Determinants of Treasury Bond Yields in Singapore[1]

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Abstract: Using quarterly data over 20 years, the paper examines the shape of the term structure of interest rates in Singapore. The results generally support the liquidity premium hypothesis finding a strong relationship between the maturity premium and the difference in the yield rates. Interest-rate expectations exert some impact on the shape of the yield curve. Changes in inflation do not appear to be a determinant of changes in the bond yields.

1. Introduction

Despite considerable progress, the bond markets in the developing Asian economies are less developed than in industrialised economies. Consequently, bond prices in such markets may be less efficiently determined as proposed in theories than in their industrialised counterparts due to such factors as a lack of depth and liquidity. Much theoretical and empirical work exists on term structure of interest rates. Far fewer studies, however, examine the yield behaviour of bond markets in developing Asian economies, specifically Singapore, to determine if they conform to the predictions of traditional term structure theories or hypotheses.

In this study, we empirically examined the shape of the term structure of interest rates in Singapore. Specifically, we examined three hypotheses – the expectations hypothesis, the liquidity premium hypothesis, and the expected inflation hypothesis – to determine which hypothesis best explains Treasury bond yields in Singapore. We examined a recent 20-year period covering two full business cycles but excluded the period when a financial crisis in 1997 adversely affected the term structure.[2] We studied Treasury bonds because they do not have default risk but may incorporate one or more of these other effects into

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1 This paper benefited from the useful comments of conference participants at the PACAP 2001 conference and the insightful comments of an anonymous reviewer of the journal.

2 With the onset of the Asian Financial Crisis that occurred in July 1997, three major factors affected bond prices: (i) the massive systemic risk, (ii) the collapse of trade; and (iii) the attendant political risk variables. Hence, including the data over 1997-1999 would have distorted the findings. The hand-collected data set used in our analysis covers two full business cycles unaffected by the financial crisis, and hence the findings are comparable to those in the literature.

their yields. This study contributes to the literature by providing new evidence about the theoretical determinants of the shape of the term structure in Singapore.

McEnally and Jordan (1995) note that determining which hypothesis of the term structure is most nearly valid is extremely difficult in practice. For example, market consensus expectations are observable only with difficulty and imperfectly. In addition, measuring liquidity premiums is hard in an uncertain world and these liquidity premiums may change over time. Van Horne (1998) notes that both the real rate and expected inflation are not directly observable. Moreover, the real rate is not necessarily constant over time or independent of inflation. These problems are heightened when studying theoretical determinants of the shape of the term structure in developing economies. Despite these difficulties, we focused on testing several *basic* term structure models to help understand Treasury bond yields in Singapore.

The remainder of this paper is organised as follows: Several term structure theories involving expectations, liquidity premiums, and inflation are discussed followed by a discussion on the Singapore bond market in Section 3. Next, is the research methodology followed by the empirical findings. In our final section, we provide several conclusions.

2. Term Structure Theories

The term structure of interest rates defines the relationship between maturity and annualised yield. Of all the factors that affect yields offered on debt securities, perhaps the most difficult factor to understand is the term to maturity. Yields typically vary among securities of differing maturity. Otherwise, yield curves would be perfectly horizontal and no meaningful term structure would exist.

Numerous theories attempt to explain the term structure of interest rates such as expectations theory, liquidity premium theory, and market segmentation theory.[3] An abundance of research exists on the term structure of interest rates and offers insight into the various theories. In his summary of research on term structure theories, Madura (2003) notes that researchers have found that interest rate expectations have a strong influence on the term structure of interest rates. Yet, the forward rate derived from a yield curve does not accurately predict future interest rates. An implication of this finding is that other factors are relevant. For example, the liquidity premium could cause consistent positive forecasting errors. This would mean that forward rates tend to overestimate future interest rates. Studies also show that interest rate expectations or liquidity cannot fully explain the yield-maturity relationship. Thus, different supply and demand conditions for particular maturity segments could contribute to the variation. Although the research evidence suggests that each theory has some validity, the importance of various factors that affect the shape of the yield curve can vary among countries. Thus, the shape of the yield curve at any given point in time varies among countries.

This paper reports the findings of an analysis of three theoretical determinants of the shape of the term structure – expectations, liquidity premiums, and inflation. In brief, hypotheses involving these determinants suggest that interest rates are formed in liquid and

[3] For a discussion of prominent theories about shape of the term structure, see McEnally and Jordan (1995), Fabozzi (1995), Van Horne (1998), Reilly and Brown (2000), and Madura (2003).

efficient markets in such a manner that yields must have predictable relations with expectations, liquidity premiums, and inflation.

2.1 The Expectations Hypothesis

Perhaps the most widely tested explanation for the shape of the term structure is the expectations theory. Fisher (1896) first expressed this theory and Lutz (1940) further developed it. According to this theory, the sole determinant of the term structure is the market's current expectations of future short term rates. The basis of expectations theory rests on several simplifying assumptions such as risk neutral investors' trivial transaction costs, and highly efficient bond markets. Hence, we chose to study the Treasury market because it closely approximates these assumptions.

One version of the expectations theory, the pure or unbiased expectations hypothesis, posits that forward rates of interest embodied in the term structure are unbiased estimates of expected future spot rates of interest.[4] That is, long term interest rates are a geometric average of expected future short-term rates. Equation 1 expresses this concept as follows:

$$(1 + r_{0,n})^n = (1 + r_{0,1})(1 + f_{1,2})\ldots..(1 + f_{n-1,n}) \quad (1)$$

where, $r_{0,n}$ is the yield with the first subscript "$_0$" referring to current time and the second "$_n$" refers to the term: hence, "$_{0,1}$" is the actual rate; $f_{1,2}$ .. $f_{n-1,n}$ are forward rates over n periods. In equilibrium, the pure expectations theory suggests the long rate $r_{0,n}$ is determined by future short rates, each of which is shown in parentheses on the right-hand side of Equation 1.

In practice, forward rates may not be unbiased estimates of expected future spot rates due to several problems. For example, technical problems may occur if serially correlated spot rates exist or if the distributions of possible future spot rates are wide. Van Horne (1998: 88) states, however, "For most situations, the biases are not large and, in many cases, can be safely ignored." Another problem of pure expectations theory is that it does not account for the risks inherent in investing in bonds. Instead, this theory assumes complete certainty exists in the market. Under this condition, forward rates would be exact forecasts of future short term interest rates. Therefore, risk or term premiums would be zero or constant through time. In an uncertain world, the pure expectations theory must be modified.

Some dispute exists among scholars such as Luckett (1959) and Fama (1976) about the ability of market participants (investors, speculators, and borrowers) to forecast future interest rates accurately and to determine current spot rates. Meiselman (1962) shows that expectations theory can be reconciled with uncertainty and risk aversion among participants. Others argue that participants can make reasonable expectations about future interest rates. For example, the development of efficient futures markets since the 1970s and the wider dissemination of financial information in the market on interest rates and inflation have

[4] Cox, Ingersoll and Ross (1981) summarise various alternative statements of the pure expectations hypothesis and show that these versions are not exact equivalents with uncertain interest rates.

enhanced the ability of market participants to form expectations.

Empirical evidence from the U.S. and other countries is inconclusive involving the validity of the expectations hypothesis.[5] Several studies reject various forms of the expectations hypothesis. For example, evidence by Shiller (1979), Singleton (1980), and Kane (1983) shows that forward rates of interest are not unbiased estimates of expected future spot rates of interest. Others provide at least some support for the notion that interest rate expectations affect the shape of the yield curve (see, for example, Choi and Wohar 1991; Froot 1989; McFadyen, *et al.* 1991). In his analysis of the term structure of interest rates in Japan, Takeda (1997) could reject the pure expectations hypothesis, even after considering the Bank of Japan's efforts to smooth interest rates. Despite the lack of uniform conclusions, one implication of the evidence is that changing expectations appear to exert some impact on the term structure but scant support exists for the pure expectations theory.

2.2 The Liquidity Premium Hypothesis

As previously mentioned, a difficulty of the pure expectations hypothesis is that it fails to account for the risk associated with investing in bonds. Some economists, initially Hicks (1946), proposed liquidity preference theory to account for this uncertainty. According to Hicks, the risk associated with future interest rates causes investors to prefer to lend short, which results in a shortage of long term investors. Borrowers, however, prefer to borrow long to reduce the risk of being unable to meet principal payments. Borrowers must offer an extra return (that is, a risk or term premium) on long term bonds to induce investors to hold them. If short term investors dominate the market, then longer term bonds will require larger premiums. This premium is above the average of the current short rate and expected future short rates. Consequently, forward rates are biased estimates of future interest rates and exceed them by the amount of the risk premium. Equation 2 explains this idea in the following manner.

Define liquidity premium over a period as $L_2 = r_{0,2} - r_{0,1}$ (2)

Then, L_n = liquidity premium at time 2 for a security bought in time 1,
$r_{a,b}$ = rate of interest on a security over an interval between *a* and *b*.

$$(1 + r_{0,n}) = [(1 + r_{0,1} + L_1)\ldots(1 + r_{n-1,n} + L_n)]^{1/n} \qquad (3)$$

where, $r_{t+(n-1),n}$ is the expected rate of interest on a security for time $_{t+n-1}$ at current time *t*.

If this relationship holds, we can predict a direct relation between the term differences in the bonds and the differences in their yields. Bonds with positive time to maturity will have to offer incentives to market participants to forego holding cash. Thus, the longer the maturity of a bond, the higher will be the liquidity premium required to hold that bond. The liquidity premium hypothesis predicts that the yield difference between a short bond and

[5] Shiller (1987) and McEnally and Jordan (1995) provide a review of numerous studies involving the expectations hypothesis.

long bond must be highly correlated with a difference in the maturity of the two bonds. In an efficient bond market, a high correlation must exist between the maturity premium in yields and the term to maturity.

According to Van Horne (1998), reasonably strong evidence supports the liquidity premium hypothesis. For example, Strongin and Tarhan (1990) investigated the reasons innovations in money supply announcements in the United States cause interest rates to change. They empirically discriminated between the liquidity premium and the expected inflation hypotheses by directly taking into account investors' expectations about the Federal Reserve's monetary policy stance. Their results support the liquidity premium hypothesis. Lee and Tse (1991) investigated the term structure of interest rates in the Singapore Asian dollar market. Their results show a significant time varying term premium.

Thus, a strong case exists for the presence of liquidity premiums. These risk premiums tend to vary with maturity and volatility. An implication of this evidence is that if the liquidity premium hypothesis is valid, the pure or unbiased expectations hypothesis cannot be. Empirical studies show that both expectations and risk premiums affect the term structure.

2.3 The Expected Inflation Hypothesis

A third factor that may affect interest rates is inflation. Fama (1975; 1984) shows that the level of interest rates revealed in an efficient market can be used to forecast inflation. Subsequent studies show that this is more so in the short term bond markets than in the long term bond markets. Although the empirical evidence is mixed, Van Horne (1998) notes that most studies after 1960 indicate a positive relationship between unanticipated changes in inflation and changes in nominal rates of interest. More recent studies, however, suggest a less than one-to-one relationship between expected inflation and nominal interest rates (see, for example, Mishkin 1992; Evans and Lewis 1995).

Mishkin (1991) developed a model to study inflation using information in the shorter maturity term structure. He postulates that interest rates are highly correlated with the distributed lags of changes in the inflation rates in an economy. His work covered ten developed markets and shows evidence supporting a moderate to strong relationship between changes in inflation and changes in interest rates.

Although economists have modelled the relation between inflation and yield rates in different ways, we followed Mishkin's approach, which may be stated as follows:

$$| \Delta_t y_{t-1} | = \gamma_0 + \gamma_1 (| \Delta \text{ Inflation } |)_{t-1} + \mu_t \quad (4)$$

where

$\| \ \|$	=	absolute symbol
$\| \Delta_t y_{t-1} \|$	=	change in current yields with respect to the previous periods
γ_n	=	regression parameters, the intercept and the slope coefficient respectively
Δ Inflation	=	change in inflation rates over the *previous* periods
μ_t	=	random residual term with no serial correlations.

3. The Singapore Bond Market

Singapore has become a successful regional financial centre especially for trading in currencies, depositing Eurodollar and Euro-yen, and managing international portfolios of high net worth individuals. The estimated daily volume of currency trading in Singapore is about USD200 billion. Next in size to London and Tokyo, the Eurodollar deposits in Singapore amount to about USD515 billion. Fund managers in Singapore reportedly manage about USD70 billion of high net worth investments. For these reasons, Singapore has the infrastructure to form an efficient market if sufficient depth and liquidity exist in its securities markets.

The government securities market in Singapore has not developed in parallel fashion with these internationally oriented transactions. Because of large budget surpluses during certain periods, the government has been reluctant to issue Treasury securities unlike such countries as India, Malaysia, and Korea. Despite this fact, the Treasury market in Singapore is larger in value and has greater liquidity than the corporate bond market.[6] Our examination of available market information suggests that the market for Treasuries in Singapore may lack depth and liquidity.

The central bank in Singapore sells Treasury securities under sealed-bid auctions done on a weekly, fortnightly and monthly basis. Institutions make this market because individuals cannot make bids. Financial institutions, especially deposit taking institutions, typically hold Treasury securities to meet the liquidity requirement imposed on them by the central bank. A resale market exists for these bonds because five discount houses actively trade Treasuries. A restructuring of the market in 1987 resulted in the appointment of market makers and other reforms that led to improvements in secondary sales of bonds.

4. Research Methodology

We compiled yield data from market clearing prices for the Treasuries traded in the Singapore government securities market. The data were collected from primary sources, which included the daily newspaper (*Straits Times*) financial reports, records in the Monetary Authority of Singapore Library (*Monthly Bulletin; Quarterly Bulletin*), the *Monthly Digest of Statistics* of the Department of Statistics, and the off-prints kept by the Stock Exchange of Singapore on past disclosure sheets, the *Daily News*. We hand-collected, punched, and checked the data against the primary sources for errors. Treasuries represent the base risk-free yields in this economy. The yields are for maturities ranging from 1 to 10 years with few bonds with maturities beyond 10 years. We excluded the yields on maturities beyond 10 years because such bond issues occur less frequently than the more liquid issues with a maturity range of 1 to 10 years. Including those infrequently traded issues could introduce potentially large errors in the yield calculations.

We used a 20-year quarterly data set before the financial crisis in 1997 to study how Treasury bond yields behave in Singapore. Although the value of outstanding government

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[6] For a discussion of fixed-income securities including Treasuries in Asia, see Kang, Liu, and Ng (1998) and Chen and Kang (2002).

bonds varies from year to year, the average outstanding value over the study period was about USD12–18 billion or about 15-18 per cent of gross domestic product. Using quarterly data reduces the problem of non-trading.

Our primary research question is: Which of the following theoretical determinants – expectations, liquidity premiums, and inflation – help to explain Treasury bonds yields in Singapore? We developed separate tests for each determinant.

4.1 Expectations and Yield

Assuming an efficient market with trivial transactions costs, expectations theory holds that the spot long term rate observed is the average of the expected future short term rates. Using the Marquardt algorithm for curve fitting available in statgraphics, we generated the forward rates implied in the yield curves in the Singapore Treasury bond market. If the average of the forward short rates from such yield curves does not differ significantly from the longterm rates, we can infer support for the expectations hypothesis.

We computed the yield curves in this market using the following nonlinear formula to fit the curve on the yield data.

$$y_j = a + b^c(t)_j + e_j \tag{5}$$

where

t = time of the yield on securities $j = 1, \ldots, N$
a = an estimate of the y-intercept for the regression line
b^c = parameter b with "c" as the exponential factor since the yield curve is a non-linear function that determines the shape of the fitted regression line
e = the normal random variable.

We used the observed yields of a different maturity of bonds, y, to fit the nonlinear regression line. Such yield curves were fitted for the years 1981, 1986, 1990, and for each year. As the Singapore government instituted bond market reforms in place during the period 1988-1990, the yield curves were fitted for each year to see if improvements existed in the way the yields are formed as suggested by the expectation hypothesis. For each period, we estimated the predicted yields based on the proposition of expectations theory that the long yield is a geometric average of the short yields implied in the yield curves for each subsequent period. Thus, actual yields observed in the next period exist for which generated yields also exist using the expectations theory.

If the market behaves as suggested by the expectations hypothesis, a very close fit must exist between the actual yields and the yields predicted by the fitted curves. In practice, this is a test of the market participants' expectation being unbiased estimates of the future state of yields. Thus, we evaluated the pure expectations hypothesis by a regression of the actual yields on the predicted yields from the fitted curves. Rejecting the null hypothesis would support the notion that yields in the Treasury bond market are formed according to the predictions of the pure expectations theory.

4.2 Liquidity Premiums and Yield

The liquidity premium hypothesis postulates a systematic premium for holding a security with positive time to maturity. The difference in Treasury yields and the difference in maturity of any two bonds must be directly related for the liquidity premium hypothesis to be true. To test this hypothesis, we measured the difference in the term of the Treasuries used in this study and then computed the yield difference of the same securities. If regressing the difference in the yields on the maturity differences produces a sufficiently large coefficient of determination, this would be consistent with the idea that the maturity premium is the reward for the liquidity preference of market participants. This is not, however, a test of robustness of the regression. The operational test of the liquidity premium hypothesis is the following regression:

$$t\,\Delta\,T = \alpha + \beta(t - T) + \varepsilon \qquad (6)$$

where

$t\,\Delta\,T$ = nominal yield differences between short *(t)* and medium or long *(T)* terms to maturity, namely, the maturity premium observed in the market yield

α = estimated intercept value

β = value of the slope coefficient in a linear regression

$t - T$ = difference in time of the maturity of the two types of bonds used

ε = regression residuals with zero serial correlation.

Thus, the maturity premium is the reward for liquidity preference. We represented the term difference by the time difference as follows: time difference in bonds of 1 to less than 5 years; bonds of more than 5 to 7 years; and bonds of more than 7 to 10 years. To support the liquidity premium hypothesis, the regression of the two variables must be significant as indicated by the *F*-ratios and must produce high coefficient of determination if the maturity premium is likely to be the determinant of the term difference, $t - T$.

4.3 Inflation and Yield

We represented inflation by a distributed lag of the changes in inflation rates as measured from the consumer price index. We measured the interest rate by the quarterly yields of the Treasury bonds. Following Mishkin (1991), the inflation-to-yield relation may be stated as

$$y_t = \gamma + \lambda_{-1}(\Delta I_{t-1}) + \lambda_{-2}(\Delta I_{t-2}) + \lambda_{-3}(\Delta I_{t-3}) + \lambda_{-4}(\Delta I_{t-4}) + \lambda_{-5}(\Delta I_{t-5}) + \nu_t \qquad (7)$$

where,

y_t = nominal yield for quarter *t*

γ = estimate of the *y*-intercept for the regression line

λ_t = estimate of the slope of the regression parameter

I_{t-T} = change in inflation at time *T* quarters ago

ν_t = normal random variable.

We modeled a five-quarter distributed lag of inflation changes and the nominal yields in this regression. The five-quarter lag roughly corresponds to the time taken for the Singapore market to fully absorb changes in international interest rates. If the relation is robust with a high coefficient of determination, it infers that a distributed lag in inflation rates determines the nominal yield rates in the Treasury bond market. Acceptance of the null hypothesis would be consistent with our interpretation that the Singapore bond market is not sufficiently developed to price inflation.

4.4 Econometric Issues

Several econometric issues relate to the tests described in testing the pure expectations and inflation/yield hypotheses. First, the presence of serial correlations in testing the pure expectations hypothesis may bias the significance of estimated coefficients in the regression. In four of the ten regressions, the serial correlation values were significant while the serial correlations in the majority of regressions were within the bounds. Since the presence of significant correlation is likely to bias the results against the hypotheses, we continued with the OLS procedure. Moreover, we used the coefficient of determination as an indicator of the model's ability to explain the variation in the dependent variable. If these values are large enough, it indicates that the model explains a large portion of the variation in the dependent variable. The absence of an *R*-square equal to one (100 per cent) would indicate that the expectations are not the only factor that determines the variation in yields.

Second, a potential problem involves the stationarity of the variables. Although we did not test for the presence of stationarity, widespread support exists in the term structure literature. Past evidence suggests that interest rates, especially in low-inflation economies, are stationary. In addition, the difference in yields in some tests, which is a second differenced variable, is a stationary variable.[7]

Finally, serial correlations affect the distributed lag coefficients in the yield-to-inflation regression. To deal with this potential problem, we used the change in inflation rates (i.e. second differenced data) rather than the inflation rates, against a first differenced variable. This approach should lessen this effect. Consequently, we believe that these econometric issues are unlikely to weaken our findings in any meaningful manner.

5. Empirical Evidence

Summary statistics on the nominal yields on Treasury bonds over the study period are reported in Table 1. The results involving the effect of expectations, liquidity premiums, and inflation of Treasury bond yields in Singapore are discussed in the following subsections. Tables 2 through 5 contain our empirical findings.

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[7] The bond yield series, unlike bond price series, conform to ARIMA (1,0,0) assumption. Hence, the results from using the yield series (first difference as well as second difference in some equations) are unlikely to contain spurious regression errors. Moreover, our data on yield and inflation do not show any strong, systematic upward or downward trends, which can give rise to potential spurious regression problems. The one error that could slightly affect the tests is likely to come from significant serial correlations in a few regressions. We believe that this would not seriously invalidate the overall findings in this study from OLS regressions.

Table 1: Treasury bond nominal yields and inflation rates from 1976 to 1995

This table presents data involving quarterly inflation rate and nominal bond yields for the Treasury bond market in Singapore during the period 1976 to 1995.

Year	Inflation rate				Nominal Bond Yields			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1976		-1.78	-0.33	0.50		6.70	6.75	6.60
1977	1.98	-0.32	2.76	0.95	6.20	6.78	6.79	6.80
1978	1.72	0.00	2.00	0.45	6.78	6.72	6.50	7.22
1979	-0.15	0.45	3.74	2.45	7.20	7.50	8.05	8.40
1980	2.39	1.47	1.76	0.80	9.52	8.60	8.65	9.05
1981	1.45	3.52	3.52	0.97	9.00	10.20	9.21	8.51
1982	1.08	-1.19	0.48	0.72	9.75	9.70	9.40	9.80
1983	0.48	-0.24	0.36	0.95	8.50	7.70	8.30	8.10
1984	1.88	-0.35	0.58	-0.57	8.60	8.80	8.70	9.00
1985	0.58	0.00	0.46	-0.46	9.05	8.60	8.40	8.45
1986	-0.57	-1.04	0.00	0.23	7.85	7.50	6.20	6.15
1987	0.00	0.23	0.81	0.23	5.92	6.30	6.60	6.00
1988	0.34	0.11	0.80	0.11	6.05	6.25	6.60	6.50
1989	0.23	1.24	0.89	0.89	6.40	6.20	6.45	6.35
1990	0.77	0.65	0.65	1.51	6.38	6.20	6.45	6.30
1991	0.85	0.84	0.42	0.52	6.10	6.25	6.20	6.10
1992	0.41	0.82	0.51	0.51	5.60	5.55	5.45	4.48
1993	0.61	0.50	0.50	0.70	4.70	4.50	4.35	4.20
1994	0.89	0.98	0.87	0.58	4.30	4.28	4.32	4.28
1995	0.10	0.57	0.09	0.09	3.35	3.25	3.15	3.05

5.1 Nominal Yields and Inflation Rates

Table 1 provides summary statistics on the nominal yields of the Treasury bonds over each quarter during the period. These data were obtained for all taxable government securities. Table 1 also reports the quarterly inflation rates.[8]

An analysis of the data contained in Table 1 provides several observations about the average yield and inflation or deflation during the period of study. First, the average yield in the Treasuries market was about 6.2 per cent per year. Second, the inflation rate in Singapore averaged about 2.7 per cent a year during the 20-year period. Inflation was high during the first period (1977-1983) compared with the later period. For example, the average inflation per year during this first period was about three to four times the inflation rate in the second

[8] One estimate of the inflation experienced in Singapore is the difference between the real and nominal yields. The Fisher effect holds that the nominal rate of interest embodies in it an inflation premium sufficient to compensate lenders for the expected loss of purchasing power associated with the receipt of future dollars. Although the Fisher effect postulates a one-to-one change in the nominal rate of interest to a change in expected inflation, others argue for less than a one-to-one (Mundell 1963; Tobin 1965) or more than one-to-one (Darby 1975; Feldstein 1976) relationship. Evidence presented later in this study suggests, however, that yields in the Treasury bond market in Singapore do not adequately reflect expected inflation.

Table 2: Results on tests of pure expectation hypothesis from regressing the fitted values and treasury bonds yields in Singapore

$$y_j = a + b^c(t)_j + e_j$$

This table presents the results of the regression analysis conducted for the nine estimated yield curves.

December	*F*-Statistic	R^2	Durbin-Watson Statistic
Test 1: (1981)	670.63*	0.1843	0.2591*
Test 2: (1986)	1,782.13*	0.8971	1.2478[a]
Test 3: (1990)	1,335.67*	0.8673	0.7161*
Test 4: (1991)	1,119.26*	0.8832	0.5976*
Test 5: (1992)	1,153.17*	0.9075	0.8848*
Test 6: (1993)	1,263.07*	0.9474	1.8565
Test 7:(1994)	974.86*	0.9468	1.6908
Test 8: (1995)	1,096.38*	0.9330	1.4889
Test 9: (1996)	247.49*	0.9031	2.0750

* Significant at the 0.05 level.

a The critical value for the Durbin-Watson statistic falls within the inconclusive range of values.

period. Third, the economy experienced deflation in some quarters during 1976-1977 and again in 1979 and 1982-1986. The deflation occurred in periods of recession. Government intervention to reduce statutory costs such as a development tax and a tax on utilities combined with a marked decline in asset prices in those years led to deflation.

The statistics on the bond yields also provide information on the term structure of interest rates in Singapore. Treasury yields were relatively high until December 1982. During the 1980-1983 period, the financial sectors experienced unsettling conditions following the world debt crisis. Interest rates were generally high as banks bid up deposits to meet liquidity problems arising from that crisis. Yields also increased in the early 1980s but started to decline sharply in the first quarter of 1984 after which time the interest rates increased moderately in the world markets as the details on the U.S.–led Baker Plan to resolve the debt problem were put in place.

A steep decline in the economic growth of Singapore in the fourth quarter of 1985 to the fourth quarter of 1986 coincided with worldwide mild recession during 1985-1989. Because the demand for credit declined, interest rates also declined substantially during those and the ensuing years. Therefore, the periods 1976–1983 and 1984–1987 represent two interest cycles when bond yields were high in Singapore whereas the second period represents one of generally declining bond yields. Thus, the 20-year period covers a period of more than one interest rate cycle. Including data over several interest rate cycles reduces contamination from cyclical effects that may affect the test results.

5.2 *Expectations and Yield*

Table 2 shows the results of our tests of the pure expectations theory. The test statistics indicate that the actual yields in Treasury bonds against the predicted yields obtained using the Marquardt algorithm appear to be a function of forward yields. Column 1 shows the nine test periods. We used the first four years of data to fit the curve for year 1981 and the next five years of data to fit the curves for the year 1986. We derived the data for the subsequent tests using the same procedure with five-year yield data.

Column 2 shows that the *F*-statistics for the nine regression tests, one each for the nine yield curves estimated. All *F*-statistics are significant at the 0.05 level or better, which suggests that the regression model does a good job of explaining variation in the dependent variable.

Column 3 shows the coefficient of determination (R^2) values. If the predicted long rates in the yield curve are perfectly correlated with the actual yields in the bond market, the R^2 would be 1.0. Not surprisingly, the R^2 values are not 1.0 as the pure expectations theory predicts if investors have perfect foresight. Except in 1981 when the R^2 was small (0.1843), the R^2 values were high ranging from 0.8971 to 0.9474. Thus, expectations are an important but not the only factor that explains the variations in the yields.

The Durbin-Watson *d*-statistics suggest significant first-order serial correlation of the disturbances in four out of nine regressions. This means that any estimates of the intercept and the slope coefficient are unlikely to be robust. The Durbin-Watson statistics indicate substantial serial positive serial correlations in the regressions especially during 1980, 1989, 1990, and 1991. Serial correlations work against acceptance of the null hypotheses, and hence, the bias is against accepting the null.

These results are consistent with the notion that expectations exert some impact on the term structure but these expectations are likely to be biased. That is, the pure or unbiased version of the expectations hypothesis is not fully supported. Furthermore, interpreting the regression results for yields on Treasury bonds involves the problem of serial correlation.

5.3 Liquidity Premiums and Yield

Table 3 shows the results of our tests of the liquidity premium hypothesis. Seventy-six tests were conducted to determine if the predictions of the liquidity premium hypothesis were good approximations of the actual behaviour in the Treasury bond market. Data was used for each of the 20 years to conduct short-to-medium, medium-to-long, short-to-long, and whole year tests. Four tests were not conducted (two in 1995 and two in 1996) due to insufficient observations for the medium-to-long term and short-to-long term yield differences.

Overall, the results generally show that a strong relationship exists between the maturity premium and the difference in the yield rates. Although the *F*-statistics are not reported, all these values are statistically significant at normal levels. With few exceptions, the slope coefficients (β) are statistically significant at normal levels. These test statistics generally show that Treasury bond behaviour during the study period is consistent with the liquidity premium hypothesis. Thus, a positive reward exists for those who part with cash to hold Treasury bonds and this premium roughly increases with maturity. This evidence lends support to the liquidity premium hypothesis. The typically high R^2 values indicate that maturity differences in the yields help to explain the variations in yield differences. The R^2 values range between 0.15 in 1987 for the short-to-medium and short-to-long term tests and 1.00 in 1983 and 1985 for the medium-to-long and short-to-long term tests. Of the 76 R^2

Table 3: Regression results for the liquidity premium hypothesis

$$t \, \Delta \, T = \alpha + \beta(t - T) + \varepsilon$$

This table presents the results of regression analysis to examine the relationship between the maturity premium and term difference for Treasury bonds in Singapore each year between 1977 and 1996. The data for each year are used to conduct tests for short-to-medium, medium-to-long, short-to-long, and entire year. The *t*-values for the intercept and slope coefficient are shown in parentheses.

	1977			1977			1978			1979			1980		
Description	α	β	R^2	α	β	R^2	α	β	R^2	α	β	R^2	α	β	R^2
Short - Med	1.698	0.114	0.981	2.313	-0.136	0.638	2.279	-0.142	0.639	1.070	0.004	0.964	0.139	0.158	0.795
	(21.20)	(7.22)		(4.45)	(-1.33)		(4.23)	(-1.33)		(256.53)	(5.20)		(0.34)	(1.97)	
Med - Long	0.878	0.009	0.854	0.446	0.125	0.772	0.460	0.143	0.853	1.185	0.027	0.987	1.353	0.015	0.750
	(58.41)	(2.42)		(1.60)	(1.84)		(1.89)	(2.41)		(91.92)	(8.66)		(38.75)	(1.73)	
Short - Long	1.809	0.019	0.855	-0.095	0.214	0.772	-0.197	0.253	0.853	1.169	0.029	0.987	1.059	0.012	0.750
	(28.45)	(2.42)		(-0.10)	(1.84)		(0.23)	(2.41)		(42.36)	(8.66)		(18.81)	(1.73)	
Entire Year	1.574	0.069	0.338	1.146	0.070	0.432	1.233	0.075	0.498	1.016	0.040	0.268	0.857	0.032	0.318
	(7.60)	(1.89)		(6.70)	(2.31)		(7.68)	(2.63)		(7.21)	(1.61)		(8.68)	(1.80)	

	1981			1982			1983			1984			1985		
	α	β	R^2	α	β	R^2	α	β	R^2	α	β	R^2	α	β	R^2
Short - Med	0.329	0.174	0.875	1.174	0.076	0.993	3.014	-0.283	0.554	1.715	0.026	0.972	1.711	0.092	0.997
	(0.99)	(2.65)		(36.98)	(12.12)		(2.34)	(-1.11)		(77.38)	(5.89)		(1.00E+2)	(27.14)	
Med - Long	1.382	0.007	1.000	1.112	0.005	0.750	1.125	0.003	0.964	1.032	0.000	1.000	1.065	0.012	0.998
	(2.16E+14)	(4.31E+12)		(103.07)	(1.73)		(516.19)	(5.196)		(6.55E+4)	(6.55E+4)		(4.82E+2)	(22.52)	
Short – Long	1.339	0.007	1.000	1.621	0.007	0.750	1.931	0.005	0.964	1.872	0.000	1.000	2.109	0.025	0.998
	(1.06E+14)	(4.26E+12)		(51.46)	(1.73)		(259.47)	(5.20)		(6.56E+13)	(1.00)		(2.33E+2)	(22.52)	
Entire Year	0.829	0.071	0.860	1.721	-0.009	0.053	1.113	0.101	0.537	1.348	0.074	0.667	1.566	0.100	0.850
	(13.59)	(6.57)		(19.10)	(-0.62)		(5.55)	(2.85)		(12.09)	(3.75)		(17.36)	(6.28)	

	1986			1987			1988			1989			1990		
	α	β	R^2	α	β	R^2	α	β	R^2	α	β	R^2	α	β	R^2
Short - Med	1.675	0.053	0.150	0.201	0.336	0.847	1.370	0.055	0.965	0.162	0.255	0.750	0.010	0.339	0.833
	(2.61)	(0.42)		(0.28)	(2.35)		(40.36)	(8.16)		(0.22)	(1.73)		(0.12)	(2.24)	
Med - Long	0.954	0.042	0.998	1.487	0.018	0.571	1.057	0.019	0.789	1.472	0.014	0.949	1.455	0.021	0.987
	(1.18E+2)	(21.36)		(23.24)	(1.15)		(25.22)	(1.94)		(1.09E+2)	(94.33)		(1.47E+2)	(8.67)	
Short - Long	1.675	0.053	0.150	2.066	0.026	0.571	1.550	0.032	0.789	1.555	0.016	0.949	1.869	0.029	0.987
	(2.61)	(0.42)		(11.22)	(1.15)		(11.84)	(1.94)		(53.23)	(4.33)		(70.36)	(8.66)	
Entire Year	1.273	0.105	0.792	1.081	0.153	0.874	1.031	0.101	0.887	0.867	0.105	0.841	1.174	0.118	0.754
	(11.09)	(5.16)		(8.77)	(6.98)		(13.47)	(7.40)		(8.95)	(6.08)		(8.20)	(4.64)	

	1991			1992			1993			1994			1996		
	α	β	R_2	α	β	R^2	α	β	R^2	α	β	R^2	α	β	R^2
Short - Med	1.594	0.097	0.999	2.680	0.059	0.990	1.656	0.300	0.998	1.037	0.192	0.998	1.892	0.487	0.948
	(84.22)	(25.98)		(88.09)	(9.81)		(26.78)	(24.60)		(26.92)	(25.29)		(3.26)	(4.25)	
Med - Long	1.076	0.020	0.871	1.093	0.019	0.980	5.939	-0.635	0.729	NA	NA	NA	NA	NA	NA
	(35.00)	(2.60)		(97.44)	(6.93)		(1.91)	(-1.64)							
Short - Long	1.979	0.039	0.871	2.963	0.055	0.980	16.923	-1.810	0.729	NA	NA	NA	NA	NA	NA
	(16.47)	(2.60)		(46.02)	(6.93)		(1.91)	(-1.64)							
Entire Year	1.172	0.147	0.872	1.559	0.243	0.864	1.148	0.360	0.944	0.948	0.196	0.947	0.434	0.769	0.974
	(9.79)	(6.90)		(7.60)	(6.68)		(6.34)	(10.05)		(10.21)	(9.43)		(1.77)	(12.20)	

	All years		
	α	β	R^2
Mean values	1.071	0.040	0.791
Std dev	1.824	0.781	0.232

Alpha had a maximum and minimum of 3.014 and -13.59; Beta had a maximum and minimum of -6.570 and 0.339; *R*-squared ranged from 0.053 to 1.00.

Table 4: Test results of the relation between maturity-premium and inflation

$$y_{t(st)} - y_{t(1t)} = \eta + \delta_{-1}(\Delta I_{t-1}) + \delta_{-2}(\Delta I_{t-2}) + \delta_{-3}(\Delta I_{t-3}) + \delta_{-4}(\Delta I_{t-4}) + \delta_{-5}(\Delta I_{t-5}) + \pi_t$$

This table presents the regression results between the maturity premium of all Treasury bonds traded during the 20-year period and 1-year period and the distributed lags in inflation changes.

η	δ_{-1}	δ_{-2}	δ_{-3}	δ_{-4}	δ_{-5}	R^2	Durbin Watson Statistic
3.855 (8.140)*	0.213 (0.450)	-0.070 (-0.148)	0.027 (0.063)	0.070 (0.148)	0.266 (0.564)	0.105	1.305

*Significant at the 0.05 level. Numbers in parentheses indicate *t*-values.

values, 59 (almost 78 per cent) are above 0.75.

Tests were also undertaken to determine whether a relationship exists between the maturity premium of all the Treasury bonds traded during the 20-year period and the distributed lags of inflation changes. As Table 4 shows, no significant relation exists between the two. An implication of this finding is that inflation is not related to the maturity premium. The R^2 value is low.

5.4 Inflation and Yield

Table 5 presents the results on the yield-to-inflation relationship. Tests were conducted for bonds with the same number of years to maturity. Although not shown, the *F*-ratios are not statistically significant at normal levels. Thus, little, if any, evidence exists that Treasury bond rates incorporate changes in inflation. The size of the R^2 values ranges from a low of 0.093 for bonds with a 1-year maturity to 0.276 for the bonds with a 3-year maturity. Thus, the changes in the inflation rates do not appear to provide a sufficient explanation for the variation in the interest rate changes. This relationship is much weaker than that found by Mishkin (1991) in developed markets.

Several implications flow from these findings about inflation and yield. First, Treasury bond yields do not incorporate all the information about level changes. Perhaps the market's inability to incorporate the inflationary effect produces less than a very high fit in the tests of the pure expectations hypothesis as shown in Table 2. Second, the Singapore bond market may not be sufficiently developed with respect to price inflation.

6. Conclusion

A study was carried out to examine whether Treasury bond yields reflect the effects of expectations, liquidity premiums, and inflation. Using data over two full business cycles, hypotheses were tested on the determinants of the shape of the term structure. The study results generally lend support to the liquidity premium hypothesis because a strong relationship exists between maturity differences and differences in the yields of bonds with

Table 5: Regression results of the relation between yield and inflation for 1 to 10 years term to maturity

$$y_t = \delta + \lambda_0(\Delta I_{t-1}) + \lambda_{-1}(\Delta I_{t-1}) + \lambda_{-2}(\Delta I_{t-2}) + \lambda_{-3}(\Delta I_{t-3}) + \lambda_{-4}(\Delta I_{t-4}) + \lambda_{-5}(\Delta I_{t-5}) + \nu_t$$

This table shows the regression results between a five-quarter distributed lag of inflation changes and the nominal yields on Treasury bonds in Singapore.

Term to maturity (Year)	δ	λ_{-0}	λ_{-1}	λ_{-2}	λ_{-3}	λ_{-4}	λ_{-5}	R^2	Durbin Watson Statistic
1	0.445	-0.173	-0.011	-0.024	0.203	0.106	0.106	0.09	1.399
	(5.178)*	(-2.013)*	(-0.130)	(-0.283)	(2.359)*	(1.234)	(1.235)		
2	0.444	-0.311	0.121	0.080	0.144	0.046	0.249	0.16	1.496
	(2.782)	(-1.956*)	(0.758)	(0.541)	(0.906)	(0.287)	(0.1.53)		
3	0.013	-0.240	0.204	0.399	0.070	-0.131	0.400	0.27	1.400
	(0.130)	(-2.346)*	(1.899)*	(3.889)*	(0.680)	(-1.217)	(3.906)*		
4	0.493	-0.255	-0.018	0.044	-0.261	0.293	-0.063	0.08	1.396
	(4.090)*	(-2.114)*	(-0.148)	(0.363)	(-2.162)*	(2.428)*	(-521)		
5	0.238	-0.573	0.308	0.245	0.397	-0.473	-0.168	0.20	1.505
	(1.039)	(-2.492)*	(1.342)	(1.068)	(1.730)	(-2.06)*	(-0.728)		
6	0.467	-0.107	-0.011	-0.283	-0.048	0.246	0.177	0.13	1.267
	(2.130)*	(-2.051)*	(-0.053)	(-1.292)	(-0.223)	(1.119)	(0.817)		
7	0.401	0.053	-0.092	-0.169	0.007	0.131	0.109	0.05	1.401
	(3.402)*	(-0.450)	(-0.780)	(-1.431)	(0.062)	(1.109)	(0.930)		
8	0.352	0.174	-0.039	-0.122	-0.053	-0.065	0.036	0.14	1.766
	(3.968)*	(1.963)*	(-0.440)	(-1.380)	(-0.659)	(-0.730)	(0.409)		
9	0.347	0.006	-0.050	-0.044	-0.084	-0.038	0.089	0.12	2.278
	(3.290)*	(0.056)	(-0.467)	(-0.412)	(-0.779)	(-0.354)	(0.834)		
10	0.264	-0.072	-0.144	-0.100	0.038	0.154	0.130	0.22	1.365
	(6.532)*	(-1.780)*	(-3.560)*	(-2.470)*	(0.940)	(3.808)*	(3.210)		

*Significant at the 0.05 level. Numbers in parentheses indicate *t*-values.

different maturity. Expectations also affect the shape of the yield curve but the pure or unbiased expectations hypothesis appears to be an oversimplification of reality. There appears no support for the yield-to-inflation relationship. Changes in inflation do not appear to be a determinant of the changes in the bond yields across short to long term bonds.

Thus, some evidence suggests that the Treasury bond yields are determined in accordance with mainstream ideas that sufficient incentives must exist to hold bonds of differing maturity and investor expectation of short rates helps to drive long term rates. The results of this study do not support the idea that Treasury bond yields incorporate inflationary expectations. Researchers need to conduct additional studies to document term structure behaviour in other Treasury markets before these results can be generalised to other Asian bond markets.

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