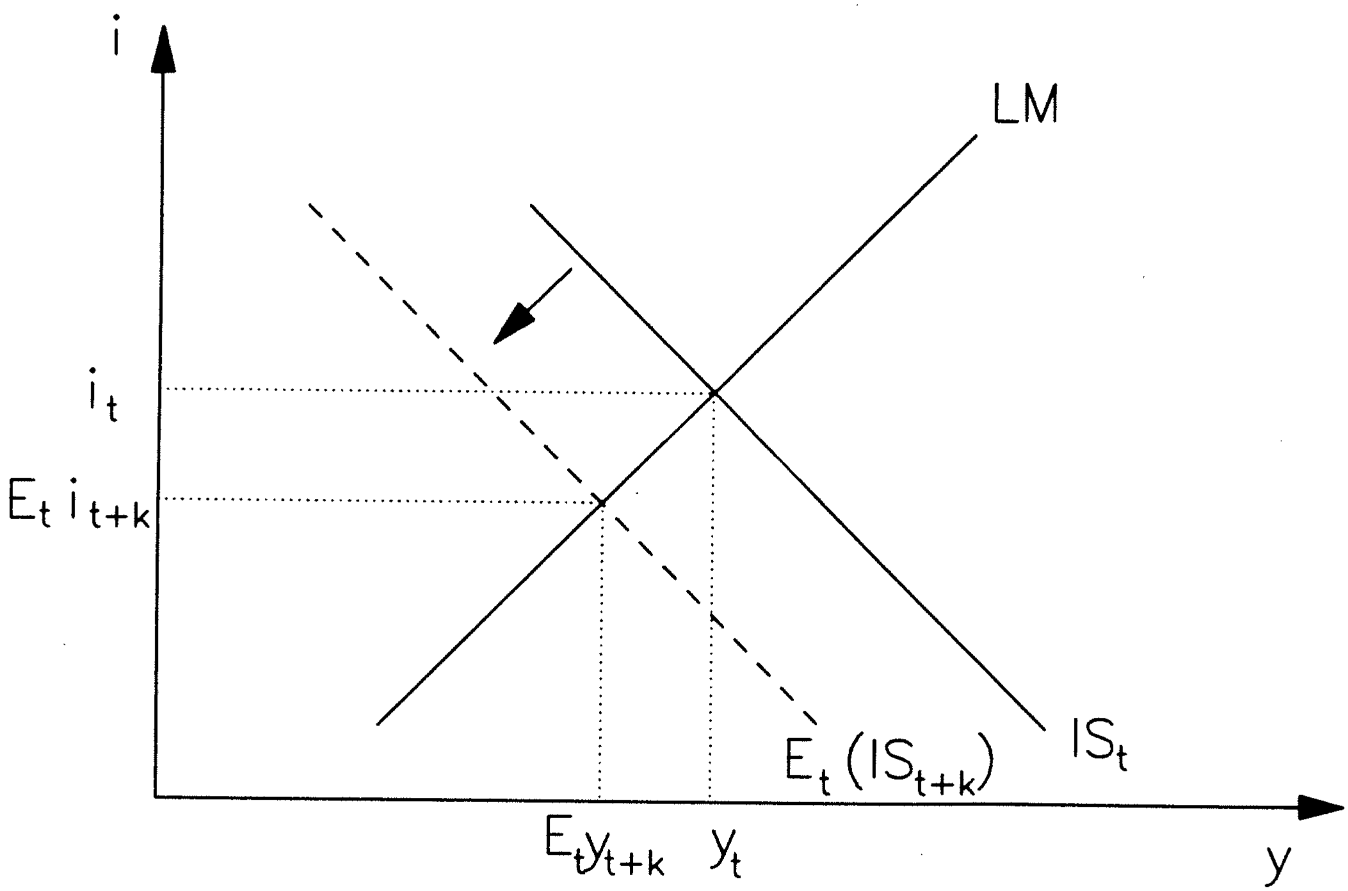
FIGURE 3
PROBABILITY OF RECESSION (OUT OF SAMPLE)
BASED ON YIELD CURVE SLOPE FOR QUARTER T-4



SHADED INTERVALS DENOTE RECESSIONS.

Figure 4

An Inverted Yield Curve and Market Expectations of a Recession
An Expected Future Shift of the IS Curve



Notes:
i_t = current short-term interest rate

$E_t i_{t+k}$ = current expectations of future short-term interest rate

y_t = current real output

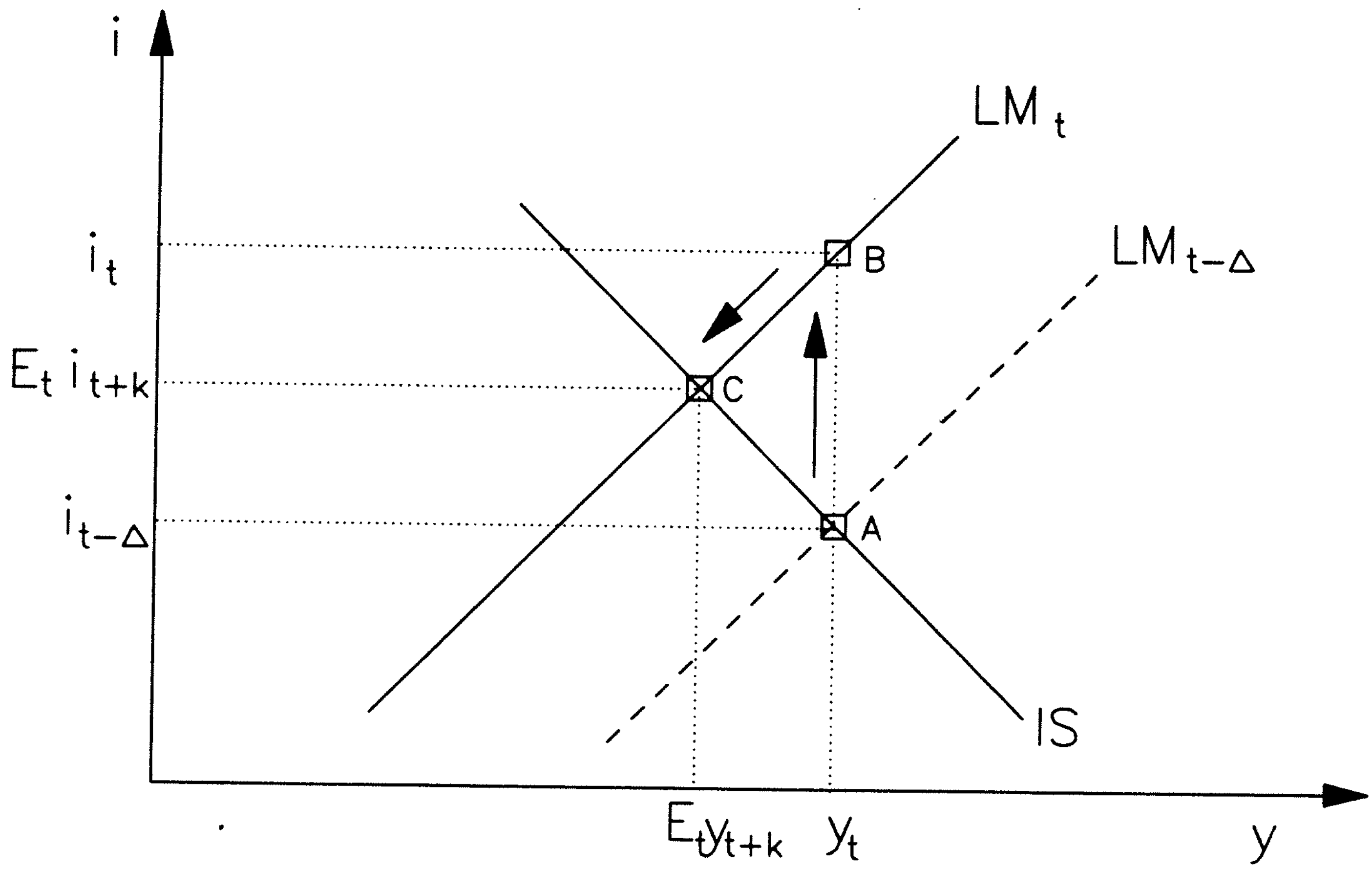
$E_t y_{t+k}$ = current expectations of future real output

IS_t = set of (i_t, y_t) pairs that satisfy equilibrium in goods market

LM_t = set of (i_t, y_t) pairs that satisfy equilibrium in money market

Figure 5

An Inverted Yield Curve and Market Expectations of a Recession
An Expected Future Movement along the LM Curve



Notes: See the notes of figure 4. During current period t, the goods market is in disequilibrium due to an upward shift of the LM schedule. Movement towards equilibrium along the LM curve is expected to occur gradually.