

## *An empirical analysis of the expert expectations hypothesis in the US Treasury bill market*

\*THOMAS C. CHIANG and †RONALD K. CHUNG

\**Department of Finance, Drexel University, 32nd and Chestnut Streets, Philadelphia, PA, 19104, USA* and †*Credit Research Foundation, 8815 Center Park Drive, Columbia, MD 21045, USA*

This paper proposes the consensus value of the experts' expectations to predict the future three-month Treasury bill rate. Applying quarterly data, 1981:Q3–1989:Q4, to three- and six-month Treasury bill markets indicates that one cannot reject the unbiasedness hypothesis. Empirical analysis indicates that experts use information from the slope of the yield curve, changes in the recent three-month bill rate, and a time-varying risk premium to predict the change in the future three-month bill rate. This study documents the consensus of experts' expectations as an optimal predictor of the future three-month bill rate.

### I. INTRODUCTION

Accuracy in predicting interest rates is important to policymakers, financial managers and investors. The knowledge of future interest rate movements is an important input in formulating effective monetary policies, achieving sound financial decisions and making appropriate intertemporal choice.

Because market predictions of interest rates are based on conditional expectations, the traditional approach to interest rate forecasting has focused on the effective use of publicly available information in financial markets (Roll, 1970; Fama, 1976, 1984; Mishkin, 1978, 1982; Pesando, 1981).

This paper proposes the use of a new informational variable—the consensus of the experts' opinions—to predict future short-term interest rates. Our results indicate that experts produce a more accurate and superior prediction, perhaps because of more effective processing of market information.

The use of expert expectations has logical appeals. First, expectations information obtained from surveys provides a composite of market measures of expectations without

relying on a particular expectations formulation scheme. Second, professional forecasters have the expertise as well as the financial incentives to achieve optimal forecasts.<sup>1</sup> Experts' expectations appear to be more reliable, instantaneously reflecting the ongoing market dynamics. Thus, measures provided by experts are consistent with market behaviour and would be a good proxy for market expectations.

### II. EFFICIENT MARKET APPROACHES TO INTEREST RATE FORECASTING

Efficient market approaches to interest rate forecasting focus on the role that market information plays in forming interest rate expectations. According to weak-form market efficiency, the current spot interest rate summarizes all the available historical information. This implies that the current spot interest rate is the best predictor of subsequent interest rates. For this statement to be true, successive changes in short-term interest rates must be drawn independently from a probability distribution with mean zero.

<sup>1</sup>Since 1968, the ASA-NBER has conducted a quarterly survey of forecasts of economic variables. Every quarter, the ASA mails out questionnaires to professional forecasters and obtains their forecasts for the current quarter, and the next four quarters for a variety of economic variables. The questionnaires are sent out in the middle month of every quarter and are to be received by the end of the month. This is to ensure that all forecasts are based on the same information set. The format of the survey remained unchanged from its inception until 1981:Q2, when the coverage of the survey was extended forecasts of three-month Treasury bill rates are not available until 1981:Q3. A description of the survey appears in Zarnowitz (1969, 1985).

Empirical evidence has shown that short-term and long-term interest rates are cointegrated and possess unit roots (Choi and Wohar, 1991) so it is most appropriate to specify the series in a differenced form, which ensures stationarity. Thus,

$$r_{t+1} - r_t = \alpha + \phi(r_t - r_{t-1}) + e_{t+1} \quad (1)$$

where  $\alpha$  and  $\phi$  are regression coefficients, and  $e_{t+1}$  is an error term. Equation 1 can be used to examine the random-walk hypothesis by testing the joint hypotheses of  $[\alpha \ \phi]' = [0 \ 0]'$ , and the error term is white noise. Rejection of the null suggests that the past serial patterns can be used to predict future interest rate movements.

Another approach to forecasting interest rates is based on the slope of the yield curve. A popular model is the expectations theory of the term structure of interest rates. It posits that the long-term interest rate is a weighted average of current and expected short-term interest rates plus, perhaps, a risk premium.

The return on a two-period bill can simply be expressed as

$$R_t = \sigma_t + (1/2)[r_t + E(r_{t+1}|I_t)] \quad (2)$$

where  $R_t$  represents the return on a two-period bill;  $\sigma_t$  is the risk premium;  $r_t$  is the one-period short-term interest rate; and  $E(\cdot|I_t)$  is the expectations operator conditional on information available at time  $t$ . Equation 2 can be rewritten as

$$E(r_{t+1}) - r_t = -2\sigma_t + 2(R_t - r_t) \quad (3)$$

Assuming that  $r_{t+1}$  is the sum of  $E(r_{t+1})$  and a random error,  $e_{t+1}$ , Equation 3 can be rewritten in regression form as

$$r_{t+1} - r_t = \alpha + \beta(R_t - r_t) + e_{t+1} \quad (4)$$

where  $\alpha = -2\sigma_t$  and  $\beta = 2$ , and  $e_{t+1}$  is orthogonal to the information set available at time  $t$ . Equation 4 represents a commonly held view that the slope of the yield curve can be used to predict short-term interest rate movements.<sup>2</sup>

The literature reveals several empirical hypotheses tested in terms of Equation 4. First, the joint hypotheses of rational expectations and the expectations theory of the term structure,  $[\alpha \ \beta]' = [0 \ 2]'$  is a test of the unbiasedness hypothesis (Mankiw and Miron, 1986). Second, to test whether the slope of the yield curve has predictive power, the appropriate test hypothesis is  $[\alpha \ \beta]' = [0 \ 0]'$ . Failure to reject the null can be interpreted as rejection either of the rational expectations hypothesis or the expectation theory of the term structure or both.<sup>3</sup>

Equations 1 and 4 represent two efficient market-based approaches to the formation of interest rate expectations. Both equations posit effective use of market information, but they are different from one another with respect to the market information used. Equation 4 derives expectations

based on the implicit forward rate, while Equation 1 uses information embodied in the current spot short rate.

Rationality suggests that forecasters would logically use information derived from a variety of sources. It is appealing, therefore, to establish a composite information set that includes both the spot interest rate and the implicit forward interest rate to forecast future interest rates (Hamburger and Platt, 1975).

A linear combination of Equations 1 and 4 as the composite hypothesis would be

$$r_{t+1} - r_t = \alpha + \beta(R_t - r_t) + \phi(r_t - r_{t-1}) + e_{t+1} \quad (5)$$

where  $R_t - r_t$  represents forward-looking information implicit in the maturity structure, and  $r_t - r_{t-1}$  represents recent market information. The null hypothesis is that  $[\alpha \ \beta \ \phi]' = [0 \ 0 \ 0]'$ . If the null is not supported by the data, this means that neither the expectations theory nor the random-walk hypothesis is sufficient to describe interest rate behaviour, resulting in biased expectations.

The main difficulty in conducting empirical tests of the expectations models arises in measuring market expectations. To avoid this difficulty, one can obtain market expectations directly from the market participants. The experts' expectations reported in the American Statistical Association-National Bureau of Economic Research survey data provide a range of market opinions on the future short-term Treasury bill rate, based on diverse quantitative techniques and judgmental factors. The data can be viewed as a weighted average of the market's expectations, reflecting the mean value of the market assessments. These consensus forecasts should more precisely describe the underlying aggregate market behaviour.

To examine this hypothesis, we specify the equation

$$r_{t+1} - r_t = \alpha + \tau(s_{t+1} - r_t) + e_{t+1} \quad (6)$$

where  $\alpha$  and  $\tau$  are regression parameters,  $s_{t+1}$  is the consensus forecast value of short-term interest rate from the experts, and  $e_{t+1}$  is the residual term in the regression.

Equation 6 states that changes in interest rates can be predicted by experts' expectations. Specifying it in the differenced form satisfies the stationary condition.

To test the unbiasedness of the expert expectations hypothesis, one can examine the restriction of  $[\alpha \ \tau]' = [0 \ 1]'$ . To test whether experts' expectations have any predictive power, however, the hypothesis is translated to test whether  $\tau$  is significantly different from zero, that is  $\tau = 0$ . We would expect the estimated  $\tau$  to be statistically different from zero if the experts' expectations provide any useful information.

### III. THE DATA AND EMPIRICAL EVIDENCE

Data on experts' expectations are obtained from the ASA-NBER survey. Quarterly observations of three-month

<sup>2</sup> A similar presentation occurs in Mankiw and Miron (1986).

<sup>3</sup> Rejection of the null can also be attributed to the existence of time-varying risk premium. To verify this hypothesis, one needs to specify an additional variable to measure the risk term,  $\sigma_t$  (Mishkin, 1981; Mankiw, 1986; Simon, 1989) and perform a significance test.

and six-month Treasury bill data are made as of the beginning of the quarter according to the respective issue of the *Federal Reserve Bulletin*. Because of the limited availability of survey data, the sample is confined to the period 1981:Q3–1989:Q4.

Table 1 provides some summary statistics for each quarter. Because average forecasts may be influenced by extreme values of individual forecasts, both mean and median values are used to measure the 'consensus' of expectations. The standard deviation and the spread of minimum and maximum values demonstrate the divergence in forecasts of the three-month Treasury bill rate among different agents.

Table 2 reports the regression estimates using various information to predict changes in the three-month bill rate according to Equations 1, 4–6. The evidence from Equations 1, 4 and 5 is consistent with prior empirical findings.

In Equation 1, the estimated coefficient is statistically insignificant, indicating that changes in the current three-month Treasury bill rate have no significant information value for predicting future movements. In Equation 4, the

estimated coefficient has a positive sign, but is not statistically significant at the 5% level. This indicates that the slope of the yield curve lacks predictive power (Mankiw and Miron, 1986). By the same token, the results from Equation 5 show that neither the information in the slope of the yield curve nor the changes of the current spot rate has predictive power for the future movements of the three-month Treasury bill rate.

These results are consistent with the findings in the literature. From the point of view of investors and policymakers, the prediction equations have very little value in predictive power.

The results obtained from Equation 6 provide a more satisfactory answer. Equation 6 is estimated using both median expectations (Equation 6a), and mean expectations (Equation 6b). Both measures produce similar results. As indicated in Table 2, the estimated coefficients have the anticipated sign and are statistically significant. Moreover, the *F*-statistics indicate that  $[\alpha \ \tau]' = [0 \ 1]'$  cannot be rejected at the 5% level. These test results indicate that the data

Table 1. Summary statistics (quarterly observations of three- and six-month US Treasury bills)

Year/Quarter	<i>n</i>	$r_{t+1}$	$s_{t+1}$ (Median)	$s_{t+1}$ (Mean)	SD	Minimum	Maximum
81/4	33	14.37	14.50	14.4390	1.0989	11.00	17.00
82/1	29	11.35	10.80	10.9810	1.8753	7.00	14.70
82/2	36	13.32	12.00	12.1740	1.1857	10.10	15.10
82/3	37	12.81	11.80	11.7530	0.9654	10.00	14.25
82/4	34	7.52	9.50	9.8197	1.4917	7.00	13.00
83/1	35	7.92	7.90	8.0341	0.8967	6.60	10.00
83/2	38	8.64	7.50	7.7020	0.5559	7.00	9.30
83/3	31	8.88	7.90	7.9366	0.5137	6.79	9.50
83/4	33	8.75	9.05	9.0332	0.6336	7.80	10.50
84/1	28	8.95	8.60	8.6509	0.4889	7.00	9.45
84/2	33	9.74	8.90	8.8500	0.4446	7.70	9.60
84/3	26	9.92	9.90	9.8706	0.4292	9.00	10.70
84/4	29	10.19	10.40	10.3470	0.4676	9.03	11.00
85/1	21	7.83	9.30	9.2207	0.5937	8.00	10.40
85/2	27	8.17	8.25	8.3343	0.7162	6.90	10.10
85/3	30	6.90	7.80	7.9293	0.5955	7.00	9.00
85/4	24	7.01	7.45	7.4710	0.4064	6.50	8.25
86/1	24	7.04	7.10	7.1679	0.3654	6.50	8.10
86/2	24	6.31	7.00	6.9750	0.3124	6.00	7.50
86/3	22	5.97	6.10	6.1642	0.4615	5.40	7.20
86/4	23	5.19	5.40	5.5141	0.4012	4.90	6.50
87/1	20	5.65	5.40	5.1657	0.2638	4.80	5.76
87/2	26	5.56	5.40	5.4260	0.3536	4.85	6.00
87/3	21	5.68	5.60	5.8877	0.2481	5.42	6.40
87/4	18	6.62	6.00	6.0124	0.3035	5.25	6.50
88/1	16	5.73	5.70	5.8467	0.5195	5.00	7.00
88/2	15	5.74	5.70	5.7013	0.2851	5.25	6.25
88/3	16	6.57	6.40	6.3260	0.3303	5.80	6.80
88/4	14	7.25	7.20	7.2056	0.3510	6.50	8.00
89/1	17	8.24	7.70	7.6679	0.3645	7.00	8.30
89/2	15	8.82	8.75	8.6853	0.3532	8.00	9.60
89/3	11	7.81	8.50	8.3567	0.4479	6.85	8.70
89/4	16	7.76	7.60	7.4782	0.2567	7.20	8.00

Notes: (1) *n* is the number of survey responses in the period. SD denotes standard deviation.

(2)  $r_{t+1}$  represents the actual observations of 3-month bill rates obtained from *Federal Reserve Bulletin* while  $s_{t+1}$  is the experts' expectations from the survey data.

Table 2. Regression estimates of various expectations models

Independent variable	Dependent variable: $r_{t+1} - r_t$				
	(1)	(4)	(5)	(6a)	(6b)
Constant	-0.0021 (0.0021)	-0.0028 (0.0025)	-0.0028 (0.0028)	0.0006 (0.0011)	0.0004 (0.0011)
$R_t - r_t$		0.2614 (0.3464)	0.1795 (0.4977)		
$r_t - r_{t-1}$	-0.1484 (0.1805)		-0.0891 (0.2461)		
$s_{t+1} - r_t$				1.1751* (0.1262)	1.2285* (0.1336)
Adjusted $R^2$	-0.0105	-0.0136	-0.0407	0.7279	0.7228
DW	1.9063	2.2008	1.9123	1.5368	1.6562
$Q(15)$	5.5442	6.1577	5.2346	15.3700	10.5152
White's test	0.8360	1.7960	3.2686	10.7350**	14.0602**
$p$ -statistics	0.6583	0.4073	0.6586	0.0046	0.0008
ARCH	0.1719	0.2916	0.1721	1.1504	1.8829
$p$ -statistics	0.6783	0.6393	0.6781	0.2834	0.1699
$F$ -statistics	20.2409 <sup>a</sup>	23.6667 <sup>b</sup>	0.5028 <sup>c</sup>	0.9966 <sup>d</sup>	1.4622 <sup>d</sup>
Heteroskedasticity-consistent covariance matrix estimator					
Constant				0.0006 (0.0008)	0.0004 (0.0008)
$s_{t+1} - r_t$				1.1751* (0.2101)	1.2285* (0.2328)
Adjusted $R^2$				0.7279	0.7228
DW				1.5368	1.6562
$Q(15)$				15.3700	10.5152
$F$ -statistics				1.4198	1.4494

The numbers in parentheses are the standard errors of the estimated regression coefficients.

\* Indicates statistical significance at the 5% level.

\*\* Indicates rejection of homoskedasticity at the 5% significance level.

For the  $F$ -tests, (a) denotes testing the null hypothesis of  $[\alpha \ \phi]' = [0 \ 1]'$ , (b) denotes testing the null hypothesis of  $[\alpha \ \beta]' = [0 \ 2]'$ , (c) denotes testing the null hypothesis of  $[\alpha \ \beta \ \phi]' = [0 \ 0 \ 0]'$ , and (d) denotes testing the null hypothesis of  $[\alpha \ \tau]' = [0 \ 1]'$ .

support the hypothesis that experts' expectations provide an unbiased predictor of the future changes in the three-month bill rate.

Recent empirical studies note that the disturbance term of the asset returns in the test equations often displays heteroskedasticity. In the presence of heteroskedasticity, the least-squares estimators of the regression coefficients remain unbiased and consistent, but the estimated variances are biased, giving misleading statistical inferences. Accordingly, we perform White's (White, 1980) and ARCH (Engle, 1982) tests of heteroskedasticity. The results show no evidence of heteroskedasticity in Equations 1, 4 and 5, but reveal the presence of heteroskedasticity in Equations 6a and 6b.

To resolve this problem, one requires additional information concerning the nature of the heteroskedasticity, but this specification may not be attainable. White's (1980) covariance matrix estimator, which is consistent in the presence of heteroskedasticity, does not require a specific formal model of heteroskedasticity. While it does not correct for heteroskedasticity, it allows proper inferences to be drawn.

The bottom panel in Table 2 presents the results of heteroskedasticity-consistent estimates for Equations 6a and

6b. These results indicate that both the median and the mean consensus of experts' expectations have strong predictive power for future movements of three-month bill rates. Moreover, evidence indicates that the null hypothesis of  $[\alpha \ T]' = [0 \ 1]'$  cannot be rejected by the data. This is consistent with the unbiasedness of the experts' expectations hypothesis.

#### IV. INFORMATION CONTENT OF EXPERTS' EXPECTATIONS

Although our empirical findings suggest that experts' expectations possess substantial predictive power for the future three-month Treasury bill rate, this tells us very little about the underlying economic meanings. To gain further insight concerning the information embodied in the experts' expectations, the expert expectations hypothesis (EEH) is specified as follows:

$$s_{t+1} - r_t = \delta + \beta(R_t - r_t) + \phi(r_t - r_{t-1}) + \mu\sigma_t + e_{t+1} \quad (7)$$

where  $\delta$ ,  $\beta$ ,  $\phi$  and  $\mu$  are constant coefficients, and  $e_{t+1}$  is the

random-error term. Equation 7 states that experts' expectations formation is associated with information implied in the slope of the yield curve,  $R_t - r_t$ , current changes in the spot interest rate,  $r_t - r_{t-1}$ , and a time-varying risk premium,  $\sigma_t$ .

Equation 7 differs from the standard specification in two respects. First, the expectations are directly and explicitly provided by the market participants. Thus, the imposition of rational expectations is not necessary. Second, the risk premium is comprised of two parts, a constant component,  $\delta$ , and a time-varying component,  $\sigma_t$  (Simon, 1989). This allows one to identify the nature of risk.

Two alternative methods were used for measuring the risk premium in Equation 7. First, following the suggestions of Engle and Simon (Engle *et al.*, 1987; Simon, 1989), the risk premium is measured by the excess return of the six-month bill over the sum of the current and the expected three-month bill. Second, the risk premium is specified as a positive function of the variation of experts' predictions, which is proxied by the standard deviation of the reported predictions across different agents or forecasters. The empirical results employing the Engle-Simon measure of risk are reported in Table 3, while the results based on the cross-sectional variations are reported in Table 4.

The evidence from Tables 3 and 4 indicates that the consensus of experts' expectations summarizes information from the term structure of interest rates, changes in the recent three-month bill rate, and the time-varying risk premium. All the estimates have the anticipated signs and are highly statistically significant. Specifically, an expected rise in the three-month Treasury bill rate projected by 'experts' is positively associated with the slope of the yield curve and negatively related to the previous spot rate changes, which reflect mean reversion or distributed-lag behaviour. More importantly, the expected change in the three-month bill rate is significantly explained by the risk premium. The negative sign associated with the risk variable is consistent with market evidence that an expected increase in risk increases the expected excess return on holding the six-month bill through a decrease in the subsequent three-month bill rate. This result provides supportive evidence for the risk premium hypothesis (Mankiw and Miron, 1986; Simon, 1989).

Results re-estimated employing White's consistent covariance matrix estimator do not change the conclusion and offer support to the experts' expectation hypothesis (see bottom panels of Tables 3 and 4).

These findings have important empirical implications. First, the lack of predictive power of the slope of the yield curve does not necessarily imply failure of the expectations theory. Rather, it could be the result of mismodelling of the expectations. Second, our evidence indicates that both forward-looking information in the yield curve and historical information obtained from past changes in interest rates are useful in formulating interest rate expectations. Earlier findings indicating a lack of predictive power for these two

Table 3. Market information of the experts' expectations: Engle-Simon risk premium

Independent variable	Dependent variable: $s_{t+1} - r_t$	
	Median	Mean
Constant	-0.0041* (0.0016)	0.0037* (0.0016)
$R_t - r_t$	0.4250** (0.2299)	0.4359* (0.3300)
$r_t - r_{t-1}$	-0.2732* (0.1147)	-0.2721* (0.1638)
$\sigma_t$	-1.6405* (0.2496)	-1.5200* (0.2408)
Adjusted $R^2$	0.5799	0.5702
DW	2.1173	2.2109
$Q(15)$	8.5772	8.6795
White's tests	31.2095***	30.9665***
<i>p</i> -statistics	0.0005	0.0005
ARCHs tests	0.3985	0.9707
<i>p</i> -statistics	0.5278	0.3244
Heteroskedasticity-consistent covariance matrix estimator		
Constant	-0.0041* (0.0016)	0.0037* (0.0015)
$R_t - r_t$	0.4250** (0.2225)	0.4359* (0.2203)
$r_t - r_{t-1}$	-0.2732* (0.1117)	-0.2721* (0.1105)
$\sigma_t$	-1.6405* (0.3883)	-1.5200* (0.3764)
DW	2.1173	2.2109
$Q(15)$	8.5772	8.6795
Adjusted $R^2$	0.5799	0.5702

The numbers in parentheses are the standard errors of the estimated regression coefficients.

\* and \*\* indicate statistical significance at the 5% and 10% levels, respectively.

\*\*\* Indicates rejection of homoskedasticity at the 5% level.

variables may be a result of misspecification of the time-varying risk premium term or the expectations formation.

Finally, the results indicate that although market participants may not know much about the underlying econometric models that produce the individual forecasts, they can use expectations obtained from experts that do convey unbiased information and appear to be superior to other traditional informational variables.

## V. SUMMARY

Empirical tests of the expectations theory of the term structure rely on a precise measurement of the expectations variable. Rather than using the traditional approach to generate market expectations on interest rates, this paper proposes a new informational variable—the consensus value of experts' opinions—which we use to predict the three-month Treasury bill rates. Our test results indicate that expert expectations produce superior predictability.

Table 4. Market information of the experts' expectations: cross-section premium

Independent variable	Dependent variable: $s_{t+1} - r_t$	
	Median	Mean
Constant	0.0067* (0.0016)	0.0063* (0.0015)
$R_t - r_t$	0.4250* (0.1986)	0.4381* (0.1908)
$r_t - r_{t-1}$	-0.1573** (0.0972)	-0.1648** (0.0934)
$\sigma_t$	-0.0202* (0.0024)	-0.0189* (0.0023)
Adjusted $R^2$	0.6849	0.6803
DW	1.7892	1.8766
$Q(15)$	6.9127	9.2327
White's tests	23.1916***	22.6682***
$p$ -statistics	0.0100	0.0120
ARCHs tests	0.5552	0.7269
$p$ -statistics	0.4561	0.3938
Heteroskedasticity-consistent covariance matrix estimator		
Constant	0.0067* (0.0014)	0.0063* (0.0014)
$R_t - r_t$	0.4250** (0.2234)	0.4381** (0.2251)
$r_t - r_{t-1}$	-0.1571** (0.0902)	-0.1648** (0.0907)
$\sigma_t$	-0.0202* (0.0030)	-0.0189* (0.0028)
DW	1.7892	1.8766
$Q(15)$	6.9127	9.2327
Adjusted $R^2$	0.6849	0.6803

The numbers in parentheses are the standard errors of the estimated regression coefficients.

\* and \*\* Indicate statistical significance at the 5% and 10% levels, respectively.

\*\*\* Indicates the rejection of homoskedasticity at the 10% level.

Further analysis of the underlying information content of the experts' expectations indicates that experts' expectations reflect information from the slope of the yield curve, changes in the recent three-month bill rate, and the time-varying risk premium. These findings also document the significance of the experts' consensus expectations as an optimal predictor of the future three-month bill rate.

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