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THE INFORMATION CONTENT OF THE TERM STRUCTURE: EVIDENCE FOR GERMANY

by

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Abstract

This paper studies the usefulness of spreads between interest rates of different maturities as indicators of future inflation and real interest rates in Germany, using monthly data starting in 1967:1. The central results are twofold. First, the interest rate spreads considered contain considerable information about future changes in inflation, but no information about the time path of real interest rates. Second, the medium-term segment of the yield curve (spreads between 6 and 2 year rates, for instance) appears to be the most informative for future inflation. These results are similar to those obtained by Mishkin (1990b) and Jorion and Mishkin (1991).

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Contents

1. Introduction 3

2. The data 5

3. Methodology 8

4. Econometric results 9

5. Interpretation 16

6. Conclusions 18

References 19

1. Introduction

The conduct of monetary policy relies on the use of indicators of current and expected future macroeconomic conditions, in particular of output and prices. With the introduction of formal inflation targets in a number of countries -- including New Zealand, Canada, the United Kingdom, Sweden, Finland, Spain and Australia -- central banks have increasingly emphasised the importance of monitoring the private sector's price expectations.[1] Such price expectations can be gauged in at least two ways.

One method relies on the use of survey measures of inflation expectations. However, such measures are subject to several problems which limit their usefulness for policy purposes. First, survey measures typically apply only for a particular, usually the following, year. Given that monetary policy tends to affect the price level with a considerable lag, it is desirable to have information about expectations of inflation further into the future. Second, surveys of price expectations are typically not made very frequently and are published with some time-lag. This naturally reduces their usefulness. Third, since respondents have little incentive to get their answers to the survey "right", one may question how well such surveys measure expectations.

An alternative way of assessing the private sector's inflation expectations, which avoids some of the problems noted above, involves extracting estimates of expected future inflation rates from interest rates. A number of central banks have recently started to use changes in the term structure of forward interest rates as indicators of financial markets' expectations about future economic conditions. For instance, the Bank of England (1995) uses term structure data for real and nominal bonds to calculate implied forward inflation rates. The Bank of Sweden (1995) also uses implied forward interest rates to assess market participants' inflation expectations.[2]

The use of measures of expected inflation rates derived from interest rates raises several questions. Some of these are fundamental. For instance, it is well known that long-term interest rates are quite volatile, and perhaps even excessively volatile given the behaviour of short-term rates (Shiller (1979, 1981)).[3] The question then arises whether inflation expectations derived from long-term interest rates are not also likely to be excessively volatile and therefore of little use to monetary policy-makers. A second question of a fundamental nature is raised by Woodford (1994), who argues that using measures of inflation expectations calculated from interest rates in a feedback rule for monetary policy may cause instability because of self-fulfilling expectations. If that is the case, inflation expectations may not be good intermediate targets for policy.

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1 The papers in Leiderman and Svensson (1995) contain a comprehensive review of several countries' experiences with inflation targets.

2 Söderlind (1995), in an interesting paper, studies the usefulness of forward interest rates as indicators of inflation expectations and finds that they work reasonably well.

3 However, Flavin (1983) demonstrates that Shiller's test is subject to small-sample bias, and shows that a proper test fails to indicate excessive volatility.

Several questions of a more technical nature also arise. First, to what extent do changes in interest rates of different maturities reflect changes in the private sector's inflation expectations? Second, are these inflation expectations unbiased predictors of future inflation rates? Third, how large are the forecast errors associated with the market participants' inflation expectations? Fourth, is there any evidence that term spreads contain information about expected future real returns? Fifth, to what extent do the answers to these questions depend on the forecast horizon considered? While there is an extensive literature on whether the term structure contains information about future interest rates, the existing empirical literature on whether yield curves contain information about future inflation and future real returns is surprisingly limited.[4]

Fama (1990) studies the information content of spreads between the yields to maturity of 1 and 5-years bonds, using US data. He finds that maturity spreads do contain information about future changes in inflation, particularly at forecast horizons of a few years. Maturity spreads also contain some information about future changes in real returns, although the forecasting power falls as longer forecast horizons are considered. Mishkin (1990a) studies the information content of interest rates on treasury bills in the United States with a 1, 3, 6 and 12-month maturity. Two findings are of particular interest to this study. First, the term structure for maturities shorter than 6 months contains virtually no information about the path of future inflation, but does contain information about the path of future real interest rates. Second, this relationship is reversed for maturities in excess of 6 months: the term structure contains information about future inflation rates, but little information about future real interest rates. Mishkin (1991) uses data for ten OECD countries to explore international differences in the information content of the term structure of short-term interest rates. The results suggest that for a majority of the countries the information on future inflation embedded in yield curves is more limited than in the United States. On the other hand, the information content for real interest rates is considerably higher. Mishkin (1990b) assesses how well 1 to 5-year maturities forecast inflation and real interest rates in the United States, and finds that interest rates do predict future inflation rates, but not future real interest rates. Finally, Jorion and Mishkin (1991), which is the starting-point for this study, use data for four countries, including Germany, to study the information content of longer-term maturities. The authors find that yield curves forecast future inflation rates in Switzerland and the United States, and to a lesser extent in Germany. However, there is less evidence that the term structure of interest rates in the United Kingdom contains information about future inflation and real interest rates.

This paper uses a more extensive German data set to assess the ability of the term structure of interest rates to forecast future inflation rates and real interest rates. The reasons for using these data are twofold. First, the Bundesbank has reported monthly data on yields on bonds with

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4 The extensive literature assessing whether yield curves contain information about future interest rates is summarised in Shiller (1990). For a non-exhaustive list of references, see Shiller, Campbell and Schoenholtz (1983), Mankiw and Summers (1984), Mankiw (1986), Fama (1984), Fama and Bliss (1987) and Hardouvelis (1994).

maturities of 1 to 10 years as from January 1967. The availability of a wide range of maturities makes it possible to address the question of what segment of the yield curve has the highest predictive content for inflation and real returns. Are spreads between 7 and 2-year rates more informative than spreads between 5 and 1-year rates? Having a long sample of data is also helpful for econometric reasons. Second, a disproportionate amount of research has focused on US data. Hardouvelis (1994) notes that the US term structure appears to forecast future interest rates less well than data for the other G-7 countries. This raises the question whether the information content of non-US interest rates differs from that of US interest rates. Further research on non-US data thus appears well warranted.

The paper differs from, and extends, the work of Jorion and Mishkin (1991) in two respects. First, while the longest sample period they use spans the period 1973-88, the longest sample period we use is 1968-93. The use of a much longer sample period makes it possible to study the information content of maturities beyond the 5-year maturity considered by Jorion and Mishkin (1991). This is particularly interesting in the light of their finding that the information content of the term structure is highest for the longest maturity spread they consider, i.e. 5 vis-à-vis 1-year. Second, we study the information content of spreads vis-à-vis 2 and 3-year rates, and not only vis-à-vis 1-year rates as do Jorion and Mishkin (1991). One interesting finding is that spreads vis-à-vis 2-year rates are more informative for future inflation than spreads vis-à-vis 1-year rates.

The paper is structured as follows. Section 2 reviews the main features of the data, and Section 3 outlines the methodology. Section 4 contains a discussion of the econometric problems that arise in studying the information content of the term structure, together with an analysis of the econometric estimates. The empirical findings suggest two conclusions. First, nominal interest rate spreads do contain considerable information about future changes in inflation, but no information about the time path of real interest rates. Second, the most informative range for inflation is the medium-term segment of the yield curve, for instance, spreads between 6 and 2-year rates. The results are broadly compatible with those of Mishkin (1990b) and Jorion and Mishkin (1991). In Section 5 we follow Mishkin (1990a) and use an error-in-variable approach to explain why the estimated parameters vary with the forecasting horizon. Finally, Section 6 summarises the conclusions.

2. The data

The data used in this study are end-of-month observations on the yields to maturity of 1 to 10-year bonds, starting in January 1967.[5] The yield data stem from yield curves fitted by the Bundesbank, using data for federal bonds (issued by the Federal Government, the Federal Post Office and the Federal Railways), which are very similar, except for the remaining time to maturity and the

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[5] The yield data for 4-year bonds start in 1984:12. Since the yield curve is very smooth we interpolated using the average of the 3 and 5-year yields in the period 1967:1-1984:11. The correlation between the interpolated and the true 4-year yields between 1984:12 and 1995:1 is essentially unity. Readers who are concerned by this interpolation may wish to disregard the results involving 4-year rates reported below. The observation for the 10-year yield in June 1983 is also missing, and was set equal to the average of the May and July 1983 yields.

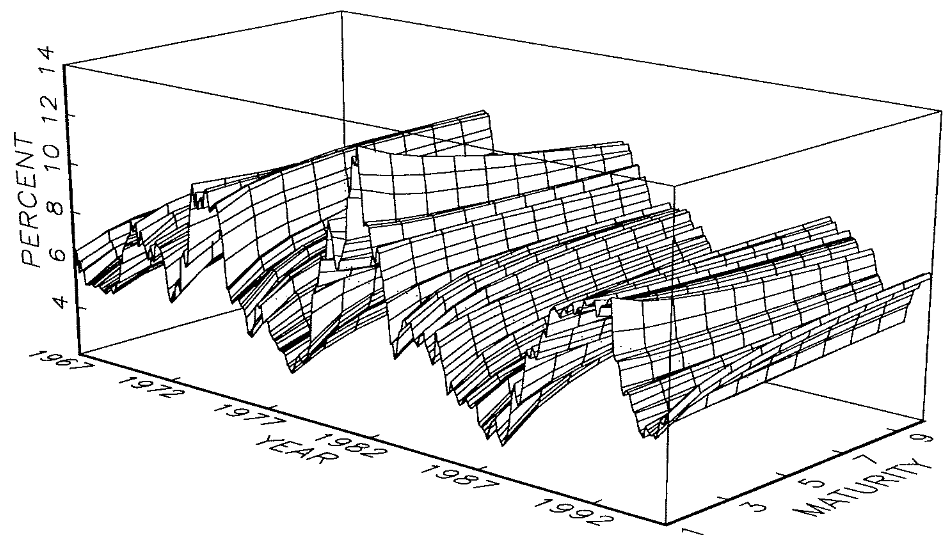
coupons.[6] The Bundesbank classifies the bonds according to their remaining time to maturity, calculates an average yield for each group, and fits a yield curve on the grouped data. Let i^m denote the average yield to maturity on bonds in maturity group m at time t, and c(m) the average coupon in maturity group m. Yield curves are assumed to obey the relationship

$$i^m = \lambda_0 + \lambda_1 m + \lambda_2 \ln(m) + \lambda_3 c(m) + \lambda_4 \ln(c(m)) + v_m,$$

where v_m is an error term. The yield curves estimated before January 1981 did not incorporate parameters for the coupon payments (i.e. $\lambda_3 = \lambda_4 = 0$), apparently because there was little evidence of a coupon effect before the late 1970s. See Deutsche Bundesbank (1983, pp. 23-24) for a fuller discussion of the estimation procedure.

Graph 1 illustrates that movements in German interest rates can be broadly divided into four episodes. During the first episode, between 1967 and the early 1970s, short-term rates were gradually rising. The yield curve initially displays a positive slope, but becomes increasingly flat as short-term interest rates continue to rise. In the second episode, between the early 1970s and the early

Graph 1
Yield curves
Monthly data 1967:1-1995:1

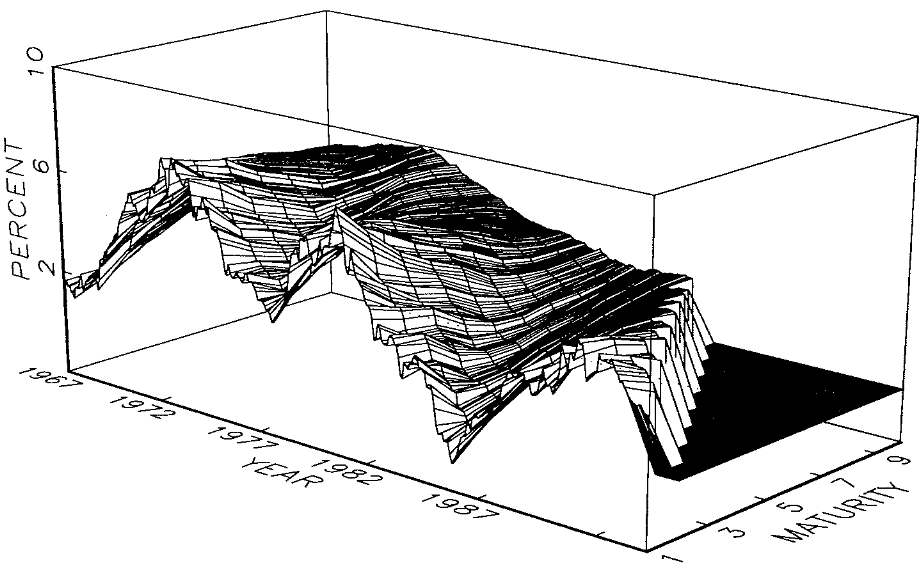


[6] Since the yields are estimated, the regressions fitted in this paper may be subject to "generated regressors bias" (see Pagan (1984)). Note, however, that because of standard errors-in-variables arguments, the use of estimated, rather than actual, yields to maturity as regressors is likely to bias the estimated slope coefficients towards zero and reduce their significance. In the light of the empirical results discussed in detail below, it is difficult to see that the use of estimated yields constitutes a serious problem.

1980s, the yields on shorter-term maturities fall gradually until the late 1970s, and then rise rapidly to peak in the early 1980s. During this period yield curves initially become steeper as longer rates fall less than those on shorter maturities. When short-term rates increase drastically in the early 1980s, the term structure becomes inverted. This behaviour of long and short-term rates repeats itself during the third episode, which occurs between the early 1980s and 1990, and during the fourth episode, from 1990 onwards.

The question addressed in this paper is the extent to which these movements in the term structure of interest rates contain information about changes in expectations held by financial market participants about the future course of inflation and real rates of interest. As a first step it may be informative to briefly review the behaviour of inflation over the same period. Graph 2 plots the behaviour of the *term structure of realised CPI inflation*, which is constructed in a way analogous to the term structure of interest rates. Thus, the graph shows the annualised rate of inflation realised between a given month and 12 months ahead, 24 months ahead, 36 months ahead and so on, up to 120 months ahead. The zeros in the upper right-hand corner of the graph indicate missing observations: for instance, since the last data point on prices is January 1995, it is not possible to calculate the realised 10-year forward inflation rate after January 1985.

Graph 2
Forward inflation rates
Monthly data 1967:1-1994:1



To interpret the graphs, consider the extreme case in which there are no risk premia, the expected real rate of interest is constant and financial markets have perfect foresight. In this case the shape of the term structure of interest rates and inflation rates would be perfectly identical, and the vertical difference between the two curves would indicate the expected real rate of interest. As this example illustrates, differences in the shapes of the two curves may stem from three factors: the presence of risk premia; movements in expected real returns; and errors made by financial markets in forming expectations about the future course of inflation.

It is notable that while the term structure of inflation is less volatile than the term structure of interest rates, the shapes of the two surfaces are broadly similar. In particular, the term structure of inflation, which was initially upward-sloping in 1967, became increasingly inverted as short-term inflation rates rose and peaked in the early 1970s. The fall in short-term inflation rates in the mid-1970s was associated with the term structure of inflation becoming increasingly upward-sloping. During the latter half of the 1970s, as short-term inflation rates rose, the term structure of inflation once more became increasingly inverted. Following the disinflation during the 1980s, the term structure of inflation again started to slope upwards.

The finding that the term structures of inflation and interest rates display broadly the same movements over time suggests that interest rates do reflect inflation expectations: when current short-term inflation rates are perceived as being unusually low, agents anticipate that they will increase and consequently require higher yields on longer-term bonds. Similarly, when current short-term inflation rates are unusually high, market participants expect them to fall, and are willing to hold longer-term bonds at rates below those they require to hold short-term bonds. Thus, spreads between interest rates of different maturities should contain information about expected changes in the behaviour of inflation. However, since the relationship between realised future inflation rates and current maturity spreads is not perfect, it is also possible that maturity spreads contain information about future real interest rates. Thus, an upward-sloping yield curve could potentially signal that market participants expected future real returns to increase. We next explore these two hypotheses more formally.

3. Methodology

Our investigation of the informational content of the term structure of interest rates follows the strategy of Mishkin (1990a, 1990b, 1991) and Jorion and Mishkin (1991). Let i_t^j denote the yield to maturity on a j-year bond, and let π_t^j denote the realised j-years-ahead rate of inflation, which is computed as $\pi_t^j = 100(p_{t+12j} - p_t)/j$, where p_t denotes the log of the price index in month t. The starting-point for the analysis that follows is the identity

$$(1) \qquad i_t^j = E_t r_t^j + E_t \pi_t^j + \phi_t^j,$$

where E_t is the expectations operator, conditional on information available at time t, r_t^j is the j-year real interest rate and ϕ_t^j a possibly time-varying term or risk premium. Equation (1) states that the nominal interest rate equals the expected real interest rate plus the expected rate of inflation between years t and t+j. To proceed, note that by definition the realised inflation rate equals the expected inflation rate plus an expectation error, that is

(2) $$\pi_t^j = E_t\pi_t^j + \varepsilon_t^j,$$

where ε_t^j denotes the expectation error, which is orthogonal to the information available at time t. Combining (1) and (2) we obtain

(3) $$\pi_t^j = i_t^j - E_t r_t^j + \varepsilon_t^j - \phi_t^j.$$

Equation (3) constitutes the key equation in this paper. Note that

(4) $$\pi_t^j - \pi_t^k = -\left(E_t r_t^j - E_t r_t^k\right) + \left(i_t^j - i_t^k\right) + \left\{\left(\varepsilon_t^j - \varepsilon_t^k\right) - \left(\phi_t^j - \phi_t^k\right)\right\}.$$

Thus, in the "inflation" regression

(5) $$\pi_t^j - \pi_t^k = \alpha^{j,k} + \beta^{j,k}\left(i_t^j - i_t^k\right) + u_t^{j,k},$$

$\alpha^{j,k} = -\left(E_t r_t^j - E_t r_t^k\right)$ and $u_t^{j,k} = \left\{\left(\varepsilon_t^j - \varepsilon_t^k\right) - \left(\phi_t^j - \phi_t^k\right)\right\}$. Equation (5) states that the realised future change in the inflation rate is a linear function of the current maturity spread. Equation (5) can also be written as a "real rate" regression

(6) $$\left\{\left(i_t^j - \pi_t^j\right) - \left(i_t^k - \pi_t^k\right)\right\} = \gamma^{j,k} + \theta^{j,k}\left(i_t^j - i_t^k\right) + z_t^{j,k},$$

where $\gamma^{j,k} = -\alpha^{j,k}$ and $z_t^{j,k} = -u_t^{j,k}$. Furthermore, if expected real interest rates are constant over time so that changes in nominal interest rates reflect changes in inflation expectations, $\beta^{j,k} = 1$. Although equations (5) and (6) are closely related (in particular, $\alpha^{j,k} + \gamma^{j,k} = 0$ and $\beta^{j,k} + \theta^{j,k} = 1$) we estimate both below because we are interested in comparing their R-squared.

4. Econometric results

Next we turn to the econometric results. The results presented below are derived from estimates of the "inflation" equation (5) and the "real rate" equation (6). The equations are estimated using all available data: the sample period starts in 1968:1 and ends between 1985:1 (when j = 10) and 1993:1 (when j = 2).

Two econometric complications arise when these equations are estimated. First, the residuals are very likely to be heteroscedastic, which needs to be taken into account when conducting inference. Second, the use of overlapping data implies that the regression errors, which can be interpreted as forecast errors, should display moving-average errors of order 12j-1. For instance, in the case of 10-year bonds, the errors should follow an MA(119) process. Since there are only 217 observations available when j = 10, it is hazardous to use asymptotic standard errors for inference. We therefore report both theoretical p-values, constructed as in Newey and West (1987), and empirical p-values, constructed in a way similar to that used by Mishkin (1990b) and Jorion and Mishkin (1991), for tests of the hypothesis that the parameters in equations (5) and (6) are zero. Note that since $\beta^{j,k} + \theta^{j,k} = 1$, the test of the hypothesis $\beta^{j,k} = 0$ is also a test of $\theta^{j,k} = 1$ and vice versa.

The empirical p-values are generated as follows. We first fit univariate AR-models for the quarterly inflation rate (incorporating seasonal dummies) and the relevant interest rate spread. The order of these AR-models is determined using the Akaike and Schwarz criteria, after testing for serial correlation in the errors. Next we bootstrap 1,000 artificial sample paths for the quarterly inflation rate (and use this to construct time paths for forward inflation rates) and bootstrap again to obtain 1,000 artificial sample paths for the interest rate spread. These artificial sample paths for inflation and the interest rate spread are independent by construction. Finally, we estimate equations (5) and (6) on each sample and calculate the fraction of times the p-values are smaller than the Newey-West p-values obtained when estimating equations (5) and (6) on the original data.

Before turning to the estimates it may be informative to consider Graph 3, which contains scatter plots of $\pi_t^j - \pi_t^k$ against $i_t^j - i_t^k$, and Graph 4, which contains scatter plots of $\left(i_t^j - \pi_t^j\right) - \left(i_t^k - \pi_t^k\right)$ against $i_t^j - i_t^k$, for j = 2, ..., 10 and k = 1 (scatter plots for k = 2, 3 are quite similar and are not shown for space reasons). The scatter plots illustrate that when j = 2, there is little evidence that the nominal interest rate spread is a useful predictor of future changes in inflation and realised real interest rates. However, as j increases a positive relationship emerges between the maturity spread and realised future inflation rates. This relationship appears to be highest for j:s between 6 and 8 years. Note, furthermore, that there is little evidence of a relationship between nominal interest rate spreads and realised real interest rate spreads.

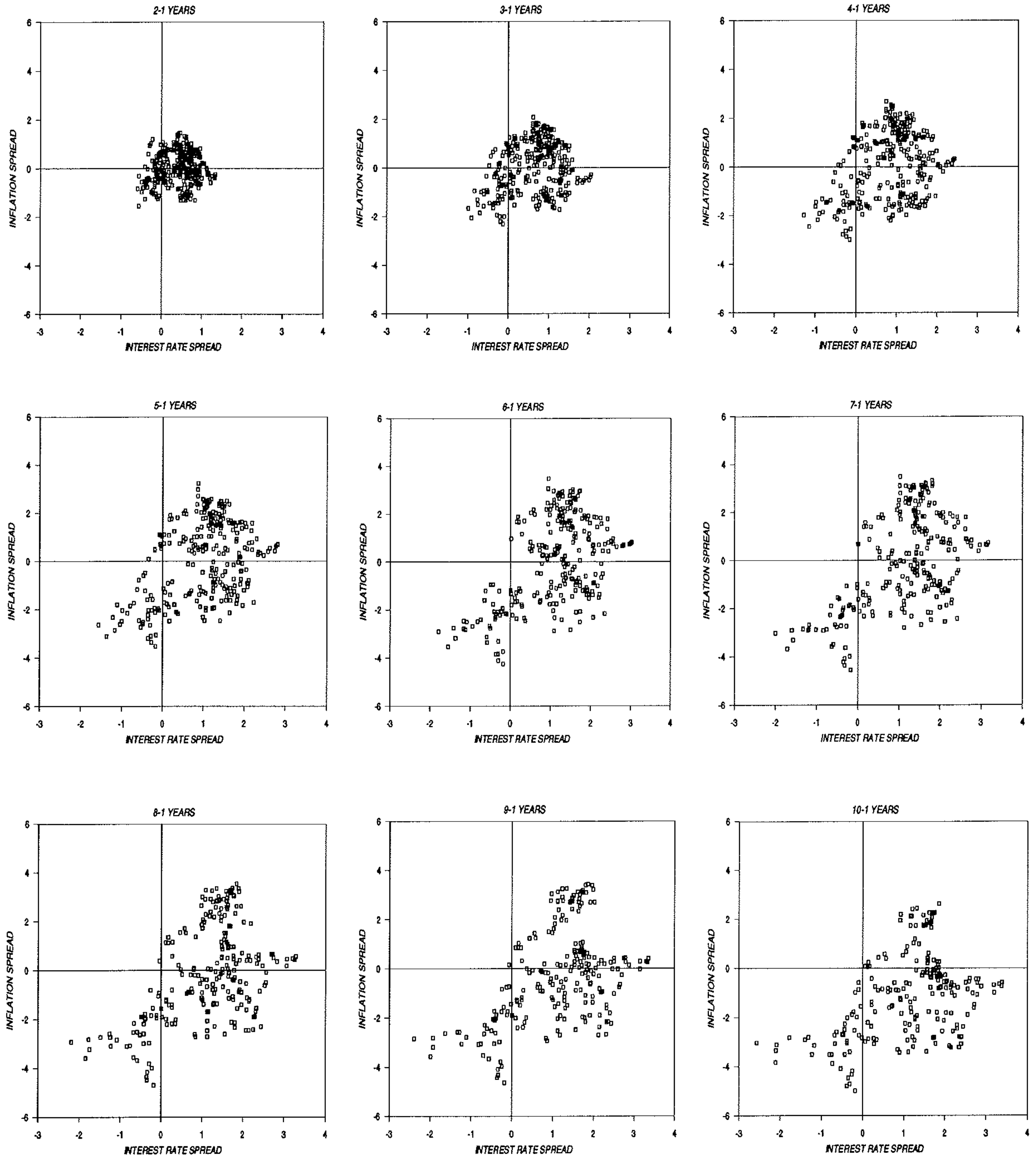
Next we estimate equations (5) and (6), letting j = 2, ..., 10 and k = 1, 2, 3, with the sample period starting in 1968:1 and ending, depending on the choice of j, between 1985:1 and 1993:1.[7] Consider first the results for the inflation equation (5) in Panel A of Table 1, in which we consider spreads against 1-year rates (k = 1). Several findings are of interest. First, as j increases from 2, the estimate of the slope parameter increases, and becomes significant. For instance, when j = 6, $\beta = 0.95$, and the p-value for the test of $\beta = 0$ is 0.00 when the theoretical Newey-West standard errors are used for inference (allowing for MA(71) errors); and 0.04 when the empirical p-value is used. Second, for higher j:s, β starts to fall towards 0 and loses its significance. Third, the R-squared for the different regressions follow the same pattern: they rise with j, peak at j = 7, and then fall. Fourth, as others have found, there are large differences between the theoretical and empirical p-values, particularly for longer forecast horizons. For instance, when k = 10, the Newey-West p-value is 0.00

7 Confining the sample period to 1968:1-1985:1 for all regressions does not materially affect the results (although the significance levels fall somewhat when the smaller data set is used).

while the empirical p-value is 0.13. Overall, however, the results suggest that maturity spreads do contain information about the future course of inflation, and thus raise the question whether maturity spreads also contain information about future real interest rates; and whether spreads against 2 or 3-year rates are more informative than the spreads against 1-year rates in Table 1.

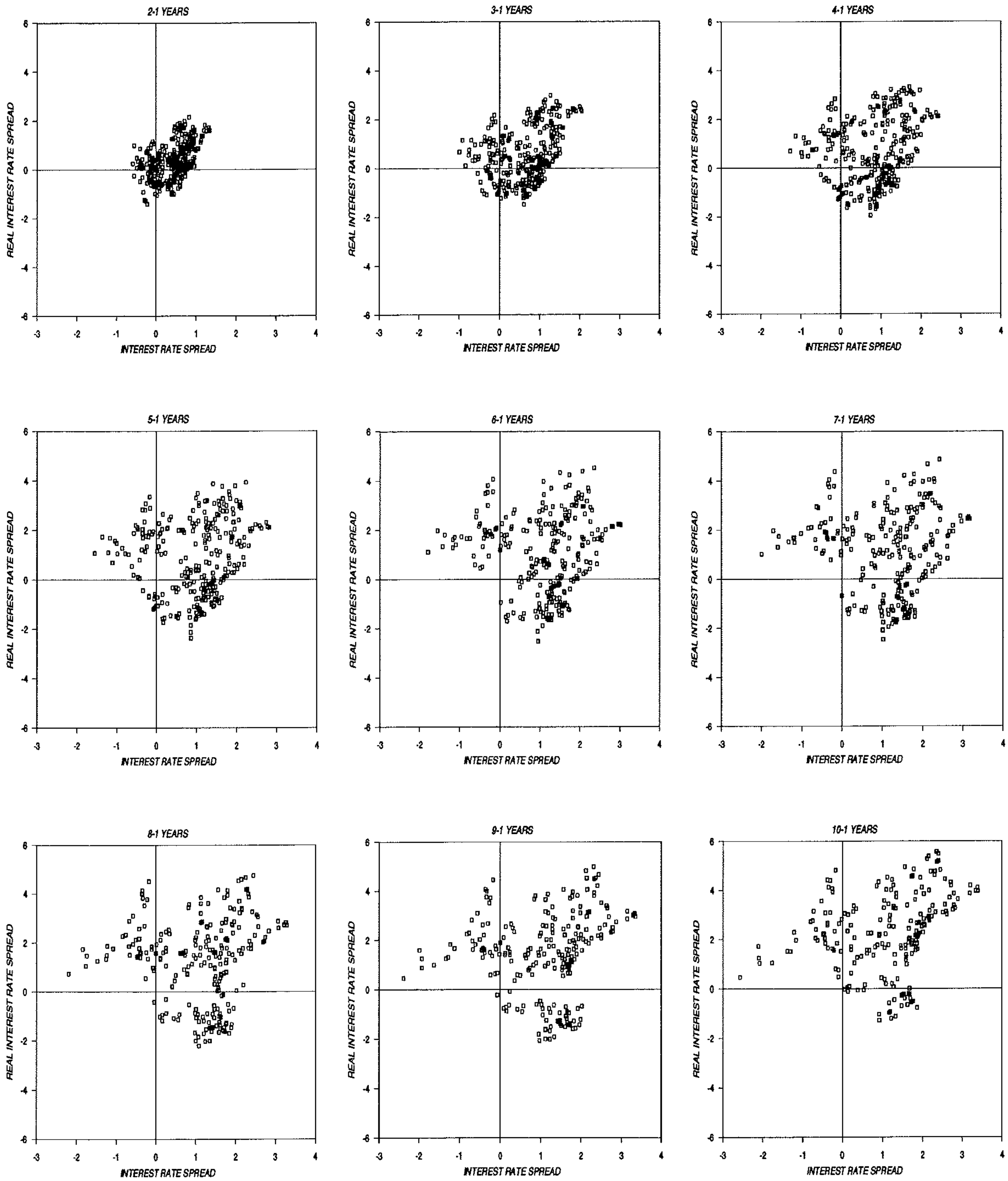
Graph 3

Scatterplots of realised future inflation against current maturity spread



Graph 4

Scatterplots of realised future real interest rates against current maturity spread



Panel B in Table 1 shows the results for realised real interest rates, which provide no evidence that interest rate spreads contain information about the future path of real interest rates. The possible exception to this appears for j = 2, 3, for which the slope parameter is sizable and significant when theoretical p-values are considered, but insignificant when the empirical p-values are considered. This is compatible with the findings in the existing literature that maturity spreads forecast real interest rates only up to about 12 months or so (e.g., Mishkin (1990a)).

Table 1
Inflation and real interest rate regressions

Spread (j-k)	Period	Panel A			Panel B	
		Inflation			Real interest rate	
		α	β	R^2	θ	R^2
2–1	1968:1–93:1	−0.06 (0.62) [0.57]	0.21 (0.37) [0.41]	0.02	0.79 (0.00) [0.37]	0.21
3–1	1968:1–92:1	−0.17 (0.52) [0.52]	0.34 (0.20) [0.31]	0.04	0.66 (0.01) [0.64]	0.15
4–1	1968:1–91:1	−0.39 (0.40) [0.36]	0.55 (0.04) [0.16]	0.09	0.45 (0.09) [0.80]	0.06
5–1	1968:1–90:1	−0.69 (0.20) [0.22]	0.75 (0.00) [0.07]	0.16	0.25 (0.31) [0.93]	0.02
6–1	1968:1–89:1	−1.08 (0.03) [0.08]	0.95 (0.00) [0.04]	0.25	0.05 (0.82) [0.99]	0.00
7–1	1968:1–88:1	−1.24 (0.01) [0.08]	0.98 (0.00) [0.05]	0.28	0.01 (0.94) [0.99]	0.00
8–1	1968:1–87:1	−1.27 (0.01) [0.08]	0.89 (0.00) [0.11]	0.25	0.11 (0.69) [0.98]	0.00
9–1	1968:1–86:1	−1.34 (0.00) [0.10]	0.78 (0.00) [0.14]	0.24	0.22 (0.31) [0.94]	0.02
10–1	1968:1–85:1	−1.97 (0.00) [0.04]	0.59 (0.00) [0.13]	0.20	0.40 (0.01) [0.74]	0.10

Note: Asymptotic heteroscedasticity-consistent p-values in parentheses. Empirical p-values in square brackets.

Panel A in Tables 2 and 3 present the results from inflation regressions when spreads against 2-year (k = 2) and 3-year rates (k = 3) are considered; and Panel B in the same tables present the results for the analogue real rate regressions. The results are similar to those reported in Table 1 and for space reasons we do not discuss them in detail, but rather summarise the main conclusions.

The most interesting finding is that the conclusion that maturity spreads contain information about future inflation but not future real interest rates is unaffected by using 2 or 3-year rates as "reference" rates. If anything, the explanatory power, as measured by the R-squared, of the inflation regressions increases somewhat when spreads against 2 or 3-year rates (k = 2, 3) are considered. Spreads against 2-year rates are more informative than spreads against 1-year rates (except for 10-year bond yields). Furthermore, spreads against 3-year rates are more informative than spreads against 2-year rates for maturities up to 6 years (that is, j = 4, 5, 6).

Table 2
Inflation and real interest rate regressions

Spread (j-k)	Period	Panel A Inflation			Panel B Real interest rate	
		α	β	R^2	θ	R^2
3–2	1968:1–92:1	–0.15 (0.28) [0.22]	0.71 (0.04) [0.11]	0.10	0.29 (0.40) [0.85]	0.02
4–2	1968:1–91:1	–0.37 (0.17) [0.18]	1.03 (0.00) [0.05]	0.17	–0.03 (0.93) [0.98]	0.00
5–2	1968:1–90:1	–0.64 (0.06) [0.11]	1.24 (0.00) [0.03]	0.25	–0.24 (0.37) [0.84]	0.01
6–2	1968:1–89:1	–0.95 (0.00) [0.06]	1.44 (0.00) [0.01]	0.32	–0.44 (0.07) [0.66]	0.04
7–2	1968:1–88:1	–1.09 (0.00) [0.05]	1.42 (0.00) [0.02]	0.32	–0.42 (0.08) [0.69]	0.04
8–2	1968:1–87:1	–1.11 (0.00) [0.06]	1.28 (0.00) [0.06]	0.28	–0.28 (0.31) [0.87]	0.02
9–2	1968:1–86:1	–1.14 (0.00) [0.05]	1.05 (0.00) [0.09]	0.24	–0.05 (0.82) [0.97]	0.00
10–2	1968:1–85:1	–1.75 (0.00) [0.02]	0.75 (0.00) [0.06]	0.18	0.25 (0.05) [0.75]	0.02

Note: See Table 1.

Table 3
Inflation and real interest rate regressions

Spread (j-k)	Period	Panel A			Panel B	
		Inflation			Real interest rate	
		α	β	R^2	θ	R^2
4–3	1968:1–91:1	–0.23 (0.03) [0.05]	1.63 (0.00) [0.01]	0.24	–0.63 (0.05) [0.42]	0.05
5–3	1968:1–90:1	–0.48 (0.01) [0.04]	1.71 (0.00) [0.00]	0.32	–0.71 (0.01) [0.32]	0.07
6–3	1968:1–89:1	–0.73 (0.00) [0.03]	1.82 (0.00) [0.00]	0.35	–0.84 (0.00) [0.24]	0.10
7–3	1968:1–88:1	–0.83 (0.00) [0.02]	1.68 (0.00) [0.01]	0.31	–0.67 (0.00) [0.38]	0.07
8–3	1968:1–87:1	–0.84 (0.00) [0.04]	1.41 (0.00) [0.09]	0.23	–0.41 (0.20) [0.78]	0.03
9–3	1968:1–86:1	–0.84 (0.00) [0.06]	1.05 (0.00) [0.14]	0.16	–0.05 (0.86) [0.97]	0.00
10–3	1968:1–85:1	–1.45 (0.00) [0.02]	0.62 (0.00) [0.24]	0.08	0.38 (0.06) [0.76]	0.03

Note: See Table 1.

A second interesting finding is that the significance of the slope parameter increases when spreads against 2 and 3-year rates are considered. For instance, while only two of the slope parameters in the nine inflation regressions using spreads against 1-year rates are significant at the 5% level, four of the eight slope parameters are significant for spreads against 2-year rates , and four of the seven slope parameters are significant for spreads against 3-year rates.

The third finding is that the estimated values for the slope parameters increase when spreads against 2 and 3-year rates are used. For instance, the slope parameter is 0.95 for spreads between 6 and 1-year rates; 1.44 for spreads between 6 and 2-year rates; and 1.82 for spreads between 6 and 3-year rates.

5. Interpretation

The empirical work discussed above indicated that the estimated slope parameter varies systematically with the forecast horizon: β initially rises as j increases, peaks at j = 6 or 7, and then starts to fall. Next we try to understand the cause of this systematic variation in β.

Mishkin (1990a, p. 255), following Fama (1984), shows that the point estimate of the slope parameter, β, can be written

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

where $\sigma^2 = \text{Var}\left(E_t(\pi_t^j - \pi_t^k)\right) / \text{Var}\left(E_t(r_t^j - r_t^k)\right)$ is the ratio of the variances of the expected change in the inflation rate and the expected change in the real term structure respectively, and $\rho = \text{Corr}\left(E_t(\pi_t^j - \pi_t^k), E_t(r_t^j - r_t^k)\right)$ is the correlation between the expected change in the inflation rate and the expected change in the real term structure. Equation (7) indicates that β can vary between $\pm\infty$, depending on the size of the variance and the correlation coefficient. In order to establish why β varies between the different regressions, we next follow Mishkin (1990a, b) and estimate σ and ρ. Since the term structure appears more informative for future inflation when k = 2 rather than when k = 1, we focus on the former case.

To obtain estimates of $E_t(\pi_t^j - \pi_t^k)$, we regress *ex post* real interest rates on current 1 to 10-year interest rates and lagged 1 to 10-year inflation rates, which are all observed at time t and are thus in the information set. The fitted variables are then viewed as the expected real interest rate; by subtracting it from the nominal interest rate we obtain the expected inflation rate. We can then finally compute σ and ρ, which are shown in Table 4 together with the estimated β; Graph 5 provides plots of β for values of σ and ρ similar to the estimated values.

Graph 5 illustrates how the estimates of β depend on σ and ρ. Note first that as σ increases the slope parameter tends to unity: as more and more of the variance of the interest rate spread is due to expected changes in the rate of inflation, the slope parameter approaches unity. In the extreme case in which all changes in the interest rate spread are due to expected changes in inflation (that is, when $\lim \sigma \to \infty$), the slope parameter is unity. Note also that β depends on ρ for finite σ:s. In particular, when ρ is positive, β approaches unity at a faster rate than when ρ =0. However, when ρ is negative, β falls initially as σ increases, and reaches a minimum as σ tends to unity, then switches sign and approaches unity from above. Thus large and positive estimates for β can arise if ρ is close to minus unity, and σ is somewhat larger than unity. Before turning to the estimated values for ρ and σ, note that the estimates of β can be very sensitive to small changes in ρ, particularly when $\rho \approx -1$ and $\sigma \approx 1$.

Graph 5

β as a function of ρ and σ

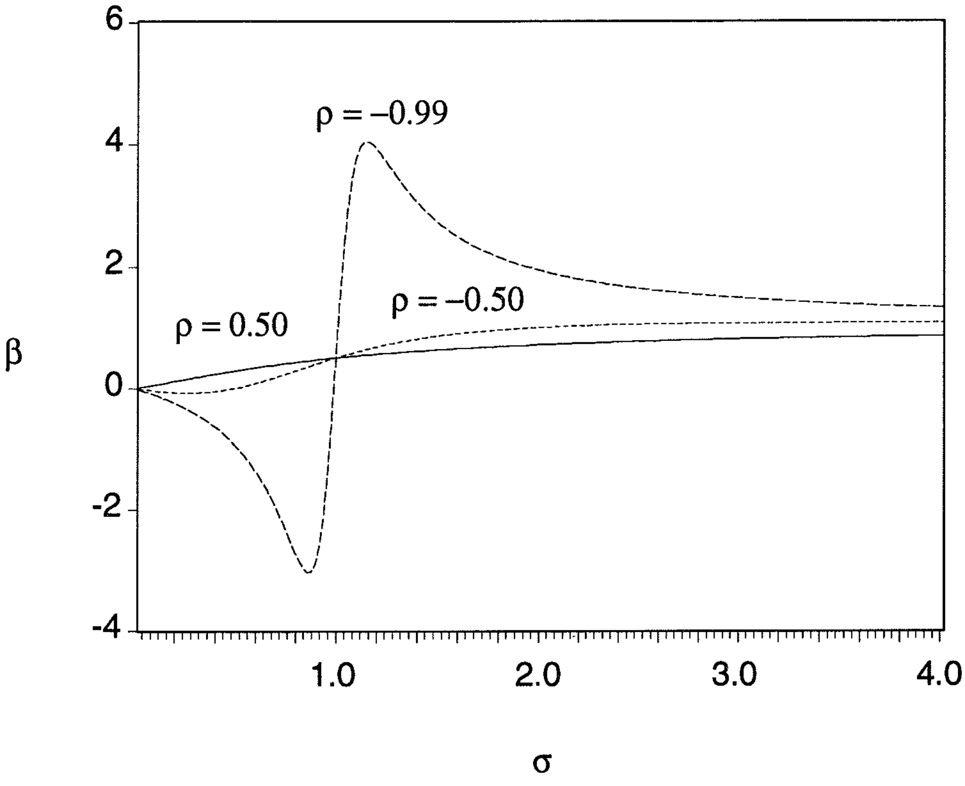


Table 4 provides the estimated values for σ and ρ, together with the previously estimated values for β. The table illustrates that the reason the estimated β:s increase as the forecast horizon increases is that the correlation between the expected change in inflation and the expected change in the real interest rate turns increasingly negative: for j = 3, the estimated value of ρ is -0.87; for j = 6, ρ = -0.92. The subsequent fall in the estimated β:s as j increases further to j = 10 is largely due to the fact that ρ starts to increase, so that for j = 10, ρ = -0.65. The estimates also indicate that there is some variation of σ between the different regressions: σ rises from 1.07 for j = 3, peaks at 1.20 for j = 6, and falls to 0.56 for j = 10. Thus, the variation in the estimated slope parameters is due to variation in both the correlation between, and the ratio of the variances of, the expected change in the inflation rate and the expected change in the real term structure.

Table 4
Estimates of ρ, σ together with β

Spread (j-k)	Period	ρ	σ	β
3–2	1968:1–92:1	–0.87	1.07	0.71
4–2	1968:1–91:1	–0.90	1.12	1.03
5–2	1968:1–90:1	–0.91	1.17	1.24
6–2	1968:1–89:1	–0.92	1.20	1.44
7–2	1968:1–88:1	–0.92	1.19	1.42
8–2	1968:1–87:1	–0.92	1.16	1.28
9–2	1968:1–86:1	–0.71	0.65	1.05
10–2	1968:1–85:1	–0.65	0.56	0.75

6. Conclusions

The empirical work presented in this paper leads to two conclusions. First, nominal interest rate spreads do contain considerable information about future changes in inflation, but no information about the time path of real interest rates. Second, medium-term segments of the yield curve, for instance spreads between 5 and 2-year rates, are the most informative in predicting the future path of inflation. While these results are obtained using German data, they are similar to those of Mishkin (1990b) and Jorion and Mishkin (1991), which suggests that they are not likely to be specific to Germany. From a monetary policy perspective, the results thus suggest that medium and long-term bond yields can play a useful role as indicators of the financial markets' inflation expectations.

References

Bank of England (1995): "Inflation report", March.

Bank of Sweden (1995): *Inflation and inflation expectations in Sweden*, March.

Deutsche Bundesbank (1983): "Monthly report", January.

Fama, E.F. (1984): "The information in the term-structure". *Journal of Financial Economics*, 13, 509-28.

Fama, E.F. (1990): "Term-structure forecasts of interest rates, inflation and real return". *Journal of Monetary Economics*, 25, 59-76.

Fama, E.F. and R.R. Bliss (1987): "The information in long maturity forward rates". *American Economic Review*, 77, 680-92.

Flavin, M. (1983): "Excess volatility in the financial markets: A reassessment of the empirical evidence". *Journal of Political Economy*, 91, 929-56.

Hardouvelis, G. (1994): "The term structure spread and future changes in long and short rates in the G7 countries". *Journal of Monetary Economics*, 33, 255-83.

Jorion, P. and F. Mishkin (1991): "A multicountry comparison of term-structure forecasts at long horizons". *Journal of Financial Economics*, 29, 59-80.

Leiderman, L. and L.E.O. Svensson (1995): *Inflation Targets*, CEPR, London.

Mankiw, N. G. (1986): "The term structure of interest rates revisited". *Brookings Papers on Economic Activity*, 1, 61-96.

Mankiw, N.G. and L.H. Summers (1984): "Do long-term interest rates overreact to short-term interest rates?" *Brookings Papers on Economic Activity*, 1, 223-42.

Mishkin, F. (1990a): "What does the term structure tell us about future inflation?" *Journal of Monetary Economics*, 25, 77-95.

Mishkin, F. (1990b): "The information in the longer maturity term structure about future inflation". *Quarterly Journal of Economics*, 55, 815-28.

Mishkin, F. (1991): "A multi-country study of the information in the shorter maturity term structure about future inflation". *Journal of International Money and Finance*, 10, 2-22.

Newey, W.K. and K.D. West (1987): "A simple, positive definite, heteroscedasticity and autocorrelation consistent covariance matrix". *Econometrica*, 55, 703-08.

Pagan, A. (1984): "Econometric issues in the analysis of regression with generated regressors". *International Economic Review*, 25, 226-47.

Shiller, R.J. (1979): "The volatility of long-term interest rates and expectations models of the term structure". *Journal of Political Economy*, 87, 1190-1219.

Shiller, R.J. (1981): "Alternative tests of rational expectations models: the case of the term structure". *Journal of Econometrics*, 16, 71-87.

Shiller, R.J. (1990): "The term structure of interest rates", in B. M. Friedman and F.H. Hahn, Elsevier (ed.), *Handbook of Monetary Economics.*

Shiller, R.J. and J.Y. Campbell and K.L. Schoenholtz (1983): "Forward rates and future policy: interpreting the term structure of interest rates". *Brookings Papers on Economic Activity*, 1, 173-217.

Söderlind, P. (1995): "Forward interest rates as indicators of inflation expectations", unpublished paper.

Woodford, M. (1994): "Nonstandard indicators for monetary policy: can their usefulness be judged from forecasting regressions?" in N.G. Mankiw, ed., *Monetary Policy.* NBER and the University of Chicago Press: Chicago.