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Risk Premium, Liquidity Premium, and Expectations Hypothesis in the Treasury Bill Market

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Abstract This paper examines whether the risk premium and the liquidity premium play an important role in explaining excess holding period return and whether two components can explain the empirical failure of expectations hypothesis. The paper finds from the study of U.S. Treasury Bill rates that the risk premium and the liquidity premium are important in explaining excess holding period return. However, the expectations hypothesis is not salvaged under the maintained hypothesis concerning the liquidity premium and risk premium although two premiums improve the forecastability of yield spread. The paper attributes the results to the possibility that the difference between the relative bid-ask spread of T-bill rates is not accurate measure for the time-varying liquidity.

Keywords Risk premium, Liquidity premium, Expectations hypothesis, Term structure

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1. Introduction

The prevalent theory of the term structure of interest rates is the rational expectations hypothesis (hereafter EH), which holds that fluctuations in the slope of the yield curve reflect expected future interest rate changes plus a constant term premium. Most empirical studies such as Shiller, Campbell, and Schoenholtz (1983), Mankiw and Mirron (1986), Fama and Bliss (1987), and Cook and Hahn (1990), Campbell and Shiller (1991), Roberds et al. (1996), among others, find that the predictability of the yield curve differs as the forecast horizon varies and regard these results as rejection of the rational expectations hypothesis under a constant term premium. The rejection of rational expectations has resulted in modeling time varying term premium.

Engle, Lilien and Robins (1987) treat the term premium as a risk premium where risk is measured by the conditional standard deviation of the excess holding period yield. They show that the risk premium is significant and time varying. Simon (1989) specifies the term premium(risk premium) to be proportional to the volatility of excess returns and shows that the predictive powers of both the yield curve and the risk premium are highly significant. Friedman and Kuttner (1992) emphasize the role of time-varying asset risk assessments in accounting for what at least appear to be time-varying differentials in ex ante asset returns. They show that the variance-covariance structures conditional on past information change over time sizably and this changing conditional variance-covariance structure in turn implies sizable changes over time in asset demand behavior, and hence in the market-clearing equilibrium structure of ex ante asset returns.

Lee (1995) shows that the risk premia in the nominal term structure depend on the uncertainties related to the macroeconomic forcing variables, output and the money supply, measured by their conditional variance-covariances. His result suggests that uncertainties related to output and the money supply are important sources of time-varying risk premia in the nominal term structure of interest rates.

Evans and Lewis (1994), however, point out that only time-varying risk premium is not sufficient to explain the time-varying term premium in the Treasury bill. Recently, Shen and Starr (1998) show that liquidity is priced in the Treasury bill market, and liquidity differences account for an important part of the term premium. Kim (2008) shows that liquidity plays an important role in explaining how banks determine their allocation of funds and in determining yield spreads between long-term rate and the short-term rate.

Liquidity refers to the ease with which an asset can be bought or sold. Asset purchases or sales are subject to transaction costs and the degree of liquidity of an asset decreases as the costs incurred in buying and selling it increase. Shen and Starr (1998) argue that liquidity is provided to the market at a price, the bid-ask spread, and the bid-ask spread is a significant determinant of the excess holding period yield of longer bills over short bills.

The purpose of this paper is to attempt to answer the following question; do risk and liquidity account for the term premium in the Treasury bill market? If so, can the expectations hypothesis be salvaged under the maintained hypothesis concerning the risk premium and the liquidity premium? The paper finds that the liquidity premium and the risk premium play an important role in explaining the excess holding period return in the Treasury bill market but the expectations hypothesis is not salvaged although two premiums improve the forecastability of the spread. The paper attributes the results to the possibility that the difference between the relative bid-ask spreads of Treasury bill rates is not accurate measure to model the liquidity premium.

The plan of this paper is as follows. Section II reviews the literature about the rational expectations hypothesis of term structure of interest rates. Section III explains the theoretical background for liquidity premium. In section IV, the model is introduced. Section V describes the data and presents the estimation results. Concluding remarks are provided in Section VI.

2. Rational Expectations Hypothesis of Term Structure of Interest Rates

2.1 Some Basic Concepts

One central concept to the test of the expectations hypothesis is the term premium. The phrase “term premium” refers to the stylized fact that typically, default free debts with longer time to maturity have higher rates of return than those with shorter time to maturity. The differences in rates of return are called term premia. Shiller (1990) summarizes several different definitions of term premia which are the forward term premium, the holding period term premium, and the rollover term premium.[1] Among these definitions, the holding period term premium is the focus of this paper.

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[1] The forward term premium is defined as the difference between the forward rate and the expectation of the corresponding future spot rate. Suppose an investor can purchase a six-month Treasury bill now or

A holding period return is the rate of return from buying at time t a bond maturing at date T and selling it at date t', where $t \leq t' \leq T$. For example, the one-period holding return for a two period to maturity bond, $Hr_{2,t}^{1}$, is defined as

$$Hr_{2,t}^{1} = \log p_{1,t+1}^{1} - \log p_{2,t}^{2}, \qquad (1)$$

where $p^{1}_{1,t+1}$ is the price of one-period bond at time $t+1$, and $p^{2}_{2,t}$ is the price of two-period bond at time t.

The holding period term premium is defined as the difference between the conditional expected holding period return and the corresponding spot rate. For example, the one-period excess holding period term premium of a two-period bill over a one-period bill, $HTP^{1}_{2,t}$, is defined as

$$HTP_{2,t}^{1} = E_t Hr_{2,t}^{1} - Hr_{1,t}^{1} (= y_{1,t}^{1}), \qquad (2)$$

where $E_t Hr^{1}_{2,t}$ is expected one-period holding return of two-period bill and $Hr^{1}_{1,t}$ is one-period holding return of one-period bill which is equal to yield to maturity (one-period spot rate).

purchase a three-month bill now and reinvest his funds three months from now in another three-month bill. The forward rate is the hypothetical rate on the three-month bill three months in the future that equalizes the rate of return from the two options, given the current three- and six-month rates.

2.2 The Rational Expectations Hypothesis

The academic literature on the rational expectations hypothesis of the term structure of interest rate is voluminous[2]. The basic idea is that with the exception of a term premium, there should not be on expected difference in the returns from holding a long-term bond or rolling over a sequence of short-term bonds.

The expectations hypothesis of the term structure of interest rates is a relationship between a longer-term *n*-period interest rate R_t^n and a shorter-term *m*-period interest rate R_t^m,

$$R_t^n = (1/k)\sum_{i=0}^{k-1} E_t R_{t+mi}^m + \theta_n , \qquad k = n / m \qquad (3)$$

where θ is a constant (term premium). Equation (1) states that the *n*-period rate is a constant (term premium), plus a simple average of the current and expected future *m*-period rates up to $n-m = (k-1)m$ periods in the future. The expectations theory of the term structure implies that the spread is a constant risk premium, plus an optimal forecast of changes in future interest rates.

The simple equation for testing the rational expectations hypothesis as in the Mankiw and Miron (1986) is as follows;

$$R_t = \theta + \frac{1}{2}(r_t + E_t r_{t+1}) , \qquad (4)$$

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[2] Examples include Shiller, Campbell, and Schoenholtz (1983), Mankiw and Miron (1986), Simon (1989, 1990), Froot (1989), Cook and Hahn (1990), Campbell and Shiller (1991), Rudebusch (1995), Roberds, Runkle and Whiteman (1996), Bekaert, Hodrick and Mashall (1997), Bekaert and Hodrick (2001), Sarno, Thornton and Valente (2007), Bataa, Kim and Osborn (2007), among others.

where r_t is the yield on a one-period bill (three-month bill), R_t is the yield on a two-period bill (six-month bill), and E_t denotes the expectation formed at time t. Assuming rational expectations,

$$r_{t+1} = E_t r_{t+1} + \varepsilon_{t+1}, \qquad (5)$$

where ε_{t+1} is a forecast error orthogonal to information available at time t. By subtracting r_t from both sides of equation (4), we then see

$$\frac{1}{2}(r_{t+1} - r_t) = b_1 + b_2(R_t - r_t) + \varepsilon_{t+1}. \qquad (6)$$

Under the rational expectations hypothesis of the term structure, b_1 and b_2 are equal to -θ and 1, respectively.

Rudebusch (1995) summarizes estimates of b_2 from previous studies that have estimated equation (6) using securities of various maturities and reports that many of the $\hat{b}_2$'s are less than one, implying that the expectations hypothesis does not hold. As pointed out in Rudebusch (1995) and Roberds and Whiteman (1999), there is a clear dependence of the size and statistical significance of the $\hat{b}_2$'s on the maturity of the securities. The ability of the term structure to predict changes in short rates is quite good for forecast horizons (i.e., the maturities of the one-period security) that are no longer than about a month. As the forecast horizon increases, the predictive power disappears, and the $\hat{b}_2$'s are insignificantly different from zero from three months to one year. However, at horizons longer than one or two years, there is some evidence that predictive power appears to improve. Roberds and Whiteman (1999) name the 'U-shaped' pattern of the predictive ability of the yield curve 'predictability smile'.

The rational expectations hypothesis of the term structure is not extensively supported by empirical test results. Most researchers attribute the lack of empirical support for the rational expectations hypothesis to the possibility that the expected term premium is not constant and to the Federal Reserve interest rate targeting behavior.

Mankiw and Mirron (1986) point out that the movements of the interest rates were more predictable before the founding of the Federal Reserve in 1913 and they attribute the more recent failure of the expectations hypothesis to the smoothness of the short rate caused by Fed behavior. Rudebusch (1995) argue that contemporary Federal Reserve operating procedures lead to predictable interest rate movements in the very short run and the very long run, but tend to smooth away predictable movements in the medium run.

Dotsey and Otrok (1995) state that a deeper understanding of interest rate behavior will be produced by jointly taking into account the behavior of the monetary authority along with a more detailed understanding of what determines term premia. Roberds and Whiteman (1996) emphasize that the most common themes in attempts to explain the term structure anomalies are that smooth short rates (Fed behavior) and time-varying term premia seem necessary.

As shown in Engle et al. (1987), Bollerslev et al. (1988), Simon (1989), Engle and Ng (1993), Evans (1994) and Lee (1995), we can generalize equation (4) as follows by allowing a time-varying risk premium;

$$R_t = \theta + \frac{1}{2}(r_t + E_t r_{t+1}) + \alpha\psi_t \, , \tag{7}$$

where ψ_t is a time varying measure of risk. Engle et al. (1987) quantify risk as the conditional standard deviation of excess holding period yield. Bollerslev et al. (1988) find that the conditional covariances of each return with a fully diversified or market portfolio are quite variable over time and are a significant determinant of the time-varying risk premia. Simon (1989) specifies the risk premium to be proportional to the volatility of excess returns and shows that from 1961 to 1972 and from 1972 to 1979, rational expectations cannot be rejected, and both the predictive powers of the yield curve and the risk premium are highly significant.

Engle and Ng (1993) show that the combined effect of the expectation component and the premium component can produce yield curves of the commonly observed shapes and argue that volatility-based premium adjustments are an important ingredient in determining the term structure of interest rates. Evans (1994) shows that the risk premia associated with interest rate risk appear to have the strongest effect on expected bill and bond returns from estimating a new empirical model based upon intertemporal capital asset pricing model (ICAPM).

Evans and Lewis (1994), however, show that the hypothesis that stationary risk premia can alone explain the behavior of excess returns to long bonds relative to rolling over short rates, is rejected by using Treasury bill returns.

3. Liquidity Premium

Liquidity refers to the ease with which an asset can be bought or sold. Though this definition of liquidity is straightforward, capturing liquidity in economic models can be challenging. Even though there are several approaches which have been taken in the literature, it can simply be posited that asset purchases or sales are subject to transactions costs, as in Aiyagari and Gertler (1991). In this approach, the degree of liquidity of an asset decreases as the costs incurred in buying and selling it increase.

Amihud and Mendelson (1986a, 1986b) point out that despite evident importance of liquidity, liquidity considerations have not received anything like the attention paid to risk in the finance literature. Amihud and Mendelson (1991b) state that investors prefer to commit capital to liquid investments, which can be traded quickly and at low cost whenever the need arises and so, investments with less liquidity must offer higher expected returns to attract investors. In equilibrium, the expected returns on capital assets are increasing functions of both risk and illiquidity.

Illiquidity can be measured by the cost of immediate execution. An investor willing to transact faces a tradeoff: he may either wait to transact at a favorable price or insist on immediate execution at the current bid or ask price. The quoted ask (offer) price includes a premium for immediate buying, and the bid price similarly reflects a concession required for immediate sale. The bid-ask spread may thus be viewed as the price the dealer (or market-maker) demands for providing liquidity services and immediacy of execution. Amihud and

Mendelson (1986a) suggest that asset liquidity is inversely related to the relative bid-ask spread and expected asset returns are increasing in the relative bid-ask spread. If investors value securities according to their returns net of trading costs, then they should require a higher expected return for higher spread stocks in order to compensate them for the higher cost of trading.

Amihud and Mendelson (1991a) examined the effects of illiquidity on the yields of Treasury bills and notes with maturities less than 6 months. For these maturities, both securities are effectively discount bonds and should be equivalent. Their liquidity, however, is different: the cost of transacting bills is lower than the cost of transacting notes. They find that the yield to maturity on notes is higher than the yield on bills of the same maturity.

Shen and Starr (1998) show that relative bid-ask spreads vary dramatically over time and over different T-bill maturities and the spreads on 6-month T-bills are much higher than those on 3-month bills. They argue that the bid-ask spread increases the illiquidity of the longer-term T-bills and the bid-ask spread is priced in the bill's expected excess returns, i.e., the term premium.

In addition, Hooker and Kohn (1994) develop an empirical measure of liquidity consistent with Keynes's definition and suggest that their liquidity measures for Treasury securities at different maturities might be applied to see whether differences in and variation in these measures help explain time-varying term premia in the term structure of interest rates.[3] Kim (2007) shows from bank's liquidity model that liquidity plays an important role in determining yield spreads.

Therefore, the liquidity effect can be likened to the widely known effect of risk on capital assets. Furthermore, this liquidity effect might provide possible explanation for the failure of the rational expectations hypothesis.

4. Formulation of the Model

If risk and liquidity are priced as the time-varying term premium in T-Bill markets, it might be possible to build a model which incorporates both a time-varying risk premium and a liquidity premium. I postulate that the term premium in equation (3), θ_t, can be decomposed into a risk premium and a liquidity premium as follows;

$$\theta_t = \delta_1 \psi_t + \delta_2 \omega_t , \qquad (8)$$

where θ_t is the time-varying term premium, ψ_t is the time-varying risk measure, and ω_t is the time-varying liquidity measure. Thus, $\delta_1 \psi_t$ is a risk premium and $\delta_2 \omega_t$ is a liquidity premium. This paper will use excess holding period return term premium as a term premium. That is, the

[3] As explained in Hooker and Kohn (1994), Keynes's definition of liquidity refers to the case that an asset is more liquid if it is "more certainly realizable at short notice without loss." They say that implications of Keynes' definition include that liquidity is forward-looking and depends on the expected future path of prices rather than current or past prices.

one-period excess holding period return of a two-period (6-month) bill over a one-period (3-month) bill is defined as equation (2).

Following Engle et. al. (1987), I assume that the time-varying risk measure, ψ_t, can be modeled by conditional standard deviation (or variance) of excess holding period return.

In addition, I postulate that the time-varying liquidity measure, ω_t, can be modeled by the difference between the relative bid-ask spread of the two-period bill (6-month) and that of the one-period bill (3-month) as in Shen and Starr (1998). That is,

$$\omega_t = S_t^2 - S_t^1, \qquad S_t^n = \frac{(p_{a,t}^n - p_{b,t}^n)}{p_{b,t}^n}, \quad \text{for } n = 1, 2 \tag{9}$$

where S_t^n is the relative bid-ask spread of an n-period bill, $p_{a,t}^n$ is the ask price of an n-period bill and $p_{b,t}^n$ is bid price of n-period bill at time t.

Therefore, equation (8) can be estimated in the framework of the GARCH-M with liquidity specification, as follows;

$$HTP_{2,t}^1 = Hr_{2,t}^1 - Hr_{1,t}^1 = \delta_0 + \delta_1\psi_t + \delta_2\omega_t + \varepsilon_t, \varepsilon_t|\Omega_{t-1} \sim N(0, h_t) \\ h_t = a_0 + \sum_{j=1}^{p} a_{i,j}\varepsilon_{t-j}^2 + \sum_{i=1}^{q} a_{2,i}h_{t-i} \quad , \tag{10}$$

where h_t is the conditional variance of excess holding period return and ψ_t is the conditional standard deviation of excess holding period return ($\sqrt{h_t}$). If risk and liquidity do account for a time-varying term premium and equation (10) is not misspecified, the two coefficients of risk and liquidity will be significantly different from zero. Since the greater the conditional standard deviations are, the riskier the two-period bill is and investors must require more compensation for bearing the two-period bill, we expect that the value of the coefficient, δ_1, will be greater than zero. Similarly, because the bigger the difference between the two relative bid-ask spreads, the less liquid the two-period bill, and the market makers must require more compensation, the coefficient, δ_2 will be positive.

Under assuming that equation (10) is correctly specified, I use the $\hat{\delta}_1\psi_t$'s as the approximate risk premium and the $\hat{\delta}_2\omega_t$'s as the approximate liquidity premium. By combining equations, (4) and (8) with these approximate risk premium and liquidity premium, we can build up the model which accommodates time-varying risk premium and liquidity premium, and test whether the rational expectations hypothesis can be salvaged under the maintained hypothesis concerning the risk premium and liquidity premium or not. That is, we can generalize equation (4) as follows;

$$R_t = \theta + \frac{1}{2}(r_t + E_t r_{t+1}) + \hat{\delta}_1\psi_t + \hat{\delta}_2\omega_t . \qquad (11)$$

By subtracting r_t from both sides of equation (11) and rearranging it, we get

$$\frac{1}{2}(E_t r_{t+1} - r_t) = -\delta_0 + (R_t - r_t) - \hat{\delta}_1\psi_t - \hat{\delta}_2\omega_t . \qquad (12)$$

By assuming rational expectations, we then see

$$\frac{1}{2}(r_{t+1} - r_t) = b_0 + b_1(R_t - r_t) + b_2\bar{\delta}_1\psi_t + b_3\bar{\delta}_2\omega_t + e_{t+1}. \quad (13)$$

Under the joint hypothesis of rational expectations, risk premium specification, and liquidity premium specification, b_0 equals to $-\delta_0$, b_1 equals to 1, b_2 equals -1, and b_3 equals -1, too. We can also test the predictability of yield curve to change in future short term interest rate under risk premium specification and liquidity premium specification by examining whether b_1 is significantly different from zero or not.

5. Estimation Results

5.1 Data Description

The data series in our empirical analysis are quarterly series. The sample period is from first quarter 1960 to last quarter 1993. I choose the 6-month bill as the two-period bill and the 3-month bill as the one-period bill. I obtained the bid, ask, and average prices of 3- and 6-month T-bill data from 1995 Fama's six-month Treasury bill term structure files in the Center for Research in Security Prices (CRSP) Government Bond Tape.[4] By using average prices of 3- and 6-month T-bills, I get the continuously compounded annual rates for 3- and 6-month bills. Moreover, I calculate the holding period returns by using equation (1) and convert these returns to annual returns. The relative bid-ask spreads for 3- and 6-month T-bills are obtained by using equation (9) and I take the difference between the two relative bid-ask spreads. Table 1 contains summary statistics of one-quarter holding period returns, excess holding period return, relative

[4] The original data in Fama files is monthly. I chose January, April, July, and October and made quarterly series.

bid-ask spreads, and difference between relative bid-ask spread of the 6-month bill and that of the 3-month. During this sample period, the annualized one-quarter holding period return of the 6-month bill is about 6.74% and that of the 3-month bill is 6.17% and thus, the annualized average excess holding period return (term premium) of the 6-month bill over the 3-month bill is about 0.57%.

Figure 1 shows the relative bid-ask spreads of the 3- and 6-month T-bills. The bid-ask spreads (dotted line) of the 6-month bill are usually higher than those (solid line) of the 3-month T-bill, which means that the 6-month T-bill is less liquid than the 3-month. These two relative bid-ask spreads have pretty similar movement over the sample period.

5.2 Estimation Results

First of all, I estimate equation (10). The main estimation results for equation (10) are summarized in Table 2. The first estimation is GARCH(1,1)-M without MA(1). Even though the Ljung Box Q-statistics for the standardized residuals and the squared standardized residuals have a p-value of 0.84 and a p-value of 0.97 at 12 lags respectively, there is significant first-order autocorrelation for the standardized residuals. So, I adjust it with moving average of order one and the bottom of Table 2 shows the estimation of a GARCH(1,1)-M with MA(1). As usually shown in modeling of financial data, GARCH (1,1) model is appropriate in our regressions. The estimation results show that the conditional variance of excess holding period returns and the relative bid-ask spread are significant variables and shows positive values for the excess holding period return, just as the theory has predicted. The estimated risk premium is similar to Engle et al. (1987). The estimated liquidity premium is lower than Shen and Starr (1998).

The estimation results, however, are different from Shen and Starr (1998). They say that in modeling the excess holding period returns, the bid-ask spread is robustly significant, while the conditional variance is only significant when the bid-ask spread is not included.[5] As shown in Table 1, the conditional standard deviation of excess holding period returns is still significant even including the bid-ask spread. These empirical results might provide support for the conjecture that the own price risk as measured by the conditional variance is priced distinctly and the bid-ask spread is priced to reflect the liquidity premium in T-bills.

By using the estimation results of the excess holding period return, I produce the estimated term premium under assuming that term premium can be decomposed into risk premium and liquidity premium. That is, the estimated term premium is the estimated risk premium ($\hat{\delta}_1\psi_t$) plus the estimated liquidity premium ($\hat{\delta}_2\omega_t$). Table 3 contains the comparison of excess holding period return with the estimated term premium. Since the difference between the standard deviation of the excess holding period return and that of the estimated term premium is great, the estimated term premium might not catch the variation of excess holding period returns. This

[5] The sample period in Shen and Starr (1998) is from 1964 to 1990 and a little different from this paper and their results are not robust on the quarterly data. In addition, they use the relative bid-ask spread of the 3-month bill as an explanatory variable to reflect liquidity premium.

point also can be seen in Figure 2. The excess holding period returns are pretty volatile over the sample period, while the estimated term premiums are not very volatile.

Table 4 shows the estimation results for testing the rational expectations hypothesis without risk and liquidity premium specifications and with risk and liquidity premium specifications. As the results of the ARCH LM test and the Ljung Box Q-statistic, I found that there is a serious ARCH effect on squared residuals and so, two regressions are conducted in the framework of GARCH(1,1). All Ljung Box Q-statistics have p-value of over 0.2.

Even though I reject the simple rational expectations hypothesis, the coefficient of the yield spread is significantly different from zero and surprisingly, this result is in contrast to previous empirical studies which found that the yield spread didn't have predictability for the future change of short term rate from three months to one year.

In addition, I test jointly the rational expectations hypothesis under maintaining risk premium and liquidity premium specification by using Wald test. I reject the joint null hypothesis of no risk premium and no liquidity premium while the coefficient of liquidity premium is not significantly different from zero, which means that there might exist the possibility of misspecification for the liquidity premium and thus, the bid-ask spread might be less accurate as a measure of the market liquidity. Even though I reject the joint hypothesis, the coefficient of the yield spread increases from 0.509 to 0.572 by maintaining the risk premium and liquidity premium. These results might imply that if we specify correctly the risk premium and liquidity premium, the rational expectations hypothesis might be salvaged under the maintained hypothesis concerning the risk premium and the liquidity premium.

6. Concluding remarks

The main purpose of this paper is to examine whether risk and liquidity premium account for the time-varying term premium and to address whether the rational expectations hypothesis can be salvaged under the maintained hypothesis concerning the risk premium and liquidity premium. Following Engle et al. (1987) and Amihud and Mendelson (1991a) and Shen and Starr (1998), this paper models the time-varying risk premium by the conditional standard deviation of excess holding period return and the time-varying liquidity premium by the difference between the relative bid-ask spread of the two-period T-bill (6-month) and that of the one-period T-bill (3-month). The empirical study shows that these two premiums are priced in the excess holding period return, implying that the risk and liquidity premium can play an important role in explaining asset returns.

However, under maintained hypothesis concerning the risk premium and the liquidity premium, the estimated coefficient on the spread is statistically different from the one indicated by the rational expectations hypothesis although two premiums improve the forecastability of the spread. Given the important role of liquidity in asset allocations (Kim, 2007), we open the possibility that the specification for liquidity premium might not be accurate. Even though a bid-ask spread reflects the illiquidity of financial assets, bid-ask spreads also reflects the compensation that the market makers receive for bearing undiversifiable risk. That is, the bid-ask spreads are not only payment for the services of immediacy (market making) that the market makers provide but also, compensation to the dealers for bearing undiversified risk. So, the bid-ask spreads also can reflect the risk and it might not be appropriate to decompose term premium into risk premium and liquidity premium by using the bid-ask spreads as the accurate measure for liquidity. The paper warrantees further investigations for accurate measure of liquidity for future research.

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Table 1. Summary statistics of holding period returns, excess holding period returns, relative bid-ask spreads, and differences of two bid-ask spreads.

	Mean	*St. Deviation*	*Max.*	*Min.*
Holding return(3)	0.061774	0.028068	0.152725	0.020352
Holding return (6)	0.067437	0.031275	0.180903	0.025351
Excess return	0.005663	0.009934	0.047623	-0.030548
Bid-ask spread (3)	0.000195	0.000188	0.000807	2.61E-05
Bid-ask spread (6)	0.000346	0.000328	0.001698	9.97E-05
Bid-ask (6) – Bid-ask (3)	0.000151	0.000226	0.001076	-0.000520

Table 2. Excess holding period return (term premium) estimation:

1) GARCH(1,1)-M without MA

$$HTP_{2,t}^{1} = Hr_{2,t}^{1} - Hr_{1,t}^{1} = \delta_0 + \delta_1 \psi_t + \delta_2 \omega_t + \varepsilon_t , \varepsilon_t | \Omega_{t-1} \sim N(0, h_t)$$
$$h_t = a_0 + a_1 \varepsilon_{t-1}^{2} + a_2 h_{t-1}$$

$\hat{\delta}_0$	$\hat{\delta}_1$	$\hat{\delta}_2$	$\hat{a}_0$	$\hat{a}_1$	$\hat{a}_2$	*Q^1(12)*	*Q^2(12)*	*LogL*
-0.0008	0.702**	3.155*	7.06E-07	0.341**	0.657**	7.133	4.287	458.07
(0.001)	(0.198)	(1.54)	(9.9E-07)	(0.026)	(0.064)			

2) GARCH(1,1)-M with MA(1)

$$HTP_{2,t}^{1} = Hr_{2,t}^{1} - Hr_{1,t}^{1} = \delta_0 + \delta_1 \psi_t + \delta_2 \omega_t + \rho \varepsilon_{t-1} + \varepsilon_t , \varepsilon_t | \Omega_{t-1} \sim N(0, h_t)$$
$$h_t = a_0 + a_1 \varepsilon_{t-1}^{2} + a_2 h_{t-1}$$

$\hat{\delta}_0$	$\hat{\delta}_1$	$\hat{\delta}_2$	$\hat{a}_0$	$\hat{a}_1$	$\hat{a}_2$	*Q^1(12)*	*Q^2(12)*	*LogL*
-0.00006	0.634**	3.075**	2.06E-06	0.343**	0.685**	3.618	7.298	464.47
(0.002)	(0.072)	(1.02)	(1.1E-06)	(0.0004)	(0.0006			

Note: ** and * denote statistical significance at 1% level and at 5% level respectively. LogL is the log likelihood value. Figures in the parentheses are Bollerslev-Wooldrige (1992) robust standard error.

Table 3. Excess holding period return and estimated risk premium plus liquidity premium

	Mean	*St. Deviation*	*Max.*	*Min.*
Excess return	0.0057	0.0099	0.0476	-0.0316
Risk pre. + liquidity pre.	0.0062	0.0036	0.0182	0.0023

Table 4. Excess holding period return (term premium) estimation

1) Test for the rational expectations hypothesis without risk and liquidity premium specifications.

$$\frac{1}{2}(r_{t+1} - r_t) = b_0 + b_1(R_t - r_t) + e_{t+1}, e_{t+1} \sim N(0, h_{t+1})$$
$$h_{t+1} = a_0 + a_1 e_t^2 + a_2 h_t$$

$\hat{b}_0$	$\hat{b}_1$	$\hat{a}_0$	$\hat{a}_1$	$\hat{a}_2$	*$Q^1(12)$*	*$Q^2(12)$*	*LogL*
-0.0007*	0.509**	7.27E-06	0.466**	0.589**	11.05	15.72	560.45
(0.0003)	(0.109)	(5.30E-07)	(0.183)	(0.118)			

Note: ** and * denote statistical significance at 1% level and at 5% level respectively. LogL is the log likelihood value. Figures in the parentheses are Bollerslev-Wooldrige (1992) robust standard error.

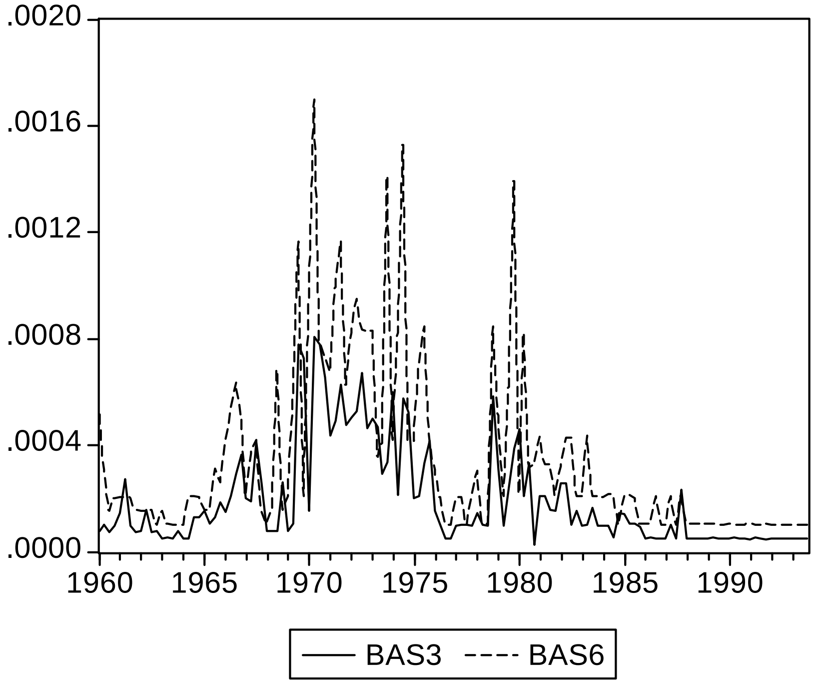
2) Test for the rational expectations hypothesis with risk and liquidity premium specifications

$$\frac{1}{2}(r_{t+1} - r_t) = b_0 + b_1(R_t - r_t) + b_2\hat{\delta}_1\psi_t + b_3\hat{\delta}_2\omega_t + e_{t+1}, e_{t+1} \sim N(0, h_{t+1})$$
$$h_{t+1} = a_0 + a_1 e_t^2 + a_2 h_t$$

$\hat{b}_0$	$\hat{b}_1$	$\hat{b}_2$	$\hat{b}_3$	$\hat{a}_0$	$\hat{a}_1$	$\hat{a}_2$	*$Q^1(12)$*	*$Q^2(12)$*	*LogL*
0.0006	0.572**	- 0.45**	0.07	7.27E-07	0.57*	0.55**	9.58	11.58	565.37
(0.0005)	(0.11)	(0.15)	(0.73)	(3.1E-07)	(0.25)	(0.12)			

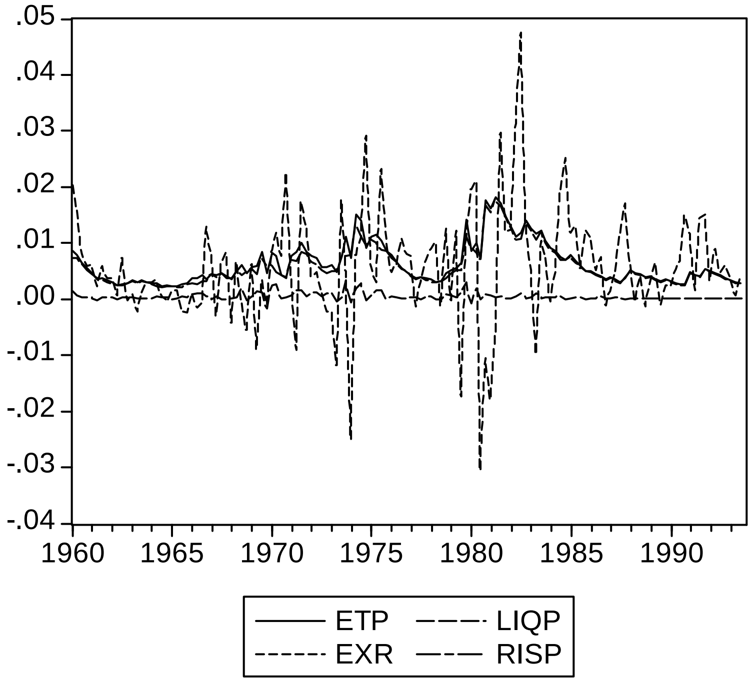
Note: ** and * are statistically significant at 1% and at 5% level respectively. LogL is the log likelihood value. The figures in the parentheses are Bollerslev-Wooldrige (1992) robust standard error.

Figure 1. The bid-ask spreads of the 3- and 6-month T-bills



Note: BAS3 and BAS6 denote the bid-ask spread of the three-month T-Bill rate and the six-month T-Bill rate respectively.

Figure 2. The excess holding period return, and the estimated risk premiu, estimated liquidity premium and estimated term premium



Note: ETR denotes the estimated term premium, LIQP denotes the estimated liquidity premium, EXR denotes the excess holding period return, and RISP denotes the estimated risk premium.

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