Jurnal Pengurusan 12 (1993) 27-38

Term Structure of Interest Rate: An Empirical Test of the Expectation Hypothesis on the Malaysian T-Bill Market

Noor Azlan Ghazali

ABSTRACT

Interrelationship between short and long term rates is vital in the understanding of interest rate behaviour Expectation hypothesis claims that the yield of the long term instrument is equal to the average of the short term rates that prevail over the long term period. According to the theory, the unobserved future spot rate can be determined from the observed spot rate. This is possible because the observed rate contains superior information of market expectation. This study investigates the validity of the expectation theory on the Malaysian T bill market for a period of 17 years (1974 - 1990). Regression and correlation analyses are used in testing the hypothesis. The result supports the validity of the expectation theory. The two expectation models employed, i.e., Perfect-Foresight Model and Error-Learning Model, confirm the notion of expectation hypothesis. The forward rate implied by the term structure form as an unbiased estimate of future spot rate. The validity of the expectation theory in different interest rate environments (declining or increasing) is also tested. The result suggests consistency in validity in all subperiods. However, the accuracy of the prediction increased substantially toward the latter end of the period under study. This reflects the interest rate deregulation process which took place in the Malaysian financial market in recent years.

ABSTRAK

Hubungan antara kadar faedah jangka pendek dan jangka panjang adalah penting dalam memahami gelagat kadar faedah. Hipotesis jangkaan menyatakan bahawa kadar hasil jangka panjang adalah bersamaan dengan purata kadar faedah jangka pendek yang wujud dalam tempoh jangka panjang tersebut. Mengikut teori ini, kadar faedah masa akan datang boleh ditentukan daripada kadar faedah yang terdapat sekarang. Ini adalah mungkin kerana kadar faedah yang ada sekarang memiliki maklumat yang berharga mengenai jangkaan pasaran. Kajian ini menguji kesahihan teori jangkaan dalam pasaran bil perbendaharaan Malaysia untuk tempoh 17 tahun (1974 - 1990). Analisis regresi dan korelasi digunakan untuk menguji kesahihan hipotesis ini. Keputusan yang diperolehi menyokong kesahihan *teori jangkaan. Kedua-dua model jangkaan yang digunakan, iaitu Perfect-Foresight Model dan Error-Learning Model, mengesahkan kenyataan hipothesis jangkaan. Kadar hadapan yang diperolehi daripada struktur jangka kematangan merupakan anggaran tidak bias bagi kadar faedah masa hadapan. Kesahihan teori jangkaan dalam suasana kadar faedah yang berbeza (turun atau naik) juga diuji. Ketepatan teori ini terbukti bagi semua subperiod yang diuji. Ketepatan jangkaan yang diperolehi meningkat lebih tinggi pada penghujung tempoh kajian. Ini menggambarkan proses pelonggaran kadar faedah yang berlaku dalam pasaran kewangan Malaysia di tahun-tahun kebelakangan ini.*

INTRODUCTION

Knowledge of relationship between yield on short and long term securities is important to the understanding of the behaviour of interest rate. The relationship commonly known as the term structure of interest rate attempts to clarify the link between yield to maturity and time to maturity of a specific type of instrument (other factors such as risk, liquidity, tax treatment are hold constant). The expectation hypothesis, also known as pure/unbiased expectation theory, is among the theories which have been put fourth to explain this relationship. The hypothesis postulates that the yield is determined by investors' expectations of future interest rate movement. Based on this unbiased expectations, investors will determine the maturity structure of their portfolio which maximizes the return over the intended holding period. According to the theory, the yield on the long term security will equal the average of short term yields that investors expect to prevail over the life of the long term instrument. The relationship between return on short and long term instruments is explained by the market expectation of future short term rates. Thus, the observed spot rates contain vital information about the market expectation of future interest rate movement.

The validity of the expectation hypothesis is tested in this study. The rest of the paper is divided into four sections. The first section contains a discussion of the theoretical framework and previous findings on the subject matter. The data description and methodology are provided in the second section. In the third section, the empirical results are presented and discussed. Finally, the conclusion section summarizes the findings and implications of the study

THEORETICAL FRAMEWORK AND PREVIOUS STUDIES

Conceptually, the expectation theory states that the expected one period rate of return on investment is the same, regardless of the maturity in which one invests. This can be expressed as

$$(1 + {}_tR_n)^n = (1 + {}_tR_1)\,(1 + {}_{t+1}r_1)\ \ldots.\ (1 + {}_{t+n-1}r_1) \qquad \ldots.(1)$$

where,

${}_tR_n$ = the observed spot rate of interest at time t for n period of maturity,

${}_{t+i}r_1$ = the unobserved forward rate beginning at time t + i for 1 period of maturity (i = 1,2,3, ..., n - 1).

Thus, an investment of 5 years will yield a return equivalent to a 1 year investment plus a series of 1 year contracts, each renewed consecutively. From equation (1), the one period forward rate beginning at t + n can be calculated as

$$1 + {}_{t+n}r_1 = \frac{(1 + {}_tR_1)(1 + {}_{t+1}r_1)\ \ldots\ldots\ (1 + {}_{t+n-1}r_1)(1 + {}_{t+n}r_1)}{(1 + {}_tR_1)(1 + {}_{t+1}r_1)\ \ldots\ldots\ (1 + {}_{t+n-1}r_1)}$$

$${}_{t+n}r_1 = \frac{(1 + {}_tR_{n+1})^{n+1}}{(1 + {}_tR_n)^n} - 1 \qquad \ldots..\ (2)$$

Equation (2) allows calculation of the implied one period forward rate for any future period based upon observed spot rates prevailing in the market at a specific time. Further, the theory states that the unbiased expectation of the future one period return expected at time t to prevail at time t+n is equal to the computed forward rate

$$E_t\,({}_{t+n}R_1) = {}_{t+n}r_1 \qquad \ldots.\ (3)$$

Statistical test of the expectation theory begins with the comparison of actual and the expected rates. The hypothesis is valid if the expected rate equal to the actual rate. The perfect foresight model employed by researchers rests on this presumption. Using the T bills and long term Treasury bonds, Culbertson (1957) measured the holding period returns for securities of different maturity He found that the equality for a given holding period as stated in equation (1) is not met. The finding rejects the expectation theory. On the other hand, Fama (1976) reported the superiority of forward rates. The computed forward rates provide high accuracy in predicting future spot rates. He concluded that the forward rates implied by the term structure are consistent with the efficient market hypothesis which requires the unbiasness in expectation.

Meiselman (1962) developed and tested an error learning model of interest rate expectations. Investors are believed to revise their forecasts systematically as they experienced forecasting errors. He found a high degree of correlation between the forecasting errors and changes in forward rates. Throughout the 55 year period (1900-1954), a strong correlation is maintained for the shorter term instruments but it declines as maturity increases. Van Horne (1965) also discovered a high degree of correlation between changes in forward rate and the forecasting error. These findings give support to the expectation hypothesis. The findings verify that the interest rate expectation are being revised systematically based on the deviation of actual rate from those that had been anticipated. The past and present learning experiences are incorporated in the investors' prediction model.

In a recent study, Tease (1988) supported the unbiased expectation theory in the Australian bills market. Based on the weekly market expectation of the 90 and 180 day bills, he verified the accuracy of the forward rate and also the existence of zero risk premium. Choi and Wohar (1991) re-examined the validity of expectation theory for 5 different subperiods: 1910 - 1914, 1919 - 1933, 1934 - 1959, 1959 - 1978, and 1979 - 1989. The weekly, monthly and quarterly data for the 3 and 6 months rates were used. Their findings supported the predictive power of the yield curve and concluded that expectation hypothesis cannot be rejected. In addition, the cointegration tests suggested the cointegration between long and short term rates. Employing the cointegration methodology, McFayden, Dickerill and Devaney (1991) constructed a bivariate autoregressive (BVAR) systems to test the expectation theory The results indicated that long term rates cause changes in short term rates. This is parallel to the hypothesis which states linkage between the observed rates. Opposite to the above findings, Cook and Hahn (1990) rejected the expectation theory They argued that the substantial term premium has reduced the ability of expectation equation to forecast interest rate. This is especially true for the 3 and 6 month horizons. Kugler (1990) tested the expectation theory in the Euro market from mid 1970s to mid 1980s. Data for the Euro franc and Euro deutsche mark interest rates supported the expectation hypothesis but not for the Euro dollar rates. He pointed that this is due to the difference in monetary policy employed in the United States, Germany and Switzerland. The Federal Reserves' attempt to stabilize interest rate results in a random behaviour of the short term rates, which reduced the accuracy of forecasting made based on the term structure equation. On the other hand, a more flexible and market determined rates in Switzerland and Germany increased the ability to forecast the interest rate.

In general, the findings described in the preceding paragraphs support the validity of the expectation hypothesis. Market expectation does influence the direction of interest rate. The long and short term rates are linked by the investors expectations of future interest rate movement. Researchers who reject the hypothesis argue that the liquidity, term and risk premium obscure the ability of the forward rates to capture market expectation accurately. In addition, differences in monetary policy will also influence the validity of the expectation theory

DATA AND METHODOLOGY

The data used for this study are obtained from the monthly issue of the Bank Negara Malaysia Statistical Bulletin. Annualized discount rates for the 3 month (90 day), 6 month (180 day) and 12 month (360 day) bills are gathered on a monthly basis for a period of 17 years (January 1974 - December 1990).

For a meaningful analysis, the reported discount rate is converted into an annual bond equivalent yield. This is necessary because T bill is a discounted non-interest bearing instrument and the computation of the discount rate is based on 360-day accrual basis. The selling price of the bill is

$$P = 1 - \frac{dn}{360} \qquad ....(4)$$

where,

P = price per dollar of face value,
d = quoted discount rate,
n = number of days to maturity.

The annual bond equivalent yield takes into account the semi-annual compounding and it is based on 365-day accrual basis. The future value of the bill bought at time t for n period to maturity can be expressed as

$$_tF_n = {}_tP_n \left[1 + \frac{_tR_n}{M}\right]^{MN} \qquad .....(5)$$

Rearranging equation (5), we get the annual bond equivalent yield

$$_tR_n = M\left\{\left[\frac{_tF_n}{_tP_n}\right]^{1/MN} - 1\right\} \qquad .....(6)$$

where,

$_tF_n$ = face (future) value of a bill bought at time t with n days to maturity,

$_tP_n$ = price per dollar of face value for bill with n days to maturity observe at time t,

$_tR_n$ = annual bond equivalent yield at time t for n days to maturity,

M = number of compounding per year,

N = number of days to maturity, n, stated in term of year (n/365).

The annual bond equivalent yield is computed for all maturity categories. Based on these observed bond yield (spot rate), the 90 day and 180 day forward rates are calculated. The forward rate is derived by adjusting equation (1) for the compounding interval and the maturity length. This is shown by the following two equations:

$$\left[1 + \frac{_tR_n}{M}\right]^{MN} = \left[1 + \frac{_tR_n}{M}\right]^{MN}\left[1 + \frac{_{t+1}r_n}{M}\right]^{MN} \quad ....(7)$$

$$_{t+1}r_n = M\left\{\left[\frac{\left[1 + \frac{_tR_n}{M}\right]^{MN}}{\left[1 + \frac{_tR_n}{M}\right]^{MN}}\right]^{1/MN} - 1\right\} \quad ....(8)$$

where,

$_tR_n$ = actual spot rate observed at time t for n days to maturity,

$_{t+1}r_n$ = forward rate expected to prevail at time t+1 for n days to maturity,

M = number of compounding per year,

N = number of days to maturity, n, stated in term of year (n/365).

The left hand side of equation (7) represents the return achieved by investing in a longer maturity asset, while the right hand side represents return by investing in the shorter maturity assets, renewed consecutively after maturity The length of the holding period is the same for both sides.

Two models of expectation are tested in this study. The perfect - foresight model assumes that investors expectations, on average, are realized. In testing the validity, the model compares the forward rate, as implied by the term structure with actual spot rates which they attempt to forecast.

The next model, error-learning model (based on Meiselman (1962)) incorporates the forecast error into the prediction equation. The model assumes that investors will revise their estimates of forward rate after experiencing error in prior prediction. The revision of the forward rate is a linear function of this error.

The linear regression estimates and the correlation analysis are used in testing the validity of the expectation hypothesis. The following equations and hypotheses are tested:

Perfect Foresight Model:

$$ {}_{t}R_{n} = a + b\,{}_{t}r_{n} + e $$

Error Learning Model:

$$ {}_{t+1}r_{n} - {}_{t}r_{n} = a + b\,{}_{t}E_{n} + e $$

where,

$$ {}_{t}E_{n} = \text{the forecasting error, } {}_{t}R_{n} - {}_{t}r_{n} $$

The two hypotheses are:

H_o . a = 0, b = 1
H_1 : a ≠ , b = 0

The null hypothesis (a = 0 and b = 1) implies the validity of the expectation hypothesis. The closer the b value to 1 the greater the accuracy of the prediction made by the expectation models. The alternative hypothesis (a ≠ 0 dan b = 0) indicates no superior information contain in the equations. If this is true, then the expectation theory can be rejected. In addition, the correlation coefficients are calculated to determine the linear association between the dependent and independent variables in both models. Higher linear association indicates the superiority of the expectation models. The empirical tests are conducted for the full period (1974 - 1990) and four subperiods. The four subperiods are tested in order to investigate the validity of the expectation theory in declining and increasing rate environment. The four subperiods are as follows:

Subperiod I	:	January 76 - June 77	- Declining rate
Subperiod II	·	July 79 - December 83	- Increasing rate
Subperiod III		January 84 - April 87	- Declining rate
Subperiod IV	:	May 87 - December 1990	- Increasing rate

RESULTS AND DISCUSSIONS

FULL PERIOD ANALYSIS (1974-1990)

Table 1 provides the regression estimates of the coefficients for the full period under study. The expectation hypothesis is proven to be valid in the Malaysian T-bill market. Forecast based on the perfect foresight model supports the hypothesis as it provides a high degree of accuracy. The computed forward rates for the 90 and 180-day bills are in close approximation of the actual spot rate. This is evidenced by the high t-value and R^2 The constant term (a) is significantly equal to 0 and coefficient of response (b) is significantly equal to 1. These allow us to reject the second hypothesis. The forward rate implied by the term structure explained approximately 72 percent and 82 percent of the variation in the 90 and 180-day spot rates, respectively

The error learning model also provides support for the expectation theory Investors are found to revise their expectations after experiencing forecast error. The revisions responded significantly to the learned error as shown by the Sig-T column. However, the forecast error does not explain the whole revision process. The coefficient of determination (R^2) is quite low, averaging at 0.34. The longer term bills show greater response to the forecast

TABLE 1. Regression estimates for the full period (January 1974 - December 1990)

	Constant a	Beta b	Calculated t - Value (t - b)	Coefficent of Determination R^2	Significant Level P-Prob
Perfect-Foresight Model					
90-day bill	0.003	0.826 (0.037)	22.533	0.716	0.000
180-day bill	-0.0007	0.937 (0.034)	27.952	0.795	0.000
Error-Learning Model					
90-day bill	0.001	0.206 (0.037)	5.569	0.134	0.000
180-day bill	0.002	0.464 (0.052)	8.983	0.287	0.000

Note: Standard errors of estimates for beta are shown in parentheses.

TABLE 2. Correlation coefficients for the full period
(January 1974 - December 1990)

	BY3	BY6	FR3	FR6	ET3	ET6	FRV3	FRV6
BY3	1.000	0.964**	0.846**	0.832**	0.240**	0.378**	0.120	0.140
BY6		1.000	0.933**	0.892**	0.177	0.331**	0.177*	0.115
FR3			1.000	0.893**	-0.314**	0.182*	-0.084	-0.102
FR6				1.000	-0.146	-0.131	0.051	-0.135
ET3					1.000	0.343**	0.366**	0.064
ET6						1.000	0.028**	0.535**
FRV3							1.000	-0.055
FRV6								1.000

Notes:

BY (n) = Annual bond equivalent yield (spot rate) for n months to maturity.
FR (n) = Forward rate for n-month to maturity.
ET (n) = Error term for n-month bill.
FRV(n) = Forward rate revision for n-month bill.
* = Significant at the .01 level.
** = Significant at the .001 level.

error. The validity of the expectation theory is further supported by the correlation coefficients in Table 2. Bond equivalent yields (spot rates) are highly associated with the forward rates. The coefficients are 0.85 and 0.89 for the 90 and 180-day bills, respectively The revision of forward rates also significantly corresponds to the forecast errors. The degree of correlation is slightly lower for the 90-day bill (0.37) as compared to the 180-day bill (0.54).

SUB-PERIOD ANALYSIS

Table 3 and 4 present the regression estimates for the two models tested in the four subperiods. As shown in Table 3, the perfect-foresight equation once again confirms the expectation hypothesis. All of the subperiods tested indicate a highly significant relationship. High coefficient of determination (R^2) averaging at 0.89 implies the superior explanatory power of the observed rate. The t-values are high in all subperiods. The accuracy of the forward rate is consistent regardless of the direction of interest rate movement. However, the accuracy seems to be improving toward the end of 1990's as shown by the larger R^2 (0.97). The constant term (a) is not significantly different from 0, and the b coefficient is significantly equal to 1 in subperiod IV (May 87 to December 1990). The null hypothesis is accepted in the last subperiod.

Table 4 shows a weak support for the expectation hypothesis in the first two subperiods. However, the significant level increased in the last two

TABLE 3 Regression estimates for the subperiods (perfect-foresight model)

	Constant a	Beta b	Calculated t - Value (t - b)	Coefficient of Determination R^2	Significant Level P-Prob
90-Day Bill					
Subperiod I	-0.019	1.124 (0.124)	9.103	0.838	0.0000
Subperiod II	0.034	1.552 (0.092)	16.963	0.847	0.0000
Subperiod III	0.010	1.128 (0.064)	17.599	0.891	0.0000
Subperiod IV	0.003	1.024 (0.029)	35.588	0.968	0.0000
180-Day Bill					
Subperiod I	-0.007	0.956 (0.094)	10.156	0.866	0.0000
Subperiod II	-0.012	1.162 (0.058)	19.986	0.884	0.0000
Subperiod III	-0.023	1.372 (0.078)	17.627	0.891	0.0000
Subperiod IV	-0.002	1.003 (0.053)	18.892	0.893	0.0000

Note: Standard errors of estimates are shown in parentheses.

subperiods. The coefficients of response (b) increase from 0.12 to 0.71 for the 90-day bill and from 0.29 to 0.68 for the 180-day bill. The R^2 values from tables 3 and 4 suggest that the superiority of the expectation equations increased substantially towards the end of period under study. The expectation theory explains the relationship between the short and long term rates very well. The accuracy of the forecast discussed in this section is in agreement with the expectation hypothesis.

CONCLUSION

The empirical tests conducted in this study show favourable results which support the expectation theory. The T-bill forward rate derived from the term structure equation is an unbiased estimator of the expected future spot rate. The accuracy of the prediction made based on the term structure equations is higher for the latter end of the period under study (subperiod IV). The findings also give support to the efficiency of the Malaysian T-bill market.

TABLE 4. Regression estimates for the subperiods (error - learning model)

	Constant a	Beta b	Calculated t - Value (t - b)	Coefficient of Determination R^2	Significant Level P-Prob
90-Day Bill					
Subperiod I	0.0005	1.124 (0.131)	0.950	0.053	0.3562
Subperiod II	0.0002	-0.014 (0.036)	-0.396	0.003	0.6935
Subperiod III	0.0006	0.325 (0.048)	6.751	0.545	0.0000
Subperiod IV	0.003	0.711 (0.109)	6.499	0.501	0.0000
180-Day Bill					
Subperiod I	0.002	0.292 (0.127)	2.305	0.249	0.0349
Subperiod II	0.0007	0.173 (0.067)	2.575	0.113	0.0129
Subperiod III	0.005	0.266 (0.037)	7.223	0.579	0.0000
Subperiod IV	0.003	0.683 (0.087)	7.783	0.591	0.0000

Notes: Standard errors of estimates are shown in parentheses.

The higher level of efficiency reflects the deregulation of interest rate determination in Malaysia which took place in late 1980's. The appointment of principal dealers creates more active trading in the secondary market. Finally, it can be concluded that investors can apply the expectation hypothesis in order to increase the accuracy of their prediction of the future interest rate movement.

REFERENCES

Choi, Seungmook & Wohar, Mark E. 1991 (Spring). New evidence concerning the expectation theory for the short end of the maturity spectrum. *Journal of Financial Research*, 83-92.

Cook, H. 1990 (Sept./Oct). Interest rate expectations and the slope of the money market yield curve. *Economic Review (Federal Reserve Bank of Richmond)*, 3-26.

Culbertson, John M. 1957 (November). The term structure of interest rates. *Quarterly Journal of Economics*, 499-509.

Fama, Eugene F 1976 (June). Forward rate as predictors of future spot rates. *Journal of Financial Economics*, 361-377

Kugler, P. 1990 (June). The term structure of euro interest rates and rational expectations. *Journal of International Money and Finance (UK)*, 234-244.

McFayden, J., Pickerill, K. & Devaney, M. 1991 (Februry). The expectations hypothesis of the term structure: More evidence. *Journal of Economics and Business*, 79-85.

Meiselman, D. 1962. *The Term Structure of Interest Rates*. Englewood Cliffs, N.J.. Printice-Hall.

Tease, W.J. 1988 (June). The expectation theory of the term structure of interest rates in Australia. *The Economic Record*, 120-127

Van Horne, James C. 1965 (August). Interest-rate risk and the term structure of interest rates. *Journal of Political Economy*, 344-51.

Van Horne, James C. 1984. *Financial Market Rates and Flows*. Englewood Cliffs, N.J.. Prentice Hall.

Jabatan Kewangan
Fakulti Pengurusan Perniagaan
Universiti Kebangsaan Malaysia
43600 UKM Bangi
Selangor D.E.