
**Extracting Market Expectations of Future
Interest Rates from the Yield Curve:
An Application Using Singapore Interbank
and Interest Rate Swap Data**

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**Economics Department
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BY

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EXECUTIVE SUMMARY

1 Of late, there has been considerable interest in using implied forward interest rates as indicators of financial market expectations of future interest rates. The appeal of the implied forward rate is that it is easier to interpret for monetary policy purposes, and can be used under appropriate assumptions to infer market expectations of the future path of nominal interest rates. In this paper, we estimate the term structure of interest rates in Singapore using interbank interest rates (for shorter maturities) and interest rate swap rates (for longer maturities). The estimated term structure then allows us to extract the implied forward rates at various points in the future. We then formally test the ability of the implied forward rate to forecast the corresponding future spot rate.

2 The term structure of interest rates shows the relationship between the spot rates on a fixed-income instrument and its maturities. At a given trade date, a spot rate curve relates spot rates to its maturities, while a forward rate curve plots forward rates as a function of different settlement dates. While the two curves are alternative ways of representing the term structure of interest rates, the forward curve is frequently more informative since it makes explicit market participants' expectations of future spot rates. According to the pure expectations theory of the term structure of interest rates, the forward rate represents market expectations of the future spot rate, if investors are risk neutral.

3 We fit spot rate curves to the data, and subsequently extract forward curves for one- and three-month rates, for two dates: 15 Jun 98 and 28 Jun 99. On 15 Jun 98, the spot curve was inverted, implying that the market expected short-term interest rates to fall over time. The 3-month implied forward curve, which was below the estimated spot curve, indicated that the market expected the three-month spot rate to fall from 9.4% on that day, to 7.7% in six months time. The position of the spot curve was much lower on 28 Jun 99, as financial markets were relatively normal compared to the crisis period. The estimated spot curve and implied forward curves were

upward-sloping, indicating that the market expected interest rates to rise. The implied three-month forward rate was 3.6% in six months time, compared to the three-month spot rate of 2.2% on that date.

4 We also test the power of the three-month forward rate to forecast the spot rate one month, two months and three months from the trade dates. Our results show that the implied forward rates extracted from the spot rate curves provide, on average, an unbiased forecast of future spot rates two and three months ahead. In addition, scatter plots of the implied forward rate against the actual spot rates generally support the test results, although there were several outliers, indicating over-prediction of the actual spot rate by the implied forward rate. These corresponded to data from two sub-periods, namely 22 Dec 97 to 2 Feb 98, and 15 Jun 98 to 13 Jul 98, and are therefore likely to reflect the increased volatility in the financial markets as a result of the Indonesian and Korean crises during the first sub-period, and the Russian crisis during the second.

5 Our analysis shows that the implied forward rate curve, especially at shorter settlement horizons, can be a reliable indicator variable providing policymakers and market participants with information on financial market expectations of monetary conditions in the near future.

"Yet everyone – and here I mean analysts, market participants and central bankers alike – continues to 'read' the market's expectations of future short rates from the yield curve, as if doing so made sense. I find it hard to explain why everyone is doing what everyone knows to be wrong. Yet it happens all the time."

- Alan Blinder (1997)
Former Vice-Chairman, Federal Reserves Board

I INTRODUCTION

1.1 Central bankers, analysts and market watches often look at forward financial asset prices for (clues concerning the latest development in the financial market and in the economy). Recently researchers and central banks like the Bank of England, the Deutsche Bundesbank, and the Sveriges Riksbank have gone beyond scrutinizing asset prices in the cash market to look at futures and option prices for information regarding the market's mean expectation of the underlying asset prices and its entire expected probability distribution of these prices. Of particular significance lately has been the interest in using implied forward rates as indicators of financial market expectations of the future interest rates. The appeal of the implied forward rate is that it presents and conveys information about the term structure of interest rates in a manner that is more easy to interpret for monetary policy purposes than the spot rate yield curve, and can be used, under appropriate assumptions, to infer the market's expectation of the future path of nominal interest rates. For example, the Bank of England Quarterly Bulletin routinely reports under "Markets and Operations" the implied forward rate extracted from the swap curve as an indicator of the interest rate outlook.

1.2 In this paper, we estimate the term structure of interest rates in Singapore using interbank interest rates (for shorter maturities) and interest rate swap rates (for longer maturities). The estimated term structure of interest rate at each point in time then allows us to extract the implied forward rates. We then test formally the ability of the implied forward rate to forecast the corresponding future spot rate.

II ESTIMATING THE TERM STRUCTURE OF INTEREST RATES

2.1 The term structure of interest rates shows the relationship between the spot rates of a fixed-income instrument and its maturities. Since the yield refers to the spot yield, the term structure analysis therefore applies to discount or zero-coupon bonds. A zero-coupon bond is a security that has no coupon payments, with its redemption value fixed and known at the time of issue. The return on the bond is therefore the difference between the issue price and its redemption value (expressed as a percentage). The bond is issued at a discount so that a positive return can be earned over the maturity period of the bond.

2.2 Let the redemption value of a unit of an n -period zero-coupon bond be $\$X$. The present value of the bond at time t is

$$PV(n)_t = \left[\frac{1}{1 + R(n)_t} \right] \$X \quad (1)$$

where $R(n)_t$ is the n -period spot interest rate (measured in percentage per annum) and $\frac{1}{1 + R(n)_t}$ is the discount factor. A function that relates the spot rate to maturity is called the spot curve or the zero-coupon curve.

2.3 The relationship between the n -period spot rate, $R(n)_t$, and a series of one-period forward rates over the n -years maturity period can be shown as follows. Let f_{t+i} be a one-period interest rate that is set at a given trade date t , for a loan from period $t+i$ to $t+i+1$. Consider first an investment of $\$Z$ in a zero-coupon bond with n -years to maturity. The terminal value of the investment is $\$Z[1 + R(n)_t]$.

2.4 An alternative investment strategy will be to reinvest the sum $\$Z$ and any interest earned, in a series of rolled-over, on a one-period investment for n years. Ignoring transaction costs, the terminal value of this series of one-period investment is

$$\$Z[1 + R(1)_t][1 + f_{t+1}][1 + f_{t+2}] \dots [1 + f_{t+n-1}] \quad (2)$$

Financial arbitrage ensures that the terminal values of the two alternative investment strategies are equalised:

$$1 + R(n)_t = [1 + R(1)_t][1 + f_{t+1}][1 + f_{t+2}] \dots [1 + f_{t+n-1}] \quad (3)$$

2.5 The n -period spot rate, $R(n)_t$, is therefore the geometric mean of the individual one-period rates. The rates f_{t+1} , f_{t+2} , ..., f_{t+n-1} are called one-period forward rates. If there is no explicit forward market, the rates can be interpreted as the implied forward rates in the sense that they constitute the rates that are implied by the current term structure of the spot rate. While the spot rate $R(n)_t$ describes the average rate of return over the period n , each forward rate, f_{t+i} describes the marginal return over the period $t+i$ to $t+i+1$.

2.6 We represent the forward rate at trade date t , for a forward contract with settlement date t and maturity date T as $f(t, t, T)$ where $t \leq t < T$. For example, a forward rate on a 3-month contract that commences in three months hence would be denoted as $f(t, 3, 6)$. A forward rate curve for a $T-t$ period contract at a given trade date t is a plot of the forward rates $f(t, t, T)$ as a function of different settlement dates t . On the other hand the spot yield curve is a plot of the spot rate $R(t, T)$ as a function of different maturity dates T , at a given trade date t . Hence both the spot rate and forward rate curves are alternative ways of representing the term structure of interest rates. However, central bankers and market analysts often find the forward curve more informative than the spot curve since it reveals explicitly the market participants' expectations of future spot rates.

2.7 According to the pure expectations theory of the term structure of interest rates, if investors are risk neutral, then the forward rate represents market expectations of the future spot rate:¹

$$f(t, t, T) = E_t R(t, T) \quad (4)$$

where E_t is the market's conditional expectation at time t and $R(t, T)$ is the spot rate of maturity date T that commences at t . If investors are not risk neutral, they would require a time-varying risk premium, giving rise to:

$$f(t, t, T) = E_t R(t, T) + f(t, t, T) \quad (5)$$

where $f(t, t, T)$ is the term premium that is needed to compensate the investors for holding the bond over the $T-t$ maturity period.

2.8 Estimates of the implied forward rates can be obtained from various procedures. One approach is to use the curve-fitting techniques. Nelson and Siegel (1987) have proposed, to represent the zero-coupon curve by a parsimonious mathematical function which can approximate a variety of yield-curve shapes depending on the estimated values of a limited number of parameters. An important feature of the Nelson and Siegel approach is that they seek to estimate directly the implied forward rate curves (rather than the term structure of the spot interest rates). The parsimonious functional form is specified as

$$f(T, b) = b_0 + b_1 e^{-T/q} + b_2 \frac{T}{q} e^{-T/q} \quad (6)$$

where $b = (b_0, b_1, b_2, q)$ is a vector of parameters, $f(T, b)$ is the instantaneous forward rate with time to maturity T . The spot rate can be derived by integrating the forward rate:

¹ See Campbell, Lo, and Mackinlay (1997) for evaluation of the term structure theories and their empirical performance.

$$\begin{aligned}
 R(T, b) &= \frac{1}{T} \int_0^T (b_0 + b_1 e^{-s/q} + b_2 \frac{T}{q} e^{-s/q}) ds \\
 &= b_0 + (b_1 + b_2) \frac{1 - e^{-T/q}}{\frac{T}{q}} - b_2 e^{-T/q}
 \end{aligned} \tag{7}$$

2.9 Both equations are linear in coefficients, given q . The spot and forward curves have the following properties. As T approaches zero, i.e., as the maturity period becomes very short, $f(0, b) = R(0, b) = b_1 + b_2$. As T approaches infinity, $f(\infty, b) = R(\infty, b) = b_0$. The third term of equation generates the hump-shape (or a U-shape if b_2 is negative) as a function of time to maturity. The parameter q governs the speed with which the monotonic convergence occurs and the hump component decays towards b_0 . Hence different combinations of b_2 and q can generate a variety of shapes of forward and spot rate curves.

2.10 Svensson (1994) extended the Nelson and Siegel functional form by adding a fourth term to equations (6) and (7) in order to increase its flexibility:

$$f(T, b) = b_0 + b_1 e^{-T/q_1} + b_2 \frac{T}{q_1} e^{-T/q_1} + b_3 \frac{T}{q_2} e^{-T/q_2} \tag{8}$$

where the b_3 and q_2 parameterize an additional hump with its own rate of decay. The spot rate, by integration is:

$$R(T, b) = b_0 + (b_1 + b_2) \frac{1 - e^{-T/q_1}}{\frac{T}{q_1}} - b_2 e^{-T/q_1} - b_3 e^{-T/q_2} \tag{9}$$

2.11 We estimated the spot curve using a sample data consisting of one to nine months Singapore dollar interbank interest rates and one to ten years fixed rate quotes of the Singapore Dollar interest rate swap (IRS). By combining the short- and long-term spot rate data, it is then possible to

obtain a graphical representation of the entire range of the yield curve using the estimates of the term structure. The interbank deposit rates are mathematically similar to those of discount or zero-coupon instruments since there is only one payment of principal plus interest earned at maturity. The IRS quotes are used to represent the medium- and the long-term segments of the term structure.

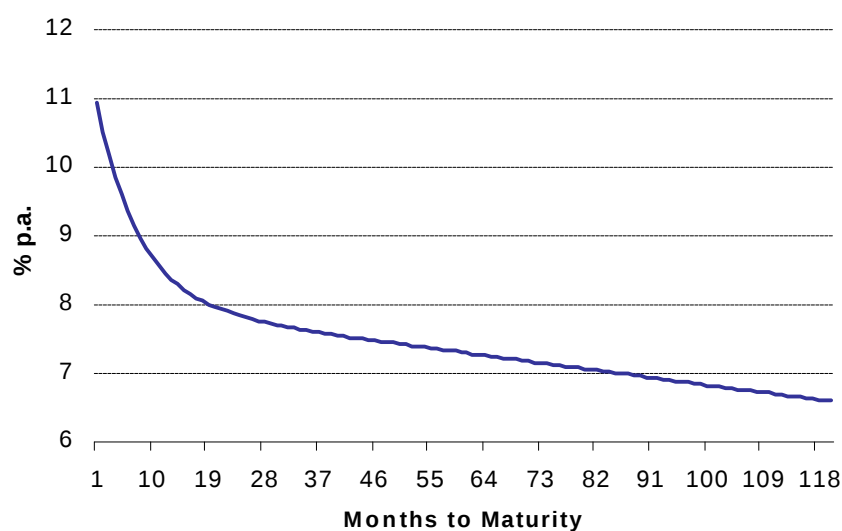
2.12 A plain-vanilla IRS is a contractual agreement between two parties in which one party agrees to pay another cash flows equal to interest at predetermined fixed rate on a notional principal for a number of years, in exchange for cash flows equal to interest at a floating rate on the same notional principal for the same period of time. The currency of denomination of the two sets of interest cash flows are the same. Hence an IRS can be viewed as an exchange of a notional floating-rate bond for a notional fixed-rate bond.

2.13 The fixed rate of the IRS swap is equivalent to the coupon rate of a par bond of the same credit risk. A par bond is one which trades at par, i.e. its yield to maturity is the same as the coupon rate. Now, the fixed rate coupon that is determined at the inception of the swap is the one that equalises the present values from the two sets of cash flows (hence the value of an IRS at the time when it is entered is zero). A freshly-issued floating rate always trades at par, so the notional swap coupon bond must also trade at par on issuance. Hence the quoted fixed rate of the swap can be treated as a coupon rate of a notional par bond.

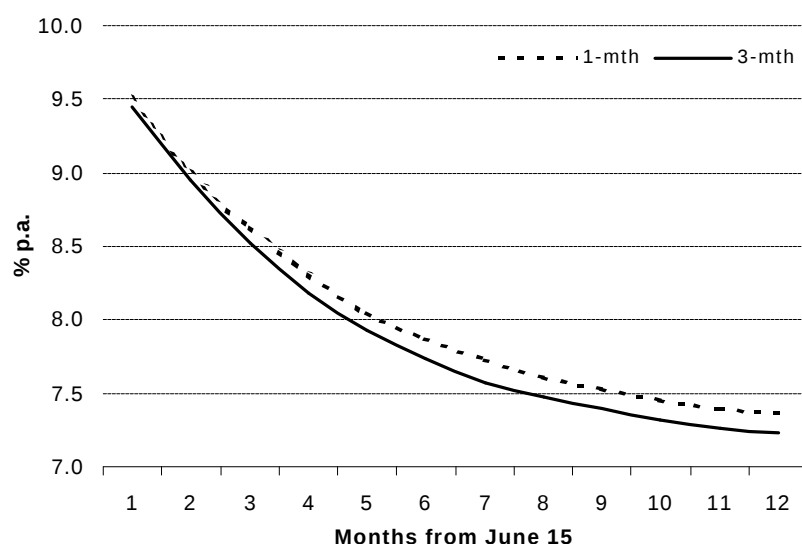
2.14 Figures 1(a) and 2(a) show the Nelson and Siegal spot curve estimated using the non-linear least squares procedure on interest rates data quoted on June 15 1998 and June 28 1999. The IRS rates are obtained from Prebon Yamane Capital Markets (Asia) Ltd. Initially we experimented also with the Svensson functional form, but for most of the sample data used, the Nelson and Siegal functional form produced a better

fit.² In their original estimates, Nelson and Siegal search for an optimal q over a grid of 10 to 200. In our sample, we found that a value of 200 for q fits the data well. For example, the R^2 for the fitted spot curve displayed in Figure 1(a) is 0.93 while the R^2 for the spot curve shown in Figure 2(a) is 0.98.

Figure 1
(a) Spot Rate Curve as at 15 Jun 98

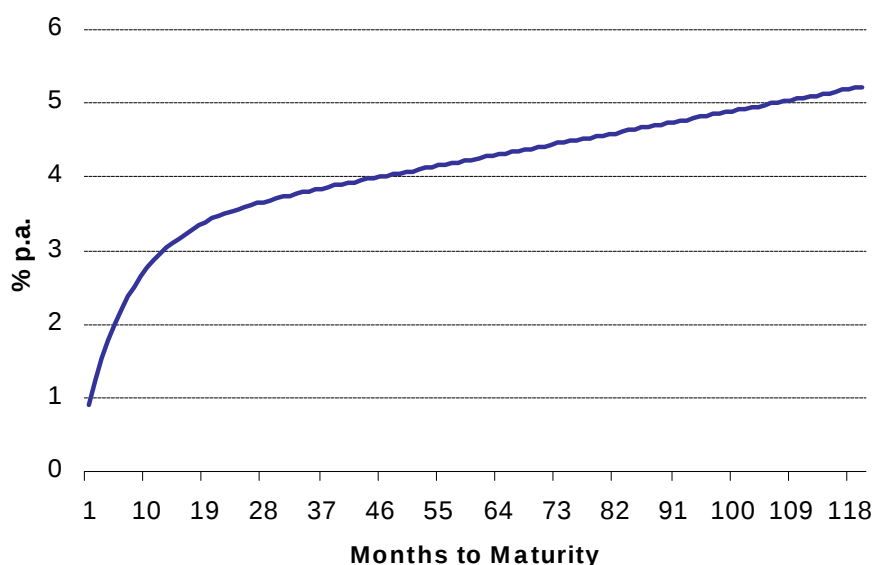


(b) Forward Rate Curves as at 15 Jun 98

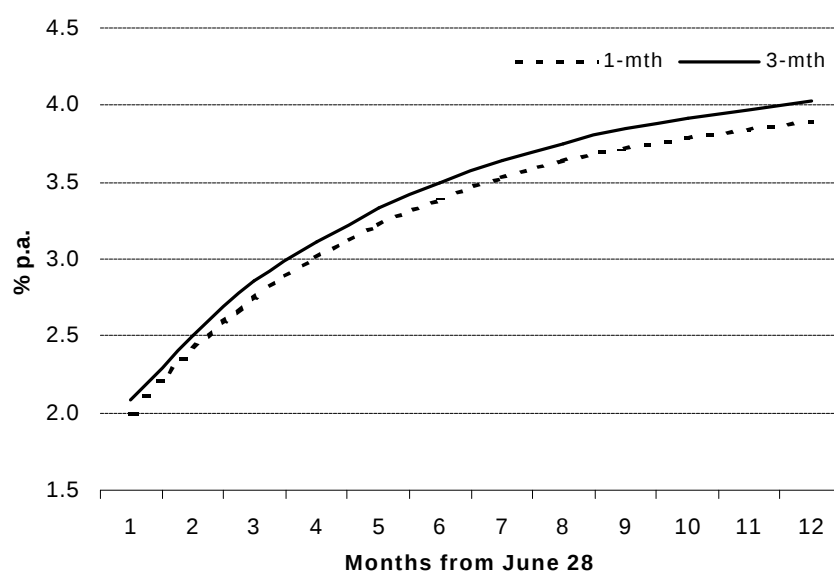


² Soderlind and Svensson (1997) in their exhaustive study reached a similar conclusion.

Figure 2
(a) Spot Rate Curve as at 28 Jun 99



(b) Forward Rate Curves as at 28 Jun 99



2.15 In Figures 1(b) and 2(b), we plot the two implied forward rate curves extracted from each of the estimated spot curves, namely the forward curves for one-month and 3-month rates. On June 15 1998, the spot curve was inverted, implying that the market expects short-term interest rates to fall over time. The 3-month implied forward curve, which was below the estimated spot curve, indicated that the market expected the 3-month spot rate to fall to 8.5%, 7.7% and 7.2% in three months, six months and twelve

months respectively from June 15 1998, from the spot rate on that day of 9.4%. The position of the spot curve was much lower on June 28 1999 than during the period of market turbulence following the outbreak of the East Asian currency crisis. However, the shape of the estimated spot curve and the configuration of the implied forward rates indicated that the market expected the future spot rate to rise. Compared to the 3-month spot rate of 2.2%, the implied forward rates three months, six months, and twelve months ahead were 2.9%, 3.6%, and 4.1% respectively.

III PREDICTIVE POWER OF THE IMPLIED FORWARD RATE

3.1 According to the pure expectation theory of the term structure of interest rates, the forward rate equals to the market expectation of the future spot rate. Therefore, under the joint hypothesis of rational expectations and risk neutrality, the realised spot rate $R(t, T)$ will differ from the expected level by the forecast error $v(t)$ that is orthogonal to any information set known at t . The test of the joint hypothesis can be conducted by estimating

$$R(t, T) = a_0 + a_1 f(t, T) + v(t) \quad (10)$$

and testing the joint restrictions $a_0 = 0$ and $a_1 = 1$.

3.2 In this section, we tested the power of the three-month forward rate ($T-t = 3$ months) to forecast the spot rate one month, two months and three months from the trade dates (i.e. for $t = 1, 2$ & 3 months).

3.3 Since the spot rate and the forward rate are often non-stationary, the test statistics obtained from the least squares estimates of equation (11) are not valid. The problem of non-stationarity of the variables is overcome by estimating the equation in the first-difference form:

$$R(t, T) - R(t, t+T-t) = a_2 + a_3 [f(t, T) - R(t, t+T-t)] + e(T) \quad (11)$$

3.4 Fama (1984) and Mishkin (1988) among others, have estimated equation (11) using US data. They found that, in general, the forward spread helped to predict changes in the spot rate several months into the future, although they found that the value of a_3 and its level of significance fell quickly as the forecast horizon t increases.

3.5 We estimate instead equation (11) using the Johansen maximum likelihood cointegration procedure. Granger (1986) has shown that for any $I(1)$ variable X_t , the optimal forecast of X_{t+n} conditioned on the full history

of X_{t-j} , for $j \geq 0$, is cointegrated with X_{t+n} itself. Therefore for the forward rate to be an unbiased forecast of the future spot rate, these two variables must be cointegrated. While the existence of a cointegrating relationship between the forward rate and the future spot rate is a necessary condition for unbiasedness, it is not a sufficient condition [Hakkio and Rush (1989)]. Two additional conditions are needed. They are: (i) the elements of the cointegrating vector (a_0, a_1) satisfy the (0,1) restrictions and (ii) the forecast error $v(t)$ is serially uncorrelated and orthogonal to known information.

3.6 Before turning to the results of the cointegration test, it is helpful to examine the scatter plots of the relationship between the three-month implied forward rate and the realised three-month spot rate one, two and three months ahead. The sample consists of weekly data from July 7 1997 to June 28 1999, spanning periods of considerable market turbulence during the height of the Asian financial crisis, where interest rates rose to unprecedented heights and the yield curve steepened sharply, and periods of relative calm where pressure on interest rates eased off considerably and the yield curve sloped downward. The sample period therefore provides a good opportunity to evaluate the ability of the forward rate to anticipate future changes in money market conditions in a rapidly changing environment.

3.7 If the pure expectations theory holds without any forecast errors, the data points would lie on the 45-degree line. Expectation errors would cause the data points to scatter around the line, but they should not lead to the rejection of null hypothesis that the intercept of the line is zero and its slope is unity. Figure 3 shows general evidence of a positive relationship between the implied forward rate and the actual spot rate at the three forecast horizons. There are several large outliers that lie above the 45-degree line, indicating over-prediction by the forward rate of the future spot rate. These outliers come mainly from two sub-periods, namely 22 December 97 to 2 February 98, and 15 June 98 to 13 July 98. This is likely to reflect increased volatility in the regional financial markets as a result

of the Indonesian and Korean crises during the first period, and the Russian crisis during the second. Contagion effects from these external developments led to a sharp increase in short-term Singapore Dollar interest rates. Once the exchange market pressures eased, these short-term interest rates declined quickly.

3.8 Table 1 shows the results of the cointegration tests of the ability of the three-month forward rate to forecast the spot rate one, two and three months in advance.³ When performing the Johansen cointegration test, it is assumed that the data has no deterministic trend and there is an intercept but no trend in the cointegration equation. As Table 1 indicates, the trace statistics reject the null hypothesis of no cointegration between the forward rates and the spot rates for the three forecast horizons. Monte Carlo studies by Cheung and Lai (1993) shows that the trace statistic, in finite samples, shows little bias in the presence of skewness or excess kurtosis in the data. The study also shows that as long as the lag length is adequately chosen, the potential bias in the trace test in the presence of a moving average process in the residual term is very small. The lag length we have chosen in the VAR is sufficient to remove the autocorrelations arising from the use of overlapping data (in which the forecast period is longer than the weekly observations).

³ The augmented Dickey-Fuller (ADF) test indicates that the null hypothesis of unit root cannot be rejected for both the 3-month implied forward rate and the 3-month spot rate. The computed ADF test statistics are -1.549 and -1.162 respectively for these two variables.

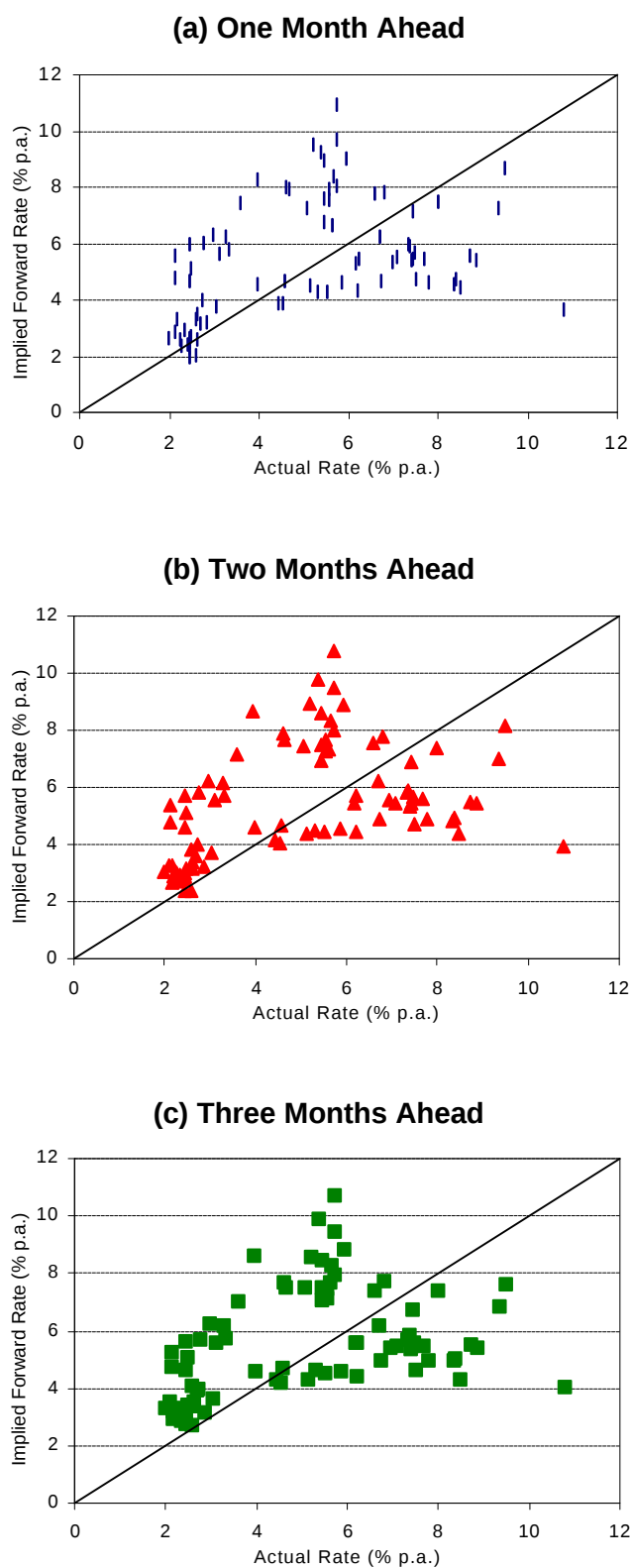
Figure 3: Scatter Plots of Actual vs Implied Forward Rates

Table 1
Tests of Cointegration and Unbiasedness of the Forward Rate

<i>Forecast Horizon</i>	$R(t, T)$	$f(t, t, T)$	<i>Constant</i>	<i>L Trace</i>	$\chi^2_{(2)}$
$t=1, T=4$	1.000	0.9595 (0.0118)	0.1092 (0.0652)	39.020**	42.14*
$t=2, T=5$	1.000	1.0569 (0.0934)	0.5064 (0.5246)	29.061*	1.29
$t=3, T=6$	1.000	1.1841 (0.2496)	1.3285 (1.4404)	21.074*	1.39

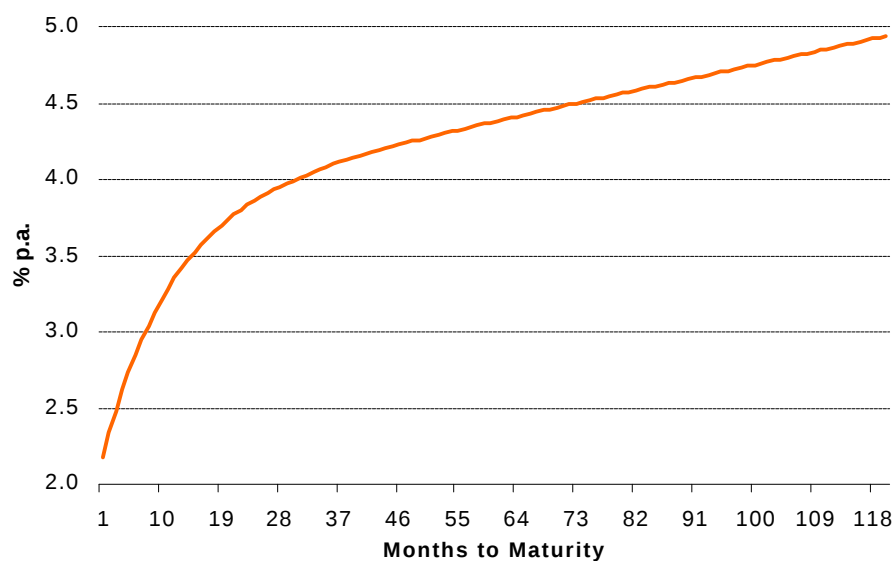
** indicates rejection of null hypothesis at 1% significance level

* indicates rejection of null hypothesis at 5% significance level

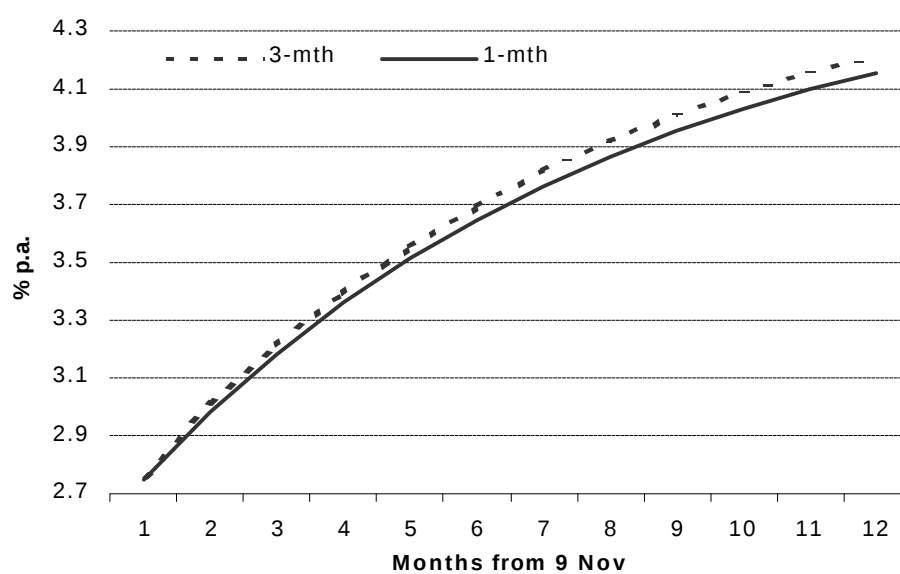
3.9 Once it is established that the forward and the spot rates are cointegrated, we perform the likelihood ratio test to evaluate the (0,1) restrictions implied by the unbiased hypothesis. As indicated in Table 1, the chi-square test statistics indicate that the unbiasedness restriction is rejected only for the one-month ahead forecast. Hence, our test results indicate that the implied forward rate that is extracted from the yield curve provides, on average, an unbiased forecast of the future spot rate two and three months ahead.

3.10 Recent concerns over further monetary policy tightening in the US has resulted in the steepening of the Singapore yield curve. Figure 4 shows our estimates of the spot yield curve as of 9 Nov 99. The implied forward rate curve indicates that the market expects the three-month spot rate to rise from 2.8% as of 9 Nov 99, to 3.2% in three months time, 3.7% in six months time, and 4.2% in twelve months time.

Figure 4
(a) Spot Rate Curve as at 9 Nov 99



(b) Forward Rate Curves as at 9 Nov 99



IV SUMMARY AND CONCLUSION

4.1 In this paper we set out to estimate the term structure of interest rates in Singapore and extract information on market expectations of future interest rates from the yield curve. Our empirical analysis indicates that the Nelson and Siegal (1987) functional form fits the term structure data well. We then evaluated how well the implied forward rate anticipated the future time-path of the corresponding spot rate. It was found that the forward rate and the future spot rate were cointegrated and the hypothesis that the forward rate is an unbiased predictor of the future spot rate cannot be rejected. Our analysis has shown that the implied forward rate curve, especially at the shorter settlement horizons, can be a reliable indicator variable providing policymakers and market participants with information on financial market expectations of monetary conditions in the near future.

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