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THE INFORMATION IN THE LONGER MATURITY TERM STRUCTURE ABOUT FUTURE INFLATION

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ABSTRACT

This paper provides empirical evidence on the information in the term structure for longer maturities about both future inflation and the term structure of real interest rates. The evidence indicates that there is substantial information in the longer maturity term structure about future inflation: the slope of the term structure does have a great deal of predictive power for future changes in inflation. On the other hand, at the longer maturities, the term structure of nominal interest rates contains very little information about the term structure of real interest rates. These results are strikingly different from those found for very short-term maturities, six months or less, in previous work. For maturities of six months or less, the term structure contains no information about the future path of inflation, but it does contain a great deal of information about the term structure of real interest rates.

The evidence in this paper does indicate that, at longer maturities, the term structure of interest rates can be used to help assess future inflationary pressures: when the slope of the term structure steepens, it is an indication that the inflation rate will rise in the future and when the slope falls, it is an indication that the inflation rate will fall. However, we must still remain cautious about using the evidence presented here to advocate that the Federal Reserve should target on the term structure in conducting monetary policy. A change in Federal Reserve operating procedures which focuses on the term structure may well cause the relationship between the term structure and future inflation to shift, with the result that the term structure no longer remains an accurate guide to the path of future inflation. If this were to occur, Federal Reserve monetary policy could go far astray by focusing on the term structure of interest rates.

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I. Introduction

Research beginning with Fama (1975) and subsequent work by Nelson and Schwert (1977), Mishkin (1981), Fama and Gibbons (1982), and Huizinga and Mishkin (1986) supports the view that the level of interest rates have predictive power for inflation in the postwar United States.[1] Recent research has also focused on the information in the term structure about future interest rate movements.[2] Together these lines of research suggest that the term structure of interest rates might contain information about the future path of inflation.

An important reason for studying the information in the term structure about future inflation is that the Federal Reserve is currently considering using data on the term structure as a policy guide for assessing inflationary pressures in the economy. With the increasing doubts about the reliability of the money supply data as a target for monetary policy, it is not surprising that the Fed is looking at other data to guide them. Examining the ability of the term structure to predict the future path of inflation can provide some indication of whether such a Fed strategy of using term structure data to guide monetary policy makes sense.

Examining the ability of the term structure to predict the future path of inflation also provides evidence on the prevalent view that a downward sloping yield curve reflects expectations of a falling rate of inflation, while a steeply upward sloping yield curve indicates expectations of a rising rate of inflation. This prevalent view leads to examination of the behavior of the term structure, as in Blanchard (1984) and Dornbusch (1988), to decide whether anti-inflation policy

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[1]There is an exception in the period from October 1979 until October 1982 when the Federal Reserve dramatically changed its operating procedures (see Huizinga and Mishkin (1986)).

[2]Shiller, Campbell and Schoenholtz (1982) and Mankiw and Summers (1984), for example, have questioned the value of the term structure in predicting future short-term interest rates, while recent evidence in Fama (1984), Fama and Bliss (1987), Campbell and Shiller (1987), Hardouvelis (1988), and Mishkin (1988a) is more positive about the ability of the term structure to forecast future interest rates.

has been credible or not. Examining the validity of this prevalent view is thus important to debates about the credibility of anti-inflation policies which is central to evaluating the cost of anti-inflation policies.

Another reason for studying the information in the term structure about future inflation is that empirical evidence on this topic can indicate whether movements in the term structure of real interest rates (which are not directly observable) are revealed by movements in the term structure of nominal interest rates (which are observable). Since researchers who are constructing models of the business cycle or asset pricing often need to use stylized facts about the real term structure, assessing whether observable data on the nominal term structure provides them with information about the behavior of the real term structure is an important topic of research.

Recent research has begun to examine what information the term structure of interest rates contains about future inflation. Mishkin (1988b) examines the term structure for U.S. Treasury bills and finds that, for maturities of six months or less, the term structure of nominal interest rates provides almost no information about the future path of inflation. On the other hand, at this shorter end of the term structure, the term structure of nominal interest rates does contain a great deal of information about the term structure of real interest rates. However, for longer maturities of nine and twelve months, the term structure of nominal interest rates does appear to contain information about the future path of inflation, although it contains little information about the term structure of real interest rates. Using a somewhat different regression framework, Fama (1989) finds that at even longer maturities the term structure helps forecast the future path of inflation.

This paper conducts a further examination of the information in the term structure of nominal interest rates about future inflation and the term structure of real interest rates. It looks at the information in the longer maturity term structure by examining data from U.S. Treasury bonds with maturities of one to five years. The next section of the paper lays out the methodology, and it is followed by a discussion of some tricky econometric issues that are critical to correct interpretation of results with long maturity, term structure data. The empirical results and concluding remarks then complete the paper.

II. The Methodology

In examining the information in the term structure about future inflation, the empirical analysis in this paper primarily focuses on estimation of the following inflation-change forecasting equation,

$$(1) \qquad \pi_t^m - \pi_t^1 = \alpha_m + \beta_m[i_t^m - i_t^1] + \eta_t^m$$

where,

π_t^m = the realized inflation rate over the next m years, starting at time t,

i_t^m = the m-year nominal interest rate at time t.

In this equation, the change in the future m-year inflation rate from the 1-year inflation rate ($\pi_t^m - \pi_t^1$) is regressed on the "slope" of the term structure ($i_t^m - i_t^1$).

Tests of the statistical significance of the β_m coefficient and whether it differs from 1.0 reveal how much information there is in the slope of the term structure about future changes in inflation. More specifically, as is described in Mishkin (1988b), a statistical rejection of $\beta_m = 0$ provides evidence that 1) the term structure contains significant information about the future path of inflation, and 2) the slopes of the term structures of real and nominal interest rates do not move one-for-one with each other. On the other hand, a statistical rejection of $\beta_m = 1$ provides evidence that 1) the slope of the real term structure is not constant over time, and 2) the term structure of nominal interest rates provides information about the term structure of real interest rates.

Note that the phrase "information in the term structure" is being used in this paper quite narrowly. Information in the term structure about the path of future inflation refers only to the ability of the slope, $i_t^m - i_t^1$, to predict the change in the inflation rate, $\pi_t^m - \pi_t^1$. This paper focuses on the predictive power of the slope term, $i_t^m - i_t^1$, because it is the most natural piece of information in the term structure to examine.

Before going on to a discussion of the data and the empirical results, several econometric issues that have important consequences for hypothesis testing need to be discussed. As is now well known, the error term η_t^m will be serially correlated when the number of periods spanned by the interest rate and inflation are greater than the observation interval, as occurs in the following empirical analysis. In this overlapping data case, the forecast error is not realized until <u>m</u>-years in the future, with the result that it will follow a MA(12m-1) time series process. Asymptotically valid standard errors are generated here using the method outlined by Hansen and Hodrick [1980], with a modification due to White [1980] that allows for conditional heteroscedasticity, and a modification suggested by Newey and West [1987] that insures the variance-covariance matrix is positive definite. Although the corrected standard errors using the method described above will lead to correct inference asymptotically, previous research (Huizinga and Mishkin [1984], for example) indicates that there could be large differences between finite sample distributions and asymptotic distributions when there is a large amount of data overlap as in the empirical analysis in this paper.

To check out whether inference using asymptotic distributions might be misleading, a series of Monte Carlo simulations have been conducted. Table 1 reports the results from Monte Carlo simulations of one-thousand t-tests of the null hypothesis $\beta_m = 0$ in the inflation-change

Table 1

Monte Carlo Simulation Results
for t-test of $\beta_* = 0$

m (years)	Critical Values of $\underline{t}$ from Monte Carlos — Significance Levels 50%	25%	10%	5%	1%	% Rejections Using Asymptotic 5% Critical Value	% Rejections Using Asymptotic 1% Critical Value
	Panel A: Full Sample						
2	0.93	1.71	2.38	2.80	4.38	18.3%	7.7%
3	0.96	1.72	2.43	3.10	4.56	18.2%	8.5%
4	0.99	1.73	2.53	3.06	4.80	18.4%	9.4%
5	0.98	1.76	2.68	3.22	4.71	20.4%	11.3%
	Panel B: Pre-October 1979 Sample						
2	0.92	1.64	2.42	2.95	4.20	16.7%	7.5%
3	1.05	1.78	2.62	3.10	4.31	21.6%	10.6%
4	1.07	1.83	2.63	3.28	4.73	22.0%	10.4%
5	1.09	1.78	2.98	3.54	5.69	21.2%	14.7%
	Panel C: Post-October 1979 Sample						
2	1.33	2.49	4.04	5.26	8.76	33.6%	23.3%
3	1.82	3.33	5.54	7.15	11.30	47.0%	35.5%
4	2.29	4.25	7.30	9.62	16.96	55.7%	45.2%
5	2.65	5.11	8.75	11.54	21.84	59.7%	50.9%

forecasting equation (1) using the Hansen-Hodrick-White-Newey-West estimation method described above.[3] The table contains results for the regressions with **m** = two to five years, and for three sample periods: Panel A for the full sample which has over three hundred and fifty observations, Panel B for the pre-October 1979 sample which has three-hundred and twenty-two observations, and Panel C for the post-October 1979 sample with less then seventy-five observations.

As the last two columns of Table 1 indicate, inference from using the asymptotic distribution can be highly misleading, even when the number of observations is in excess of three hundred and fifty. Using the 5% critical value from the asymptotic distribution, over 18% of the t-statistics from the Monte Carlo simulations using the full sample (Panel A) indicate rejection of the null hypothesis when it is true. Not surprisingly, the bias of the asymptotic distribution gets worse as the degree of overlap increases with increasing **m**. When we get to the Panel C results which have under one hundred observations, the degree of bias becomes especially severe. For

[3]For the Monte Carlo simulations, the inflation rates and the $i_t^m - i_t^1$ spread variables were constructed from ARMA models whose parameters were estimated from the relevant sample periods. Because Lagrange-multiplier tests described by Engle [1982] reveal the presence of ARCH (autoregressive conditional heteroscedasticity) in the error terms, the error terms are drawn from a normal distribution in which the variance follows an ARCH process whose parameters were also estimated from the relevant sample periods. Start-up values for AR terms in the times series models are obtained from the actual realized data from five and six years before the sample period, and then four years of draws from the random number generator produce start-up values for the error terms. Then a sample size corresponding to the relevant regression is produced using errors drawn from the distribution described above. To check out the robustness of the Monte Carlo results, I also conducted experiments where the error terms were assumed to be i.i.d. rather than ARCH and also where the parameters of the ARIMA and ARCH processes were estimated only from the full sample period; the results were very similar to those reported in the text. The Monte Carlo results reported in the text assume that the error terms for the inflation and yield slope equations are independent. Mankiw and Shapiro [1986] and Stambaugh [1986], however point out that if the data generating mechanism has yield spreads correlated with past inflation rates because of contemporaneous correlation between their error terms, the small sample distribution of test statistics can be substantially affected. This problem is not an important one in the data here because the correlations between error terms from yield spread and inflation equations were found to be small and statistically insignificant. Monte Carlo simulations which allowed for this correlation as in Mankiw and Shapiro [1986] and Stambaugh [1986] as well as for additional effects of past inflation on yield spreads, were not appreciably different from those reported in the text.

example, using the 1% critical value from the asymptotic distribution, over fifty percent of the t-statistics for **m** = 5 indicate a rejection of the null when it is true.

The second through sixth columns of Table 1 provide more information about the characteristics of the finite sample distribution by providing the critical values for different marginal significance levels. In Panel A and Panel B, the 5% critical values of the finite distribution are around 3.0 rather than 2.0 as with the asymptotic distribution, while the 1% critical values of the finite distribution are over 4.0. For samples with less than one hundred observations in Panel C, the 5% critical values of the finite sample distribution always exceed 5.0 and the 5% critical value for **m** = 5 is in the double digits.

Additional Monte Carlo experiments along the lines of those described in Table 1 have been conducted for t-tests of $1 - \beta_m = 0$ and for regressions which examine the predictive ability of forward rates. They produce results which are quite close to those in Table 1 and are not reported here in order to conserve space.

The additional experiments and those reported in Table 1 indicate that we must be quite careful in conducting inference using asymptotic distributions when the data has a large amount of overlap (which ranges from 23 periods for monthly observations with **m** = 2 years, to 59 periods for monthly observations for **m** = 5 years). For this reason, all critical values and marginal significance levels of every test statistic reported in the following empirical analysis have been obtained from Monte Carlo simulation results.

III. The Data

The empirical analysis makes use of monthly data from 1953 to 1987 for inflation rates and interest rates on one through five year Treasury bonds. The inflation and interest rate data are all in percent at an annual rate. The inflation data is calculated from a CPI series which appropriately treats housing costs on a rental-equivalence basis throughout the sample period. For more details on this series, see Huizinga and Mishkin (1984, 1986). The interest rate data is McCulloch's (1987, Table A-1) zero coupon yield curve series which is continuously compounded, end--of-month data. Because interest rate data for longer term bonds must be obtained by fitting a yield curve through interest rates on the maturities available and then using the fitted values for the desired maturity dates, it is worthwhile checking whether results are robust to a different procedure for constructing the data set. To this end, all the regressions in this paper have also been run with an alternative data set constructed by Fama and Bliss (1987), which has been obtained from the Center for Research and Security Prices (CRSP) data tape. There are no major differences between the results from the Fama and Bliss data set versus the McCulloch data set. However, standard errors of coefficients tended to be somewhat smaller with the McCulloch data set, so the results with this data set are the ones reported in the text.

The timing of the variables is as follows. A January 1980 interest rate observation, for example, uses the end of December 1979 bond rate data. A January 1980 observation for the one-year inflation rate is calculated from the December 1979 and December 1980 CPI; a two-year inflation rate from the December 1979 and December 1981 CPI; and so on.[4]

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[4]Since the last CPI observation is December 1987, the last observation for the full sample in a regression when **m** = 2 years is December 1985; for **m** = 3 years it is December 1984; for **m** = 4 years it is December 1983; and for **m** = 5 years it is December 1982. Note also that the appropriate dating for the CPI in a particular month is not clear since price quotations on the component items of the index are collected at different times during the month. As a result there is some misalignment of the inflation data and the interest rate data which is calculated for the end of the month. To see if this misalignment could have an appreciable effect on the results, the regressions in this paper have also been estimated lagging the interest rate one month (i.e., for the January 1980 observation, I used the November 1979 bond rate). Not surprisingly, the results with the lagged interest rate data are very close to those found in the text.

V. The Empirical Results

Table 2 contains the estimates of the inflation-change forecasting equations for horizons of one through five years. Panel A contains the results for the full sample period, while Panel B reports the results for the pre-October 1979 period and Panel C the results for the post-October 1979 period. The sample has been split into these two sub-periods because results in Clarida and Friedman (1984), Huizinga and Mishkin (1986) and Roley (1986) indicate that the relationship of nominal interest rates and inflation shifted dramatically with the monetary regime change of October 1979.[5]

The results in Table 2 indicate that there is a great deal of information in the longer maturity term structure about the future path of inflation. For the full sample in Panel A, the β_m coefficients at all horizons are positive and significantly different from zero (as indicated by the t-tests of $\beta_m = 0$), and for $m = 4$ and $m = 5$ the β_m coefficients are even significant at the 1% level. (Recall that statistical significance is determined using critical values derived from the finite sample distribution obtained from Monte Carlo simulations.) Furthermore, the R^2's of the forecasting regressions are quite high, particularly for the longer horizons: indeed for $m > 3$, over forty percent of the variation in the change in inflation is explained by forecasts using the slope of the term structure.

The results for the two sub-periods also reach the same conclusion that the term structure for maturities greater than a year contains a great deal of predictive power for changes in future inflation. The results are even somewhat stronger for the pre-October 1979 period in Panel B, with all the β_m significant at the 5% level and three out of four significant at the 1% level. In addition, the R^2's of the forecasting regressions are higher than in the full sample. The post-

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[5]The sample is not split again in October 1982, as in Mishkin (1988b), because with the long horizons used in this paper there are often few data points after October 1982. For example, with m = 5 years, the last data point is December 1982.

Table 2

Estimates of Inflation-Change Forecasting Equations

$$\pi_t^m - \pi_t^1 = \alpha_m + \beta_m[i_t^m - i_t^1] + \eta_t^m$$

m (years)	α_m	β_m	R^2	SE	t-test of $\beta_m=0$	t-test of $1-\beta_m=1$
			Panel A: Full Sample			
2	-0.1439	1.0641	0.199	0.750	3.08*	-0.19
	(0.1152)	(0.3452)				
3	-0.2804	1.4096	0.306	1.097	3.38*	-0.98
	(0.1738)	(0.4167)				
4	-0.3568	1.6795	0.422	1.214	4.82**	-1.95
	(0.2359)	(0.3487)				
5	-0.3508	1.7700	0.480	1.265	8.08**	-3.52*
	(0.3367)	(0.2190)				
			Panel B: Pre-October 1979 Sample			
2	-0.0546	1.5426	0.309	0.654	4.40**	-1.55
	(0.1047)	(0.3503)				
3	-0.1634	1.9506	0.451	0.916	5.90**	-2.88
	(0.1575)	(0.3305)				
4	-0.2322	2.0569	0.546	0.983	7.27**	-3.74*
	(0.2195)	(0.2829)				
5	-0.1905	1.8280	0.498	1.093	5.62*	-2.55
	(0.3393)	(0.3250)				

Table 2 Continued

m (years)	α_m	β_m	R^2	SE	t-test of $\beta_m=0$	t-test of $1-\beta_m=1$
			Panel C: Post-October 1979 Sample			
2	-0.7793 (0.1152)	0.8749 (0.1835)	0.320	0.694	4.77	0.68
3	-1.3962 (0.1763)	0.7514 (0.0665)	0.445	0.719	11.30**	3.74
4	-1.8124 (0.2239)	0.7412 (0.0539)	0.445	0.858	13.75*	4.80
5	-2.1476 (0.3459)	0.7468 (0.1567)	0.340	1.124	4.77	1.62

Notes for all tables:

Asymptotic standard Errors of coefficients in parentheses.
SE = standard error of the regression.
* = significant at the 5% level using Monte Carlo results.
** = significant at the 1% level using Monte Carlo results.

October 1979 results in Panel C are somewhat weaker than the pre-October 1979 results: the R^2's of the regressions are lower and only two of the β_m coefficients are significant. However, the β_m coefficients still always remain positive and the R^2's are still quite high.

The results found in Table 2 are quite different from those found in Mishkin (1988b) for term structure maturities of one to twelve months. For maturities under nine months, the term structure contains no information about future changes in inflation: R^2's of regressions similar to those in Table 2 are never larger than .05. Even though for maturities of nine and twelve months Mishkin (1988b) finds that there is significant information about the path of future inflation, the R^2's of the forecasting regressions are still quite low, typically below .10. Taking these results and those in Table 2 together suggests that the term structure provides better forecasts of future changes in inflation at longer maturities.[6]

The t-tests of $1 - \beta_m = 0$ in the last column of Table 2 indicate that the nominal term structure for maturities greater than one year contains very little information about the term structure of real interest rates. Only in two cases can the null hypotheses that the slope of the real term structure is constant or that the slope of the nominal term structure reveals no information about the slope of the real term structure be rejected. However, even in these two cases of statistically significant $[1 - \beta_m]$ terms, the $[1 - \beta_m]$ are negative, indicating a negative correlation of the slope of the real term structure with the slope of the nominal term structure. Indeed for the full sample in Panel A and the pre-October 1979 sample of Panel B, all of the $[1 - \beta_m]$ terms

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[6]Another way to look at the information in the term structure follows along the lines of Fama (1984) who looks at whether forward rates help predict future changes in one-month interest rates. Table A1 in the appendix looks at whether forward rates help predict future changes in the one-year inflation rate; it reports regressions of the change in the one-year inflation rate, $\pi^1_{t+m} - \pi^1_t$, on the forward-spot rate differential at time t, $f_{t+m} - i^1_t$. (f_{t+m} = the forward rate at time t for the one-year interest rate m-years in the future.) For both the full sample period and the pre-October 1979 sample period, forward rates do have significant explanatory power for changes in one-year inflation rates up to three years out into the future. However, by the time one goes four years out, the forward-spot differential no longer has a significant β_m coefficient. This suggests that the information in the term structure about future inflation may begin to decrease when maturities begin to exceed five years.

are negative; only in the post-October 1979 period are the $[1 - \beta_m]$ terms positive, suggesting a positive correlation of the slopes of the nominal and real term structures.

Again the results on tests of $1 - \beta_m = 0$ in Table 2 are quite different than those found for shorter maturities in Mishkin (1988b). In contrast to the results in Table 2, Mishkin (1988b) finds that for maturities of six months or less the nominal term structure contains a great deal of information about the term structure of real interest rates. Indeed, the hypothesis that the slopes of the real and nominal term structure move one-for-one with each other cannot be rejected for these shorter maturities. This is exactly the opposite of what is found for the longer maturities reported on in Table 2, where there is typically a negative relationship between the slopes of the nominal and real term structure.

Because there are differences in the β_m coefficients between the pre and post-October 1979 periods, with the β_m coefficients declining somewhat in the post-October 1979 period, it is worth asking whether these differences across the sub-periods are statistically significant. Table 3 reports on the results of tests for parameter shifts in the inflation change equations. As can be seen from the marginal significance levels of these tests, in no case can the null hypothesis that the coefficients are equal in the two periods be rejected at the 5% level. However, because the change in the coefficients across the periods is substantial in magnitude, the failure to reject equality of the coefficients may be a reflection of the low power of the tests.

A. Interpretation

The most striking feature of the Table 2 results is how different they are from those found at shorter maturities of the term structure in Mishkin (1988b). What explains why there is so much more information in the term structure about future inflation at longer maturities then there is at shorter maturities?

Table 3

Tests for Parameter Shifts in the Inflation-Change Forecasting Equations

m (years)	Test of Shift in β_m $\chi^2(2)$ =	Marginal Significance Level	Tests of Shift in α_m and β_m $\chi^2(4)$ =	Marginal Significance Level
2	2.94	0.35	23.11	0.09
3	12.42	0.13	47.90	0.06
4	21.09	0.07	52.94	0.08
5	7.37	0.24	29.22	0.26

Tests of the null hypothesis that the parameters are equal in the pre-October 1979 and post-October 1979 sample periods.

Note that the marginal significance levels are derived from Monte Carlo simulations.

We can answer this question under the assumption of rational expectations by deriving the following formula for the inflation-change, forecasting equation β_m along the lines suggested by Fama (1984) and Hardouvelis (1988).

$$(7) \qquad \beta_m = \frac{\tilde{\sigma}^2 + \rho\tilde{\sigma}}{1 + \tilde{\sigma}^2 + 2\rho\tilde{\sigma}}$$

where,

$\tilde{\sigma}$ = $\sigma[E_t(\pi_t^m - \pi_t^1)]/\sigma[rr_t^m - rr_t^1]$ = the ratio of the standard deviation of the expected inflation change to the standard deviation of the slope of the real term structure,

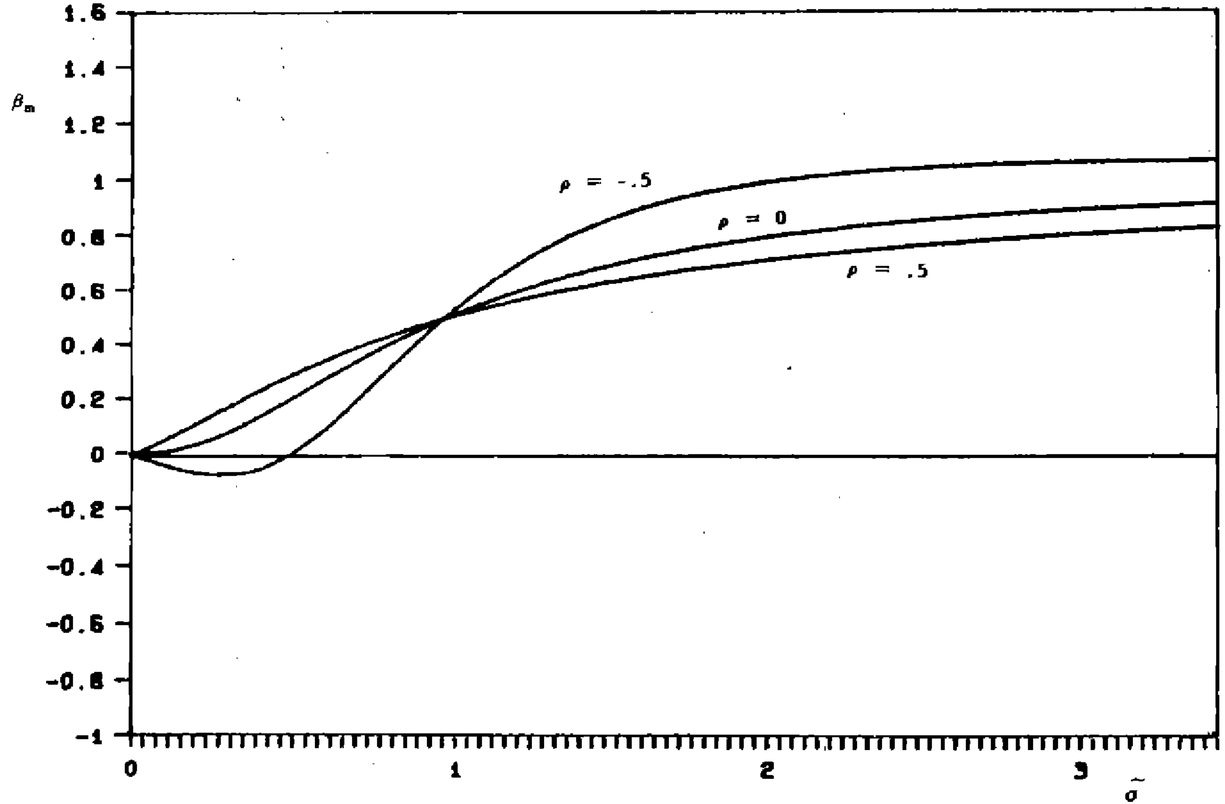
ρ = the correlation between the expected inflation change, $E_t(\pi_t^m - \pi_t^1)$, and the slope of the real term structure, $rr_t^m - rr_t^1$.

This expression is derived by writing down the standard formula for the projection equation coefficient β_m, and recognizing that the covariance of the inflation forecast error with $rr_t^m - rr_t^1$ equals zero given rational expectations.

The equation above indicates that β_m is determined by how variable the expected inflation change is relative to the variability of the slope of the real term structure [represented by $\tilde{\sigma}$, the ratio of the standard deviations of $E_t(\pi_t^m - \pi_t^1)$ and $(rr_t^m - rr_t^1)$], as well as by the correlation of the expected inflation change with the real term structure slope (ρ). Figure 1 shows how β_m varies with $\tilde{\sigma}$ and ρ. The key fact visible in Figure 1 is that β_m will be substantially above zero if the variability of expected inflation changes is greater than the variability of real term structure slopes so that $\tilde{\sigma}$ is greater than one.

We can calculate estimated values of $\tilde{\sigma}$ and ρ using the procedure outlined in Mishkin

Figure I



How β_m Varies with $\tilde{\sigma}$ and ρ

(1981), in which estimates of $rr_t^m - rr_t^1$ are obtained from fitted values of regressions of the ex-post real rate differentials on past inflation changes and past interest rate spreads.[7] Then the estimated expected inflation change is calculated from the following definitional relationship,

$$(8) \qquad E_t(\pi_t^m - \pi_t^1) = i_t^m - i_t^1 - (rr_t^m - rr_t^1)$$

Finally estimates of $\tilde{\sigma}$ and ρ are calculated from the estimated $E_t(\pi_t^m - \pi_t^1)$ and $(rr_t^m - rr_t^1)$.

The above calculations readily explain why the $\hat{\beta}_m$ estimated at the longer maturities in this paper are so much higher than those found in Mishkin (1988b) at shorter maturities, particularly under nine months. For the longer maturities studied in this paper, the variation in expected inflation changes are substantially greater than the variation in real term structure slopes. In the full sample period, the $\tilde{\sigma}$'s at all horizons are above 2.0, while in the two sub-samples the $\tilde{\sigma}$'s hover around 1.5. As we can see in Figure 1, these high $\tilde{\sigma}$'s lead to high β_m's. On the other hand at shorter maturities under nine months, the variability of expected inflation changes are dominated by the variability of the real term structure slopes, so that the resulting small $\tilde{\sigma}$'s generate low estimated β_m's.

Empirical research that has investigated the time-variation of term premiums[8] provide a rationale why the $\tilde{\sigma}$'s are so much lower at the shortest end of the term structure and hence why only at longer maturities is the term structure able to provide information about the future path of inflation. Variation in the slope of the real term structure can be attributed to the variation

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[7]The estimates described in the text were generated from OLS regressions in which the ex-post real rate differential, $eprr_t^m - eprr_t^1$, was regressed on $i_t^m - i_t^1$, this differential lagged one through five years, and on the inflation change $(\pi^m - \pi^1)$ lagged two to five years, not including lagged values if they are not realized at time t. I also experimented with other choices of lags and the estimated values of σ and ρ were robust to different specifications of the regression equations.

[8]Startz (1982), Jones and Roley (1983), Shiller, Campbell and Schoenholtz (1983), Fama (1984), Mankiw and Summers (1984), and Fama and Bliss (1987).

of term premiums over time as well as changes in the average of expected one-period real interest rates over the next **m**-periods versus the next **n**-periods. High variation in these term premiums will then produce high variation in the slope of the real term structure and make it more likely that the variation of the real term structure slope will dominate the variation of expected future inflation changes. However, research such as Fama and Bliss (1987) has found that variation in these term premiums is less important at longer maturities, and so at longer maturities it is more likely that the variation of expected inflation changes will now dominate the variation of real term structure slopes. The corollary of this argument is that at longer maturities in which the variation in term premiums no longer dominates, the term structure of nominal interest rates should contain very little information about the term structure of real interest rates.

The estimates of ρ, along with those for $\tilde{\sigma}$ discussed above, help explain the pattern of the $\hat{\beta}_m$ coefficients in Table 2. For the Panel A, full sample, the estimated ρ's are negative at all horizons and decline as **m** lengthens, reaching the most negative value of -0.4 for **m** = 5. As Figure 1 indicates, β_m will grow as the maturity lengthens and the ρ becomes more negative. The Panel B, pre-October 1979 sample displays similar estimated values of ρ with a similar pattern, except that ρ stops declining at **m** = 4 and rises somewhat, which explains why the $\hat{\beta}_m$ coefficient does not rise as we move from **m** = 4 years to **m** = 5 years. The Panel C, post-October 1979 sample, on the other hand, has estimated ρ's that are positive, ranging from .10 to .35, leading to lower $\hat{\beta}_m$'s. Not too much should be made, however, of this decline in $\hat{\beta}_m$'s in the post-October 1979 sample periods because there isn't enough data to indicate that this decline is statistically significant.

VI. Conclusions

This paper provides empirical evidence on the information in the term structure for longer maturities about both future inflation and the term structure of real interest rates. The evidence indicates that there is substantial information in the longer maturity term structure about future inflation: the slope of the term structure does have a great deal of predictive power for future changes in inflation. These results are consistent with those in Fama (1989) who also finds that at longer maturities the term structure helps forecast future inflation. On the other hand, at the longer maturities, the term structure of nominal interest rates contains very little information about the term structure of real interest rates. These results are strikingly different from those found for very short-term maturities, six months or less, in previous work. For maturities of six months or less, the term structure contains no information about the future path of inflation, but it does contain a great deal of information about the term structure of real interest rates.

The evidence in this paper does indicate that, at longer maturities, the term structure of interest rates can be used to help assess future inflationary pressures: when the slope of the term structure steepens, it is an indication that the inflation rate will rise in the future and when the slope falls, it is an indication that the inflation rate will fall. Furthermore, the results here also lend support to research which uses the term structure spread between long (over two years) and short-term interest rates to assess the credibility of anti-inflation policies.

However, we must still remain cautious about using the evidence presented here to advocate that the Federal Reserve should target on the term structure in conducting monetary policy. Although there is significant information in the term structure about the future path of inflation for long-term maturities, Mishkin (1988b) has found that there is little information about the future path of inflation in the shorter end of the term structure. Furthermore, as the interpretation of the results indicates, the β_m-regression coefficients are sensitive to the relative variability of expected future inflation changes and real term structure slopes, as well as to the correlation of these two variables. A change in Federal Reserve operating procedures which focuses on the term structure may well cause the correlation and relative variability of expected future inflation changes and real term structure slopes to shift, thus causing the regression coefficients to change in the inflation-change forecasting equation. The result might then be that the term structure no longer remains an accurate guide to the path of future inflation. If this were to occur, Federal Reserve monetary policy could go far astray by focusing on the term structure of interest rates. This is, of course, just another example of the Lucas (1976) critique.

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Appendix

Table A1

Estimates of Predictive Power of Forward Rates
For Future Changes in One-Year Inflation Rates

$$\pi^1_{t+m} - \pi^1_t = \alpha_m + \beta_m[f_{t+m} - i^1_t] + \eta^m$$

m (years)	α_m	β_m	R^2	SE	t-test of β_m=0
		Panel A: Full Sample			
1	-0.2878 (0.2305)	1.0641 (0.3452)	0.199	1.500	3.08*
2	-0.5427 (0.3249)	1.6152 (0.4517)	0.327	2.091	3.58*
3	-0.5883 (0.5617)	1.7324 (0.3778)	0.348	2.326	4.59**
4	-0.3356 (0.9053)	1.2862 (0.4770)	0.203	2.643	2.70
		Panel B: Pre-October 1979 Sample			
1	-0.1091 (0.2093)	1.5426 (0.3503)	0.309	1.307	4.40**
2	-0.3893 (0.3067)	2.2379 (0.3471)	0.464	1.762	6.45**
3	-0.3514 (0.5844)	2.0403 (0.4357)	0.409	2.079	4.68*
4	0.1500 (0.9080)	1.0404 (0.6328)	0.126	2.484	1.64

Table A1 Continued

m (years)	α_m	β_m	R^2	SE	t-test of β_m=0
		Panel C: Post-October 1979 Sample			
1	-1.5587 (0.2303)	0.8749 (0.1835)	0.320	1.387	4.77
2	-2.4473 (0.3444)	0.8022 (0.1473)	0.373	1.581	5.45
3	-2.9876 (0.3769)	0.7747 (0.1320)	0.406	1.488	5.87
4	-3.4163 (0.6281)	0.8056 (0.2500)	0.300	1.937	3.22