The Term Structure of Interest Rates, Inflationary Expectations and Economic Activity: Some Recent US Evidence

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EXECUTIVE SUMMARY

1 Short-term interest rates are typically expected to fall as an economy slows down and heads toward a recession. In response to comments that a negative-sloping yield curve for US Treasury securities is the harbinger of deflation in the US economy, this paper assesses the reliability of the yield curve in providing information about future inflation and economic activity.

2 Our analysis indicates that the positive relationship between yield spreads on Treasury securities of different maturities and future changes in inflation becomes more evident, as the difference in maturities increases. The strength of this relationship may be expressed as a function of the variations of the expected change in inflation and the *ex ante* real interest rate spread. We find that as we move along the Treasury yield curve, variations in expected inflation changes become large relative to variations in the real interest rate spread, so that inflation becomes the dominant factor driving the returns on Treasury securities. In other words, the relationship between the yield spread and future changes in inflation becomes stronger.

3 Next, we evaluate the effectiveness of the nominal term structure in predicting growth in real GDP. Our findings indicate that while yield spreads calculated using different segments of the yield curve are all statistically significant, the yield spread between three- and one-year Treasury bills provides the maximum predictive power of growth over the next one and two years. For a given segment of the yield curve, the forecasting power of the spread diminishes as the forecast horizon increases.

4 We also use the nominal term structure to forecast the probability of a recession. The results show that yield spreads from various segments of the yield curve are significant predictors of recessions four quarters ahead for the period 1960Q1 to 1998Q3. However, the forecasting power of our equation diminishes substantially when it is used to forecast the probability of a recession eight quarters ahead. Plots of the estimated probabilities show that they are relatively higher in

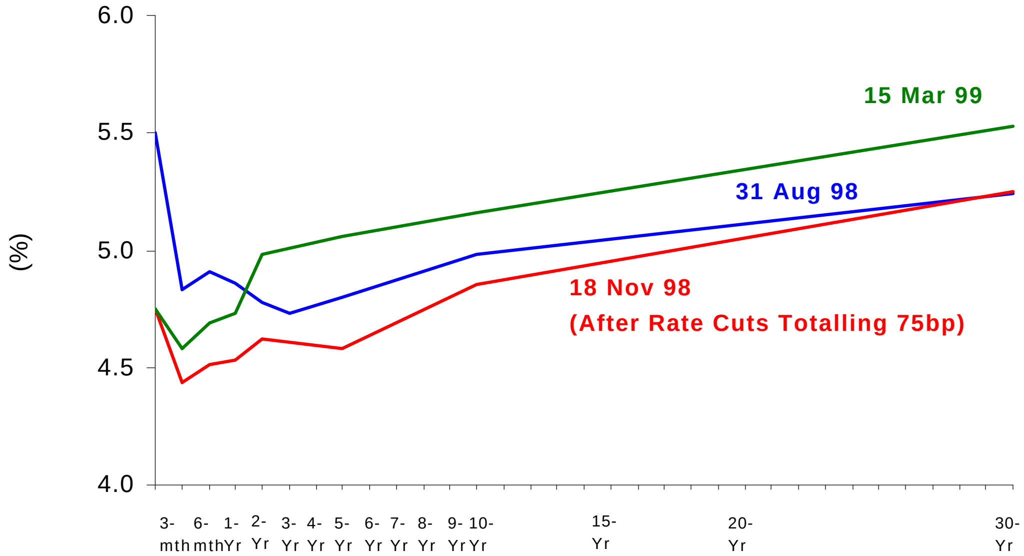
recession quarters than in non-recession quarters, although there a false alarm was generated in the early 1980s.

5 Based on our model estimates and the yield spread between three- and one-year Treasury bills, the probability of a recession in the next four quarters fell from 29% on 31 Aug 98 (before the rate cuts instituted by the Federal Reserve) to 27% on 4 Jan 99 (after the rate cuts) and 17% on 15 Mar 99. Furthermore, the positive yield spread between three- and one-year Treasury bills on 15 Mar 99 suggests that real GDP will grow by 3.0% over the next four quarters. This compares favourably with 1999 growth of 3.3% projected by Consensus Forecasts on 8 Mar 99.

1 INTRODUCTION

1.1 Before the series of cuts in the Federal funds rate by the Federal Reserve, analysts and market commentators have often cited the negative-sloping Treasury bond yield curve up to two years as one of the indicators that the US economy was heading towards a deflationary condition. However, following interest rate cuts of 25 basis points each on 29 Sep 98, 15 Oct 98 and 17 Nov 98 (totalling 75 basis points), the yield curve has become flatter. (See Figure 1.) This paper assesses the reliability of the yield curve in assimilating information about future inflation and economic activity, and in predicting the probability of a recession.

Figure 1
Treasury Yield Curve Before and After Rate Cuts



2 THE TERM STRUCTURE OF INTEREST RATES, ECONOMIC ACTIVITY AND INFLATIONARY EXPECTATIONS

2.1 The theoretical foundation of the yield curve as a predictor of real economic activity and future inflationary conditions is grounded in the expectation theory of the term structure. According to the expectation theory, an *n*-period nominal interest rate at time *t* should be equated to the expected nominal return on a one-period investment, rolled over *n* times, plus a certain term premium:

$$(1 + R_t^{(n)})^n = q_t^n + \prod_{i=o}^{n-1}(1 + E_t r_{t+i}^{(1)}) \quad (1)$$

where $R_t^{(n)}$ is the *n*-period interest rate and $r_t^{(1)}$ is the one-period interest rate, E_t is the conditional expectation formed at time t, and q_t is the time-varying term premium. Linearising, we have (approximately):

$$R_t^{(n)} \approx \frac{q^n}{n} + \frac{r_t^{(1)}}{n} + \sum_{i=1}^{n-1} E_t r_{t+i}^{(1)} \quad (2)$$

2.2 If the one-period interest rate is expected to increase in the future, (i.e. $E_t r_{t+j}^{(1)} > E_t r_{t+j-1}^{(1)}$ for all *j*), then the current long rate for maturity *n*, $R_t^{(n)}$, will rise above the current one-period rate, $r_t^{(1)}$. The yield curve will then be upward-sloping since $R_t^{(n)} > R_t^{(n-1)} > \ldots > r_t^{(1)}$. Even if the short-term rate is expected to remain constant, the yield curve would slope upward since the holders of longer-term securities would require a positive term premium to compensate them for the risk of capital loss in the event that future interest rates are higher than expected. The empirical evidence so far, however, has indicated that changes in the term premium are rather small compared to the shifts in the market expectation about future short-term rates in accounting for the changes in the slope of the yield curve. [Fama (1984)]

2.3 As the economy slows down, perhaps into a recession, short-term interest rates typically decline. According to the expectations theory, the longer-term rates should fall in order to equalise expected future holding period returns. How the yields of bonds of different maturities will actually respond will depend on market expectations about the time path of future short rates during the maturity periods of the securities. The short-term rates can be expected to decline as the economy heads toward a recession and exhibits deflationary conditions. This occurs for two reasons. First, the monetary policy is anticipated to loosen as measures are designed to stimulate the economy. Second, independent of the anticipated stance of future monetary policy, the lower future short-term rates could reflect the market expectation of low real returns during the period of economic contraction.

3 THE YIELD SPREAD AS A PREDICTOR OF FUTURE INFLATION

3.1 The theoretical framework that links the existing nominal yield curve spread with the future path of inflation is based on the Fisher relationship and the rational expectations version of the term structure of interest rates.

3.2 The Fisher equation states that the nominal interest rate on an *m*-period bond equals the *ex ante* *m*-period real interest rate and the expected inflation over the *m* holding period:

$$i_t^m = rr_t^m + E_t\, p_t^m \tag{3}$$

where i_t^m is the *m*-period nominal interest rate at time *t*, rr_t^m is the *ex ante* real interest rate at time *t*, p_t^m is the inflation rate from *t* to *(t+m)*, and E_t denotes the expectations at time *t*. Actual inflation over the *m* periods is:

$$p_t^m = E_t\, p_t^m + e_t^m \tag{4}$$

where e_t^m is the forecast error over the *m* periods. If expectations are rational, the forecast error would have zero mean, be serially uncorrelated and orthogonal to any relevant information known at time *t*. Substituting (4) into (3) yields:

$$p_t^m = i_t^m - rr_t^m + e_t^m \tag{5}$$

3.3 To obtain an expression on the relationship between the spread in the term structure of interest rates and future inflation, we subtract equation (5) from a similarly-specified *n*-period inflation equation (where *m* > *n*) to yield:

$$p_t^m - p_t^n = i_t^m - i_t^n - rr_t^m + rr_t^n + e_t^m - e_t^n \tag{6}$$

3.4 Following Mishkin (1990a, 1990b), we assume that the slope of the real interest rate is constant. This allows us to specify the following regression:

$$p_t^m - p_t^n = a_{m,n} + b_{m,n}(i_t^m - i_t^n) + m_t \qquad (7)$$

Note that the dependent variable represents the difference between the *m*-period inflation from time *t* to *(t+m)* and the *n*-period inflation from *t* to *(t+n)*. For example, for *m* = 2 years and *n* = 1 year, the regression seeks to determine the extent to which the current 2-year interest rate less the current 1-year interest rate is a good predictor of the average inflation rate over one year, one year from now. A value of $b_{m,n}$ that is statistically different from zero indicates that the slope of the interest rate yield curve and the size of its spread provides information about the direction of the future path of inflation. A value of $b_{m,n}$ that is not statistically different from one implies that nominal yield spread movements mirror only changes in inflationary expectations rather than changes in the term structure of real interest rates. This can be seen from equation (8), which is simply derived by subtracting $(i_t^m - i_t^n)$ from both sides of equation (7) and multiplying through by -1.

$$rr_t^m - rr_t^n = -a_{m,n} + [1 - b_{m,n}](i_t^m - i_t^n) - m_t \qquad (8)$$

A value of $b_{m,n}$ that is not statistically different from one indicates that the nominal yield curve reflects fully the information about future changes in inflation; and therefore, the nominal yield curve is unrelated to the real term structure.

3.5 Ordinary least squares (OLS) provides a consistent estimate of $b_{m,n}$ if rational expectations holds. Under rational expectations, the forecast errors, m_t, would be orthogonal to the regressor $(i_t^m - i_t^n)$. However, the OLS standard errors would be biased as a result of serial correlation in the regression error term. Serial correlation arises since we are employing monthly data to estimate regressions over longer inflation forecast horizons.

With monthly data, the regression error terms are likely to follow a moving-average process of order (12m - 1). We resolve this problem by using the Newey-West (1987) procedure to obtain consistent covariance matrices. The correlated standard errors will in general lead to correct inference asymptotically.

3.6 We estimated the inflation change equation (7) using month-average constant maturity yield data for the United States from the CEIC Database, where available, from April 1953 to October 1998. To evaluate the information content along a broad segment of the term structure of nominal interest rates, we employ yield data for maturities stretching from 3 months (US Treasury bills) to 5 years (Treasury bonds). The inflation data is calculated from the urban CPI series. Table 1 presents the results of our estimates for different *m* and *n* horizons.

3.7 The estimates indicate that the shorter end of the nominal term structure contains no information about the future movement of inflation. The coefficient of the (6 - 3) month Treasury bill spread is not statistically different from zero, implying that changes in the nominal yield spread at this maturity spectrum of the yield curve mainly reflects changes in the term structure of real interest rates. The coefficient of the (12 - 6) month Treasury bill spread is almost one, although it is not significant at the conventional level. As we move further up the yield curve, the statistical significance of the $b_{m,n}$ coefficient increases. In addition, along these segments of the yield curve, the null hypothesis that $b_{m,n} = 1$ cannot generally be rejected, thereby indicating that changes in the term structure relationship reflect mainly changes in inflationary expectations. Our findings here are consistent with the results obtained by Mishkin (1990a, 1990b) and Jorion and Mishkin (1991), for the US and other industrial countries. The results indicate that changes in the term structure at maturities over a year reflect mainly changes in bond market expectations about the future course of inflation.

Table 1
Estimates of Inflation Change Equations

m, n	Sample Period	$a_{m,n}$	$b_{m,n}$	R^2	*t*-test:$b_{m,n} = 1$
Months					
6,3	1982:1 - 1998:3	-0.021 (0.148) [0.889]	0.002 (0.564) [0.998]	0.00	3.131 [0.078]
12,6	1982:1 - 1997:9	-0.289 (0.222) [0.194]	0.945 (0.667) [0.158]	0.04	0.007 [0.934]
Years					
2,1	1976:6 - 1996:9	-0.261 (0.191) [0.174]	0.828 (0.269) [0.002]	0.11	0.408 [0.523]
3,1	1953:4 - 1995:9	-0.249 (0.151) [0.100]	1.444 (0.245) [0.000]	0.23	3.283 [0.071]
5,1	1953:4 - 1993:9	-0.120 (0.238) [0.614]	1.395 (0.305) [0.000]	0.24	1.674 [0.196]

Note: Figures in parentheses are standard errors corrected according to the Newey-West procedure. Figures in square brackets are p-values.

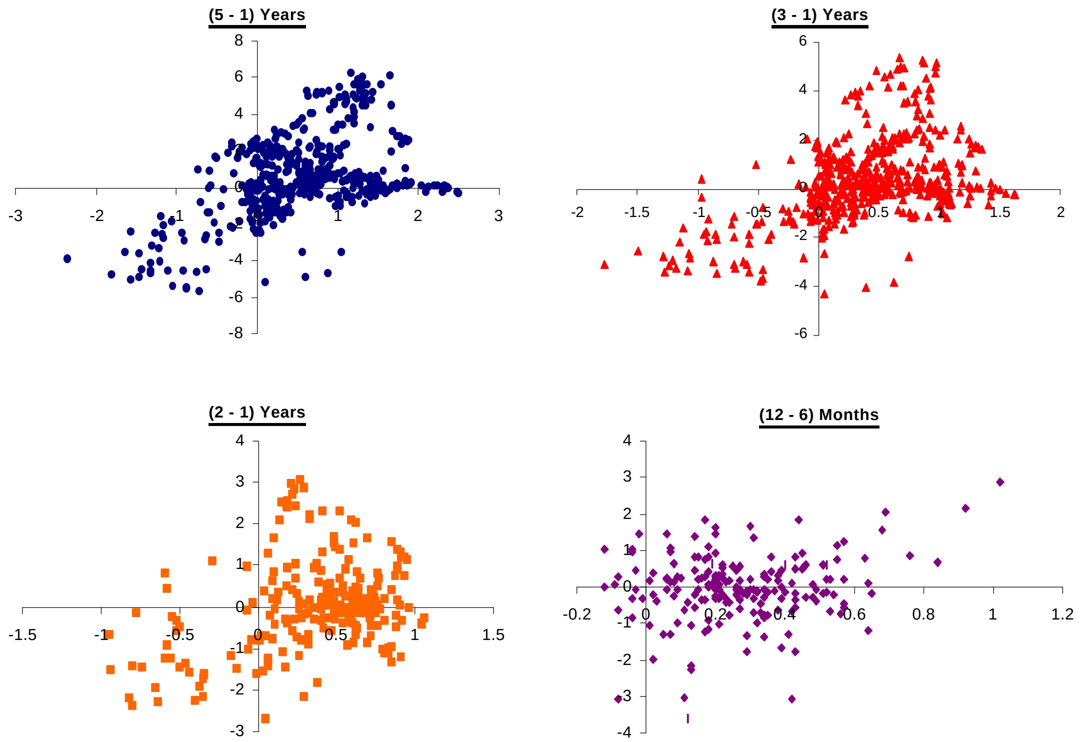
3.8 Graphically, the relationship between the maturity structure of the yield spread and future changes in inflation can be seen from the scatter plots in Figure 2. As the maturity increases, the positive relationship between the spread and the corresponding realised future inflation becomes more evident.

3.9 The ability of the longer-term maturity yield spread to forecast future changes in inflation relative to the shorter-term maturity spread can be explained in terms of the expression for $b_{m,n}$. [Fama (1984), Mishkin (1990)]:

$$b_{m,n} = \frac{s^2 + rs}{1 + s^2 + 2rs} \qquad (9)$$

where $s = s\ [E_t\ (p_t^m\ -\ p_t^n)]\ /\ s\ [rr_t^m\ -\ rr_t^n]$ = ratio of the standard deviation of the expected inflation change to the standard deviation of the real term structure, and r is the correlation between the expected inflation change $E_t(p_t^m - p_t^n)$ and the spread of the real term structure, $(rr_t^m - rr_t^n)$.

Figure 2
Scatter Plots of Realised Inflation Change Against Current Yield Spread



3.10 From (9), the $b_{m,n}$ coefficient is small when the variability of expected inflation change is small relative to the variability of the slope of the real term structure. In Table 2, we present our estimates of s and r for six pairs of m and n. To obtain an estimate of s, we need first to determine the expected inflation change. Following Mishkin (1990), we regressed the *ex post* real interest rate spread, $\overline{rr}^m - \overline{rr}^n$, against the current and four lags of the nominal yield spread, i^m - i^n, and four lags of the inflation change, p^m - p^n. The fitted values of the regression are taken to represent the *ex ante* real interest rate spread, rr^m - rr^n. We then subtract the fitted value from the nominal interest rate spread to obtain estimates of expected inflation rate change. The procedure is repeated for all *(m – n)* period combinations.

3.11 As Table 2 indicates, at the shorter end of the maturity spectrum, the variance of the expected change in inflation is smaller than the variance of the *ex ante* real interest rate spread. As we move along the yield curve, the variance of the expected inflation change becomes large relative to the variance of the real interest rate spread. Hence, as expected, inflation becomes the dominant factor in driving the returns on holding bonds relative to the real interest rate, the value of $b_{m,n}$ rises.

Table 2
The Relationship Between b, s, and r

m, n	Sample Period	r	s^2	$b_{m,n}$
6,3 months	1982:1 - 1998:3	-0.977	0.975	0.002
12,6 months	1982:1 - 1997:9	-0.964	1.065	0.945
2,1 years	1976:6 - 1996:9	-0.919	1.149	0.828
3,1 years	1953:4 - 1995:4	-0.879	1.296	1.444
5,1 years	1953:4 - 1993:9	-0.802	1.309	1.395

4 THE YIELD SPREAD AS A PREDICTOR OF ECONOMIC GROWTH AND RECESSION

4.1 In this section, we evaluate the effectiveness of the nominal term structure in predicting growth in real GDP and in forecasting the probability of an economic recession.

4.2 We estimate the following regression to evaluate the power of the yield spread to predict cumulative growth in real GDP for different forecast horizons:

$$(400/k)\,[(Y_{t+k} - Y_t) / Y_t] = l_0 + l_1 (i^m - i^n)_t + e_t \qquad (10)$$

where Y_t is the quarterly real GDP. We set the forecast horizon, k, to four and eight quarters ahead. The data we use is the seasonally-adjusted GDP series at 1992 prices obtained from the CEIC Database.

4.3 The regression results are presented in Table 3. While the spreads at different segments of the term structure are all statistically significant, it is the spread between the three- and one-year maturities that provides the maximum predictive power of growth over the next one and two years. For a given segment of the term structure, the forecasting power of the spread diminishes as the forecast horizon increases. The latter finding is consistent with the results obtained by Estrella and Hardouvelis (1991), Bonser-Neal and Morley (1997), and Haubrich and Dombrosky (1996) for the US. Similar findings for other industrial economies were obtained by Estrella and Mishkin (1997), Kozicki (1997), and Bonser-Neal and Morley (1997).

Table 3
Estimates of Real GDP Growth Equations

m, n (years)	*k* = 4 quarters		*k* = 8 quarters	
	λ_1	$\bar{R}^2$	λ_1	$\bar{R}^2$
3, 1	2.047 (0.518) [0.000]	0.208	1.546 (0.376) [0.000]	0.203
5, 1	1.405 (0.419) [0.001]	0.195	1.026 (0.310) [0.001]	0.178
10, 1	1.055 (0.336) [0.002]	0.190	0.725 (0.242) [0.003]	0.159

Note: Figures in parentheses are standard errors, while those in square brackets are p-values.

4.4 Next, we examine the ability of the term structure spread to predict the onset of a recession using a probit model described in Estrella and Mishkin (1998). In the probit model, the dependent dummy variable, R_t, takes a value of 1 if the economy is in recession in period *t* and 0 otherwise. We write:

$$Prob\ (R_t = 1) = f\ [S_0 + S_1\ (i^m - i^n)_{t-k}] + m_t \qquad (11)$$

where *f(.)* is the standard normal cumulative density function. The model is then used to forecast the probability of a recession at time t, on the basis of the observed yield curve at time *(t – k)*. The dating of the recession quarters are taken from Artis et al (1995), which were shown by the authors to have similar turning points to the NBER dates.

4.5 We estimated equation (11) using quarterly data from 1960Q1 to 1998Q3. The results are reported in Table 4. The estimates are obtained by setting k = 4 and 8 quarters respectively. The results show that the yield spreads, at different segments of the term structure, are significant predictors of recessions four quarters ahead. The statistical significance of the spread weakens considerably when it is used to forecast the probability of a recession eight quarters ahead. Similarly, the McFadden R^2 shows that the forecasting power of the equation declined substantially when it is used to forecast the probability of a recession eight quarters ahead when compared to forecasting the recession probability four quarters ahead.[1]

4.6 Figure 3 shows our estimates of the probability that the US economy will be in recession in a given quarter on the basis of the observed spread between the three- and one-year Treasury bond yields observed four and eight quarters earlier. Ideally, the probability should be 0 for non-recession quarters and should be 1 in the recession quarters. The recession quarters are shaded in Figure 3. In general, the estimated probabilities in the recession quarters are relatively higher than the probabilities in the non-recession quarters. The estimated probabilities are particularly high for the recession quarters 1974Q2-1975Q3 and 1984Q1-1984Q3. On the other hand, the estimated probabilities of the most recent recession quarters of 1989Q2- 1991Q1 are somewhat low. Note also the false alarm generated by the high estimated probabilities between the two recession periods during the early 1980s.

4.7 As indicated by the results presented in Table 4, the estimated probability of a recession based on the yield spread eight quarters earlier is less precise, and the values of the estimated probabilities during the recession quarters are much lower than the estimates obtained from the yield spread four quarters earlier.

1 The McFadden R^2 is computed as $\frac{1-l}{\tilde{e}}$, where l is the log-likelihood of the estimated model and $\tilde{e}$ is the restricted log-likelihood of the model estimated with only the constant term.

Figure 3
Estimates of the Probability of a Recession

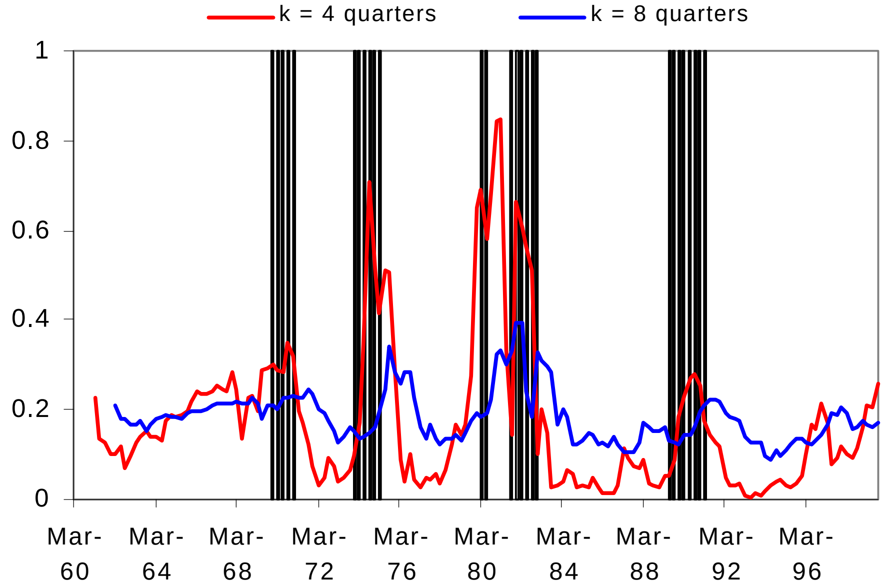


Table 4
Estimates of Probit Model of the Probability of a Recession

m,n (years)	*k* = 4 quarters			*k* = 8 quarters		
	S_0	S_1	Mc R^2	S_0	S_1	Mc R^2
3, 1	-0.625 (0.138) [0.000]	-1.232 (0.246) [0.000]	0.206	-0.769 (0.139) [0.000]	-0.374 (0.211) [0.075]	0.023
5,1	-0.600 (0.140) [0.000]	-0.989 (0.193) [0.000]	0.231	-0.758 (0.141) [0.000]	-0.281 (0.153) [0.067]	0.025
10,1	-0.605 (0.139) [0.000]	-0.763 (0.152) [0.000]	0.226	-0.775 (0.141) [0.000]	-0.191 (0.118) [0.104]	0.019

Note: Figures in parentheses are standard errors, while those in square brackets are p-values. Mc R^2 is the McFadden R-squared.

4.8 Finally, we generate the forecasts for changes in GDP and the probability of a recession four quarters ahead on the basis of the slope of the yield curve that was observed on 31 Aug 98, before the Federal Reserve initiated the three rounds of interest rate cuts totalling 75bp, and on

4 Jan 99 and 15 Mar 99. On the basis of the yield spread between three- and one-year Treasury securities of -0.13% on 31 Aug 98, our model forecasts real GDP growth of 2.2% over the following four quarters. The probability of a recession during the period is found to be 32%. After the series of Fed fund rate cuts, the entire term structure for US government securities shifted downward. The yield spread between three- and one-year Treasury securities narrowed to -0.02% on 4 Jan 99. On the basis of a narrower yield spread, our model forecasts growth over the next four quarters to be 2.4%. The probability of a recession during the next one year fell to 27%.

4.9 More recently, the yield curve has shifted upwards, while the yield spread between three- and one-year Treasury securities has become positive. Based on the (3 - 1) year yield spread of 0.28% on 15 Mar 99, the model forecasts GDP growth of 3.0% and a 17% probability of a recession over the next four quarters, suggesting an improved economic outlook for the US. This growth forecast compares favourably with the projections of private sector economists. The 8 Mar 99 publication of Consensus Forecasts projected US growth to be 3.3% in 1999.

REFERENCES

Artis, M.I., Z.G. Kontolemis and D.R. Osborn. 1995. "Classical Business Cycles for G7 and European Countries", *CEPR Discussion Paper 1137*.

Bosner-Neal, C. and T.R. Morley. 1997. "Does the Yield Spread Predict Real Economic Activity? A Multicountry Analysis", *Federal Reserve Bank of Kansas City Economic Review*, 82:37-53.

Estrella, A. and F.S. Mishkin. 1998. "Predicting U.S. Recessions: Financial Variables as Leading Indicators", *Review of Economics and Statistics*, 80:46-61.

Estrella, A. and G. Hardouvelis. 1991. "The Term Structure as a Predictor of Real Economic Activity", *Journal of Finance*, 46:555-576.

Fama, E.F. 1984. "Forward and Spot Exchange Rates", *Journal of Monetary Economics*, 14:319-338.

Fama, E.F. 1990. "Term Structure Forecasts of Interest Rates, Inflation and Real Returns", *Journal of Monetary Economics*, 25:59-76.

Haubrich, J.G. and A.M. Dombrosky. 1996. "Predicting Real Growth Using the Yield Curve", *Federal Reserve Bank of Cleveland Economic Review*, 26-35.

Jorion, P. and F.S. Mishkin. 1991. "A Multicountry Comparison of Term Structure Forecasts at Long Horizons", *Journal of Financial Economics*, 29:59-80.

Kozicki, S. 1997. "Predicting Real Growth and Inflation with the Yield Spread", *Federal Reserve Bank of Kansas City Economic Review*, 82:39-57.

Mishkin, F.S. 1990. "What Does the Term Structure Tell Us About Future Inflation?", *Journal of Monetary Economics*, 25:77-95.

Mishkin, F.S. 1990. "The Information in the Longer Maturity Term Structure About Future Inflation", *Quarterly Journal of Economics*, 55:815-828.

Mishkin, F.S. 1991. "A Multi-country Study of the Information in the Term Structure About Future Inflation", *Journal of International Money and Finance*, 19:2-22.

Newey, W.K. and K.D. West. 1987. "A Simple Positive Definite, Heteroscedasticity, and Autocorrelation Consistent Covariance Matrix", *Econometrica*, 55:703-708.

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