Interpreting the Term Structure of Interbank Rates in Hong Kong

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Abstract

This paper studies the term structure of short-term interbank rates in Hong Kong. Principal components analysis suggests that the variation of the term structure can be largely attributed to two components which capture shifts in the level and slope of the yield curve. We find that term spreads contain no information about future short-term rates. The Expectations Hypothesis, which states that long-term rates depend on expected future short-term rates plus a constant term premium, is also soundly rejected by the data. However, we are unable to reject a modified version of the EH that incorporates time-varying term premia.

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1. Introduction

Central banks typically pay considerable attention to the term structure of interest rates in their day-to-day monitoring of financial markets.[1] This is so for several reasons. First, there is empirical work using data from a range of economies indicating that the slope of the term structure contains evidence of economic activity in the near term. Estrella and Hardouvelis (1991) demonstrate that a downward-sloping term structure appears to be associated with an increased likelihood of low future economic growth or a recession.[2] Second, the slope of the term structure may be informative about the future path of inflation (see Mishkin (1990a, b, 1991)).[3] Thus, an upward-sloping term structure is commonly interpreted as suggesting that inflation is expected to rise. Third, and arguably of more direct importance to monetary policy makers, the term structure may contain information about market participants' expectations regarding the future path of short-term interest rates. Since monetary policy in most countries, although not in Hong Kong, is conducted by the central bank actively influencing very short-term interest rates, the term structure can alternatively be seen as capturing market participants' expectations of the future stance of monetary policy.[4] However, while economic theory suggests that longer-term interest rates are influenced by expectations of future short-term interest rates, other factors also play a role in determining interest rates. For instance, shifts in liquidity or market participants' assessment of the riskiness of holding deposits or securities of different maturities may affect the term structure. If the importance of such factors changes over time, the induced variation in liquidity and risk premia can render the interpretation of the term structure more difficult.

In this paper we study monthly data spanning 1992:01-2001:02 on the term structure of short-term interbank rates in Hong Kong. The purpose of the analysis is to assess to what extent the term structure contains information about the future path of short-term interest rates. In Section 2 we characterise the evolution over time of short-term interest rates and term spreads. Particular attention is paid to the statistical properties of the data. As a prelude to the econometric analysis, we use principal component analysis to explore informally the number of different factors influencing the term structure and test for unit roots in the different interest rates and term spreads.

1 For a review of the literature on the term structure of interest rates, see Shiller (1990).

2 See also Bernanke (1990). Bernard and Gerlach (1998) provide international evidence.

3 See also Jorion and Mishkin (1991) and Gerlach (1997).

4 Hardouvelis (1994) provides an international comparison of the information contained in the term structure of longer-term rates for the future path of interest rates. Gerlach and Smets (1997) do the same but focus on the short end.

In Section 3 we test whether the data obey the Expectations Hypothesis (EH) of the term structure, that is, whether we can reject the hypothesis that term premia are constant over time and longer-term interest rates are determined solely by the expected future path of short-term rates. We show that the data reject soundly this hypothesis and conclude that time-varying term premia are present. Indeed, we find that there appears to be no information about the future path of interest rates embedded in the term spreads. In light of this, we incorporate time-varying term premia in the econometric analysis. For simplicity, we model these as given by the conditional variance of innovations to the one-month interest rate, which we estimate using an ARCH model. Our proxy for the term premia is highly significant in the different regressions, and we find strong evidence that interest rate spreads are informative for the future path of short-term rates. Nevertheless, the EH is rejected by the data. However, since the ARCH model yields at best a noisy estimate of the true volatility, these regressions are subject to errors-in-variables bias of unknown magnitude. We therefore re-estimate the equations, using a moving average of lagged squared changes of the one-month rate to instrument volatility, as suggested by Pagan and Ullah (1988). In these final estimates the risk premia remain highly significant. More importantly, we can reject the hypothesis that the slope parameters are zero, but are unable to reject the hypothesis that they are unity as suggested by theory.

Finally, Section 4 contains our conclusions. Overall, the results suggest that the term structure of interbank rates in Hong Kong can be thought of as being driven by expectations of future short-term rates and a term premium that is related to the volatility of the one-month rate.

2. Preliminaries

In this section we review the data and present some simple stylised facts with respect to their behaviour. The data used are from the Hong Kong Monetary Authority's website (www.hkma.gov.hk) and represent the Hong Kong dollar interbank offered rates with one, three, six, nine and twelve months maturity. The data are monthly and span the period 1992:01 to 2001:02.[5]

5 The data are averages for the month and are available in Table 5.3.2 in the HKMA's Monthly Statistical Bulletin.

2.1 Univariate Analysis

Figure 1 shows that the term structure of interbank rates experienced several episodes of turbulence. Particularly noteworthy are the sharp increases in the middle of 1997 following the floating of the Thai baht and in the third quarter of 1998 following the Russian debt moratorium and a speculative attack against the Hong Kong dollar. However, less pronounced interest rate increases took place in late 1994 and late 1992 at the time of speculative attacks against a number of European currencies pegged to the ECU.

Figure 1 indicates that movements in interest rates tend to be associated with changes in term spreads, that is, spreads between interest rates of different maturity. To demonstrate this more clearly, Figure 2 plots the spreads of three-, six-, nine- and twelve-month interest rates against the one-month rate. Two aspects of the figure are of particular interest. First, longer interest rates tend to exceed short-term rates, that is, the term structure is generally upward sloping. Second, movements in the three-one month spread are reflected in movements in the longer-term spreads, with the extent of the reactions positively related to the maturity of the long rate used to construct the spread. Thus, the spread between twelve- and one-month rates is more variable than the spread between nine- and one-month rates, which in turn is more variable than the spread between six- and one-month rates.

This is demonstrated more clearly by Figure 3, which shows the average size of term spreads (defined as the longer interest rate minus the one-month rate) over the sample period. The figure shows that the average spreads of three-, six-, nine- and twelve-month interest rates against one-month rates are about 0.002, 0.005, 0.007 and 0.009. The fact that the term spreads are positively related to the maturity of the long rate used to compute them suggests that term premia are present. However and as we discuss below, that does not imply that the EH, defined formally in Section 3, is inconsistent with the data.

Next we perform Phillips-Perron tests on the interest rates and the term spreads. This is an important preliminary step to the econometric analysis that follows below since any use of non-stationary data would have important implications for the ways in which inference should be conducted. The first column of Table 2 indicates that we can reject the hypothesis of a unit root for the one- and three-month rate and for the term spreads. However, for the level of the six-, nine- and twelve-month rates we are unable to reject the hypothesis of a unit root.[6] These results imply that the variables used in the econometric analysis below are stationary, which implies that hypothesis testing can be carried out using standard procedures.

6 The finding that we can reject the unit root hypothesis for one-month rates is important in light of the finding of Bekaert et al. (1997) that strong persistence of the short rate can lead to a bias in the tests we run below.

2.2 Multivariate Analysis

As already noted, Figure 2 suggests that the term spreads are strongly correlated.[7] This makes it likely that most of the variation in the five interest rates can be attributed to a much smaller number of underlying economic forces. To explore this issue further, we apply principal components analysis to the interest rates. This method allows us to decompose a number of time series into an equal number of orthogonal factors.[8] The first of these is a linear combination of the data constructed so as to explain as large a fraction as possible of the variances of the different series. The second is a linear combination of the data selected so as to explain the largest possible fraction of the variance left unexplained by the first component. (The remaining principal components are defined analogously.) The purpose of the analysis is to determine how large a fraction of the variance is explained by the different components and to explore the weights attached to the underlying time series in computing the different components. While the principal components do not have an economic interpretation, they are, as we show below, nevertheless useful in analysing the data.

To see this, consider the results in Table 2 and Figure 4. Monthly changes are used since the level of the six-, nine-, and twelve-month interest rates are non-stationary.[9] The analysis is based on the covariance, rather than the correlation, matrix of the interest rates since the interest rates are measured in the same units.

Table 2 shows that the first principal component explains 94.0% of the variance of the data considered. The second principal component explains an additional 5.3% of the variation of the data. It is thus clear that two factors drive most of the movements in the different interest rates. To better understand their implications for the term structure, we turn to the factor loadings. It is notable that the loadings for the first component are all positive and similar (but tend to decline for the longer maturities).[10] The first principal component can therefore be thought of as representing level shifts of the term structure. The factor loadings for the second principal component are more interesting in that they are negative for the one- and three-month rates, but positive for the six-, nine-, and twelve-month rates. The second component thus captures changes in the slope of the yield curve.

3. Testing the Expectations Hypothesis

So far we have merely described the statistical properties of the data. In this section we attempt to interpret them, using the EH of the term structure as our point of reference. The critical implication of the EH is the (testable) assumption that the expected return from investing in alternative segments of the term structure is the same, except possibly for a time-invariant term premium.[11] More formally, let $R_t^{(N)}$ denote the *N*-period spot rate at time t. The EH can then be written as:

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7 In fact, estimated correlation coefficients are all above 0.85.

8 Principal components analysis is discussed in many textbooks, e.g. Johnston (1984, Appendix A-10).

9 If non-stationary data are used, the fraction of the variance accounted for by the first principal component will depend on the sample size (and tend to unity as the sample size grows). It thus captures the “spurious” correlation in the data.

10 It should be noted that the sum of the squared factor loadings equals unity by construction.

11 The term premium may, however, differ between maturities.

$$(1+R_t^{(N)})^N = (1+E_t R_t^{(1)})\times(1+E_t R_{t+1}^{(1)})\times(1+E_t R_{t+2}^{(1)})\times\cdots\times(1+E_t R_{t+N-1}^{(1)})\times\Theta^{(N)}, \tag{1}$$

where $\Theta^{(N)}$ denotes the term premium. Letting lower case letters denote compounded rates (so that $r_t^{(N)} = \ln(1+R_t^{(N)})$) and $\theta^{(N)} = \ln\Theta^{(N)}$, we have that

$$r_t^{(N)} = \theta^{(N)} + \tfrac{1}{N}\sum_{i=0}^{N-1} E_t r_{t+i}^{(1)} \,. \tag{2}$$

To proceed, we subtract $r_t^{(1)}$ from both sides and rearrange:

$$\tfrac{1}{N}\sum_{i=0}^{N-1}\left(E_t r_{t+i}^{(1)} - r_t^{(1)}\right) = -\theta^{(N)} + r_t^{(N)} - r_t^{(1)} \,. \tag{3}$$

To interpret (3), consider the simplest case, in which $N = 2$:

$$\tfrac{1}{2}\left(E_t r_{t+1}^{(1)} - r_t^{(1)}\right) = -\theta^{(2)} + r_t^{(2)} - r_t^{(1)} \,, \tag{4}$$

and suppose, for simplicity, that the term premium is zero. Equation (4) then states that there is a linear relationship between the expected change in the one-month rate, $E_t r_{t+1}^{(1)} - r_t^{(1)}$, and the spread between the two- and one-month rates, $r_t^{(2)} - r_t^{(1)}$. Thus, if short-term rates are expected to rise (fall), the term structure will be upward- (downward-) sloping.

Before proceeding, two points warrant discussion. First, since the Hong Kong dollar is tied to the US dollar using a currency board arrangement ("the Link"), short-term interest rates in Hong Kong are closely related to those in the United States. While this implies that $r_t^{(1)}$ is determined by forces external to the domestic economy, that does not have any implications for tests of the EH since this merely states that there is a relationship between interest rates of different maturities, whatever the factors are that determine them. Second, note that equation (4) explains why the slope of the term structure is useful for predicting future inflation and output. To understand this, suppose that central banks raise interest rates in response to inflation and that this in turn reduces economic activity. If market participants come to believe that inflation is about to rise, they will expect the central bank to increase short-term rates in the future. According to equation (4), this implies that longer-term rates start to rise already now. If, on average, market participants are correct in their assessments of economic developments, we will see an upward-sloping term structure associated with higher future short-term rates, higher future inflation, and lower future economic growth.

One problem with testing the EH is that equation (4) contains expectations of future short-term rates and can therefore not be estimated directly. To overcome this problem, note that by definition $r_{t+j}^{(1)} \equiv E_t r_{t+j}^{(1)} + \varepsilon_{t+j}^{(1)}$, which states that the actual one-month rate is equal to its expected value plus an expectation error (defined by $\varepsilon_{t+j}^{(1)} \equiv r_{t+j}^{(1)} - E_t r_{t+j}^{(1)}$). If we are willing to make the assumption that the expectation errors are serially uncorrelated, we can use this result to rewrite (4) as:

$$\frac{1}{N}\sum_{i=0}^{N-1}\left(r_{t+i}^{(1)} - r_t^{(1)}\right) = -\theta^{(N)} + r_t^{(N)} - r_t^{(1)} + \frac{1}{N}\sum_{i=0}^{N-1}\varepsilon_{t+i}^{(1)}. \quad (5)$$

Consider next the regression equation:

$$\frac{1}{N}\sum_{i=0}^{N-1}\left(r_{t+i}^{(1)} - r_t^{(1)}\right) = \alpha^{(N)} + \beta^{(N)}\left(r_t^{(N)} - r_t^{(1)}\right) + v_t^{(N)}. \quad (6)$$

The EH then holds that $\alpha^{(N)} = -\theta^{(N)}$ and $\beta^{(N)} = 1$. Thus, by estimating (6) and testing whether the slope parameter is unity we can test the EH.[12] Doing so is straightforward, with the minor complication that the error term, $v_t^{(N)} = \frac{1}{N}\sum_{i=0}^{N-1}\varepsilon_{t+i}^{(1)}$, obeys a moving-average structure of order N-1.

3.1 Preliminary Estimates

We first estimate equation (6) using GMM on monthly data spanning 1992:01-2000:03. Standard errors are computed as in Newey and West (1987), which allow the errors to be heteroscedastic and to obey an MA(N-1) structure. The results in Table 3 are very discouraging for the EH in that the slope parameters are close to zero, ranging from 0.16 to 0.37. More importantly, they are significantly different from unity, but, except for the case of N = 9, not significantly different from zero. Moreover, the constants are all negative, but not significant. Finally, the adjusted R-squared is extremely low in all regressions. Of course, this is merely a reflection of the fact that the turbulence the term structure underwent in the latter part of the sample was unexpected and led to very large expectation errors.

3.2 Time-Varying Term Premia

The fact that the slope parameters are estimated to be between zero and unity suggests that allowing for time-variation in the term premium may be critical for understanding the movements of the term structure of interbank rates in Hong Kong. To see this, rewrite equation (3) as:

$$E\Delta r_t^{(N)} = -\theta_t^{(N)} + TS_t^{(N)}, \quad (3')$$

where $E\Delta r_t^{(N)} \equiv \frac{1}{N}\sum_{i=0}^{N-1}\left(E_t r_{t+i}^{(1)} - r_t^{(1)}\right)$ and $TS_t^{(N)} \equiv r_t^{(N)} - r_t^{(1)}$. Mankiw and Miron (1986) show that in the presence of a time-varying term premium, the estimated value of $\beta^{(N)}$ in equation (6) is given by:[13]

$$\beta^{(N)} = \frac{Var(E\Delta r^{(N)}) + Cov(E\Delta r^{(N)}, \theta^{(N)})}{Var(E\Delta r^{(N)}) + Var(\theta^{(N)}) + 2Cov(E\Delta r^{(N)}, \theta^{(N)})}. \quad (7)$$

Equation (7) indicates that if the variance of the term premium is zero (implying that the covariance of the term premium and the expected change in the interest rate is zero), the slope parameter is indeed unity.

12 It should be noted that this is merely one of several ways in which the EH hypothesis can be tested. The reason for concentrating on this aspect is that it focuses on the issue of how much information term spreads contain about market participants' expectations of future short rates, which arguably is the most interesting question from the perspective of central banks.

13 See also Chapter 10 in Campbell et al. (1997).

However, if there is a term premium, the slope parameter can be negative or larger than unity. Only if the covariance is not too large, $\beta^{(N)}$ will range between zero and unity.

To understand equation (7) better, consider Figure 5, which contains plots of $\beta^{(N)}$ against $\omega = Var(E\Delta r^{(N)})/Var(\theta^{(N)})$, drawn for different $\rho = Cov(E\Delta r^{(N)}, \theta^{(N)})$. The first of these variables can be thought of as a signal-to-noise ratio that captures the importance of movements of expected future short-term rates relative to the term premium in accounting for movements in term spreads (thus, under the EH $\omega = \infty$). We construct the plot for ρ = -0.65, 0, and 0.65. Consider first the case in which the term premium is uncorrelated with expected future changes in interest rates (ρ = 0). The figure shows that for low signal-to-noise ratios, $\beta^{(N)}$ is close to zero. As ω rises, $\beta^{(N)}$ increases gradually towards unity. When ρ = -0.65, $\beta^{(N)}$ is negative for low values of ω, above unity for ω in an intermediate range, and approaches unity as the signal-to-noise ratio tends to infinity. This case is particularly interesting in light of the fact that Gerlach and Smets (1997) estimate ρ = -0.5 using data for 17 countries and the same four term spreads as considered in this paper. Finally, note that when ρ = 0.65, $\beta^{(N)}$ rises initially faster towards unity for low values of ω than in the benchmark case in which ρ = 0, but more gradually for higher values of ω. The main lesson from Figure 5 is that $\beta^{(N)}$ can differ considerably from unity if there are time-varying term premia.

Next we develop an empirical measure of the term premium. While economic theory suggests that term premia depend on the covariance of the return of the asset in question with the market, we assume for simplicity that the term premium is proportional to the variance of the innovation to the one-month rate, σ_t^2.[14] We can then estimate an augmented version of equation (6):

$$\tfrac{1}{N}\sum_{i=0}^{N-1}\left(r_{t+i}^{(1)} - r_t^{(1)}\right) = \alpha^{(N)} + \beta^{(N)}\left(r_t^{(N)} - r_t^{(1)}\right) + \delta^{(N)}\sigma_t^2 + v_t^{(1)}, \tag{8}$$

where $\delta^{(N)}$ captures the impact of the term premium. We first estimate (8) directly using GMM. One problem in doing so is that since σ_t^2 is not observed, we are required to use an estimate thereof, $\hat{\sigma}_t^2$. Since any such estimate is imperfect, this procedure introduces an errors-in-variables problem that potentially could lead to biased estimates of $\delta^{(N)}$. In the econometric analysis reported on below, we initially disregard this problem. Next, we follow the suggestion of Pagan and Ullah (1988) and use instrumental variables to overcome the measurement error in volatility. Before turning to the results, we first estimate the volatility of the one-month rate.

3.3 GARCH Models

The starting point for the empirical analysis of the term premium is a low-order GARCH model for the monthly innovation in the one-month rate. Since GARCH(1,1) models tend to capture the volatility of many financial time series, we purposely overfit the data by estimating a GARCH(2,2) model.[15] More precisely, we estimate:

$$\Delta r_t^{(1)} = \gamma_0 + \gamma_1 r_{t-1}^{(1)} + \varepsilon_t, \tag{9}$$

14 See Chapter 19 in Cuthbertson (1996).

15 Allowing for higher-order models leads to occasional convergence problems, suggesting that the models are overfitted.

where $\varepsilon_t \sim N(0,\sigma_t^2)$ and where:

$$\sigma_t^2 = \mu_0 + \sum_{i=1}^{2} \varphi_i \sigma_{t-i}^2 + \sum_{j=1}^{2} \phi_j \varepsilon_{t-j}^2 . \tag{10}$$

Next we estimate restricted GARCH(i,j) versions of this model and calculate the p-values associated with likelihood ratio tests for the restrictions. The results in Table 4 indicate that a GARCH(0,2) - or, equivalently, an ARCH(2) - model fit the data well and we therefore use the implied series of $\hat{\sigma}_t^2$ as a measure of the risk premium. Table 5 provides the parameter estimates of this model.

Before proceeding, it is of interest to consider the estimated values for $\hat{\sigma}_t^2$ in Figure 6. The plot indicates that the volatility of the one-month rate was generally low during the sample, but rose dramatically following the onset of the Asian financial crisis in 1997 and during the latter half of 1998 when the Hong Kong currency board was subject to a massive speculative attack. This suggests that the term premium largely reflects the need for an additional return on Hong Kong dollar assets to induce market participants to hold them in periods of uncertainty regarding the peg.

3.4 Estimates Incorporating Risk Premia

Having obtained an estimate of the variance of shocks to the one-month rate, $\hat{\sigma}_t^2$, we estimate:

$$\tfrac{1}{N}\sum_{i=0}^{N-1}\left(r_{t+i}^{(1)} - r_t^{(1)}\right) = \alpha^{(N)} + \beta^{(N)}\left(r_t^{(N)} - r_t^{(1)}\right) + \delta^{(N)}\hat{\sigma}_t^2 + v_t^{(1)} \tag{11}$$

using GMM, employing the regressors as instruments.[16] The results in Table 6 are more supportive of the EH than those in Table 3. In particular, the estimated β parameters are numerically larger than before. While they are insignificantly different from zero and unity for N = 3, 6, they are significantly different from zero but insignificantly different from unity when N = 9, 12. Moreover, while the parameters attached to the volatility of the one-month rate, which we take as a measure of the term premium, are insignificant for the three- and six-month rates, they are highly significant in the cases of nine- and twelve-month rates. Note that although the values of $\overline{R}^2$ are higher than in Table 3, they are nevertheless extremely low.

Finally, we re-estimate the equations in Table 6, but use a three-month moving average of squared changes in the one-month rate as an instrument for the volatility measure used above (see also Figure 6). To be valid, the instrument must be correlated with true volatility, σ_t^2, but uncorrelated with the error in equation (11). Note that this latter condition requires it to be uncorrelated with the error made in estimating $\hat{\sigma}_t^2$ using the GARCH model. If so, the approach would result in unbiased estimates of β and δ. The results in Table 7 indicate that the use of the instrumental variables technique has an important impact on the estimates. The table shows that the estimated β parameters are numerically larger than those in Table 6 and that they are significantly different from zero and insignificantly different from unity. In fact, they are numerically close to unity: depending on the maturity of the long rate, the

16 Thus, we effectively estimate (11) using OLS, but ensure that the standard errors are robust to moving-average errors of order (N-1).

slope parameter ranges between 0.86 and 1.09. Moreover, the δ parameters are all highly significant. Overall, these findings suggest that, in the presence of the term premium, term spreads are unbiased, but poor, predictors of future short-term rates.[17]

4. Conclusions

In this paper we have studied the term structure of interbank rates in Hong Kong, using data spanning 1992:01-2000:03. The main finding of the paper is that the term structure in Hong Kong does not seem to evolve over time in accordance with the simple EH. The reason for this appears to be the presence of time-varying term premia, which can be modelled quite well as depending on the volatility of innovations to the one-month rate. However, even if we incorporate term premia in the analysis, the forecasting ability of the term spreads remains poor. Overall, the results thus suggest that term spreads are unbiased, but poor, predictors of future short-term rates. Extracting this information, however, requires a model of the term premium. The difficulties in developing such a model coupled with the fact it may change over time urges caution in using the slope of the term structure as a measure of interest rate expectations.

17 To understand why they are poor predictors, recall that the parameters in Table 6 (which are identical to those given by applying OLS) are selected to minimise the variance of the errors, the parameters in Table 7 (which stem from applying instrumental variables) are not. Thus, these regressions explain at best a lower fraction of the variance of the dependent variable than the GMM estimates in Table 6.

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Table 1: Phillips-Perron Tests for Unit Roots

	1992:01 - 2000:03
Interest rates	Test statistic
1-month	-4.06***
3-month	-3.16**
6-month	-2.83
9-month	-2.66
12-month	-2.60
Term spreads	
3-1 month	-6.22***
6-1 month	-5.68***
9-1 month	-5.55***
12-1 month	-5.34***

Notes: */**/*** denotes significance at the 10%/5%/1% level. A constant and a time trend were included in the tests and three lags were used.

Table 2: Principal Components Analysis of Monthly Changes in Interest Rates (1992:01 - 2000:03)

	Principal component				
	1	**2**	**3**	**4**	**5**
Variance explained:	94.0%	5.3%	0.5%	0.1%	0.0%
Cumulative variance:	94.0%	99.3%	99.8%	100.0%	100.0%
	Factor loadings				
Change in					
1-month rate	0.58	-0.71	0.34	0.18	0.00
3-month rate	0.48	-0.05	-0.61	-0.61	0.09
6-month rate	0.42	0.31	-0.40	0.65	-0.39
9-month rate	0.37	0.44	0.21	0.15	0.80
12-month rate	0.34	0.45	0.55	-0.39	-0.48

Table 3:

GMM Estimates of:

$$\tfrac{1}{N}\sum_{i=0}^{N-1}\left(r_{t+i}^{(1)}-r_t^{(1)}\right)=\alpha^{(N)}+\beta^{(N)}\left(r_t^{(N)}-r_t^{(1)}\right)+v_t^{(N)}$$

1992:01 - 2000:03

Maturity of long rate (N)	$\alpha^{(N)}$	$\beta^{(N)}$	$\overline{R}^2$
3 months	-0.000	0.155	-0.00
	(0.001)	(0.273)	
	[0.810]	[0.570]	
6 months	-0.000	0.177	-0.00
	(0.002)	(0.225)	
	[0.774]	[0.432]	
9 months	-0.002	0.371	0.04
	(0.003)	(0.157)	
	[0.478]	[0.021]	
12 months	-0.001	0.242	0.01
	(0.003)	(0.161)	
	[0.730]	[0.136]	

Notes: Newey-West standard errors in parentheses; ρ-values in brackets.

Table 4: Value of Log-likelihood Function for GARCH (i, j) Models 1992:01 - 2000:03

	ARCH terms (i):	
	1	2
GARCH terms (j)**:**		
0	406.03	433.69
	[0.000]	[0.720]
1	428.01	433.97
	[0.002]	[0.752]
2	429.71	434.02
	[0.003]	

Note: ρ-values for test of restrictions against GARCH (2,2) model.

Table 5:

Estimates of:

$$\Delta r_t^{(1)} = \gamma_0 + \gamma_1 r_t^{(1)} + \varepsilon_t$$

$$\sigma_t^2 = \mu_0 + \sum_{j=1}^{2} \phi_j \varepsilon_{t-j}^2 \ .$$

1992:01 - 2001:02

γ_0	0.002
	(0.001)
	[0.070]
γ_1	-0.043
	(0.025)
	[0.085]
μ_0	2.39E-06
	(1.46E-06)
	[0.102]
ϕ_1	0.705
	(0.239)
	[0.003]
ϕ_2	0.853
	(0.190)
	[0.000]
$\overline{R}^2$	0.002
DW	2.55

Note: Newey-West standard errors in parentheses; p-values in brackets.

Table 6:

GMM Estimates of:

$$\frac{1}{N}\sum_{i=0}^{N-1}\left(r_{t+i}^{(1)} - r_t^{(1)}\right) = \alpha^{(N)} + \beta^{(N)}\left(r_t^{(N)} - r_t^{(1)}\right) + \delta^{(N)}\hat{\sigma}_t^2 + v_t^{(1)}$$

1992:01 - 2000:03

Maturity of long rate *(N)*	$\alpha^{(N)}$	$\beta^{(N)}$	$\delta^{(N)}$	$\overline{R}^2$
3 months	-0.000	0.433	-4.076	0.02
	(0.001)	(0.439)	(4.054)	
	[0.687]	[0.327]	[0.317]	
6 months	-0.001	0.397	-4.883	0.01
	(0.002)	(0.343)	(6.460)	
	[0.609]	[0.251]	[0.452]	
9 months	-0.003	0.764	-10.790	0.14
	(0.003)	(0.272)	(3.702)	
	[0.273]	[0.006]	[0.004]	
12 months	-0.003	0.640	-11.938	0.12
	(0.004)	(0.264)	(3.237)	
	[0.391]	[0.017]	(0.000)	

Notes: Newey-West standard errors in parentheses; ρ-values in brackets.

Table 7:

GMM Estimates of:

$$\frac{1}{N}\sum_{i=0}^{N-1}\left(r_{t+i}^{(1)}-r_t^{(1)}\right)=\alpha^{(N)}+\beta^{(N)}\left(r_t^{(N)}-r_t^{(1)}\right)+\delta^{(N)}\hat{\sigma}_t^2+v_t^{(1)}$$

1992:01 - 2000:03

Maturity of long rate *(N)*	$\alpha^{(N)}$	$\beta^{(N)}$	$\delta^{(N)}$
3 months	-0.001	0.908	-11.070
	(0.001)	(0.443)	(5.201)
	[0.452]	[0.043]	[0.036]
6 months	-0.002	0.859	-15.164
	(0.002)	(0.450)	(6.193)
	[0.353]	[0.059]	[0.016]
9 months	-0.004	1.089	-19.715
	(0.003)	(0.376)	(4.741)
	[0.177]	[0.005]	[0.000]
12 months	-0.005	0.948	-21.185
	(0.004)	(0.355)	(4.690)
	[0.210]	[0.009]	[0.000]

Note: A three-month moving average of the change in the one-month rate is used as an instrument for volatility. Newey-West standard errors in parentheses; ρ-values in brackets.

Figure 1: Interbank Rates

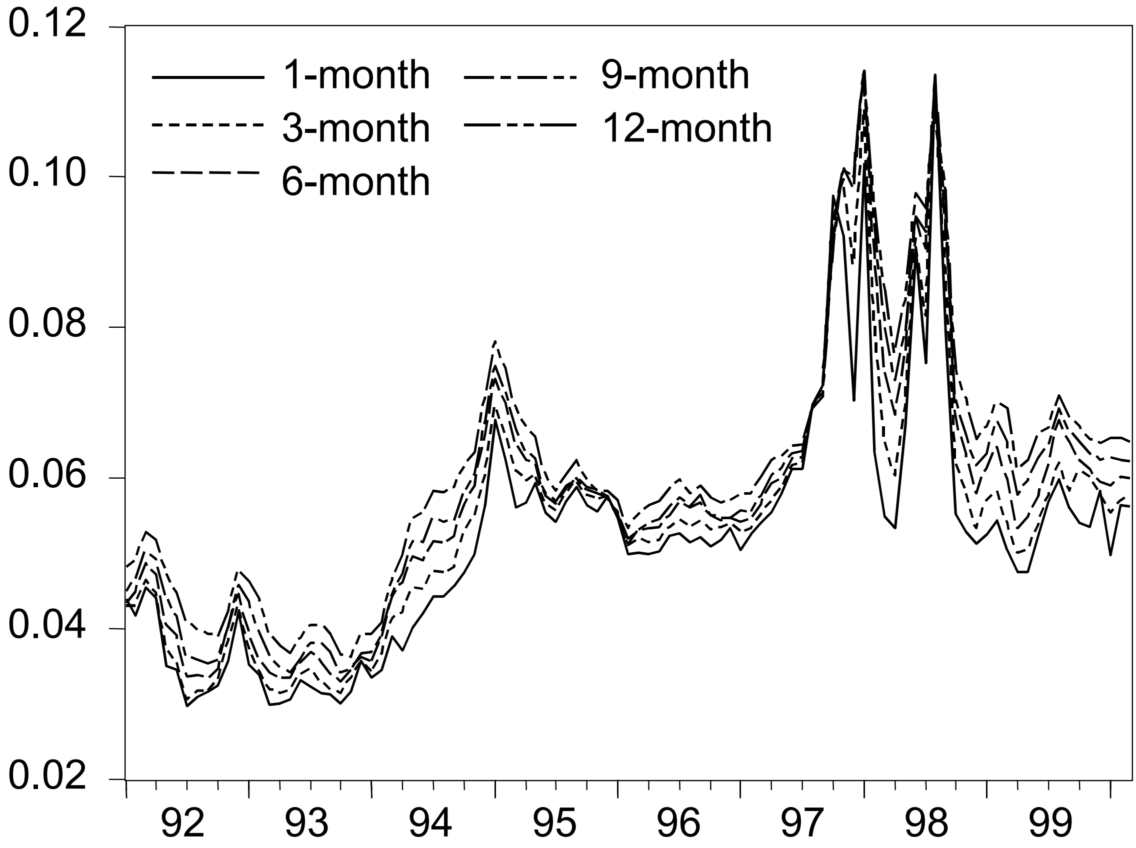

Figure 2: Term Spreads

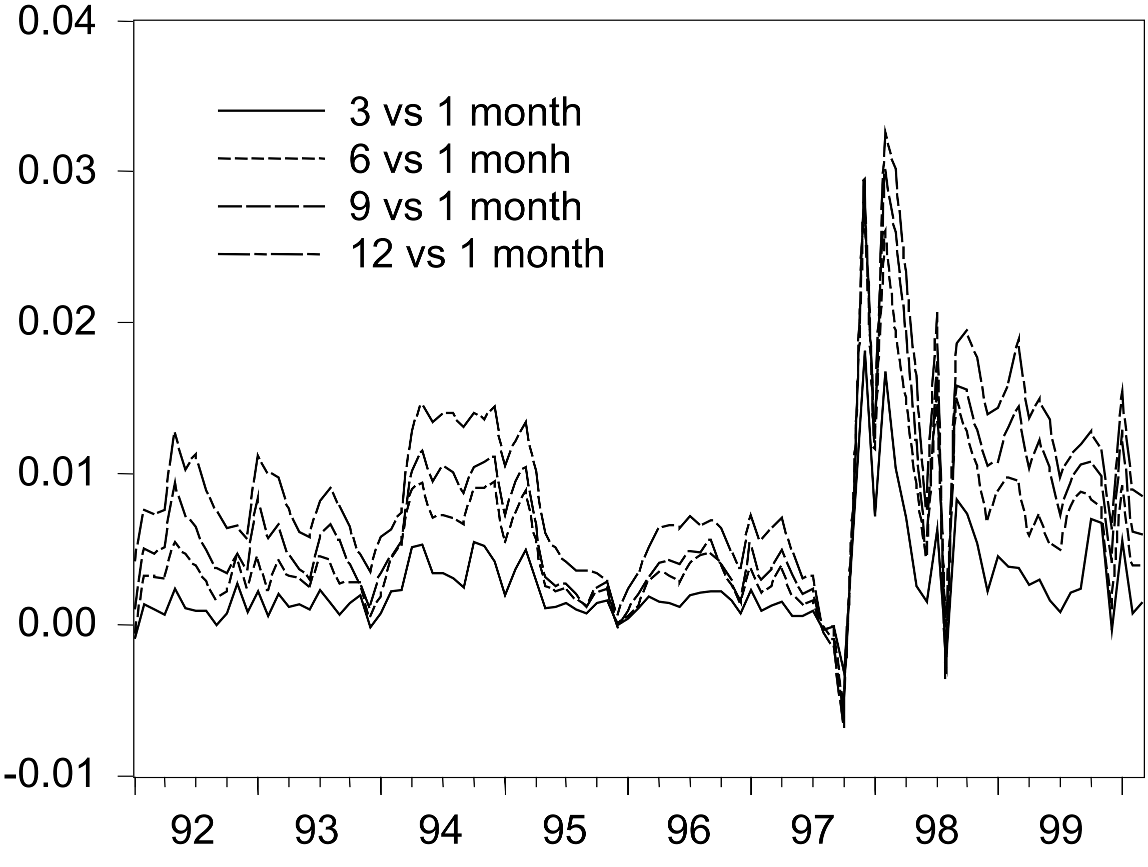

Figure 3: Average Term Spreads

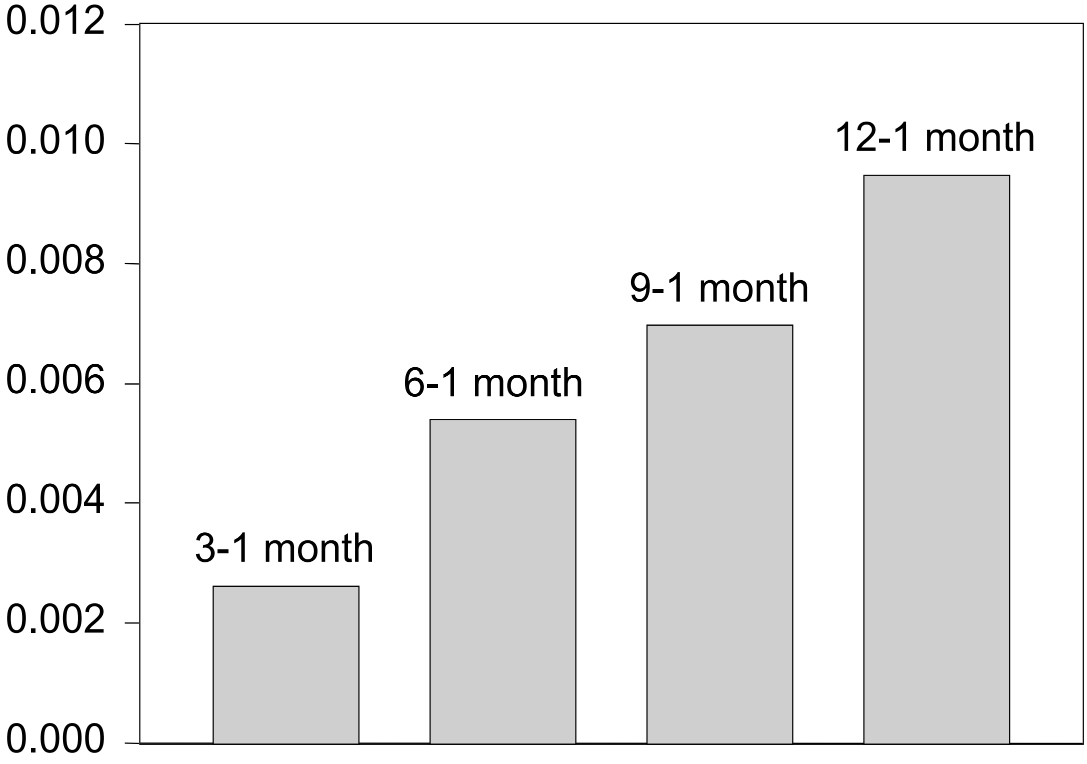

Figure 4: Factor Loadings for First and Second Principal Component (Computed on Monthly Changes in Interest Rates)

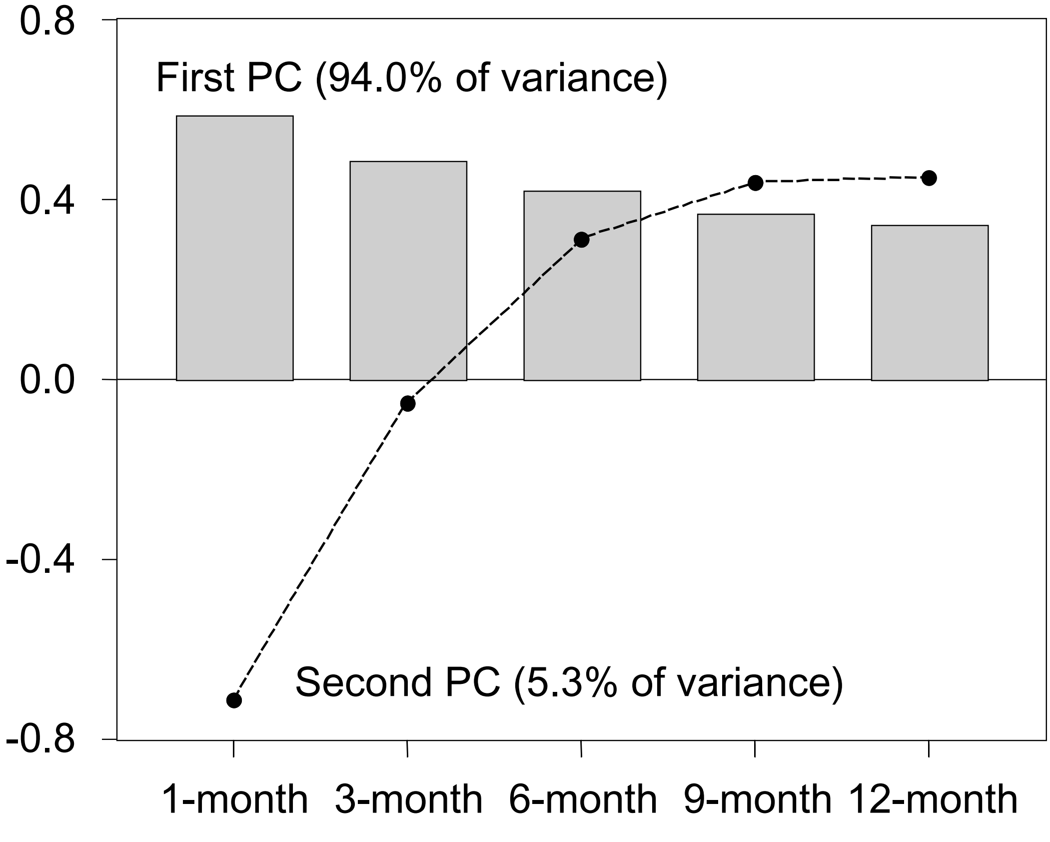

Figure 5: Plots of Slope Parameter Against Signal-to-Noise Ratio

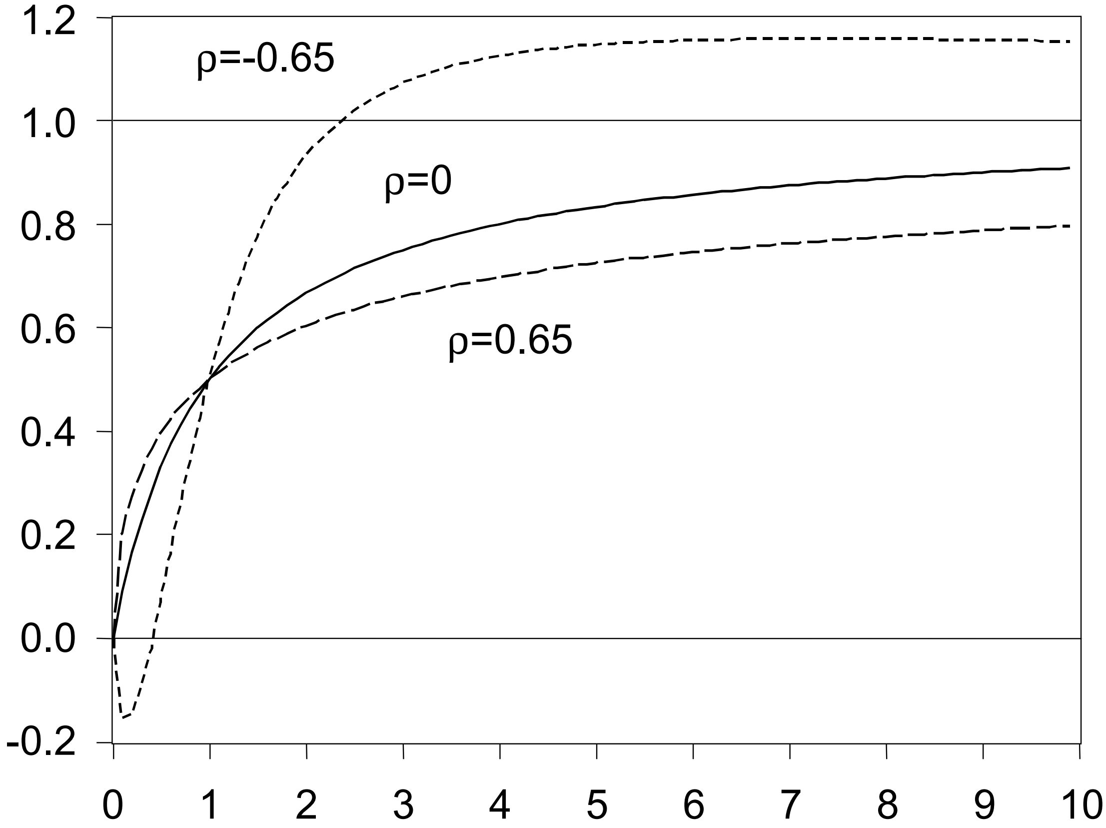

Figure 6: Risk Measures