CHAPTER III

Sample and Methodology

3.1 Sample and Data

The sample covers the trading data of treasury bills and Thai government bonds for each trading day during January 1999 to January 2004. Data on these bonds were taken from the Thai Bond Dealing Center (ThaiBDC).

All data used in this study are consisted of trading price of government bonds and treasury bills. For each price corresponding time to maturity as well as the coupon payment, the number of payment remaining and the time of next payment were used.

To enhance understanding for the bond market characteristics and the estimated parameter, the overview of Thai bond market is introduced before estimating procedure.

The Thai bond market has grown rapidly in recent year after 1997's financial crisis. To help support cash-strapped financial institutions, in June 1998 the government issued government bonds for the first time in a decade. The government continued issuing bonds since then with the primary objective to finance budget deficit that resulted from the crisis. The substantial amount of new government bonds coupled with a successive downtrend of interest rates have contributed to the robust of bond market evident by a significant rise in both market size and trading value.

Bond issued in Thailand can be divided into two major types; government[5] and corporate debt securities. The market is dominated by government debt securities,

---

[5] Government debt securities consist of four major types; Treasury Bills, Government bonds, Bank of Thailand bonds and State Owned Enterprise bonds.

which currently account for approximately 85% of total market outstanding as shown in Table I.

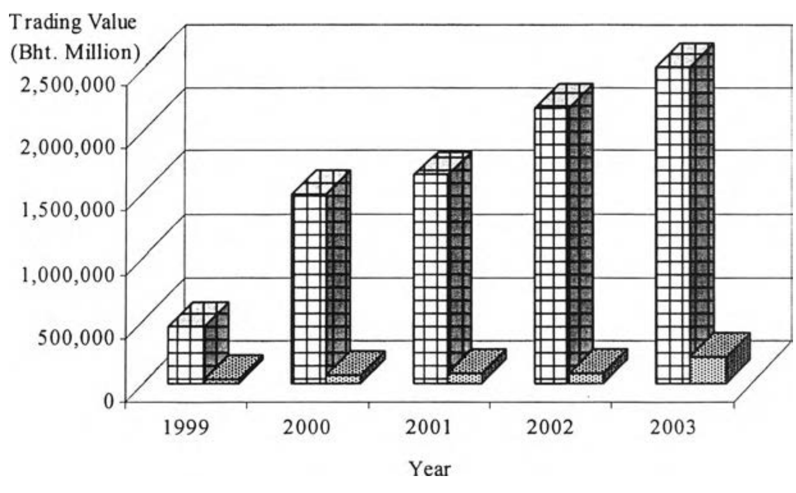
Table I
Thai Bond Market Trading and Outstanding Value 1999-2003

This table reveals the background of Thai bond market since 1999. The total value is the total value of bond trading at the end of year. The number of transaction is also the total transaction at the end of year.

Unit: Bht million

Type of Bond	1999 Trading Value	2000 Trading Value	2001 Trading Value	2002 Trading Value	2003 Trading Value
Government	341,084	1,027,781	916,473	1,177,212	1,154,578
State enterprise	50,784	207,864	140,383	113,549	101,634
- Guaranteed	42,535	191,688	123,871	104,597	69,714
- Non-guaranteed	8,249	16,176	16,512	8,952	31,920
T-Bills	3,777	47,414	350,837	700,850	578,817
State agency	2,732	662	93,233	63,347	557,423
Corporate	32,819	73,400	91,294	90,082	214,188
Total Value	431,197	1,357,121	1,592,219	2,145,040	2,606,640
No. of transaction	9,993	31,876	44,588	57,449	51,569

Table I provides some background of the bond trading and the characteristic of bond market. The trading value of bond has rapidly increased after 1999 as show in Figure I.

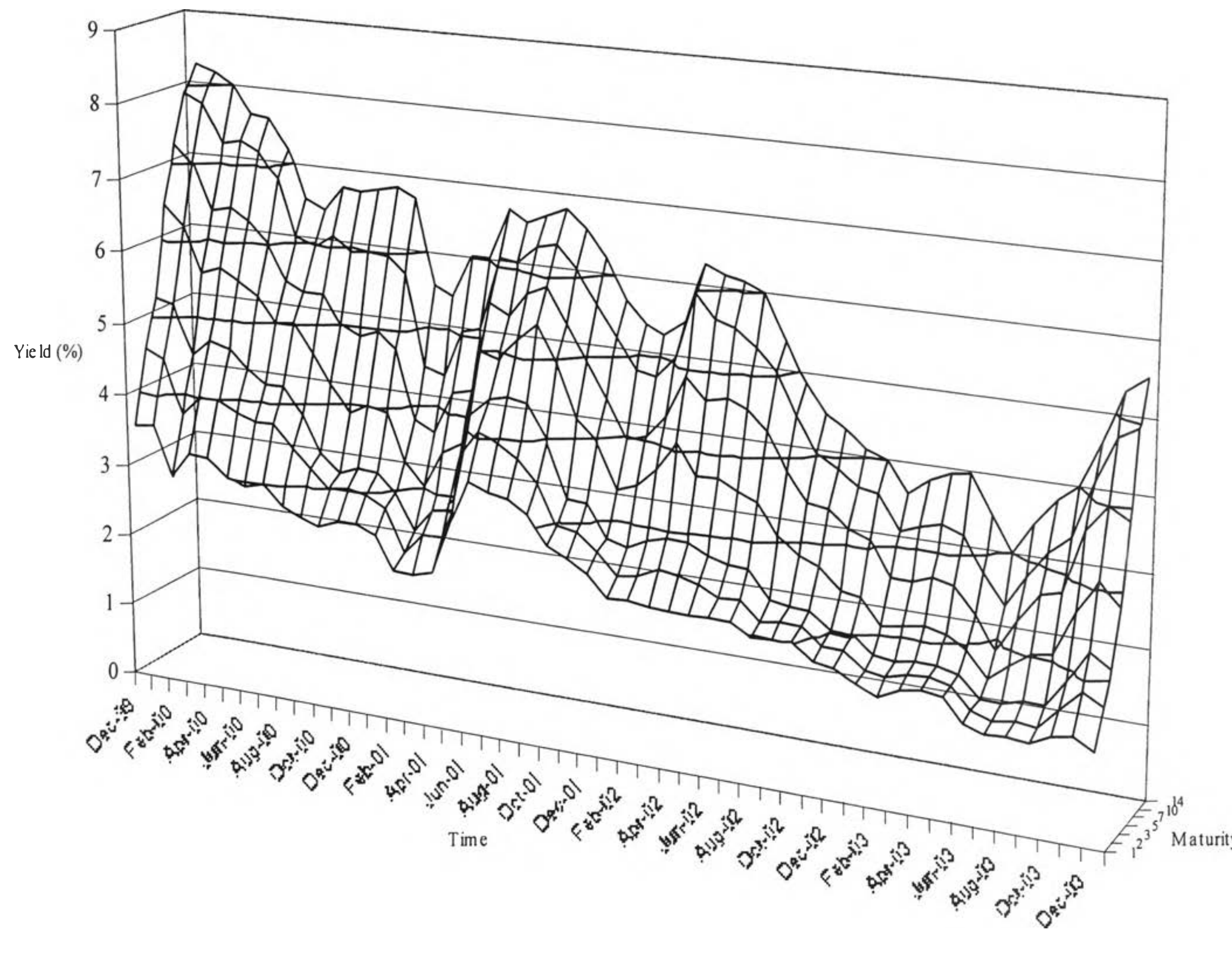


Source: The Thai Bond Dealing Center

Figure I The histogram of Thai Bond Market Trading Value. This figure presents the trading value between the government bond and the corporate bond in the Thai bond market. The trading value of Government bond includes the trading value of state enterprise, T-bills and state agency.

The sample selection procedure produces a sample that covers the entire yield curve and predominantly consists of currently traded active bonds.

Figure II provides the surfaces of the Treasury yield curves for the entire sample period, and in the Table II the summary statistic for bonds data.



Source: Bank of Thailand

Figure II The historical Thai yield curve. This figure presents a three dimension of the historical yield to maturity of government bonds. The sample contains 60 monthly observations from January 1999 to December 2003. The historical Thai yield curve has the upward sloping yield curve over the sample period

415 trading treasury bills and 32 trading government bonds are used in the estimation procedure. Table II provides a summary of the dataset description.

Table II
Summary of Thai Treasury Bills and Government Bonds Data

This table reports the summary of dataset during sample period starting from January 1999 to December, 2003. The yield to maturity is presented in term of mean value. The total number of bond trading month in a month is 60 and the total observation number is 20,176. Most observations have a maturity range from under 1 year up to 10 years. For the number of actual bonds under each maturity, there are 447 data points used to estimate term structure functions.

Time to maturity	No. of observation	No. of actual bond
< 1Y	7,396	415
1Y-5Y	6,108	11
5Y-10Y	5,076	10
10Y-15Y	1,260	5
>15Y	336	6
Total	20,176	447

For each month data for every Treasury bills and bond trading as of that quote date were used for calculation. Table II confirms that the Thai bond market is dominated by the short term debt instruments with maturity less than one year. The government bonds which are medium to long term debt instruments issued by the Ministry of Finance also attractive to bond traders. Government bonds capture the majority of the market as they are issued for financing deficit. However, the Thai bond market is still lacking in the long term bonds since bonds of the longer maturity number only six.

3.2 Methodology

3.2.1Estimation Method of Term Structure of Interest Rates

There are two common approaches to model the term structure of interest rates. The first approach starts with the specification of a time series process to describe the behavior of the short term interest rate over time. An advantage of the continuous time models is that they usually provide an analytically tractable between yield and maturity. However, the estimation of mean reversion parameter will be very difficult with time series data since it requires many observations spanning a large number of years in order to estimate the mean reversion parameter and unit root econometric is concerned. Also, along time series creates its own problems, since the empirical model has to cope with structural break.

While the cross-sectional estimation, it does not need more data than just one day if market has liquidity. Also, the estimated model will provide the best possible fit for the term structure. However, if there are not enough different bonds are traded on the market. The drawback of this estimation is that the parameters are not very stable over time.

Although there are many approaches and functional forms in estimating the yield curve, this study choose to investigate only two function form as in the recent work of Munnik and Schotman (1997) and Sercu and Wu (1997), in order to compare the results of estimation. In particular, the Vasicek model (1977) and CIR (1985) model are used with the Thai data. These functions are defined as equation (4) and (11).

However, the estimation procedure in this study is differing from these two previous works in term of instantaneous spot rate $[r(t)]$. The previous works treat $[r(t)]$ as an additional unknown parameter, which is estimated jointly with structural parameter. But the result of estimated parameter $[r(t)]$ with Thai bond data is nonsensical (negative interest rate). Therefore, the shortest available maturity is a one-month interest rate is required since the true instantaneous spot rate is not observable.

To estimate the parameters on a cross section of bonds at given month for each model, the study has to deal with the practice that all traded bonds carry coupons. Estimation is achieved by nonlinear least squares (NLS) by minimizing the sum of square errors and choosing the parameter κ, R_∞ and σ (or $\sigma\sqrt{r}$ for the CIR model).

$$\min_{R_\infty,\kappa,\sigma} \sum_{i=1}^{n} \left[P_{i,\tau}(c,t) - P^{*}_{i,\tau}(c,t)\right]^2 \quad \text{for bond i at time } \tau \tag{18}$$

Since $P_{i,\tau}(c,t)$ is the quoted bond price

$P^{*}_{i,\tau}(c,t)$ is the model price

$$\text{when } P^{*}_{\tau}(c,t) = \sum_{j=1}^{K} c_j P_{\tau_j}[r(t)] \tag{19}$$

c is the vector of bond cash flow; $c = (c_1,\ldots,c_K)$

τ is the corresponding payment dates; $\tau = (\tau_1,\ldots,\tau_K)$

$P_{\tau_j}[r(t)]$ is the discount bond prices are given by the Vasicek model and the CIR model[13]

---

[13] The Vasicek model can be expressed as follow ;

$$P_\tau[r(t)] = \exp\left(\frac{1-e^{-\kappa\tau}}{\kappa}[R_\infty - r(t)] - \tau R_\infty - \frac{(1-e^{-\kappa\tau})^2}{4\kappa^3}\sigma^2\right)$$

On the other hand , the closed form of the CIR model can be expressed as

$$P_\tau[r(t)] = A(\tau)^{R_\infty} e^{-B(\tau)r^{\tau}}$$

Equation (19) can be estimated for each trading day. A preliminary estimation revealed that the parameters for both models were hardly done using data for a single trading day. Since there may not be sufficient government securities to estimate using cross sectional data, therefore the pooled data are used in estimating procedure by keeping the structural parameter constant for one month while the risk free rate is allowed to take a different value each day. In case of my pooling interval of one month, the parameter (κ), (R_∞) and (σ) are constant for the whole period while $[r(t)]$ is different for each trading day as present in Figure II.

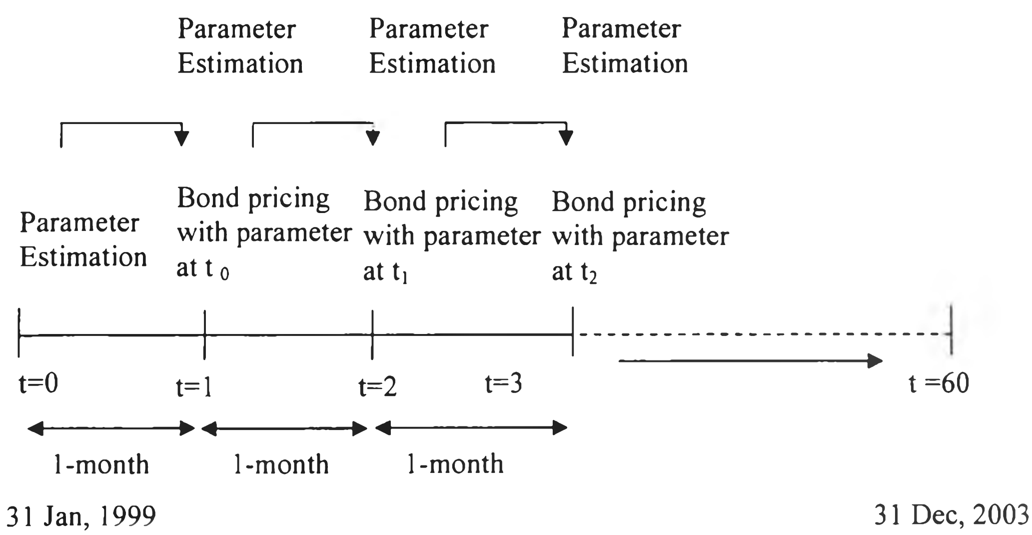


Figure III The estimation procedure. This figure represents the parameter estimation procedure during January, 1999 to December, 2003. The estimated models are then applied to the out of sample testing period. The model's parameters are also re-estimated using roll over procedure each month.

The one important parameter of both models is the speed of mean reversion (κ). The mean reverting parameter is an intuitive way of describing how long it takes a factor to revert to its long term rate. The implications of mean reversion for the term structure of volatility and factor shape may be better understood by reinterpreting the assumption that short rate tend toward a long term rate. In this interpretation, mean reversion measures the length of economic news or shock to the economy system. After all, regardless of shock, the short rate will reach at the same long term rate in a term structure model. Rates of every term are a combination of current economic conditions, as measured by the short term rate and of long term economic conditions, as measured by the long term rate.

From the parameter estimation, the conclusion can be that if the mean of the mean reversion is greater than zero ($\kappa > 0$), it implies that the short rate will quickly that tend toward to a long term rate while the economic shock occurred but for how long it depends on value of κ. Furthermore, it indicates that there is an equilibrium borrowing and lending adjustment in the economic system.

3.3.2 Pricing Error

The estimated models are then applied to the out of sample testing period from February 1999 to January 2004. Specially, each month each model prices are calculated comparing to the market observed price. The model's parameters are also re-estimated using a roll over procedure each month as shown in Figure III.

The standard error measurement such as mean absolute percentage error (MAPE) and root man square error (RMSE) of each model are then calculated and compared.

In this study, the initial forecast error refers to the percentage difference or error between a model price prediction and the real trading price for the same date. Calculating percentage error is useful for examining the error magnitude and identifying outliers in the forecasting without regard to the distribution of error. Hence this measure gives an approximate guide as to whether the forecasts are biased.

Mean absolute percentage error (MAPE) is calculated as

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|P_{it} - P^{*}_{it}\right| / P_{it} \qquad (20)$$

While the Root Mean Squared Error (RMSE) is the most commonly used measure of success of numeric prediction, take to give it the same dimensions as the predicted values themselves. It provides a function as:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(P_{it} - P_{it}^{*}\right)^2} \tag{21}$$

Where n is a number of trading bonds, P_{it} and P_{it}^{*} represent the realized price at time t and the model's forecast of it respectively. If the prediction error is large, it refer to the outlier from a given baseline or fit.

The first of these calculates the average difference between observed price and the set of fitted values by express accuracy in relative terms. Whereas the second statistically squaring each error term, this places greater weight upon larger errors and it therefore gives a greater indication as how well the model fits the data at each particular observation.

Nicola et al. (1996) pointed out that both set of statistics measure error as a general problem and do not distinguish between bias (consistent error of one sign) and goodness of fit. The mean and standard deviation of each are measure of days to demonstrate the trade off between flexibility and reliability by each of the models. In other words, a low value for the mean of each measure is assumed to indicate that the model is flexible and, on average, is able to fit the yield curve fairly accurately. The standard deviation of each measure, on the other hand, indicates how reliable this fit is across the sample of trading days.

The CIR model proposes a mean reverting process for the short rate where the standard deviation of the change in interest rate is proportional to the square root of the level of the rate. This means that the volatility of short rate is uncertain. So, the CIR model should price more accuracy than the Vasicek model, which has a constant volatility and results in the pricing error from the CIR model is less than the Vasicek model.

3.3.3 Trading Strategy Based on An Estimated Yield Curve

This section examine whether the estimated model has any economic significant by constructing a portfolio based on an estimated yield curve.

From each month's estimated Vasicek term structure, the study computes the month's Vasicek residual for each bond, i.e. the model price minus the actual bond price. The procedure is repeated for the CIR model. If the given bond pricing model is correct and reliably estimated, then a positive residual implies that the corresponding bond is undervalued, while a negative residual implies that the bond is overvalued and weighing each by a factor proportional to the size of mispricing.

To be specific, at the beginning of each month starting from February 1999, a portfolio of long and short bond is formed and held for one month. A portfolio is formed by buying undervalued bonds and selling overvalued bonds relative to model price in order to obtain an impression of the economic relevance. At the end of one month the portfolio is rebalanced and a new portfolio is formed.

The weight of each bond for each trading direction (buy and sell) in a portfolio is calculated by

$$W_i = \frac{\left|P_i - \hat{P}_i\right|}{\sum_i \left|P_i - \hat{P}_i\right|} \tag{22}$$

The performance of the portfolio is measure by

$$AR_t = \prod_{t=1}^{t+1}\left(1 + R_t^{vw}\right) - \prod_{t=1}^{t+1}\left(1 + R_t^{ew}\right) \tag{23}$$

where AR_t is the abnormal return of portfolio

R_t^{vw} is the return of portfolio at time t measured using value weighted average

R_t^{ew} is the return of portfolio at time t measured using equally weighted average

This study provides return of equally weighted portfolio as benchmarks in order to compare return of portfolio in each model. The term structure of interest rates from the CIR model can be a better benchmark in bond trading than the Vasicek model since the CIR model has better pricing. From the trading strategy based on an estimated yield curve, an abnormal return from the Vasicek model should be higher than the CIR model.

Figure IV Flow Chart of Estimation Procedure and Portfolio Formation

This figure shows the estimation procedure and portfolio formation. The procedure uses the historical data of bond feature as input parameters in order to pricing bond. The estimated parameters are calculated by Nonlinear Least Square. The estimated models are then applied to the out of sample. The model prices are calculated comparing to the market price in each month. The last procedure is portfolio formation by using the bond residuals. A portfolio is formed and held for one month and at the end of month the portfolio is rebalanced. The performance of portfolio is measure by the abnormal return.