"THE INFORMATION IN THE TERM STRUCTURE OF INTEREST RATES: OUT-OF-SAMPLE FORECASTING PERFORMANCE"

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ABSTRACT

This paper examines the predictive power of forward rates implicit in the term structure of the U.S. Treasury bill interest rates. It compares the out-of-sample forecasting accuracy and the information content of ex ante forecasts based on forward rates with several alternative forecasts for future interest rates. The out-of-sample forecast based on forward rates is extracted through a recursive estimation of the regression equation of interest rate changes on forward spreads, the coefficients of which are allowed to change over time in order to allow for the changes in their relationship due to the existence of the time-varying risk premium.

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THE INFORMATION IN THE TERM STRUCTURE OF INTEREST RATES : OUT-OF-SAMPLE FORECASTING PERFORMANCE

[1] Introduction

The information content of the term structure of interest rates has been investigated by many empirical studies.[1] Although the expectations hypothesis which states that long-term interest rate is a weighted average of the expected future short-term interest rates over the maturity of long-term bond plus possibly constant risk premium has been strongly rejected by a number of researchers, the idea that the term structure will provide some valuable information about the future interest rates has always been prevalent among the practitioners in financial markets. Also, there has been recent interest in using the slope of the term structure as a policy guide for measuring inflationary pressures in the economy.[2]

Shiller, Campbell and Schoenholtz (1982), and Mankiw and Summers (1984) documented the negative evidence on the value of the term structure in predicting future interest rates. For instance, Shiller, Campbell and Schoenholtz (1982) argued that the simple theory that the slope of the term

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[1]For the survey of the literature on the term structure of interest rates, see Melino (1986) and Shiller (1987).

[2]Mishkin (1989a,b) investigates the information in the term structure about future inflation and finds that for the majority of ten OECD countries, the term structure does not contain a great deal of information about the future path of inflation.

structure can be used to forecast the direction of the future changes in the interest rate seems worthless.

However, there have been several recent empirical studies which document some positive evidence on the predictive ability of the term structure. Fama (1984) examined one-to-six month Treasury bills from 1959 through 1982 and found that the predictive power in forward rates lasts about three to five months during the first half of his sample and one month during the second half of his sample. Mishkin (1988) uses refined econometric techniques that properly correct standard errors for overlapping data and conditional heteroscedasticity and updates Fama's (1984) findings with more recent data set. Overall, his results are in broad agreement with those of Fama that the term structure does help predict spot interest rate movements several months into the future.

Mankiw and Miron (1986) extend the sample period back to year 1890. They use three- and six-month rates and find strong predictive ability during the period 1890 through 1914 before the establishment of the Federal Reserve, some predictive ability during the period 1915 through 1933, and, contrary to Fama's results, no predictive ability after 1933 or after 1959. They argue that the predictive ability of the term structure during the earlier periods was due to the absence of the Fed intervention in the money market. Hardouvelis (1988) uses weekly Treasury bill rates with maturities of one to twenty-six weeks to examine the information in forward rates during 1970s and 1980s. He finds that forward rates contain better information about future changes in spot rates than the information captured by autoregressive and vector-autoregressive models. In contrast to Mankiw and Miron (1986), his results show that forward rates also have considerable predictive power, which increased after October 1979 and remained strong after October 1982, although the Fed changed its operating procedures from interest rate targeting to monetary aggregate targeting after October 1979.

In most studies mentioned above, the common econometric techniques applied were the least squares estimation of the regression of changes in interest rates on forward spreads and the evaluation of the predictive ability was based on the statistical significance of the coefficient of the forward spread and R^2 in the within-sample estimation.

This paper examines the out-of-sample forecasting performance of ex ante forecast based on the term structure for the future interest rates in comparison with other alternative forecasts and attempts to answer the question of whether ex ante forecasts based on the term structure are better than alternative forecasts in terms of forecasting accuracy and information content. This question is more relevant one than the question of whether there exist any statistically significant ex post relationship between the changes in interest rates and the term structure, especially when you are interested in using the term structure to forecast the future interest rates, because the existence of a significant ex post relationship between the changes in interest rates and the term structure does not mean that the term structure can be used to form a good ex ante forecast for the future interest rate changes.

In order to generate the out-of-sample forecast from forward rates implicit in the term structure, this paper recursively estimates the regression equation of the one-month interest rate changes on the corresponding forward spreads. The regression coefficients are allowed to change over time since the relationship between these two variables are expected to change over time when there exist time-varying risk premia in forward rates. The Kalman filter algorithm is applied in recursively estimating the time-varying coefficients and generating multi-step-ahead forecasts from the term structure forecasting equation. The nice feature of the Kalman filtering methodology is that the coefficients in each period are estimated using information available only up to that period. Therefore the out-of-sample forecasts of the term structure for the future changes in interest rates are based on the information available only up to the time the forecasts are made. The accuracy and the information content of this term structure forecasts are compared with those of the Bayesian vector autoregression (BVAR) forecasts, the univariate time series forecast and the simple random walk forecasts in order to evaluate the relative forecasting performance of the term structure.

Section [2] develops the basic empirical model to forecast the future changes in interest rates from the term structure and section [3] discusses the econometric issues involved in estimating this forecasting model. Section [4] presents the empirical results on the forecasting accuracy and the information content of the term structure of the U.S. Treasury bill interest rates with one-to-six month maturities. Finally, section [5] contains the concluding remarks.

[2] Model

We define an n-period ahead one-period forward rate implicit in the term structure at time t, F_t^n, as follows:[1]

$$F_t^n = (n+1)R_{n+1,t} - nR_{n,t}$$

where $R_{n,t}$ is the nominal interest rate on an n-period discount bond at time t. From now on, we denote the interest rate on an one-period bond at time t by R_t rather than $R_{1,t}$ for notational convenience. And this forward rate can always be decomposed into the market forecast of the n-period ahead interest rate and the time-varying risk premium:

$$F_t^n = E[R_{t+n}|I_t] + RP_t^n \tag{1}$$

where RP_t^n is the time-varying risk premium in forward rate, and $E[\cdot|I_t]$ is the expectations operator conditional on the information available to agents at time t. Equation (1) is not a theory, but simply defines the risk premium as the difference between the current forward rate and the market expectation of the future interest rate conditional on the current available information.

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[1]Throughout this paper we use continuous compounding simply for computational convenience.

From equation (1) note that changes in forward rate can be due to either changes in the market expectation of the future interest rate or changes in the risk premium. The expectations hypothesis asserts that the risk premium in the term structure is constant over time and thus attributes all movements in forward rates to the changes in the market expectations.

The realized level of one-period interest rate at time t+n can be written as the sum of the expected level at time t plus a forecast error, u_{t+n}

$$(2) \qquad R_{t+n} = E[R_{t+n}|I_t] + u_{t+n}$$

Substituting (2) into (1) and rearranging, we get

$$(3) \qquad R_{t+n} = -RP_t^n + F_t^n + u_{t+n}$$

Then subtracting R_t from both sides of eq. (3) gives

$$(4) \qquad R_{t+n}-R_t = -RP_t^n + (F_t^n-R_t) + u_{t+n}$$

Under the assumption of the rational expectations that forecast error, u_{t+n}, is orthogonal to the information set at time t which includes forward spread, $F_t^n-R_t$, the expectations hypothesis of the term structure can be tested by the OLS estimation of the following regression

$$(5) \qquad R_{t+n}-R_t = \alpha + \beta[F_t^n-R_t] + u_{t+n}$$

Under the null hypothesis of the expectations theory, β should be equal to one and α will capture the constant risk premium.

Most previous empirical studies found that the expectations hypothesis is strongly rejected (i.e., the estimate of β in (5) is significantly different from one) and these results were considered as strong evidence of the existence of the time-varying risk premium. Among these, Shiller, Campbell and Schoenholtz (1983) suggested that the changes in the slope of the term structure must be explained primarily by changes in the risk premium. Using different statistical methodology, Startz (1982) concluded that, for one-month treasury bill rates, one to two thirds of the variation in the difference between forward rates and realized spot rates is due to variation in the risk premium.

In spite of these findings, recently, Fama (1984), Fama and Bliss (1987), Campbell and Shiller (1988), Hardouvelis (1988), and Mishkin (1988) have investigated the information content of the term structure of interest rates and documented more positive evidence on the ability of the term structure to forecast the future interest rates. As emphasized in Fama (1984), the most important implication of the results of these studies is that, although the presence of time-varying risk premia can obscure the predictive ability of forward rates, yet forward rates may optimally incorporate publicly available information on future interest rates.

Most empirical studies mentioned in the previous paragraph were focused on whether forward rates contain any information on the future interest rates and their evaluation of the information content of forward rates was based on the size and significance of the OLS estimate of β and a with-in-sample measure of goodness-of-fit R^2 in the regression equation of changes in interest rates and forward spreads such as (5). However the evaluation of the predictive power of the forward rates based on <u>with-in-sample</u> estimation is subject to two major problems. First, it does not provide any answer to the question of whether the term structure can be used to make an useful <u>ex ante</u> forecast of the future interest rate. Estimating the regression equation (5) over the particular sample period simply gives <u>ex post</u> relationship between actual changes in interest rates and forward spreads, which is unlikely to be known ex ante to agents in the economy and thus can not be used to forecast the future interest rates. Second, the relationship between changes in interest rates and forward spreads may change over time. The reason is as follows; when there exist time-varying risk premia in forward rates, as Fama (1984), Mankiw and Summers (1986), and Hardouvelis (1988) have shown, the true value of β in the regression equation (5) can be written as[1]

(6) $$\beta = (\sigma^2+\rho\sigma)/(1+\sigma^2+2\rho\sigma)$$

where $\sigma = \mathrm{var}[E_t(R_{t+n}-R_t)]/\mathrm{var}[RP_t^n]$

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[1] The derivation of eq. (6) assumes the rational expectations that the forecast errors are orthogonal to the information available to agents.

$$\rho = \text{corr}[E_t(R_{t+n}-R_t),RP_t^n]$$

This indicates that the value of β in the regression equation (5) is determined by how variable the expected interest rate change is relative to the risk premium in forward rate (represented by σ, the ratio of the standard deviations of $E_t(R_{t+n}-R_t)$ and RP_t^n) and by the correlation of the expected interest rate change with risk premium (ρ). If risk premium is constant over time, it is easy to show that β equals one. But when the risk premium is varying over time, β will deviate from one. Notice that two parameters which determine the value of β (i.e., σ and ρ) are not structural parameters and that in general they will vary with any change in factors which determine the relative variability of expected future interest rate changes and risk premia or the correlation between these two variables. Hence the regression coefficient β in (5) will fluctuate over time independently of the information content of forward rates.[1] If this is the case, then the regression equation with fixed coefficients such as (5) is mis-specified and the inference based on the estimation of the regression equation with fixed coefficients will lead to misleading judgement on the predictive power of forward rates. Later, in section [4], we formally test the null hypothesis of the stability of α and β in the regression equation (5) and provide strong statistical evidence for their fluctuation over time.

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[1] In general, the time-variation in β would cause the intercept term $\tilde{a}$ to change as well.

In this paper, in order to extract ex ante forecasts in forward rates, we recursively estimate the following forecasting equation for interest rate changes, which will be referred to as the term structure forecasting equation,

$$(7) \qquad R_{t+n} - R_t = \alpha_{t+n} + \beta_{t+n}(F_t^n - R_t) + u_{t+n}$$

Notice that equation (7) explicitly takes into account the possibility of the time-variations in σ and ρ in (6) by allowing the coefficients to vary over time. This can be considered as a unrestricted specification of the forecasting equations employed in the previous studies on the information content of forward rates, where αt and β_t have been assumed to be constant over time.

Due to the absence of any available theory for the determinants of α_t and β_t, we rely on a time-series model in order to capture their time-variation. We assume that both αt and βt follow stable first-order autoregressive process as follows

$$(8a) \qquad \beta_{t+n} - \beta = \delta_1(\beta_{t+n-1} - \beta) + \epsilon_{1t+n}$$

$$(8b) \qquad \alpha_{t+n} - \alpha = \delta_2(\alpha_{t+n-1} - \alpha) + \epsilon_{2t+n}, \qquad |\delta_i| < 1 \quad i=1,2$$

where ϵ_{1t} and ϵ_{2t} are independently distributed with mean zero and finite variance respectively. This is particularly attractive specification because it captures some of the best features of both the random walk and the random coefficients models for the time-varying coefficients. If δ_i is close to one, the coefficient will vary with strong persistence, a feature present in the random walk model, and if δ_i is close to zero, then the coefficient will randomly vary around a constant mean as in the random coefficient model.

Then, as we will describe in detail in the next section, we can extract ex ante forecasts from forward rates by generating the out-of-sample forecasts through the recursive estimation of $\bar{a}_{t+n}$ and β_{t+n} in (7) using the information only up to time t.

In order to evaluate the relative value of the term structure as ex ante predictor of the future interest rate changes, this ex ante forecast extracted from forward rates is compared with four alternative ex ante forecasts: 1) the simple random walk forecasts 2) the out-of-sample forecasts from the Bayesian vector autoregression (BVAR) model which includes six lags of one-month interest rates, inflation rates, M1 growth rates and industrial production growth rates, 3) the out-of-sample forecast from univariate ARIMA model, and 4) the "naive" forward rate forecast.

[3] Econometric Issues

In this section we describe the recursive estimation procedure employed in generating the out-of-sample forecast from the term structure forecasting equations (7) and (8). First, notice that the error term, u_{t+n}, in (7) is likely to be serially correlated when the forecasting interval is longer than the observation interval (i.e., n is greater than one). The error term, u_{t+n}, which can be thought of as a forecast error is not realized until time t+n, and is likely to be correlated with u_{t+1}, u_{t+2},...,u_{t+n-1}. Hence we assume that it follows a moving average of order n-1 process.

We rewrite the regression equation (7) as follows

$$R_{t+n} - R_t = \alpha + \beta[F_t^n - R_t] + \beta_{t+n}^*[F_t^n - R_t] + w_{t+n} \tag{9}$$

where $\beta_{t+n}^* = \beta_{t+n} - \beta$

$$w_{t+n} = (\alpha_{t+n} - \alpha) + u_{t+n}$$

From (8a), we know that

$$\beta_{t+n}^* = \delta_1 \beta_{t+n-1}^* + \epsilon_{1t+n} \tag{10}$$

Also since $(\alpha_{t+n}-\alpha)$ follows an AR(1) process from (8b) and u_{t+n} follows a MA(n-1) process, we specify the composite error term, w_{t+n}, as an ARMA(1,n-1), i.e.,

$$w_{t+n} = \delta_3 w_{t+n-1} + e_{t+n} + \theta_1 e_{t+n-1} + \cdots + \theta_{n-1} e_{t+1} \tag{11}$$

where e_t is serially uncorrelated with mean zero.

Now equations (9), (10) and (11) can be put in state space form as follows

(12) $$Y_{t+n} = Z'_{t+n}X_t$$

(13) $$Z_{t+n} = AZ_{t+n-1} + RQ_{t+n}$$

where $Y_{t+n} = R_{t+n} - R_t$

$$\underset{(n+3)x1}{Z_{t+n}} = [\alpha, \beta, \beta_{t+n}^{*}, w_{t+n}, e_{t+n}, e_{t+n-1}, \cdots, e_{t+3}, e_{t+2}]'$$

$$\underset{(n+3)x1}{X_t} = [1, (F_t^{n}-R_t), (F_t^{n}-R_t), 1, 0, 0, \cdots, 0, 0]'$$

$$\underset{2x1}{Q_{t+n}} = [\epsilon_{1t+n}, e_{t+n}]'$$

$$\underset{(n+3)x(n+3)}{A} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0\ldots & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0\ldots & 0 & 0 \\ 0 & 0 & \delta_1 & 0 & 0 & 0\ldots & 0 & 0 \\ 0 & 0 & 0 & \delta_3 & \theta_1 & \theta_2\cdot\cdot & \theta_{n-2} & \theta_{n-1} \\ 0 & 0 & 0 & 0 & 0 & 0\ldots & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0\ldots & 0 & 0 \\ \multicolumn{8}{l}{\cdots\cdots\cdots\cdots\ 1\ \cdots\cdots} \\ 0 & 0 & 0 & 0 & 0 & 0\ldots & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0\ldots & 1 & 0 \end{bmatrix}$$

$$\underset{(n+3)\times 2}{R} = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 1 \\ 0 & 0 \\ \cdots & \cdots \\ 0 & 0 \\ 0 & 0 \end{bmatrix}$$

where we assume the following properties: a) Q_t is normal distributed with mean zero and variance V which is a diagonal matrix, $\mathrm{Diag}(\sigma_1^2, \sigma_2^2)$, i.e.,$\epsilon_{1t}$ and e_t are uncorrelated, b) X_t is nonstochastic.

Equations (12) and (13) together form a standard state space model where (12) can be called the measurement equation and (13) the transition equation for the unobservable state vector, Z_t. If the prior distribution of Z_0 is given as $N(Z_{0|0}, P_{0|0})$ and the parameters in A and V are known a priori, the coefficient vector Z_t can be updated by applying the Kalman filter techniques as follows[1]

(14a) $$Z_{t|t-1} = AZ_{t-1|t-1}$$

(14b) $$P_{t|t-1} = AP_{t-1|t-1}A' + RVR'$$

(14c) $$Z_{t|t} = Z_{t|t-1} + k_t[Y_t - Z_{t|t-1}'X_{t-n}]$$

(14d) $$P_{t|t} = P_{t|t-1} - k_t X_{t-n}'P_{t|t-1}$$

(14e) $$k_t = P_{t|t-1}X_{t-n}[X_{t-n}'P_{t|t-1}X_{t-n}]^{-1}$$

where $Z_{t|t-s}$ is the minimum mean sqaure estimator of Z_t based on all the observations up to time s and $P_{t|t-s}$ is its covariance matrix. (14a) and (14b) are the prediction equations, and (14c) and (14d) the updating equations for the mean and variance of Z_t. k_t in (14e) is the so-called kalman gain.

Therefore, given the parameters in A and V and the observations up to time t, the optimal (or minimum mean square) forecast for Y_{t+n} (i.e., the change in one-period interest rate from time t to t+n) based on the forward

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[1]For the detailed derivation of the Kalman filter equations, see Harvey (1981, ch. 4).

rate at time t can be made by employing the prediction equation (14a) repeatedly as follows

$$(15) \qquad Y_{t+n|t} = Z_{t+n|t}'X_t = (A^n Z_{t|t})'X_t$$

Moreover, the Kalman filter equations (14a) to (14e) can be used to estimate the parameters in A and V which are unknown in general, because they enable the likelihood function to be decomposed in terms of one-step-ahead prediction errors,

$$v_t = Y_t - Y_{t|t-1} \qquad t = 1,\cdots,T,$$

Since v_t has mean zero and variance $f_t = X_{t-n}'P_{t|t-1}X_{t-n}$,[1] the log likelihood function becomes

$$(16) \qquad \log(L) = \text{constant} - \tfrac{1}{2}\Sigma\log f_t - \tfrac{1}{2}\Sigma v_t^2/f_t$$

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[1] v_t can be written as $(Z_t-Z_{t|t-1})'X_{t-n}$ and $(Z_t-Z_{t|t-1})$ has mean zero and covariance $P_{t|t-1}$.

where f_t and v_t are implicit functions of the parameters in A and V. Thus the maximum likelihood estimate of the parameters in A and V can be obtained by numerical maximization of equation (16). In the maximum likelihood estimation of the parameters in A and V, in order to start off the recursions, we use a diffuse (or noninformative) prior for Z_0 by setting $P_{0|0}$ equal to μI, where μ is a large number and I is an identity matrix. This effectively gives the same result as using the first k observations to compute the starting values.

Among the four alternative forecasts, two alternative forecasts are obtained as follows: first, we construct a Bayesian vector autoregressive (BVAR) model which includes six lags of short-term interest rates, inflation rates, money growth rates and industrial production growth rates. To avoid over-parameterization which usually results in large out-of-sample forecast errors, we impose the Litterman (1980) prior that gives the prior means of the coefficients values that imply that the variables follow univariate random walks. The standard deviations of the prior take the form

$$S(i,j,l) = kg(l)f(i,j)(s_i/s_j)$$

where i indexes the left-hand-side variables, j indexes the right-hand-side variables and l indexes the lag. s_i is the standard error of a univariate autoregression on variable i.[1] We choose relatively "tight" priors: 1) $f(i,j) = 1$ for $i=j$ and $f(i,j) = .5$ otherwise, 2) $g(l) = l^{-1}$ and 3) $k = .1$. Each period this BVAR model is re-estimated using information available only up to that period and out-of-sample forecasts are made for the future short-term interest rates.

Second, a univariate time series model for short-term interest rates is used to generate out-of-sample forecast. After examining the autocorrelation and the partial autocorrelation of one-month interest rate, we choose ARIMA(0,1,1) to represent the time series properties of one-month interest rates over the sample period. Each period this ARIMA model is re-estimated using the data only for the previous three years.

In many forecasting exercises, a simple random walk forecast, i.e., "no change" forecast is shown to be very powerful. For example, Meese and Rogoff (1983) found that the random walk model performs no worse than estimated univariate time series models, vector autoregression or structural models in forecasting exchange rates. Hence the out-of-sample forecast from the term structure is also compared with the random walk forecast which is simply "no change" forecast.

Out-of-sample forecasting accuracy is measured by four summary statistics: the mean error (ME), the mean absolute error (MAE), the root mean squared error (RMSE), and the U statistic. These are defined as follows:

$$ME = \Sigma[A(t+j+k) - F(t+j+k)]/N$$

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[1]This scaling by the standard errors is done to correct for the different magnitudes of the variables in the system.

$$MAE = \Sigma|A(t+j+k) - F(t+j+k)|/N$$

$$RMSE = [\Sigma\{A(t+j+k) - F(t+j+k)\}^2/N]^{1/2}$$

where k denotes the forecast step, N the total number of forecasts in the projection for which the actual value of the short-term interest rate, A(t) is known, and F(t) denotes the forecast value. Theil's U statistic is the ratio of the RMSE to the RMSE of the naive random walk forecast.

[4] Empirical Results

We use monthly data on one to six month U.S. Treasury bills for the period from January 1959 to December 1986. End of month T-bill data is originally obtained from the Center for Research in Security Prices (CRSP) at the University of Chicago. As in Mishkin (1988), the one-month bill is defined to have a maturity of 30.4 days and the two-month bill 60.8 days, etc. For each defined maturity the interest rate is interpolated from two bills that were closest to the defined maturity.[1] The interest rates are expressed on a continuously compounded basis at an annual rate in percent. The one to five month ahead forward rates are calculated by the formula in section [2]. The

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[1]This amounts to assuming that the slope of the term structure is constant between these two bills.

inflation data is calculated from a CPI series which appropriately treats housing costs on a rental-equivalence basis.[1] Monthly M1 growth rates and industrial production growth rates are calculated from the seasonally adjusted series which are obtained from the Citibase tape. As interest rates, all of them are expressed on a continuously compounded basis at an annual rate in percent.

Table 1 reports the results of the fluctuation test of α and β in the regression equation (5). This test has been recently proposed by Ploberger, Krämer and Kontrus (1989) and is based on successive OLS parameter estimates. The basic idea of this test is to reject the null hypothesis of parameter constancy whenever successive OLS parameter estimates fluctuate too much. Unlike the well known Chow test, this test does not require that the location of possible shifts in the parameters be known and, for certain types of structural shifts, is shown to have higher power than both the CUSUM and CUSUM of squares tests of Brown, Durbin and Evans (1975) which are based on recursive OLS residuals.[2] Table 1 contains the results for both the full sample period and three sub-periods which are split into two ten-year periods and the remaining period. As we can see, for all n, the null hypothesis of the constancy of α and β in the full sample period is rejected at the 1% significance level. And in 10 out of 15 sub-periods, the null hypothesis is rejected at least at the 10% significance level. Given the low

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[1]The data on interest rates and inflation rates were kindly provided by Professor Mishkin.

[2]For the detailed description of the fluctuation test statistic, see Appendix.

power of this test, these results indicate that the regression equation with fixed coefficients employed in the previous empirical studies on the predictive power of the term structure are mis-specified.

Table 2 reports the maximum likelihood estimates of the parameters in the equations (12) and (13) which are the state space representation of the term structure forecasting equations (7) and (8). For n = 1 to 4, σ_1s, the standard deviations of innovations in β_t are significantly different from zero at the 1% significance level and for n = 5 it is significantly different from zero at 10 % significance level, which confirms the results of the fluctuation test in Table 1. The autoregressive coefficient of β_t, δ_1, is significantly different from zero only for n = 3 and 5, and δ_3 is significant only for n = 3. However, all of the moving average parameters, θ_is, are significantly different from zero.

Figures 1 to 5 plot the estimates of β_t for n = 1 to 5, which were obtained by recursive application of the Kalman filter equations in (14). They clearly shows the wide variation of β_t over time. For n = 2, the plot indicates some evidence of non-stationarity of the variation of β_t. One might argue that the rejection of the constancy of the regression coefficients in Table 1 is only due to the shifts in the stochastic process of interest rates in October 1979 and October 1982.[1] However the Figures 1 through 5 show that the time variations of B_t are very evident even before October 1979.

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[1]Huizinga and Mishkin (1986) documented that the monetary policy regime changes in October 1979 and October 1982 were followed by shifts in the stochastic process of interest rates.

4.1 The Forecasting Accuracy of the Term Structure

Tables 3A, 3B, 3C and 3D report the mean errors (ME), mean absolute errors (MAE) and root mean squared errors (RMSE) of the out-of-sample forecasts of the term structure model and four alternative models; 1) the Bayesian VAR model, 2) the ARIMA model 3) the simple random walk ("no change") model and 4) the "naive" forward rate model where the forecasts of future interest rates are current forward rates. In order to allow the time-varying coefficients in the term structure model to adjust from the diffuse prior and also to start off the recursive estimation of the BVAR and ARIMA models, when we calculate the above summary statistics, we exclude forecasts before May 1963. Table 3A contains the results of the full sample period, May 1963 to December 1986, while Tables 3B, 3C and 3D contain the results for three sub-periods, May 1963 to October 1979, November 1979 to October 1982, and November 1982 to December 1986. The sample is split into these three sub-periods to see whether the relative forecasting accuracy of the term structure is different across different monetary policy regimes, as suggested by Mankiw and Miron (1986).

Except for "naive" forward rate forecast, the mean errors in each Table are small in absolute value relative to the corresponding mean absolute errors, indicating that none of the forecasting models did systematically overpredict or underpredict over the sample period. The mean errors of "naive" forward rate forecast, however, are negative and have roughly the same magnitude as the MAEs. It implies that forward rates systematically overpredicted future interest rates over the sample period, indicating the existence of positive risk premium.

For one month horizon, the term structure forecast gives the smallest MAE and RMSE in both the full sample period and each sub-period but for the longer horizons, in general, it seems to be slightly outperformed by either the simple random walk forecast or the Bayesian VAR forecast. The ARIMA forecast and the "naive" forward rate forecast almost always give much larger MAEs and RMSEs than the term structure forecast. In the second sub-period when interest rates were highly volatile due to the Fed's abandoning the interest rate targeting, both MAEs and RMSEs of all forecasts sharply increase. But we can not find any evidence for changes in the forecasting accuracy of the term structure model relative to other alternative forecasts across different monetary policy regimes.

Since the differences in RMSE among the term structure forecast, the random walk forecast and the BVAR forecast are very small, we conduct the test suggested by Ashley, Granger and Schmalensee (1980) in order to test whether the RMSE of the term structure forecast is statistically significantly different from that of alternative forecasts. This test which allows for the existence of the cross and auto correlations in different forecast errors unlike a simple mean t-test is derived from the decomposition of the mean squared error into the variance of the forecast error and the square of the bias. Therefore the difference between two mean squared errors is the sum of the difference between the two variances and the difference between the two squared bias. Furthermore the difference between the two variances can be re-written as the covariance between the difference of the forecast errors and the sum of the errors. Thus the test involves regressing the difference in the two forecast errors on the constant term and the sum of the two mean-adjusted forecast errors,[1] i.e.,

$$(17) \qquad e_{1t} - e_{2t} = d_0 + d_1[(e_{1t}+e_{2t})-\text{mean}(e_{1t}+e_{2t})] + \epsilon_t$$

where e_{it} is out-of-sample forecast error at time t of the i-th model at time t. The null hypothesis that the two mean squared errors are equal is equivalent to the hypothesis that both d_0 and d_1 are zero. The alternative hypothesis that $MSE(e_1)$ is greater than $MSE(e_2)$ is that both d_0 and d_1 are nonnegative and at least one is positive. If either of the two estimates is significantly negative, the null hypothesis can not be rejected. If one estimate is negative but not significant, a one-tailed t-test on the other estimated coefficient can be used. If both estimates are positive, an F test of the null hypothesis that both coefficients are zero can be employed. The same regression can be used to test the null hypothesis against the alternative that $MSE(e_2)$ is greater than $MSE(e_1)$ which is equivalent to the hypothesis that both d_0 and d_1 are nonpositive and at least one is negative.

Table 4 presents the OLS estimates of the regression equation (17) where e_{1t} is the forecast error from either the random walk model or the

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[1]If the mean of the forecast errors of any model is negative, all errors from that model is multiplied by a minus one and the regression is performed with the new error series, $-e_{it}$.

BVAR model and e_{2t} is the forecast error from the term structure model. For the full sample period, the one-month MSE of the term structure model is significantly smaller than that of both the random walk and the BVAR models.[1] However for the longer horizons except two month, the null hypothesis is rejected against the alternative that the MSEs of the alternative models for the full sample period are smaller than that of the term structure model. Especially the MSE of the BVAR model for the second sub-period is significantly lower than that of the term structure model for the horizons longer than two month.

The results in tables 3 and 4 suggest that the term structure forecast is relatively accurate only for one-month ahead forecast but for the horizons longer than two month it seems to be dominated by either the simple no change forecast or the BVAR forecast which is based on the several macro-variables. In other words, the relative forecasting accuracy of forward rates seems to be limited to the forecast for one-month ahead interest rates.

4.2 The Information Content of the Term Structure

Even when the term structure generates significantly larger out-of-sample forecast errors than alternative forecasting models, it is possible that the term structure forecast contains an additional useful information, vice versa. In order to formally test whether the forecast based on the term

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[1] In the second sub-period, the random walk forecast for one-month ahead interest rates seems to be more accurate than that of the term structure.

structure contains any additional information over alternative forecasts based on the BVAR forecast or the random walk forecast, we follow the procedure described by Fair and Shiller (1989) which is based on the following regression equation,

$$(14) \qquad R_{t+n} - R_t = a + bFCT(n)_{1,t} + cFCT(n)_{2,t} + \epsilon_{t+n}$$

where $FCT(n)_{i,t}$ is out-of-sample forecast made at time t by the model i for the change in interest rate from time t to t+n. If neither forecast 1 nor forecast 2 contains any useful information for the short-term interest rate changes, then the estimates of b and c should both be zero. If both forecasts contain independent information, then both b and c should be different from zero. If both forecasts contain information, but the information in forecast 2 is completely contained in forecast 1 and forecast 1 contains further relevant information as well, b should be different from zero but c should be zero.

We estimate the regression equation (14) with forecast 1 being forecast from the term structure model and forecast 2 being forecast from the BVAR model and the simple random walk model. and test the hypothesis H_1 that b=0 and the hypothesis H_2 that c=0. H_1 is the hypothesis that the forecast from the term structure contains no additional information which is not in the constant term and in the alternative forecast. H_2 is the hypothesis that the alternative forecast contains no information not in the constant term and in forecast from the term structure. Since the forecast for the interest rate changes from the random walk model is always zero, the comparison with the random walk forecast involves regressing the actual interest rate changes (which are equal to random walk forecast errors) on the constant and the term structure forecast and testing whether the term structure forecast can explain some of random walk forecast errors. When we estimate eq. (14), we correct for both heteroskedasticity and the moving average process in the estimation of the standard errors of the coefficient estimates. As we noted earlier, when the forecasting interval is longer than the observation interval (i.e., $n > 1$), the error term in eq.(14) is likely to follow a MA(n-1) process.

Table 5 reports the results of regressing the actual changes in one-month interest rate on the constant and the term structure forecast. The coefficients on the one-month ahead term structure forecast are significantly positive and close to one, suggesting that the term structure contains useful information for one-month ahead interest rates. However, none of the coefficient estimates of the two to five-month ahead term structure forecasts provide any favorable evidence. Especially some of coefficients of the four-month ahead forecast are significantly negative, i.e., the term structure predicts the wrong direction in the future change in interest rates.

Table 6 presents the estimates of the regression of the actual interest rate change on the constant, the term structure forecast and the BVAR forecast. For the full sample period, the one and two-month ahead BVAR forecasts are significantly positive coefficients as well as the term structure forecasts, implying that the information content of the term structure forecast does not seem to completely dominate that of the BVAR model. However, for the longer horizons, the coefficients on the term structure forecasts are either significantly negative or statistically indifferent from zero while some of the BVAR forecasts have significantly positive coefficients.

In summary, the term structure forecast seems to contain some useful information on one-month ahead interest rate (and also possibly two-month ahead interest rate) but for the longer horizons, the term structure forecast appears to be worthless or even misleading.

[5] Conclusion

This paper has investigated the out-of-sample forecasting performance of the term structure of the one-to-six month U.S. Treasury Bill interest rates in comparison with those of the BVAR forecasting model based on the key macro-variables, the random walk (no change) model, and the univariate ARIMA model. The out-of-sample forecast for the future one-month interest rate changes are extracted from the term structure through recursive estimation of the regression equation of changes in interest rates on forward spreads The time-varying nature of the relationship between interest rate changes and forward spreads are documented and incorporated into the forecasting procedure by allowing the regression coefficients to change over time. The Kalman filter techniques are employed to update these time-varying coefficients and to generate out-of-sample forecast, using the observations up to the time when forecast is made.

The empirical results indicate that the term structure forecast for one-month ahead interest rate is accurate and informative relative to other alternative forecasts. However, the term structure forecasts for more distant future interest rates seem to be inferior to alternative forecasts in their forecasting accuracy and information content. This casts some doubts on a recent attempt to use the term structure in predicting the future interest rates since, except for the very short end of the term structure, the out-of-sample forecasting power of forward rates implicit in the term structure is worse than other available forecasts.

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APPENDIX

The Fluctuation Test by Ploberger, Krämer and Kontrus (1989)

Consider the linear regression model

$$y_t = x_t'\beta_t + u_t, \qquad t = 1,\cdots,T$$

where y_t is the dependent variable and x_t is a (Kx1) vector of observation of the independent variables at time t, β_t is a (Kx1) vector of unknown regression coefficients and u_t is a disturbance term. Define

$$X^{(t)} = [x_1,\ldots,x_t], \qquad Y^{(t)} = [y_1,\ldots,y_t]', \quad t = 1,\ldots,T$$

and then the successive OLS parameter estimates can be written as

$$b^{(t)} = (X^{(t)\prime}X^{(t)})^{-1}X^{(t)\prime}Y^{(t)}, \quad t = K,\ldots,T.$$

Then the null hypothesis that $\beta_t = \beta_0$ is the same for $t = 1,\ldots,T$ is tested by the following test statistic

$$S^{(T)} = \max_{t=K,\ldots,T} (t/sT)\|(X^{(T)\prime}X^{(T)})^{\frac{1}{2}}(b^{(t)}-b^{(T)})\|$$

where

$$s = \{\Sigma(y_t-x_t'b^{(T)})^2/(T-K)\ \}^{\frac{1}{2}}$$

and $\|\cdot\|$ denotes the maximum norm.

The basic idea of the test is to reject the null whenever the absolute difference between $b^{(t)}$ and $b^{(T)}$ fluctuates excessively. The asymptotic distribution of $S^{(T)}$ under the null hypothesis is derived in Ploberger, Krämer and Kontrus (1989) under the certain assumptions. For K=2, the critical values of the test statistic for the 10%, 5% and 1% significance tests are 1.35, 1.48 and 1.73 respectively.

TABLE 1

Test of the Constancy of α and β in
$R_{t+n} - R_t = \alpha + \beta[F_t^n - R_t] + u_{t+n}$

n	Sample Period	No. of Obs.	Test Statistic
1 MONTH			
	2/59 - 12/86	335	2.053**
	2/59 - 1/69	120	1.541*
	2/69 - 1/79	120	0.798
	2/79 - 12/86	95	2.110**
2 MONTH			
	3/59 - 12/86	334	2.357**
	3/59 - 2/69	120	1.726**
	3/69 - 2/79	120	1.077
	3/79 - 12/86	94	0.938
3 MONTH			
	4/59 - 12/86	333	2.471**
	4/59 - 3/69	120	1.352a
	4/69 - 3/79	120	1.265
	4/79 - 12/86	93	1.212
4 MONTH			
	5/59 - 12/86	332	2.174**
	5/59 - 4/69	120	1.524*
	5/69 - 4/79	120	1.640*
	5/79 - 12/86	92	1.787**
5 MONTH			
	6/59 - 12/86	331	1.976**
	6/59 - 5/69	120	2.480**
	6/69 - 5/79	120	1.839**
	6/79 - 12/86	91	1.801**

The critical values of the test statistic for 10%, 5% and 1% significance tests are 1.35, 1.48 and 1.73 respectively (see Ploberger, Krämer and Kontrus (1989)).

** = significant at the 1% level
* = significant at the 5% level
a = significant at the 10% level

TABLE 2

Parameter Estimates in the Term Structure Forecasting Equations

n	1 MONTH	2 MONTH	3 MONTH	4 MONTH	5 MONTH
σ_1	0.420**	0.070**	0.440**	0.052**	0.036a
	(0.049)	(0.025)	(0.053)	(0.019)	(0.020)
σ_2	0.647**	0.731**	0.541**	0.740**	0.760**
	(0.021)	(0.023)	(0.039)	(0.028)	(0.025)
δ_1	0.068	-0.059	0.310**	-0.201	0.882**
	(0.107)	(0.298)	(0.114)	(0.314)	(0.128)
δ_2	0.031	0.063	0.290**	0.019	-0.040
	(0.053)	(0.041)	(0.064)	(0.045)	(0.043)
θ_1		0.999**	1.016**	1.007**	1.029**
		(0.021)	(0.066)	(0.030)	(0.023)
θ_2			0.978**	1.004**	1.009**
			(0.076)	(0.035)	(0.027)
θ_3				0.991**	1.023**
				(0.039)	(0.037)
θ_4					0.993**
					(0.030)

Standard errors are in parentheses.

** = significant at the 1% level
a = significant at the 10% level

TABLE 3

Summary Statistics on the Forecasting Performance of the Term Structure Model and Alternative Models
Full Sample Period: 5/63 - 12/86 (No. of Obs. 284)

HORIZON	MODEL	ME	MAE	RMSE	U-Statistic
1 MONTH					
	TS	-.068	.466	.785	.952
	BVAR	.022	.492	.816	.989
	RW	.008	.499	.825	1.000
	ARIMA	-.039	.551	.928	1.125
	Forward	-.538	.675	1.035	1.255
2 MONTH					
	TS	-.026	.709	1.148	1.000
	BVAR	.055	.713	1.133	.987
	RW	.016	.709	1.148	1.000
	ARIMA	-.050	.779	1.269	1.105
	Forward	-.767	.962	1.455	1.267
3 MONTH					
	TS	-.082	.844	1.414	1.019
	BVAR	.094	.855	1.372	.989
	RW	.024	.846	1.387	1.000
	ARIMA	-.062	.940	1.514	1.092
	Forward	-.725	1.046	1.626	1.172
4 MONTH					
	TS	-.045	.968	1.556	1.010
	BVAR	.136	.986	1.522	.988
	RW	.030	.967	1.540	1.000
	ARIMA	-.076	1.069	1.686	1.095
	Forward	-1.045	1.352	1.991	1.293
5 MONTH					
	TS	-.006	1.085	1.656	1.010
	BVAR	.181	1.111	1.608	.980
	RW	.039	1.073	1.640	1.000
	ARIMA	-.087	1.188	1.808	1.102
	Forward	-1.108	1.490	2.152	1.312

TS: Term Structure model with the Time-varying coefficients
BVAR: Bayesian Vector Autoregressive model
RW: Random Walk (simple "no change") model
ARIMA: Univariate ARIMA(0,1,1) model
FORWARD: "naive" Forward Rate model

TABLE 3B

Summary Statistics on the Forecasting Performance of the Term Structure Model and Alternative Models
First Sub-period: 5/63 - 10/79 (No. of Obs. 198)

HORIZON	MODEL	ME	MAE	RMSE	U-Statistic
1 MONTH					
	TS	.042	.315	.466	.943
	BVAR	.052	.335	.491	.994
	RW	.036	.335	.494	1.000
	ARIMA	-.003	.374	.546	1.105
	Forward	-.302	.429	.597	1.209
2 MONTH					
	TS	.042	.482	.645	1.002
	BVAR	.107	.494	.650	1.009
	RW	.072	.478	.644	1.000
	ARIMA	.011	.539	.716	1.112
	Forward	-.533	.679	.898	1.394
3 MONTH					
	TS	.022	.566	.741	.984
	BVAR	.159	.595	.765	1.016
	RW	.103	.575	.753	1.000
	ARIMA	.022	.655	.856	1.137
	Forward	-.499	.695	.932	1.238
4 MONTH					
	TS	.068	.649	.862	1.001
	BVAR	.212	.690	.881	1.023
	RW	.133	.654	.861	1.000
	ARIMA	.034	.749	.993	1.153
	Forward	-.757	.934	1.270	1.475
5 MONTH					
	TS	.156	.769	1.000	1.009
	BVAR	.270	.805	1.020	1.029
	RW	.169	.753	.991	1.000
	ARIMA	.053	.862	1.153	1.163
	Forward	-.907	1.103	1.603	1.618

TS: Term Structure model with the Time-varying coefficients
BVAR: Bayesian Vector Autoregressive model
RW: Random Walk (simple "no change") model
ARIMA: Univariate ARIMA(0,1,1) model
FORWARD: "naive" Forward Rate model

TABLE 3C

Summary Statistics on the Forecasting Performance of the Term Structure Model and Alternative Models
Second Sub-period: 11/79 - 10/82 (No. of Obs. 36)

HORIZON	MODEL	ME	MAE	RMSE	U-Statistic
1 MONTH					
	TS	-.516	1.398	1.816	.957
	BVAR	.049	1.471	1.875	.988
	RW	-.082	1.517	1.897	1.000
	ARIMA	-.408	1.700	2.193	1.156
	Forward	-1.413	1.786	2.242	1.182
2 MONTH					
	TS	-.293	2.133	2.692	.999
	BVAR	.086	2.149	2.652	.984
	RW	-.180	2.155	2.695	1.000
	ARIMA	-.692	2.395	3.067	1.138
	Forward	-1.631	2.369	3.147	1.168
3 MONTH					
	TS	-.449	2.669	3.416	.948
	BVAR	.195	2.577	3.260	.983
	RW	-.183	2.611	3.316	1.000
	ARIMA	-.888	2.977	3.727	1.124
	Forward	-1.374	2.775	3.621	1.092
4 MONTH					
	TS	-.248	2.950	3.645	1.011
	BVAR	.336	2.880	3.540	.982
	RW	-.110	2.931	3.605	1.000
	ARIMA	-1.059	3.390	4.097	1.136
	Forward	-1.567	3.005	3.883	1.077
5 MONTH					
	TS	-.220	3.078	3.713	1.006
	BVAR	.447	3.087	3.577	.969
	RW	-.059	3.078	3.692	1.000
	ARIMA	-1.300	3.567	4.265	1.155
	Forward	-1.282	3.110	3.833	1.038

TS: Term Structure model with the Time-varying coefficients
BVAR: Bayesian Vector Autoregressive model
RW: Random Walk (simple "no change") model
ARIMA: Univariate ARIMA(0,1,1) model
FORWARD: "naive" Forward Rate model

TABLE 3D

Summary Statistics on the Forecasting Performance of the Term Structure Model and Alternative Models
Third Sub-period: 11/82 - 12/86 (No. of Obs. 50)

HORIZON	MODEL	ME	MAE	RMSE	U-Statistic
1 MONTH					
	TS	-.177	.396	.519	.939
	BVAR	-.119	.409	.542	.980
	RW	-.038	.416	.553	1.000
	ARIMA	.037	.429	.558	1.009
	Forward	-.845	.852	1.029	1.861
2 MONTH					
	TS	-.102	.584	.783	1.000
	BVAR	-.174	.548	.741	.946
	RW	-.062	.583	.783	1.000
	ARIMA	.070	.609	.804	1.027
	Forward	-1.073	1.074	1.303	1.664
3 MONTH					
	TS	-.228	.635	.881	1.005
	BVAR	-.237	.643	.852	.971
	RW	-.138	.650	.877	1.000
	ARIMA	.087	.671	.877	1.000
	Forward	-1.152	1.189	1.464	1.669
4 MONTH					
	TS	-.347	.807	1.112	1.024
	BVAR	-.308	.795	1.034	.952
	RW	-.276	.790	1.086	1.000
	ARIMA	.091	.720	.947	.916
	Forward	-1.812	1.817	2.295	2.113
5 MONTH					
	TS	-.492	.899	1.281	1.022
	BVAR	-.363	.902	1.162	.927
	RW	-.405	.894	1.254	1.000
	ARIMA	.120	.846	1.043	.832
	Forward	-1.780	1.856	2.358	1.880

TS: Term Structure model with the Time-varying coefficients
BVAR: Bayesian Vector Autoregressive model
RW: Random Walk (simple "no change") model
ARIMA: Univariate ARIMA(0,1,1) model
FORWARD: "naive" Forward Rate model

TABLE 4

Tests of the Statistical Differences
in the Out-of-Sample Forecast Errors

H_0 : the RMSEs of the term structure forecast and the alternative forecast are equal.

H_1 : the RMSE of the term structure forecast is smaller than that of the alternative forecast.

H_2 : the RMSE of the term structure forecast is greater than that of the alternative forecast.

A. Random Walk Model

		d_0	d_1	F
1 Month	5/63-12/86	-0.06	0.76	15.59 A
		(0.06)	(0.20)	
	5/63-10/79	-0.01	0.03	0.18
		(0.07)	(0.08)	
	11/79-10/82	-0.43	0.04	7.66 B
		(0.17)	(0.05)	
	11/82-12/86	-0.14	0.06	1.18
		(0.14)	(0.14)	
2 Month	5/63-12/86	-0.01	0.06	0.02
		(0.10)	(0.69)	
	5/63-10/79	0.03	-0.03	0.06
		(0.12)	(0.07)	
	11/79-10/82	-0.11	0.00	0.16
		(0.29)	(0.04)	
	11/82-12/86	-0.04	0.00	0.03
		(0.24)	(0.12)	
3 Month	5/63-12/86	-0.06	-1.08	10.01 B
		(0.13)	(0.34)	
	5/63-10/79	0.08	0.00	0.26
		(0.16)	(0.08)	

	11/79-10/82	-0.27 (0.37)	-0.01 (0.04)	0.62
	11/82-12/86	-0.09 (0.31)	0.01 (0.11)	0.09
4 Month	5/63-12/86	-0.02 (0.16)	-18.26 (2.51)	52.76 B
	5/63-10/79	0.07 (0.19)	-0.01 (0.08)	0.12
	11/79-10/82	-0.14 (0.43)	-0.00 (0.04)	0.12
	11/82-12/86	-0.07 (0.38)	-0.00 (0.09)	0.04
5 Month	5/63-12/86	0.33 (0.18)	-4.58 (1.51)	9.28 B
	5/63-10/79	0.01 (0.21)	-0.01 (0.08)	0.01
	11/79-10/82	-0.16 (0.48)	-0.00 (0.04)	0.12
	11/82-12/86	-0.09 (0.41)	0.00 (0.10)	0.04
B. Bayesian VAR Model				
1 Month	5/63-12/86	-0.05 (0.06)	0.44 (0.17)	7.20 A
	5/63-10/79	0.01 (0.07)	0.03 (0.07)	0.15
	11/79-10/82	-0.47 (0.17)	1.51 (0.30)	33.85
	11/82-12/86	-0.06 (0.14)	0.05 (0.15)	0.27
2 Month	5/63-12/86	0.03 (0.10)	-0.36 (0.28)	1.72

	5/63-10/79	0.07	-0.00	0.29
		(0.12)	(0.07)	
	11/79-10/82	-0.21	-0.42	1.46
		(0.29)	(0.42)	
	11/82-12/86	0.07	-0.04	0.19
		(0.24)	(0.13)	
3 Month	5/63-12/86	0.12	-0.53	6.10 B
		(0.13)	(0.22)	
	5/63-10/79	0.14	0.01	0.76
		(0.16)	(0.08)	
	11/79-10/82	-0.25	-1.23	16.06 B
		(0.37)	(0.31)	
	11/82-12/86	0.01	-0.02	0.03
		(0.31)	(0.13)	
4 Month	5/63-12/86	0.09	-0.77	7.12 B
		(0.16)	(0.30)	
	5/63-10/79	0.14	-0.00	0.60
		(0.19)	(0.09)	
	11/79-10/82	0.09	-1.74	18.63 B
		(0.43)	(0.41)	
	11/82-12/86	-0.04	-0.04	0.13
		(0.37)	(0.11)	
5 Month	5/63-12/86	0.18	-1.12	12.95 B
		(0.18)	(0.33)	
	5/63-10/79	0.11	-0.00	0.01
		(0.21)	(0.08)	
	11/79-10/82	0.23	-2.60	35.51 B
		(0.48)	(0.44)	
	11/82-12/86	-0.13	-0.04	0.23
		(0.41)	(0.12)	

A : H_0 is rejected against H_1, i.e., the RMSE of the term structure forecast is significantly smaller than that of the alternative forecast

B : H_0 is rejected against H_2, i.e., the RMSE of the term structure forecast is significantly larger than that of the alternative forecast

Standard errors in parentheses are obtained from Hansen (1982)'s heteroscedasticity and autocorrelation consistent covariance matrix.

TABLE 5

Tests of the Information Content of the Term Structure Forecast: Regressions of the actual change in one-month interest rate on the constant and the term structure forecast.

n	Sample Period	constant	Term Structure Forecast
1 Month			
	5/63 - 12/86	-0.06	0.88**
		(0.06)	(0.20)
	5/63 - 10/79	0.04	0.90**
		(0.07)	(0.38)
	11/79 - 10/82	-0.74**	1.53**
		(0.22)	(0.33)
	11/82 - 12/86	-0.19	1.12a
		(0.16)	(0.61)
2 Month			
	5/63 - 12/86	-0.01	0.53
		(0.11)	(0.69)
	5/63 - 10/79	0.06	0.33
		(0.12)	(0.78)
	11/79 - 10/82	-0.47	2.59
		(0.34)	(1.59)
	11/82 - 12/86	-0.14	1.85
		(0.30)	(4.35)
3 Month			
	5/63 - 12/86	0.03	-0.04
		(0.14)	(0.34)
	5/63 - 10/79	0.05	0.60
		(0.16)	(0.55)
	11/79 - 10/82	0.01	-0.74
		(0.39)	(0.47)
	11/82 - 12/86	-0.21	0.77
		(0.32)	(1.02)

4 Month			
	5/63 - 12/86	0.68**	-8.63**
		(0.24)	(2.51)
	5/63 - 10/79	0.37	-3.62
		(0.30)	(3.61)
	11/79 - 10/82	3.46**	-25.87**
		(0.68)	(3.88)
	11/82 - 12/86	0.14	-5.87
		(0.74)	(9.09)
5 Month			
	5/63 - 12/86	0.12	-1.79
		(0.19)	(1.51)
	5/63 - 10/79	0.19	-1.30
		(0.21)	(2.44)
	11/79 - 10/82	0.73	-4.88a
		(0.64)	(2.70)
	11/82 - 12/86	-0.49	0.96
		(0.48)	(2.63)

Standard errors are in parentheses.

** = significant at the 1% level
* = significant at the 5% level
a = significant at the 10% level

TABLE 6

Tests of the Information Content of the Term Structure Forecast:
Regressions of the actual change in one-month interest rate on the constant, the term structure forecast and the BVAR forecast.

n	Sample Period	constant	Term Structure Forecast	BVAR Forecast
1 Month				
	5/63 - 12/86	-0.05	0.86**	0.65*
		(0.06)	(0.20)	(0.32)
	5/63 - 10/79	0.05	0.87*	0.72
		(0.07)	(0.38)	(1.04)
	11/79 - 10/82	-0.69	1.48**	0.27
		(0.24)	(0.33)	(0.45)
	11/82 - 12/86	-0.25	1.13a	0.73
		(0.17)	(0.61)	(0.59)
2 Month				
	5/63 - 12/86	0.01	0.85**	0.79*
		(0.11)	(0.32)	(0.32)
	5/63 - 10/79	0.08	0.33	0.45
		(0.13)	(0.78)	(1.01)
	11/79 - 10/82	-0.32	3.91*	1.13*
		(0.35)	(1.63)	(0.47)
	11/82 - 12/86	-0.31	3.72	0.90
		(0.31)	(4.34)	(0.55)
3 Month				
	5/63 - 12/86	0.05	0.20	0.75*
		(0.14)	(0.34)	(0.31)
	5/63 - 10/79	0.08	0.62	0.42
		(0.17)	(0.55)	(1.04)
	11/79 - 10/82	0.28	-0.41	0.93*
		(0.42)	(0.46)	(0.45)
	11/82 - 12/86	-0.31	1.08	0.76
		(0.33)	(1.02)	(0.49)

4 Month

	5/63 - 12/86	0.64	-7.77**	0.25
		(0.25)	(2.72)	(0.33)
	5/63 - 10/79	0.37	-3.57	0.04
		(0.30)	(3.80)	(1.10)
	11/79 - 10/82	3.56	-27.80**	-0.38
		(1.26)	(9.45)	(1.00)
	11/82 - 12/86	-0.44	1.99	0.80
		(0.76)	(9.35)	(0.47)
5 Month				
	5/63 - 12/86	0.24	-1.53	0.93**
		(0.20)	(1.49)	(0.31)
	5/63 - 10/79	0.22	-1.35	0.33
		(0.24)	(2.44)	(1.01)
	11/79 - 10/82	1.82	-6.12*	1.76**
		(0.74)	(2.79)	(0.43)
	11/82 - 12/86	-0.41	0.45	0.82
		(0.49)	(2.80)	(0.51)

Standard errors are in parentheses.

** = significant at the 1% level
* = significant at the 5% level
a = significant at the 10% level

Figure 1

Coefficient of 1 Month Forward Spread

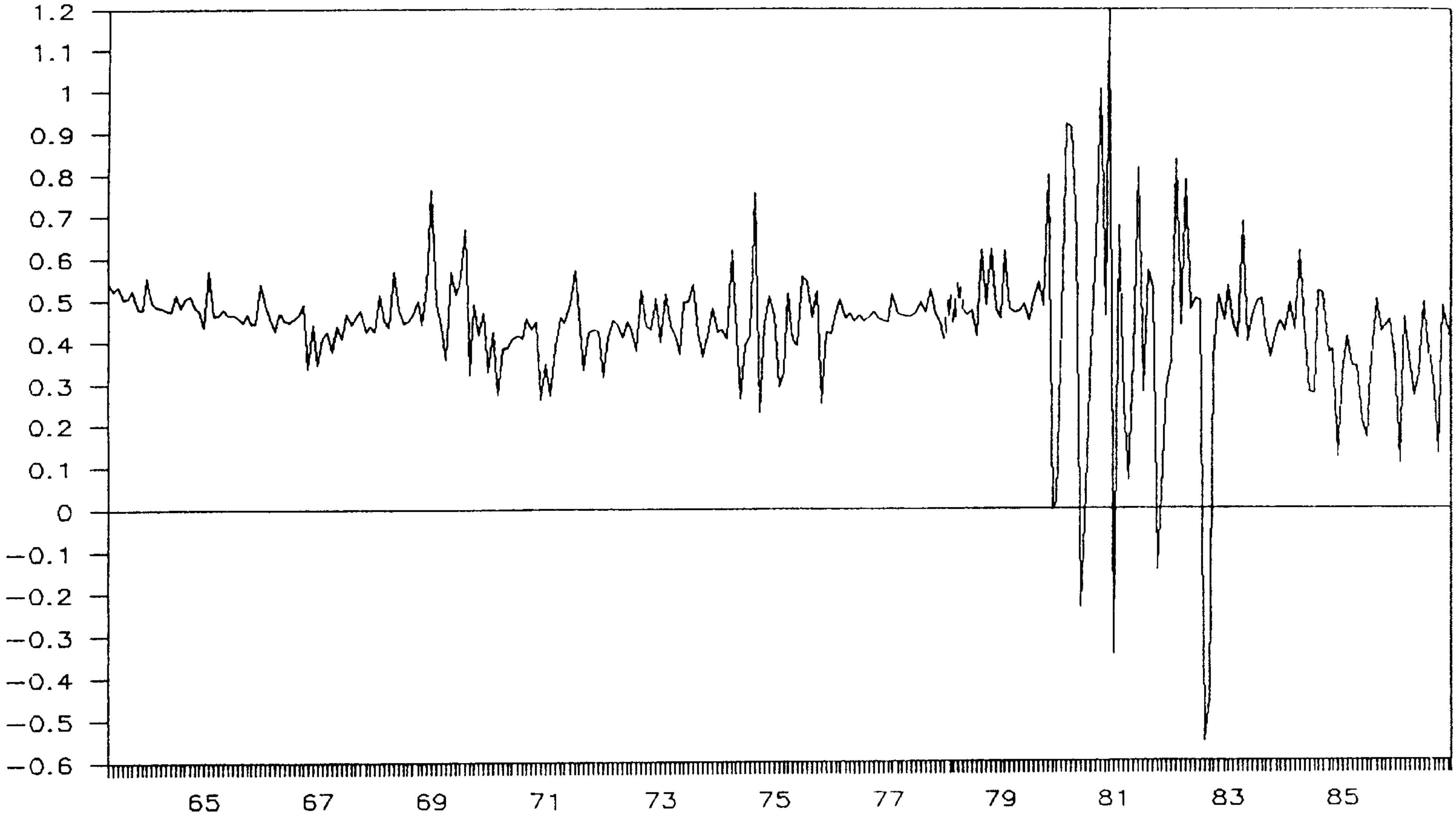


Figure 2

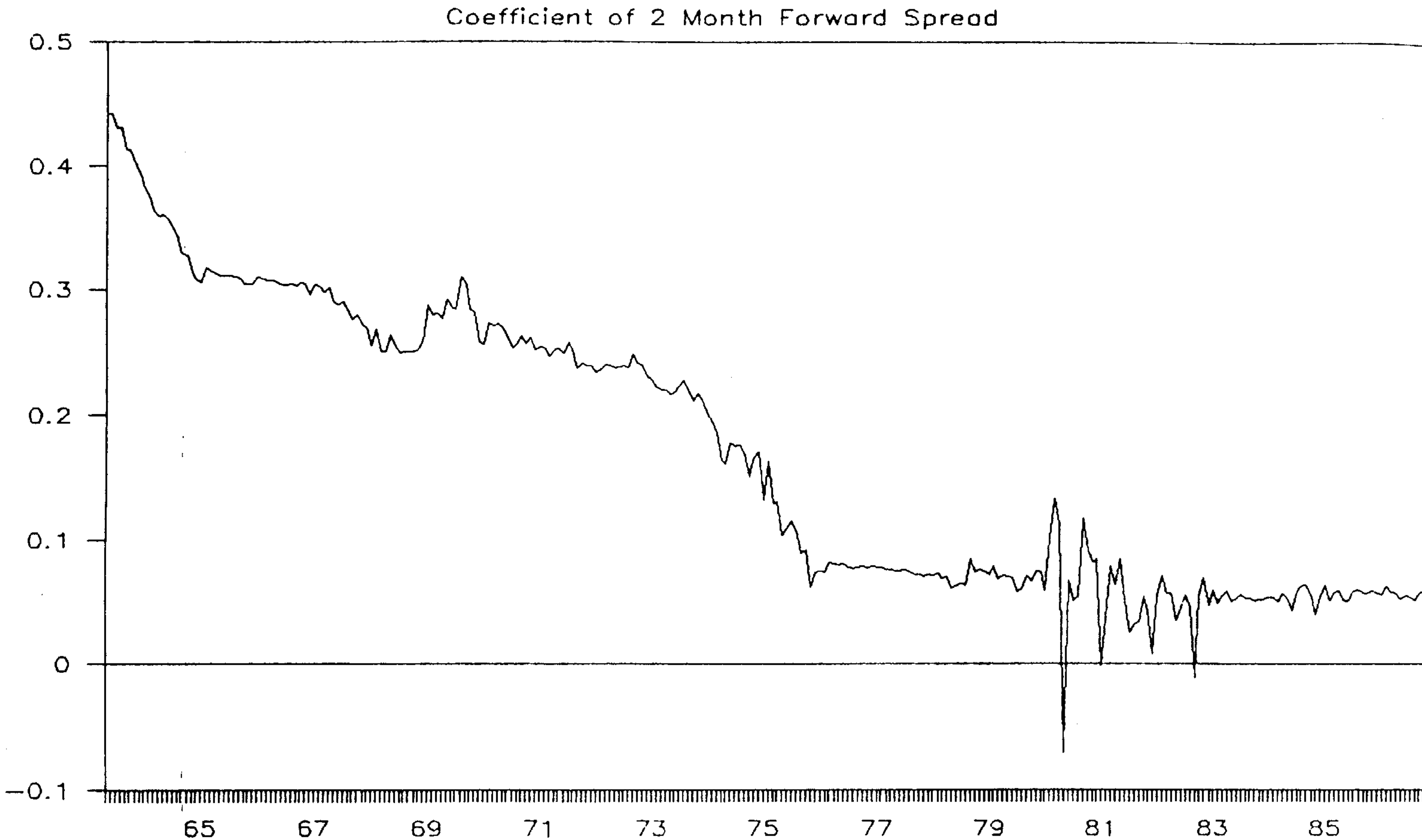

Coefficient of 2 Month Forward Spread
0.5
0.4
0.3
0.2
0.1
0
−0.1
65
67
69
71
73
75
77
79
81
83
85

Figure 3

Coefficient of 3 Month Forward Spread

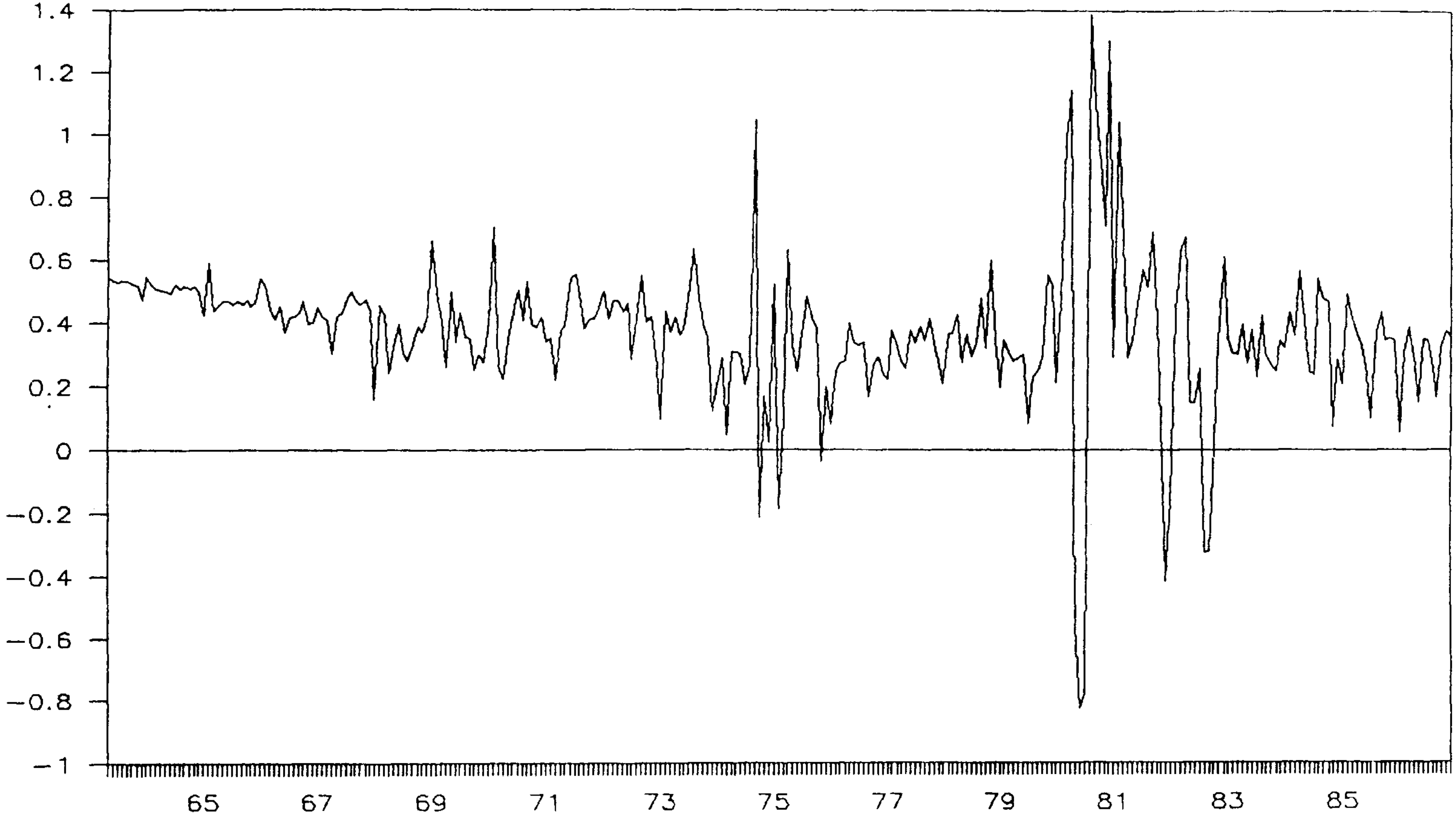
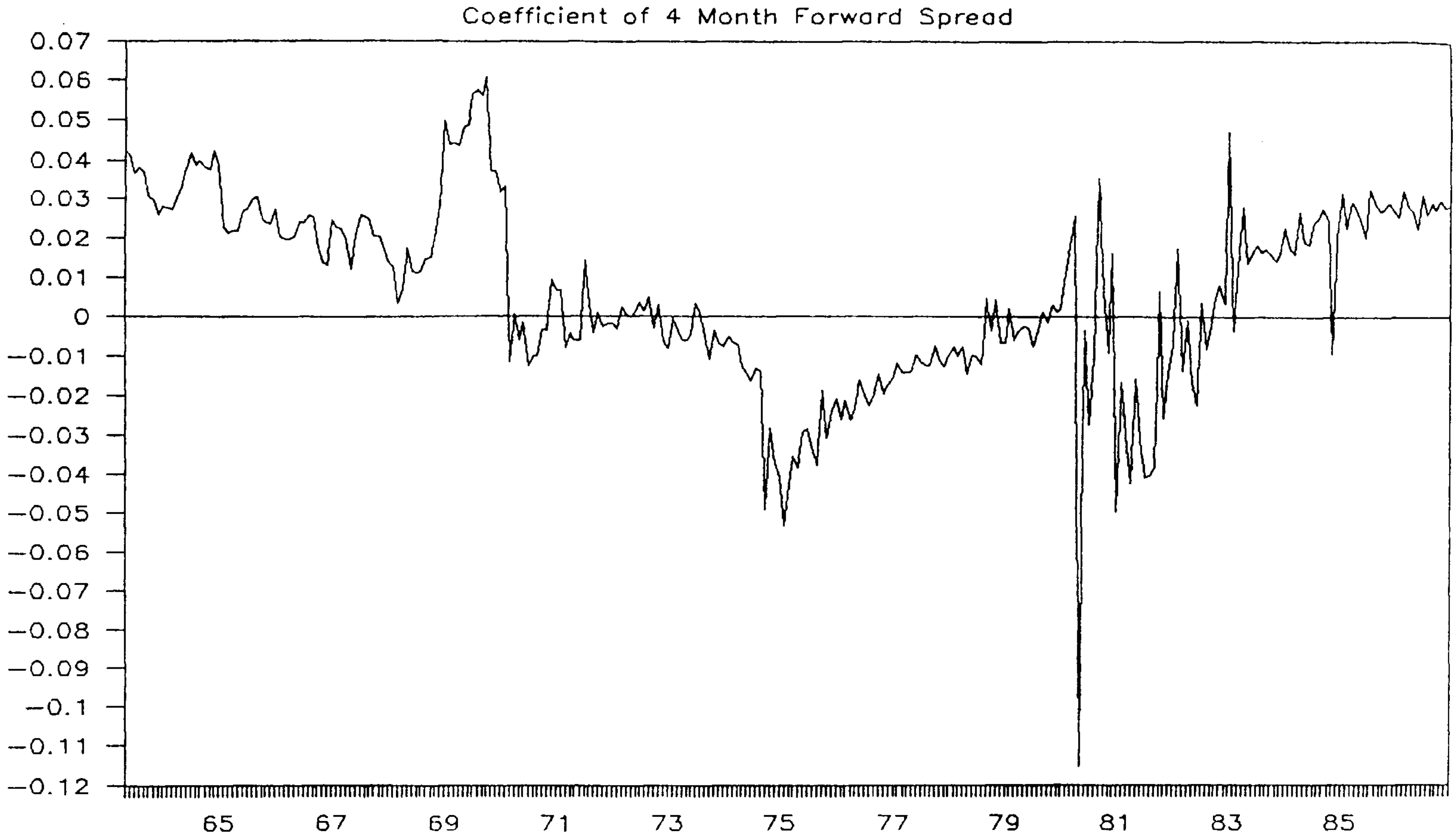
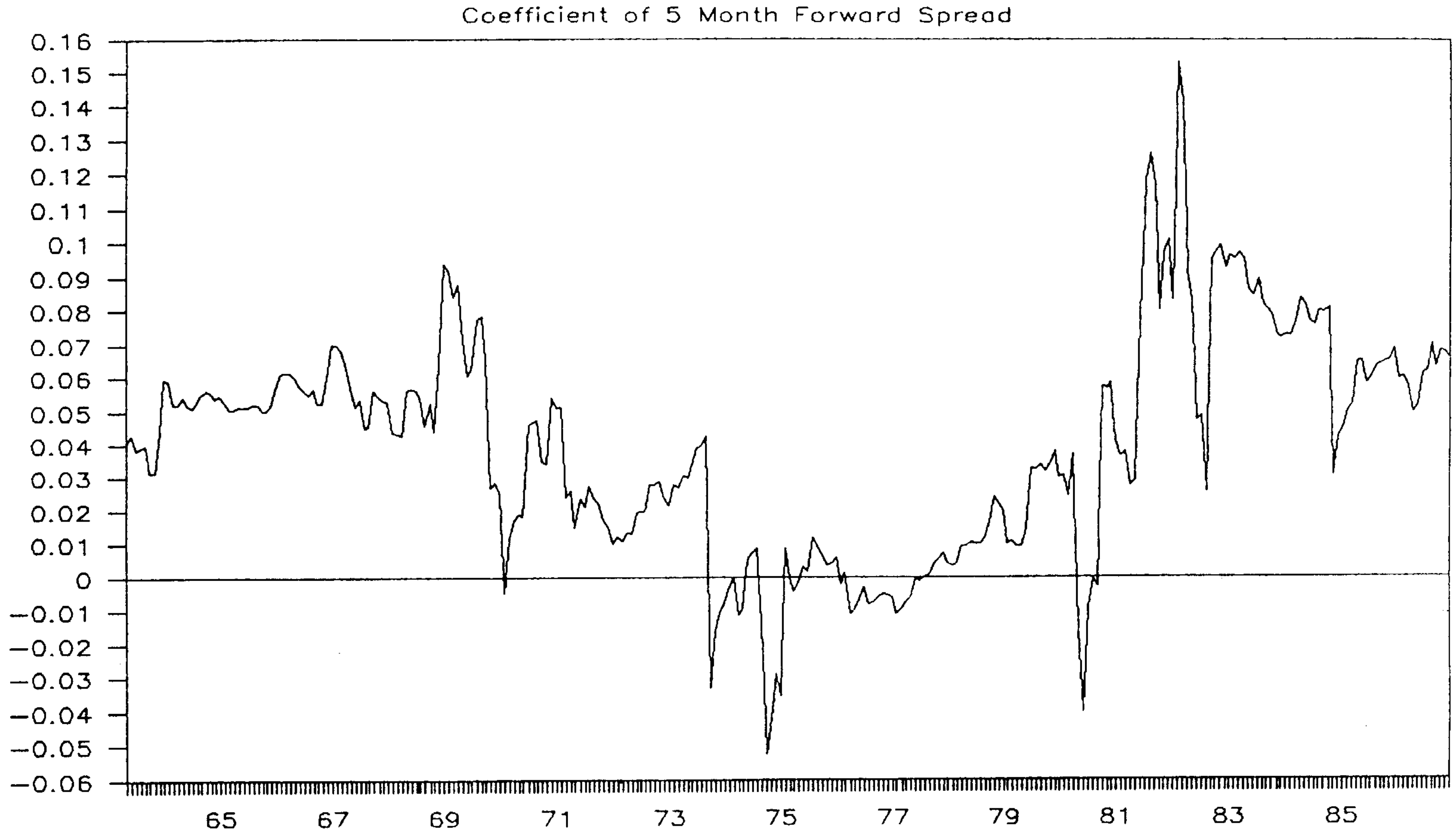


Figure 4



Coefficient of 4 Month Forward Spread
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
−0.04
−0.05
−0.06
−0.07
−0.08
−0.09
−0.1
−0.11
−0.12
65
67
69
71
73
75
77
79
81
83
85

Figure 5



Coefficient of 5 Month Forward Spread
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
−0.04
−0.05
−0.06
65
67
69
71
73
75
77
79
81
83
85

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<u>1989</u>

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1990

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