# Long Term Interest Rates in Japan

## − Analysis of Market Structure and International Linkage −

（日本における長期金利－市場構造と国際間での連動性に関する分析－）

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Chapter 1

# Introduction

## 1. Background

Japanese long term interest rates are comprised of interest rate swap market and Japanese Government Bond market[1]. An interest rate swap is an agreement between two parties to exchange cash flows in the future. In a typical agreement, two counterparties exchange streams of fixed and floating interest payments. Thus fixed interest rate payment can be transformed into floating payment and vice versa. The amount of each floating rate payment is based on a variable rate that has been mutually agreed upon by both counterparties. For example, the floating rate payments could be based on the 6 month LIBOR (London Interbank Offered Rate). Interest rate swap is traded with the maturities from 2 year through 30 year[2].

On the other hand, Japanese Government Bonds are the bonds issued by the Japanese Government, which is responsible for interest and principal payments. Interest is paid every six months, and principal payments are secured at maturity. Government bonds are available with various maturity periods. Coupon-bearing bonds, which feature semiannual interest payment and principal payment at maturity, have maturities of 2 year, 4 year, 5 year ,6 year, 10 year ,20 year and 30 year. Also offered are 3-year and 5-year discount government bonds

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1 The markets of interest rate swap and Japanese Government Bond are traded with enough liquidity. Corporate bond market in Japan lacks in liquidty.

2 Interest rate swap transactions over 12 year are sparse because the number of participants is small due to the credit risk.

that feature principal payment at maturity with no interest.

Differences between swap rates and government bond yields of the same maturity are referred to as swap spreads. If the swap and government bond markets are efficiently priced, swap spreads may reveal something about the perception of the systemic risk of the banking sector. The market for interest rate swaps has grown exponentially in the 1990's. According to a survey by BIS (Bank for International Settlements), the notional outstanding volume of transactions of Japanese yen interest rate derivatives amounted to 15,270 billions of US dollars at the end of June 2003.

In Japan before 1997, defaults by large companies were rare. But after 1997 defaults of Yamaichi Securities, one of the four largest securities firms in Japan, the Long Term Credit Bank of Japan and the Nippon Credit Bank, two of the three long term lending institutions in Japan, show that defaults of large companies are not rare any more. In this sense, credit risk in Japanese market increased and market participants got more conscious of credit risk than before.

When we turn to the international perspective under floating exchange rate, interest rates such as interest rate swap and government bonds differ across countries because the existing pressures on financial markets are absorbed by movements in the exchange rates or expected exchange rate development.

The international integration of financial markets has increased dramatically since the beginning of 1980's. The development and increase of new financial instruments such as currency and interest rate swaps have stimulated international financial integration by giving investors a wider range of choices than previously available in domestic markets. However the international integration of financial markets does not necessarily work to equalize interest rates among different countries.

## 2. Structure and Purpose

This thesis deals with empirical analysis on the long term interest rates in Japan. It can be divided into two parts. Chapters from 2 through 4 deal with the structure of long term interest markets in Japan. Chapters from 5 through 6 covers Japanese and US interest rates. Finally

Chapter 7 concludes.

**At Chapter 2**, I investigate the movement of swap spreads by analyzing Japanese Government Bond and interest rate swap market. I use a cointegration approach to analyze how swap spreads respond to interest rate movements. This approach has never been used in the analysis of swap spreads. Morris/Neal/Rolph (1998) use it to analyze the corporate bonds spread to US government securities.

This approach enables us to know not only if Japanese interest rate swap rates are in the long run equilibrium with Japanese Government Bond yields in the corresponding term, but also if a rise or a decline in Japanese Government Bond yield is associated with a rise or a decline in the swap spread. In addition to cointegration tests, Granger causality tests are conducted to check whether Japanese Interest Rate Swap rates affect Japanese Government Bond yields or vice versa.

**At Chapter 3,** I investigate the effects of TED spread and default risk on the swap spreads. For the variables of determinants, I use TED spread, credit risk and slope of the yield curve. First I use unit root test if the data contains unit root. Since all the variables are considered to be $I$ (1), I change all the data into first differenced data. Then the *VAR* model without error correction term is estimated for the analysis of variance decomposition and impulse response function.

**At Chapter 4,** a consideration is given to common trends underlying the term structure of Japanese yen yield curve up to 15 year. The purpose of this chapter is to investigate the existence of fourth trend by using the Johansen (1988) cointegration test and principal component analysis. We have known that the yield curve is usually driven by 3 common trends - level, slope and curvature. But especially in the Japanese yen market, it's believed that yield curve over 10 year has another driving force since the number of participants is limited and the motive for the transaction is very special.

**At Chapter 5**, I analyze the relationship of interest rates between Japan and US from October 1990 through August 2000 in the framework of uncovered interest rate parity (UIP) relationship. The whole sample period is divided into two based upon the monetary policy regimes. Thus investigating the interest rate linkages in different monetary policy regimes can be possible. First I use KPSS test to check if the data contain unit root. Then I use

Engle/Granger (1987) cointegration test. Finally I use Toda/Yamamoto (1995) Granger causality test to check if Japanese interest rates influenced US data or vice versa.

**At Chapter 6**, I compare the number of common trends that explain the dynamics of the term structure of interest rates by analyzing the interest rate swap yield curves in Japan and US. First I use unit root tests of ADF and PP to confirm if the data contain unit root. Next I use Johansen (1998) cointegration test to determine the area in the yield curve driven by a single common trend. This is done not only by using the entire yield curve but also by subtracting a series from a longer maturity.

**At Chapter 7**, I provide concluding remarks.

Chapter 2

# Japanese Interest Rates and Swap Spreads*

## 1. Introduction

An interest rate swap is an agreement between two parties to exchange cash flows in the future. In a typical agreement, two counterparties exchange streams of fixed and floating interest rate payments. Thus fixed interest rate payment can be transformed into floating payment and vice versa. The amount of each floating rate payment is based on a variable rate that has been mutually agreed upon by both counterparties. For example, the floating rate payments could be based on the 6 month LIBOR (London InterBank Offered Rate).

Differences between swap rates and government bond yields of the same maturity are referred to as swap spreads. If the swap and government bond markets are efficiently priced, swap spreads may reveal something about the perception of the systemic risk of the banking sector. The market for interest rate swaps has grown exponentially in the 1990's. According to a survey by BIS (Bank for International Settlements), the notional outstanding volume of transactions of Japanese yen interest rate derivatives amounted to 15,270 billions of US dollars at the end of June 2003[1].

In Japan before 1997 defaults by large companies were rare. But after 1997 , defaults of Yamaichi Securities, one of the four largest securities firms in Japan, the Long Term Credit Bank of Japan and the Nippon Credit Bank, two of the three long term lending institutions in Japan, show that defaults of large companies are not rare any more. In this sense, credit risk in

* This chapter is based on Ito (2005a).

1 Statistics are cited from OTC Derivatives Market Activity in the first half of 2003. At the end of June 1998, the notional outstanding volume of transactions of yen interest rate derivatives was 7,164 billions of US dollars. For details, see BIS (1998) and BIS (2003).

Japanese market increased and market participants got more conscious of credit risk than before.

As for the analysis of the interest rate swap spreads in US dollar markets, previous studies such as Duffie/Huang (1996), Brown/Harlow/Smith (1994), Cossin/Pirotte (1997), Lang/Litzenberger/Liu (1998), Lekkos/Milas (2001), Minton (1997), Sun/Sundaresan/Wang (1993) are cited. On the other hand, previous studies analyzing the Japanese yen interest rate swap are very limited to such as Hamano (1997), and Eom/Subrahmanyam/Uno (2000) .

Hamano (1997) focuses not on credit risk but on market factors such as TED spread and finds that swap spreads reflect TED spread and longer term swap spreads are less influenced by TED spread. On the other hand, Eom/Subrahmanyam/Uno (2000) focuses on the credit risk and concludes that yen swap spread is significantly related to proxies for the long term credit risk factor. They also find that swap spread is also negatively related to the level and slope of the term structure.

The approach of this chapter differs from previous studies mentioned above. In this chapter, I use a cointegration approach to analyze how swap spreads respond to interest rate movements. This approach has never been used in the analysis of swap spreads. Morris/Neal/Rolph (1998) use it to analyze the corporate bonds spread to US government securities.

This approach enables us to know not only if Japanese Yen Interest Rate Swap rates are in the long run equilibrium with Japanese Government Bond yields in the corresponding term, but also if a rise or a decline in Japanese Government Bond yield is associated with a rise or a decline in the swap spread.

In addition to cointegration tests, Granger causality tests are conducted to check whether Japanese Yen Interest Rate Swap rates ( $y_t$ ) affects Japanese Government Bond yields ( $jy_t$ ) or $jy_t$ affects $y_t$ or $y_t$ and $jy_t$ affect mutually.

This chapter covers the sample periods of almost 10 years from January 4,1994 through July 30,2003. After the Bank of Japan introduced zero interest rate policy in February 15 1999, interest rates market is considered to be structurally changed since there is a little room for the BOJ to change the uncollateralized overnight call rate as before. Especially after the BOJ introduced quantitative easing in March 2001, swap spreads of 7 year and 10 year sometimes became negative[2].

In this chapter, the entire sample period is divided in half at the time when the BOJ introduced zero interest rate policy in February,15 1999. Thus it's possible to know the characteristics of swap spreads movement in both sample periods.

The remainder of this chapter is as follows. Section 2 describes the data and provides summary statistics. Section 3 discusses the framework of the analysis. Section 4 presents the results. Section 6 concludes.

## 2. Data

### *2.1 Japanese Government Bond Yield*

Par rates of Japanese Government Bond are used[3]. These par rates for the maturities of 2 year, 3 year, 4 year, 5 year, 7 year and 10 year are calculated by cubic spline as mentioned in McCulloch (1975). Japanese Government Bond data of 10 year and 20 year are used from January 4, 1994 through July 30,2003[4].

### *2.2 Japanese Yen Interest Rate Swap Rate*

Japanese Yen Interest Rate Swap rates (2 year, 3 year, 4 year, 5 year, 7 year and 10 year) as of 3 pm at Tokyo time are used on a daily basis from January 4, 1994 through July 30,2003.

### *2.3 Sample Period*

The whole sample is divided into two sub periods. The first sub period, named Sample A, is from January 4,1994 through February 12,1999. Sample A covers the period just before the introduction of zero interest rate policy. Figure 2.1 shows the data in Sample A. The second sub period, named Sample B, is from February 15,1999 through July 30,2003 . Sample B covers the period of zero interest rate policy and quantitative easing. Figure 2.2 shows the data in Sample B.

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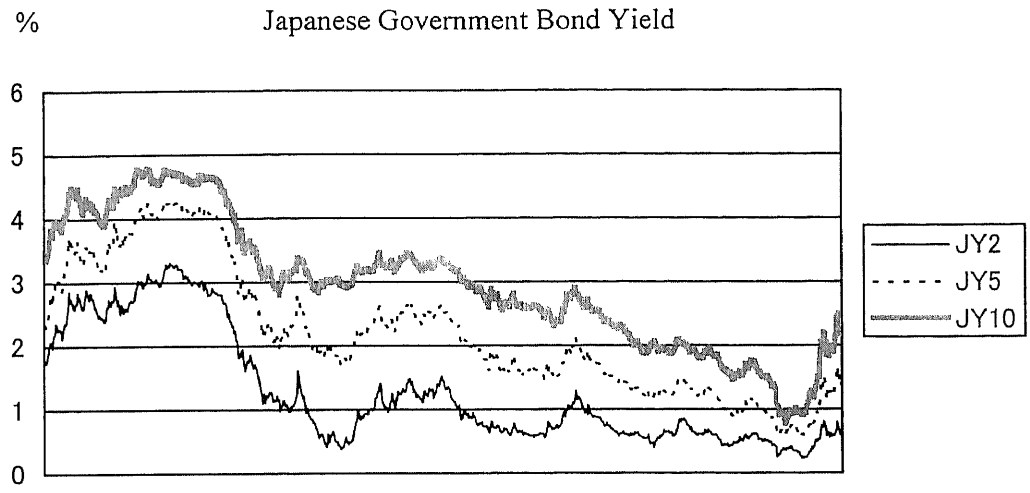
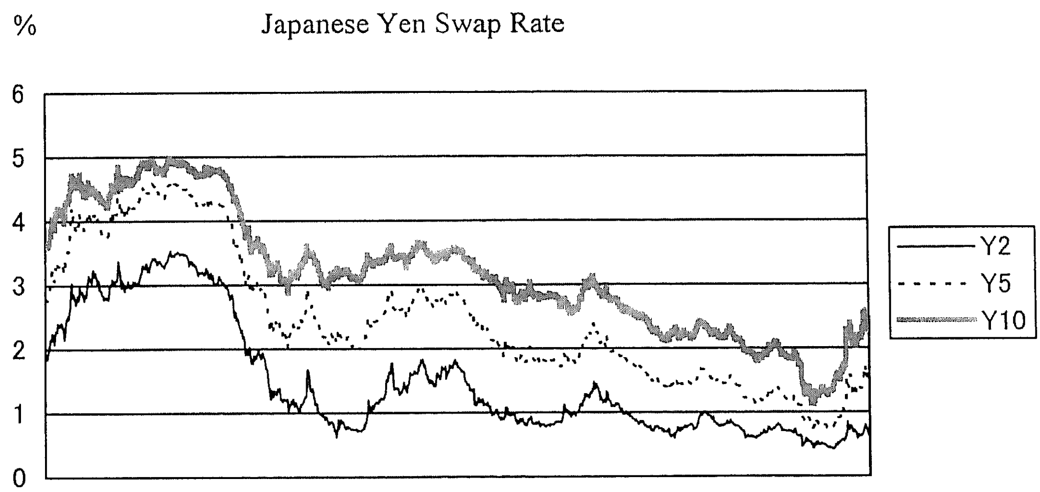
[2] Starting in March 21,2001, the BOJ changed their operating target from uncollateralized overnight call rate to current account balance held by financial institutions with the introduction of quantitative easing.

[3] Japanese Government Bonds are traded on a simple yield basis. Par rates are compounded yield.

[4] By the end of November in 1998, JGB closing prices listed on the Tokyo Stock Exchange are used. After December in 1999, JGB closing prices provided by a major security house is utilized.

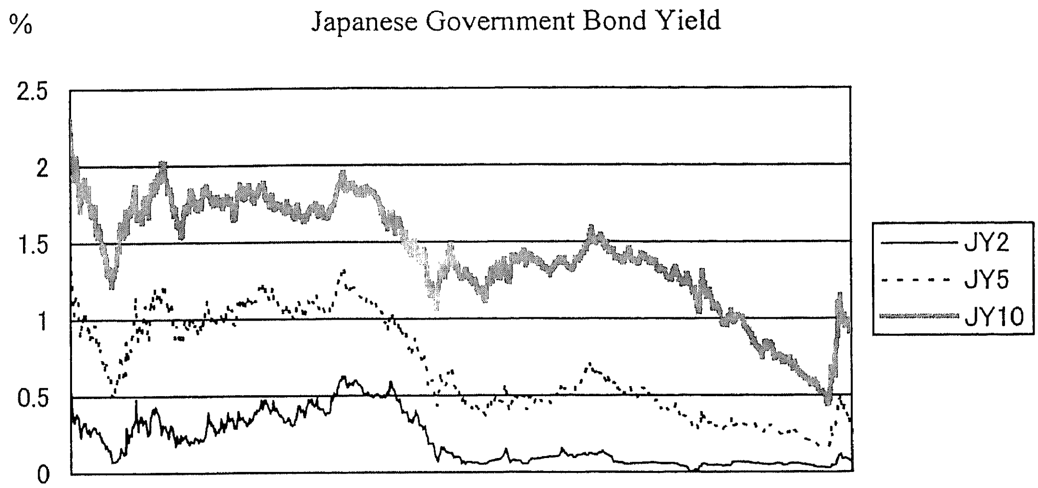
**Figure 2.1 Data in Sample A**

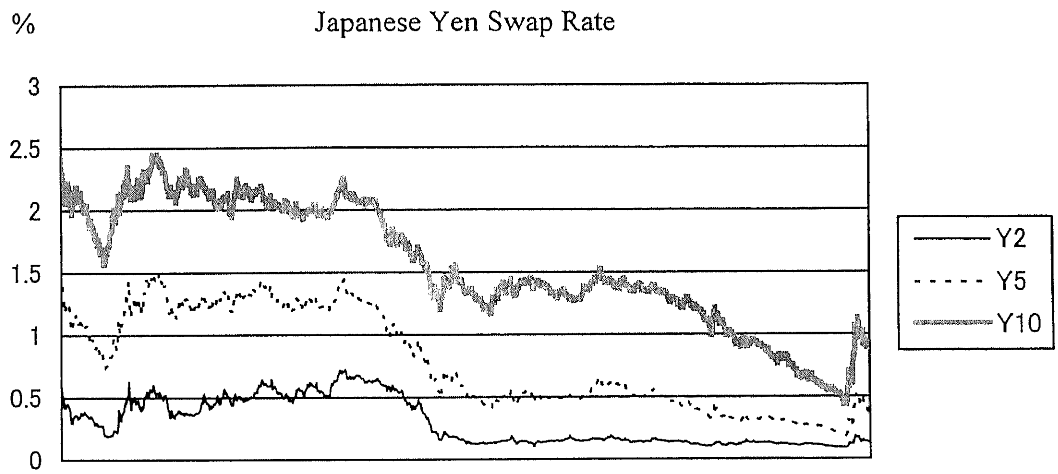



Daily data from January 4, 1994 through Feburary 12, 1999.

**Figure 2.2 Data in Sample B**




Daily data from Feburary 15, 1999 through July 30 2003.

## 3. Framework of Analysis

### *3.1 Unit Root Test*

Since the empirical analysis from mid-1980's through mid-1990's show that such data as interest rates, foreign exchange and stocks are non-stationary, it's necessary to check if the data used in this paper contain unit roots. The ADF (Augmented Dickey Fuller) test and the

PP (Phillips Perron) test are used[5][6]. Both the ADF and PP tests define null hypothesis as 'unit roots exist' and alternative hypothesis as 'unit roots don't exist'. Fuller (1976) provides the table for ADF and PP test.

*3.2 Cointegration Test*

A cointegration framework is presented to analyze the relation between swap rate and Japanese government bond yield. Generally OLS method is used to analyze the relationship among the variables. However when the non-stationary variables are included, ordinary hypothesis test tends to draw the mistaken results since the coefficient of determination and *t*-statistics do not follow the simple distribution.

Granger/Newbold (1974) called this problem 'Spurious Regression'. Phillips (1986) pointed out two points as to the analysis of non-stationary data — (1) the coefficient of determination tend not to measure the relationship among variables, (2)estimated equation with low Durbin-Watson ratio can possibly have a problem of spurious regression.

Non-stationary time series wander widely with their own short-run dynamics, but a linear combination of the series can sometimes be stationary so that they show co-movement with long-run dynamics. This is called as cointegration by Engle/Granger (1987). In the test of cointegration, the equation (2.1) is estimated by OLS to find if residual contains unit root.

$$y_t = \alpha + \beta\ jy_t + u_t \qquad (2.1)$$

$y_t$ = Japanese Yen Interest Rate Swap rate

$jy_t$ = Japanese Government Bond yield

When series $y_t$ and $jy_t$ are both non-stationary $I$ (1), they are called to be in a relationship of cointegration if their linear combination is stationary $I$ (0). The cointegration relationship between $y_t$ and $jy_t$ implies that Japanese Yen Interest Rate swap rate and Japanese Government Bond yield move together in the long run equilibrium. In testing a cointegration relationship, a pair of Japanese Yen Interest Rate swap rate and Japanese

[5] See Dickey/Fuller(1979) and Dickey/Fuller(1981).
[6] See Phillips/Perron(1988).

Government Bond yield in the same maturity is used.

In addition to testing if Japanese Yen Interest Rate swap rate and Japanese Government Bond yield are in a relationship of cointegration, cointegration vector (1,-1), $\beta$ in the equation (2.1), is checked with the method of dynamic OLS by Stock/Watson (1993). The equation (2.2) is used to test if $\beta$ = 1 can be rejected. $\Delta jy_{t-i}$ is lead and lag variables of Japanese Government Bond yield[7].

$$y_t = \alpha + \beta jy_t + \sum_{i=-p}^{p} b_i \Delta jy_{t-i} + u_t \qquad (2.2)$$

When $\beta$ is one, a 1 % increase in Japanese Government Bond yield will lead to a 1% increase in Japanese Yen Interest Rate swap rate. When $\beta$ is less than one, a 1 % increase in Japanese Government Bond yield will lead to a less than 1% increase in Japanese Yen Interest Rate swap rate. In other words, a rise (a decline) in Japanese Government Bond yield is associated with a decline (an increase) in the swap spread.

On the other hand, when β is more than one, a 1 % increase in Japanese Government Bond yields will lead to a more than 1% increase in Japanese Yen Interest Rate swap rate. In other words, an increase (a decrease) in Japanese Government Bond yield is associated with an increase (a decrease) in the swap spread.

### 3.3 *Granger Causality Test*

The Granger causality test checks whether Japanese Yen Interest Rate Swap rate ($y_t$) affects Japanese Government Bond yields ($jy_t$) or $jy_t$ affects $y_t$ or $y_t$ and $jy_t$ affect mutually in the time series model with regard to variables $y_t$ and $jy_t$. The original data are usually transformed into the change ratio to avoid a problem of spurious regression. But using these data is considered to cause an error. Toda/Yamamoto (1995) developed the Granger causality test in which non-stationary data are directly used.

According to their method, the null hypothesis $H_0$ is tested as for the influence from $y_t$ on $jy_t$ and for the influence from $jy_t$ on $y_t$. But trend term $t$ and $p$ + 1 (original lag plus one) are added for the estimation.

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[7] As for the number of lead and lag terms, 12 is used. In the case of 6 and 9, the results are the same.

$$y_t = \kappa_0 + \lambda t + \sum_{i=1}^{p+1} \alpha_i y_{t-i} + \sum_{i=1}^{p+1} \beta_i jy_{t-i} + u_t \quad (2.3)$$

$H_0 : \beta_1 = \beta_2 = \cdots \beta_p = 0$

$H_1$ : Either $\beta_i \neq 0 \quad (i = 1, 2, \cdots, p)$

$$jy_t = \varsigma_0 + \eta t + \sum_{i=1}^{p+1} \gamma_i jy_{t-i} + \sum_{i=1}^{p+1} \delta_i y_{t-i} + v_t \quad (2.4)$$

$H_0 : \delta_1 = \delta_2 = \cdots \delta_p = 0$

$H_1$ : Either $\gamma_i \neq 0 \quad (i = 1, 2, \cdots, p)$

$y_t$ = Japanese Yen Interest Rate Swap rate

$jy_t$ = Japanese Government Bond yield

The *F* test is conducted by estimating the equation (2.3) and equation (2.4) through OLS and summing the squared error. If the null hypothesis of $H_0$ in the equation (2.3) is rejected, $jy_t$ is considered to explain $y_t$. If the null hypothesis of $H_0$ in the equation (2.4) is rejected, $y_t$ is considered to explain $jy_t$.

**4. Result**

*4.1 Unit Root Test*

ADF and PP tests are conducted both for with time trend and without time trend. AIC standard is used for the determination of lag length in the ADF test. The critical point of 5% for the t type of $T = \infty$ is –2.86 (without trend) and –3.41 (with trend)[8].

The results are shown on Table 2.1 and Table 2.2. There is no denying that all the variables for both Sample A and Sample B are no stationary. Next, the data with first difference from original data are analyzed by ADF and PP test. It's possible to conclude that all the variables in both Sample A and Sample B are $I(1)$. The results are shown on the Table 2.3 and 2.4.

[8] Fuller (1976) provides table for critical values.

**Table 2.1 ADF Test Original Series**

Sample A

| Variable | Without Trend | With Trend |
|---|---|---|
| JY2 | -0.873 | -1.603 |
| JY3 | -0.879 | -1.832 |
| JY4 | -0.840 | -2.051 |
| JY5 | -0.716 | -2.365 |
| JY7 | -0.757 | -2.409 |
| JY10 | -0.680 | -1.970 |
| Y2 | -0.805 | -1.843 |
| Y3 | -0.793 | -2.063 |
| Y4 | -0.644 | -2.045 |
| Y5 | -0.640 | -2.242 |
| Y7 | -0.669 | -2.410 |
| Y10 | -0.777 | -2.547 |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(With Trend) .
JY=Japanese Government Bond Yield ,Y=Japanese Yen Interest Rate Swap Rate

Sample B

| Variable | Without Trend | With Trend |
|---|---|---|
| JY2 | -2.120 | -2.349 |
| JY3 | -2.295 | -2.366 |
| JY4 | -2.259 | -2.581 |
| JY5 | -2.188 | -2.745 |
| JY7 | -2.137 | -3.072 |
| JY10 | -2.217 | -2.807 |
| Y2 | -1.387 | -1.951 |
| Y3 | -1.398 | -1.945 |
| Y4 | -1.663 | -1.990 |
| Y5 | -1.595 | -2.107 |
| Y7 | -1.504 | -2.510 |
| Y10 | -1.395 | -2.799 |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(With Trend) .
JY=Japanese Government Bond Yield ,Y=Japanese Yen Interest Rate Swap Rate

## Table 2.2 PP Test Original Series

Sample A

| Variable | Without Trend | With Trend |
|---|---|---|
| JY2 | -0.725 | -1.624 |
| JY3 | -0.755 | -1.969 |
| JY4 | -0.737 | -2.322 |
| JY5 | -0.716 | -2.782 |
| JY7 | -0.758 | -2.908 |
| JY10 | -0.681 | -2.466 |
| Y2 | -0.667 | -1.988 |
| Y3 | -0.678 | -2.270 |
| Y4 | -0.645 | -2.495 |
| Y5 | -0.640 | -2.705 |
| Y7 | -0.669 | -2.962 |
| Y10 | -0.778 | -2.940 |

* indicates significance at the 5 % level.
5% critical values are -2.86 (Without Trend)-3.41(With Trend) .
JY=Japanese Government Bond Yield ,Y=Japanese Yen Interest Rate Swap Rate

Sample B

| Variable | Without Trend | With Trend |
|---|---|---|
| JY2 | -2.137 | -2.353 |
| JY3 | -2.297 | -2.645 |
| JY4 | -2.261 | -2.866 |
| JY5 | -2.190 | -3.028 |
| JY7 | -2.139 | -3.319 |
| JY10 | -2.219 | -3.191 |
| Y2 | -1.599 | -1.879 |
| Y3 | -1.647 | -1.931 |
| Y4 | -1.664 | -2.039 |
| Y5 | -1.597 | -2.135 |
| Y7 | -1.506 | -2.519 |
| Y10 | -1.396 | -2.800 |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(With Trend) .
JY=Japanese Government Bond Yield ,Y=Japanese Yen Interest Rate Swap Rate

**Table 2.3 ADF Test Series with First Difference**

Sample A

| Variable | Without Trend | With Trend |
|---|---|---|
| ⊿JY2 | -30.388* | -30.336* |
| ⊿JY3 | -31.396* | -31.374* |
| ⊿JY4 | -32.166* | -32.147* |
| ⊿JY5 | -32.949* | -33.002* |
| ⊿JY7 | -35.248* | -35.667* |
| ⊿JY10 | -32.878* | -33.147* |
| ⊿Y2 | -31.653* | -31.535* |
| ⊿Y3 | -32.126* | -32.058* |
| ⊿Y4 | -33.047* | -32.970* |
| ⊿Y5 | -33.619* | -33.553* |
| ⊿Y7 | -34.640* | -34.831* |
| ⊿Y10 | -27.092* | -27.335* |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(With Trend) .
JY=Japanese Government Bond Yield ,Y=Japanese Yen Interest Rate Swap Rate

Sample B

| Variable | Without Trend | With Trend |
|---|---|---|
| ⊿JY2 | -24.098* | -24.145* |
| ⊿JY3 | -24.241* | -24.513* |
| ⊿JY4 | -24.797* | -25.153* |
| ⊿JY5 | -25.148* | -25.442* |
| ⊿JY7 | -33.645* | -33.839* |
| ⊿JY10 | -32.878* | -32.828* |
| ⊿Y2 | -24.316* | -24.372* |
| ⊿Y3 | -23.920* | -24.099* |
| ⊿Y4 | -30.670* | -31.125* |
| ⊿Y5 | -31.596* | -32.043* |
| ⊿Y7 | -33.374* | -33.639* |
| ⊿Y10 | -33.037* | -33.087* |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(With Trend) .
JY=Japanese Government Bond Yield ,Y=Japanese Yen Interest Rate Swap Rate

**Table 2.4 PP Test Series with First Difference**

Sample A

| Variable | Without Trend | With Trend |
|---|---|---|
| ⊿JY2 | -30.412* | -31.424* |
| ⊿JY3 | -31.421* | -31.424* |
| ⊿JY4 | -32.191* | -32.197* |
| ⊿JY5 | -32.975* | -32.984* |
| ⊿JY7 | -32.276* | -35.280* |
| ⊿JY10 | -32.904* | -32.951* |
| ⊿Y2 | -31.678* | -31.684* |
| ⊿Y3 | -32.152* | -32.159* |
| ⊿Y4 | -33.073* | -33.082* |
| ⊿Y5 | -33.646* | -33.654* |
| ⊿Y7 | -34.667* | -34.673* |
| ⊿Y10 | -35.516* | -35.519* |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(With Trend) .
JY=Japanese Government Bond Yield ,Y=Japanese Yen Interest Rate Swap Rate

Sample B

| Variable | Without Trend | With Trend |
|---|---|---|
| ⊿JY2 | -30.026* | -30.029* |
| ⊿JY3 | -30.263* | -30.271* |
| ⊿JY4 | -31.250* | -31.257* |
| ⊿JY5 | -32.402* | -32.408* |
| ⊿JY7 | -33.676* | -33.680* |
| ⊿JY10 | -32.908* | -32.911* |
| ⊿Y2 | -28.966* | -28.966* |
| ⊿Y3 | -29.236* | -29.239* |
| ⊿Y4 | -30.698* | -30.703* |
| ⊿Y5 | -31.624* | -31.630* |
| ⊿Y7 | -33.405* | -33.408* |
| ⊿Y10 | -33.097* | -33.097* |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(With Trend) .
JY=Japanese Government Bond Yield ,Y=Japanese Yen Interest Rate Swap Rate

*4.2 Cointegration Test*

Cointegration test by Engle/Granger (1987) are conducted. For the critical values, numbers provided by MacKinnon (1991) are used. The results are shown on the Table 2.5. In Sample A, Japanese Yen Interest Rate Swap rates and Japanese Government Bond yield are in the relationship of cointegration from 2 year through 10 year.

On the other hand, in Sample B, Japanese Yen Interest Rate Swap rates are cointegrated with Japanese Government Bond from 2 year through 4 year. In the term structure from 5 year through 10 year, no cointegration relationship is found.

**Table 2.5 Cointegration Test**

Sample A

| Variables | Test Statistics |
|---|---|
| JY2-Y2 | -3.966* |
| JY3-Y3 | -3.568* |
| JY4-Y4 | -3.336** |
| JY5-Y5 | -3.317* |
| JY7-Y7 | -3.662* |
| JY10-Y10 | -5.192* |

Sample B

| Variables | Test Statistics |
|---|---|
| JY2-Y2 | -4.187* |
| JY3-Y3 | -4.092* |
| JY4-Y4 | -4.242* |
| JY5-Y5 | -2.254 |
| JY7-Y7 | -2.400 |
| JY10-Y10 | -2.726 |

Critical value is -3.338(5%) ,-3.046(10%) from MacKinnon(1991).

*,** indicates significant at the 5% and 10% level respectively.

JY=Japanese Government Bond Yield

Y=Japanese Yen Interest Rate Swap Rate

Next, dynamic OLS by Stock/Watson (1993) are used to check if $\beta$ indicated in the equation (2.1) is one. The results are shown on the table 2.6. In Sample A , $\beta = 1$ can't be rejected from 2 year through 7 year, which means that a 1 % increase in Japanese Government Bond yield lead to a 1 % increase in Japanese Yen Interest Rate swap rate. In 10 year $\beta$ is 0.952 ,which means that a 1 % increase in Japanese Government Bond yields lead to a less than 1 % increase (0.952) in Japanese Yen Interest Rate swap rate.

On the other hand, in Sample B $\beta$ is larger than one from 2 year through 10 year, which means that a 1 % increase in Japanese Government Bond yields lead to a more than 1 % increase in Japanese Yen Interest Rate swap rate.

**Table 2.6 Test on the Cointegrating Vector**

Sample A

| Variables | $\beta$ | Modified SE | Test Statistics |
|---|---|---|---|
| JY2-Y2 | 1.026 | 0.021 | 1.235* |
| JY3-Y3 | 1.055 | 0.032 | 1.732* |
| JY4-Y4 | 1.067 | 0.035 | 1.901* |
| JY5-Y5 | 1.046 | 0.030 | 1.546* |
| JY7-Y7 | 0.983 | 0.016 | 1.096* |
| JY10-Y10 | 0.952 | 0.013 | 3.692 |

Sample B

| Variables | $\beta$ | Modified SE | Test Statistics |
|---|---|---|---|
| JY2-Y2 | 1.146 | 0.069 | 2.123 |
| JY3-Y3 | 1.188 | 0.040 | 2.224 |
| JY4-Y4 | 1.215 | 0.077 | 2.792 |
| JY5-Y5 | 1.243 | 0.082 | 2.983 |
| JY7-Y7 | 1.281 | 0.107 | 2.633 |
| JY10-Y10 | 1.386 | 0.155 | 2.498 |

Dynamic OLS by Stcok/Watson(1993) is used to test if β is one.

* indicates test statistics is smaller than 5 % critical value(1.96) and $\beta = 1$ can't be rejected.

JY=Japanese Government Bond Yield

Y=Japanese Yen Interest Rate Swap Rate

*4.3 Granger Causality Test*

Granger causality test is conducted by using the method developed by Toda/Yamamoto (1995). The results are shown on the Table 2.7 and 2.8. In Sample A except for 5 year, Japanese Yen Interest Rate swap rate and Japanese Government Bond yield affected mutually. In 5 year the causality from Japanese Yen Interest Rate swap rate to Japanese Government Bond yield isn't observed.

**Table 2.7 Granger Causality -Sample A**

From JY on Y

| Variables | Lag | Test Statistics |
|---|---|---|
| JY2 → Y2 | 13 | 2.173* |
| JY3 → Y3 | 7 | 2.463* |
| JY4 → Y4 | 11 | 2.202* |
| JY5 → Y5 | 4 | 2.680* |
| JY7 → Y7 | 9 | 3.684* |
| JY10 → Y10 | 10 | 1.964* |

From Y on JY

| Variables | Lag | Test Statistics |
|---|---|---|
| Y2 → JY2 | 13 | 1.868* |
| Y3 → JY3 | 7 | 2.270* |
| Y4 → JY4 | 11 | 2.048* |
| Y5 → JY5 | 4 | 1.566 |
| Y7 → JY7 | 9 | 2.365* |
| Y10 → JY10 | 10 | 2.035* |

* indicates significant at the 5% level.
Original lag is chosen by AIC standard.
The method by Toda /Yamamoto(1995) is used.
JY=Japanese Government Bond Yield ,Y=Japanese Yen Interest Rate Swap Rate

In Sample B except for 10 year, Japanese Yen Interest Rate swap rate and Japanese Government Bond yield affected mutually. In 10 year no causality is found between Japanese Yen Interest Rate swap rate and Japanese Government Bond yield.

As for the comparison of causality impacts made between Sample A and Sample B, in Sample A Japanese Government Bond yield is stronger than Japanese Yen Interest Rate Swap rate, but in Sample B Japanese Yen Interest Rate swap rate is stronger than Japanese

Government Bond yield.

**Table 2.10 Granger Causality -Sample B**

From JY on Y

| Variables | Lag | Test Statistics |
|---|---|---|
| JY2 → Y2 | 12 | 2.282* |
| JY3 → Y3 | 11 | 3.664* |
| JY4 → Y4 | 9 | 5.704* |
| JY5 → Y5 | 5 | 7.297* |
| JY7 → Y7 | 7 | 4.704* |
| JY10 → Y10 | 10 | 1.188 |

From Y on JY

| Variables | Lag | Test Statistics |
|---|---|---|
| Y2 → JY2 | 12 | 2.920* |
| Y3 → JY3 | 11 | 3.971* |
| Y4 → JY4 | 9 | 5.804* |
| Y5 → JY5 | 5 | 7.379* |
| Y7 → JY7 | 7 | 5.560* |
| Y10 → JY10 | 10 | 1.566 |

* indicates significant at the 5% level.
Original lag is chosen by AIC standard.
The method by Toda /Yamamoto(1995) is used.
JY=Japanese Government Bond Yield ,Y=Japanese Yen Interest Rate Swap Rate

## 5. Concluding Remarks

In this chapter, first Engle/Granger cointegration test is used if Japanese Yen Interest Rate Swap rates are in the long run equilibrium with Japanese Government Bond yields in the corresponding term. Next, coinegration vector (1,-1) is checked if a rise or a decline in Japanese Government Bond yield is associated with a rise or a decline in the swap spread. Finally Granger causality tests are conducted to check whether Japanese Yen Interest Rate Swap rate ($y_t$) affects Japanese Government Bond yields ($jy_t$) or $jy_t$ affects $y_t$ or $y_t$ and $jy_t$ affect mutually.

First the results of cointegration test are summarized. In Sample A, Japanese Yen Interest

Rate Swap rates are in the long run equilibrium with Japanese Government Bond yield in the structure from 2 year through 10 year. On the other hand, in Sample B, Japanese Yen Interest Rate Swap rates are in the long run equilibrium with Japanese Government Bond yield only in the structure from 2 year through 4 year. Thus it's considered that market segmentation in the structure from 5 year through 10 year between Japanese Government Bond and Japanese Yen Interest Rate Swap became apparent in sample B.

Next, the results of cointegration vector tests are summarized. In Sample A, a 1 % increase (a decrease) in Japanese Government Bond yield lead to a 1 % increase (decrease) in Japanese Yen Interest Rate swap rate in the structure of 2 year, 3 year, 4 year, 5 year , and 7 year. A 1 % increase in Japanese Government Bond yield lead to a less than 1 % increase in Japanese Yen Interest Rate swap rate in 10 year. In other words, a rise (a decline) in Japanese Government Bond yield is associated with a decline (a rise) in the swap spread in 10 year.

On the other hand, in Sample B, a 1 % increase in Japanese Government Bond yields lead to a more than 1 % increase in Japanese Yen Interest Rate swap rate in the structure of 2 year, 3 year, 4 year, 5 year , 7 year and 10 year. In other words, a rise (a decline) in Japanese Government Bond yield is associated with a rise (a decline) in the swap spread.

Finally the results of Granger causality tests are summarized. In Sample A except for 5 year, Japanese Yen Interest Rate swap rate and Japanese Government Bond yield affected mutually. In 5 year the causality from Japanese Yen Interest Rate swap rate to Japanese Government Bond yield isn't observed.

In Sample B except for 10 year, Japanese Yen Interest Rate swap rate and Japanese Government Bond yield affected mutually. In 10 year no causality is found between Japanese Yen Interest Rate swap rate and Japanese Government Bond yield.

As for the comparison of causality impacts made between Sample A and Sample B, in Sample A Japanese Government Bond yield is stronger than Japanese Yen Interest Rate swap rate, but in Sample B Japanese Yen Interest Rate swap rate is stronger than Japanese Government Bond yield. Thus it's considered that in Sample A Japanese Government Bond market possibly lead interest rate swap market, but in sample B interest rate swap market lead Japanese Government Bond market.

There seems to be two factors to support the phenomenon that market segmentation was observed and interest rate swap market lead Japanese Government Bond market in Sample B -

(1) Japanese banks activated receiving in swap to increase profit[9], (2) In the phase of interest rate increase, Japanese banks tended to unwind the receive position of interest rate swaps in the quicker timing than before February 1999.

As for the remaining topics, (1) Analyzing the term structure of swap spreads, (2) Analyzing the determinants of swap spreads by using such data as TED spreads, yield spreads and corporate bond spreads—these two points are pointed out.

[9] The extension of abolishing macro hedge accounting for another year promoted receiving activity. It was abolished on March 31,2003.

# Chapter 3

## Determinants of Japanese Interest Rate Swap Spreads*

### 1. Introduction

An interest rate swap is an agreement between two parties to exchange cash flows in the future. In a typical agreement, two counterparties exchange streams of fixed and floating interest rate payments. Thus fixed interest rate payment can be transformed into floating payment and vice versa. The amount of each floating rate payment is based on a variable rate base that has been mutually agreed upon by both counterparties. For example, the floating rate payments could be based on the 6 month LIBOR (London Interbank Offered Rate).

Differences between swap rate and government bond yields of the same maturity are referred to as swap spreads. If the swap and government bond markets are priced efficiently, swap spreads may reveal something about the perception of the systemic risk of the banking sector. The market for interest rate swaps has grown exponentially in the 1990's. According to a survey by BIS (Bank for International Settlements), the notional outstanding volume of transactions of yen interest rate derivatives amounted to 15,270 billions of US dollars[1].

In Japan before 1997 defaults by large companies were rare. But after 1997, defaults of Yamaichi Securities, one of the four largest securities firms in Japan, the Long Term Credit Bank of Japan and the Nippon Credit Bank of Japan, two of the three long term lending institutions in Japan show that defaults of large companies are not rare any more.

As for the analysis of the interest rate swap spread in US dollar markets, previous studies

* This chapter is based on Ito (2005b).

1 Statistics are cited from OTC Derivatives Market Activity in the first half of 2003. At the end of June 1998, the notional outstanding volume of transactions of yen interest rate derivatives was 7,164 billions of US dollars.

such as Duffie/Huang (1996), Brown/Harlow/Smith (1994), Cossin/Pirotte (1997), Lang/Litzenberger/Liu (1998), Lekkos/Milas (2001), Minton (1997), Sun/Sundaresan/Wang (1993) are cited. On the other hand, previous studies analyzing the Japanese yen interest rate swap are very limited to such as Hamano (1997), and Eom/Subrahmanyam/Uno (2000) .

Hamano (1997) focuses not on credit risk, but on market factors such as TED spread and finds that swap spreads reflect TED spread and longer term swap spreads are less influenced by TED spread. On the other hand, Eom/Subrahmanyam/Uno (2000) focuses on the credit risk and concludes that yen swap spread is significantly related to proxies for the long term credit risk factor.

The purpose of this chapter is to investigate the effects of TED spread and default risk on the swap spreads. This chapter covers the sample periods of almost 10 years from January 1994. After the Bank of Japan introduced zero interest rate policy in February 1999, interest rates market is considered to be structurally changed since there is a little room for the BOJ to change the uncollateralized overnight call rate as before. Especially after the BOJ introduced quantitative easing in March 2001, swap spreads of 7 year and 10 year sometimes became negative[2].

In this chapter the entire sample period is divided in half at the time when the BOJ introduced zero interest rate policy in February 1999. Thus it's possible to know the characteristics of swap spreads movement in both sample periods.

The remainder of this chapter is as follows. Section 2 discusses the determinants of swap spread. Section 3 describes the data and provides summary statistics. Section 4 discusses the framework of the analysis. Section 5 presents the results. Section 6 concludes.

## 2. Determinants of Swap Spread

### *2.1 TED Spread*

Here the difference between LIBOR (London Interbank Offered Rate) and short-term government bill is defined as TED spread. Swap rate and TED spread are in the relationship as described in the equation (3.1).

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[2] Starting in March 21,2001, the BOJ changed their operating target from unsecured uncollateralized overnight call rate to current account balance held by financial institutions with the introduction of quantitative easing.

$$\frac{f_1}{(1+R_1)}+\frac{E(f_2)}{(1+R_2)^2}+\cdots+\frac{E(f_n)}{(1+R_n)^n}=\frac{C}{(1+R_1)}+\frac{C}{(1+R_2)^2}+\cdots+\frac{C}{(1+R_n)^n}$$

(3.1)

$E(\,)$ is an operator indicating expectation, $f_n$ is a floating rate, $R_n$ is a spot rate of government bond, $C$ is a fixed rate.

In the equation (3.1), floating rate and fixed rate are swapped on the condition that there is no credit risk in swap transaction. Present values of both floating rate and fixed rate get equal. Here exchange of cash flows is presupposed to happen once a year.

In the case of swap transaction, floating rate is LIBOR which is usually higher than short-term government bill, resulting in higher fixed rate. The equation (3.1) is redefined as the equation (3.2).

$$\frac{f_1+TED_1}{(1+R_1)}+\frac{E(f_2+TED_2)}{(1+R_2)^2}+\cdots+\frac{E(f_n+TED_n)}{(1+R_n)^n}=\frac{C+SS}{(1+R_1)}+\frac{C+SS}{(1+R_2)^2}+\cdots+\frac{C+SS}{(1+R_n)^n}$$

(3.2)

$TED_n$ is TED spread, SS is swap spread.

Equation (3.2) can be rewritten into equation (3.3) to show that swap spread is a weighted average of present and future TED spreads.

$$\frac{TED_1}{(1+R_1)}+\frac{E(TED_2)}{(1+R_2)^2}+\cdots+\frac{E(TED_n)}{(1+R_n)^n}=SS\left(\frac{1}{(1+R_1)}+\frac{1}{(1+R_2)^2}+\cdots+\frac{1}{(1+R_n)^n}\right)$$

(3.3)

Hamano (1997), Minton (1997), Brown/Harlow/Smith (1994), Eom /Subrahmanyam /Uno (2000), Lekkos/Milas (2001) checked the influence of TED on swap spread. Hamano (1997) found that Japanese yen swap spreads are influenced by TED and their influences get weaker as the maturities of spread get longer from 1992 through 1996. On the other hand, Eom/

Subrahmanyam/Uno (2000) found that the influences of TED on Japanese swap spreads get stronger as the maturities of spread get longer from 1990 through 1996.

*2.2 Default Risk*

According to Minton (1997), Brown/Harlow/Smith (1994), Eom/ Subrahmanyam/Uno (2000), Lekkos/Milas (2001), the default risk in swaps can be proxied with the information from the corporate bond market. Any such proxy is imperfect as mentioned in the previous studies because the characteristics of the swap and corporate bond are not totally comparable.

Nevertheless, since swap default spreads are unobservable, the difference between the yield on a portfolio of corporate bonds and the yield on an equivalent government bond can be used as a proxy for the default premium.

Longstaff/Schwartz (1995) found that corporate bond spreads are negatively correlated with the slope of the term structure with the development of a two-factor model for corporate bond spreads. The significant influence of the slope on the swap spread is also checked since default risk of swap can be proxied by corporate bond. Eom/Subrahmanyam/Uno (2000) found that swap spreads are negatively related to the slope of the term structure.

## 3. Data

*3.1 Japanese Yen Swap Spreads*

Japanese yen interest swap rate minus Japanese government bond yield is defined as swap spread. As for Japanese government bond yield, par rates of Japanese Government Bond are used[3]. These par rates for the maturities of 2 year, 3 year, 4 year, 5 year, 7 year and 10 year are calculated by cubic spline as mentioned in McCulloch (1975). Japanese Government Bond data of 10 year and 20 year are used from January, 1994 through July,2003[4]. The monthly averages are calculated from daily data.

As for the Japanese interest rate swap market, rates of 2 year, 3 year, 4 year, 5 year, 7 year and 10 year as of 3 pm at Tokyo time are used on a daily basis from January 4, 1994 through July 30,2003. The monthly averages are calculated from daily data.

---

[3] Japanese Government Bonds are traded on a simple yield basis. Par rates are compounded yield.

[4] By the end of November in 1998, JGB closing prices listed on the Tokyo Stock Exchange are used. After December in 1998, JGB closing prices provided by a major security house is utilized.

*3.2 Determinants of the Swap Spread*

As for the TED spread, monthly averaged 6 month LIBOR minus 6 month TB (Treasury Bill) YTM on a day of auction are used[5]. As for the default risk (CBS), monthly averaged corporate bonds (12 years) minus 12 year Japanese Government bond yield are used[6]. As for the slope (SLOPE), corresponding maturity of monthly averaged swap rates minus 6 month TB yields are used.

*3.3 Sample Period*

The whole sample is divided into two sub periods. The first sub period, named Sample A, is from January,1994 through January,1999. Sample A covers the period just before the introduction of zero interest rate policy. The second sub period, named Sample B, is from February 1999 through July,2003. Sample B covers the period of zero interest rate policy and quantitative easing.

*3.4 Summary Statistics*

Table 3.1 provides the sample statistics of swap spreads, TED spread (TED), corporate bond spread (CBS) and slope (SLOPE) in sample period A. Table 3.2 provides swap spreads, TED spread, corporate bond spread and slope in sample period B.

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[5] Since LIBOR is 360 day basis, LIBOR is transformed into 365 day basis.

[6] Corporate bonds with maturities of 12 year are chosen from all ratings by JSDA (Japanese Securities Dealers Association).

**Table 3.1 Summary Statistics of Data in Sample A**

| Variable | Mean | Standard Deviation | Kurtosis | Skewness |
|---|---|---|---|---|
| SY2 | 0.213 | 0.082 | -0.331 | 0.187 |
| SY3 | 0.278 | 0.114 | 0.424 | 0.675 |
| SY4 | 0.279 | 0.114 | 2.374 | 1.299 |
| SY5 | 0.252 | 0.107 | 2.749 | 1.452 |
| SY7 | 0.206 | 0.063 | 0.910 | 0.535 |
| SY10 | 0.218 | 0.077 | -0.033 | 0.533 |
| TED | 0.169 | 0.109 | 2.446 | 0.043 |
| CBS | 0.519 | 0.262 | 0.172 | 1.109 |
| SLOPE2 | 0.363 | 0.215 | -0.790 | 0.353 |
| SLOPE3 | 0.661 | 0.296 | -0.868 | 0.303 |
| SLOPE4 | 0.987 | 0.375 | -1.060 | 0.058 |
| SLOPE5 | 1.280 | 0.438 | -1.090 | -0.201 |
| SLOPE7 | 1.742 | 0.538 | -0.890 | -0.433 |
| SLOPE10 | 2.037 | 0.536 | -0.468 | -0.577 |

Monthly data from January, 1994 through January, 1999.

SY = Japanese Yen Swap Spread ( Interest Rate Swap rate — Japanese Government Bond)

TED= TED Spread ( 6MLIBOR —6MTB)

CBS= Corporate Bond Spread (12Year Corporate Bond — 12Year Japanese Government Bond)

SLOPE2=2 year swap rate —6MTB

SLOPE3=3year swap rate —6MTB

SLOPE4=4 year swap rate —6MTB

SLOPE5=5 year swap rate —6MTB

SLOPE7=7 year swap rate —6MTB

SLOPE10=10 year swap rate —6MTB

**Table 3.2 Summary Statistics of Data in Sample B**

| Variable | Mean | Standard Deviation | Kurtosis | Skewness |
|---|---|---|---|---|
| SY2 | 0.093 | 0.043 | -0.423 | 0.893 |
| SY3 | 0.088 | 0.064 | -0.483 | 0.791 |
| SY4 | 0.084 | 0.080 | -0.730 | 0.693 |
| SY5 | 0.095 | 0.100 | -0.790 | 0.710 |
| SY7 | 0.102 | 0.132 | -0.890 | 0.466 |
| SY10 | 0.135 | 0.178 | -1.197 | 0.497 |
| TED | 0.093 | 0.049 | 4.939 | 2.047 |
| CBS | 0.430 | 0.230 | 6.971 | 2.460 |
| SLOPE2 | 0.119 | 0.094 | -0.170 | 0.847 |
| SLOPE3 | 0.264 | 0.153 | -0.722 | 0.741 |
| SLOPE4 | 0.434 | 0.213 | -1.038 | 0.529 |
| SLOPE5 | 0.600 | 0.262 | -1.148 | 0.323 |
| SLOPE7 | 0.942 | 0.323 | -0.978 | -0.013 |
| SLOPE10 | 1.326 | 0.317 | 0.081 | -0.644 |

Monthly data from February, 1999 through July, 2004.

SY = Japanese Yen Swap Spread ( Interest Rate Swap rate − Japanese Government Bond)

TED= TED Spread ( 6MLIBOR −6MTB)

CBS= Corporate Bond Spread (12Year Corporate Bond − 12Year Japanese Government Bond)

SLOPE2=2 year swap rate −6MTB

SLOPE3=3year swap rate −6MTB

SLOPE4=4 year swap rate −6MTB

SLOPE5=5 year swap rate −6MTB

SLOPE7=7 year swap rate −6MTB

SLOPE10=10 year swap rate −6MTB

## 4. Framework of Analysis

### *4.1 Unit Root Test*

Since the empirical analysis from mid-1980's through mid-1990's show that such data as interest rates, foreign exchange and stocks are non-stationary, it's necessary to check if the data used in this chapter contain unit roots. The ADF (Augmented Dickey Fuller) test and KPSS (Kwiatowski/ Phillips/ Schmidt/ Shin) test are used[7]. The ADF defines null hypothesis as 'unit roots exist' and alternative hypothesis as 'unit roots don't exist'. Fuller (1976)

[7] See Dickey/Fuller(1979) and Dickey/Fuller(1981).

provides the table for ADF test. On the other hand, KPSS test defines null hypothesis as 'unit roots don't exist' and alternative hypothesis as 'unit roots exist'[8].

*4.2 Cointegration Test of Johansen*

Here cointegraion is tested to know if there is a long-run relationship among the variables- swap spread, TED spread, corporate bond spread, and slope. There are mainly two types of cointegration test- (1)Engle/Granger(1987), (2) Johansen(1988). The most difficult part of cointegration analysis starting from *VAR* model is how to decide the number of cointegration relationship. When 3 variables are analyzed, the number of cointegration relationship may be 1 or 2. Engle/Granger can't cope with this problem, but Johansen is able to decide the number of cointegration relationship and to get a *MLE* of unknown parameters.

Johansen suggested the analysis with the *k* order *VAR* mode. Here *VAR* model is presented with k order against vector $X_t$ with p variables.

$$X_t = \Pi_1 X_{t-1} + \ldots + \Pi_k X_{t-k} + \lambda + u_t \qquad (3.4)$$

All the p elements of $X_t$ is considered to be $I$ (1) variables. $u_t$ is an error term with zero mean. λ is a constant term. The equation (3.4) is expressed by using a first difference.

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi \Delta X_{t-k} + \lambda + u_t \qquad (3.5)$$

Here

$$\Gamma_i = -I + \Pi_1 + \ldots + \Pi_i, \quad (i = 1, \ldots, k-1)$$
$$\Pi = -I + \Pi_1 + \ldots + \Pi_k$$

Under the assumption that all the elements of $X_t$ are $I$ (1), $\Pi X_{t-1}$ needs to be $I$ (0). This means the rank of matrix $\Pi$ satisfies $0 \le rank(\Pi) < p$. When the elements of $X_t$ are in the relationship of cointegration, $0 < rank(\Pi) < p$ is established. Thus matrix $\Pi$ can be expressed as $\Pi = \alpha\beta'$ by using the $\alpha$ and $\beta$ of $p$ x $r$ matrix $\Pi$. Finally the equation (3.5) can be expressed as follows.

---

[8] See Kwiatowski/Phillips/Scmidt/Shin (1992).

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \alpha\beta' \Delta X_{t-k} + \lambda + u_t \qquad (3.6)$$

$\beta'$ is a cointegration vector and $\beta' X_{t-k}$ is an error correction term. The Johansen methodology tests $r$ consecutively by comparing the likelihood ratio of model estimated to have $r$ number of cointegration under null hypothesis with the likelihood ratio of model under the alternative hypothesis. The alternative hypothesis has two types mentioned below.

(1) Type not considering the number of cointegration (trace test).

(2) Type increasing the number of cointegration by one to ask for the redundancy of the model (maximum eigenvalue test).

Johansen methodology is used in this paper since the number of dada series is 6. Osterwald-Lenum (1992) provides the table for maximal eigen value test and trace test.

*4.3 VAR (Vector AutoRegression) Analysis*

When the data is found to have unit roots, the first differenced data are used to estimate *VAR* (Vector AutoRegression) model as in equation (3.7). As for the length of lags, AIC standard is used.

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \lambda + u_t \qquad (3.7)$$

When cointegration relation is found, *VAR* is estimated with error correction terms. First, variance decomposition is checked. The ordering of the variables is TED, CBS and SLOPE. I estimate this four variable system and then compute a 20- day-ahead forecast error variance decomposition.

Next, impulse response function is investigated. A *VAR* model can be written in vector *MA* ($\infty$) form and the coefficients are known as impulse response functions (IRF). They identify the response of a variable to one standard deviation increase in the innovation of all the endogenous variables.

## 5. Result

*5.1 Unit Root Test*

ADF and KPSS Tests are conducted both for with time trend and without time trend. AIC standard is used for the determination of lag length in the ADF Test. The results are shown on Table 3.3 and Table 3.4. There is no denying that all the variables for both Sample A and Sample B are non- stationary.

Next, the data with first difference from original data are analyzed by ADF and KPSS tests. It's possible to conclude that all the variables both Sample A and Sample B are $I$ (1). The results are shown on the Table 3.5 and 3.6.

*5.2 Cointegration Test*

Johansen cointegration test is conducted for three variables such as TED,CBS and SLOPE. The results are shown on the Table 3.7. No cointegration relation is found by maximal eigen value tests in both Sample A and Sample B. In Sample A the trace tests of 2 year, 3 year and 4 year spreads show that there are cointegration relationships. In Sample B the trace test of 2 year shows the relationship of cointegration.

Since maximal eigen value tests indicate no sign of cointegration, Engle/Granger cointegration test is conducted to find that there is no cointegration relationship in the spreads of 2 year, 3 year and 4 year in Sample A and 2 year in Sample B.

**Table 3.3 ADF Test - Original Series**

Sample A

| Variable | Without Trend | With Trend |
|---|---|---|
| SY2 | -2.289 | -1.913 |
| SY3 | -1.388 | -1.426 |
| SY4 | -1.245 | -1.883 |
| SY5 | -1.696 | -2.040 |
| SY7 | -2.267 | -1.985 |
| SY10 | -1.385 | -3.210 |
| TED | -5.301* | -5.866* |
| CBS | -1.863 | -3.264 |
| SLOPE2 | -3.276 | -3.557* |
| SLOPE3 | -2.734 | -3.188 |
| SLOPE4 | -2.224 | -2.596 |
| SLOPE5 | -1.907 | -2.430 |
| SLOPE7 | -1.432 | -2.114 |
| SLOPE10 | -1.303 | -1.919 |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(With Trend) .

Sample B

| Variable | Without Trend | With Trend |
|---|---|---|
| SY2 | -1.657 | -1.235 |
| SY3 | -1.141 | -1.696 |
| SY4 | -0.892 | -1.296 |
| SY5 | -0.780 | -1.083 |
| SY7 | -0.691 | -0.583 |
| SY10 | -0.583 | -0.451 |
| TED | -2.999 | -2.176 |
| CBS | -2.236 | -2.276 |
| SLOPE2 | -2.577 | -2.715 |
| SLOPE3 | -2.125 | -1.782 |
| SLOPE4 | -1.903 | -1.455 |
| SLOPE5 | -1.782 | -1.428 |
| SLOPE7 | -2.195 | -3.978* |
| SLOPE10 | -2.292 | -4.390* |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(With Trend) .

**Table 3.4 KPSS Test -Original Series**

Sample A

| | Lag=0 | | Lag=6 | |
|---|---|---|---|---|
| Variable | $\eta_\mu$ | $\eta_\tau$ | $\eta_\mu$ | $\eta_\tau$ |
| SY2 | 0.663* | 0.274* | 0.189 | 0.084 |
| SY3 | 1.907* | 0.277* | 0.429 | 0.075 |
| SY4 | 2.619* | 0.248* | 0.573* | 0.068 |
| SY5 | 1.669* | 0.458* | 0.387 | 0.102 |
| SY7 | 0.928* | 0.493* | 0.219 | 0.127 |
| SY10 | 3.086* | 0.786* | 0.556* | 0.176* |
| TED | 1.113* | 0.198* | 0.472* | 0.125 |
| CBS | 2.544* | 0.567* | 0.584* | 0.192* |
| SLOPE2 | 1.639* | 0.198* | 0.411 | 0.068 |
| SLOPE3 | 2.250* | 0.3340 | 0.488* | 0.102 |
| SLOPE4 | 2.666* | 0.585* | 0.520* | 0.151 |
| SLOPE5 | 3.103* | 0.849* | 0.560* | 0.195* |
| SLOPE7 | 3.564* | 1.034* | 0.609* | 0.215* |
| SLOPE10 | 3.102* | 0.525* | 1.218* | 0.227* |

Sample B

| | Lag=0 | | Lag=6 | |
|---|---|---|---|---|
| Variable | $\eta_\mu$ | $\eta_\tau$ | $\eta_\mu$ | $\eta_\tau$ |
| SY2 | 2.660* | 0.439* | 0.481* | 0.1040 |
| SY3 | 3.449* | 0.557* | 0.582* | 0.1260 |
| SY4 | 3.923* | 0.678* | 0.636* | 0.147* |
| SY5 | 4.177* | 0.713* | 0.661* | 0.151* |
| SY7 | 4.606* | 0.571* | 0.729* | 0.136 |
| SY10 | 4.807* | 0.555* | 0.753* | 0.135 |
| TED | 0.885* | 0.0640 | 0.449 | 0.056 |
| CBS | 1.492* | 0.275* | 0.520* | 0.142 |
| SLOPE2 | 2.753* | 0.259* | 0.573* | 0.083 |
| SLOPE3 | 3.414* | 0.275* | 0.847* | 0.081 |
| SLOPE4 | 3.891* | 0.257* | 0.698* | 0.075 |
| SLOPE5 | 4.177* | 0.225* | 0.733* | 0.068 |
| SLOPE7 | 4.077* | 0.194* | 0.722* | 0.056 |
| SLOPE10 | 3.602* | 0.276* | 0.677* | 0.074 |

* indicates significance at the 5 % level.

5% critical values are 0.463 (trend stationary) 、 0.146(level stationary) .

$\eta_\mu$ indicates trend stationarity. $\eta_\tau$ indicates level stationarity.

**Table 3.5 ADF Test - Series with First Difference**

Sample A

| Variable | Without Trend | With Trend |
|---|---|---|
| ⊿SY2 | -5.470* | -5.997* |
| ⊿SY3 | -6.695* | -6.684* |
| ⊿SY4 | -6.633* | -7.320* |
| ⊿SY5 | -6.534* | -6.465* |
| ⊿SY7 | -7.090* | -7.367* |
| ⊿SY10 | -6.512* | -5.760* |
| ⊿TED | -5.351* | -5.411* |
| ⊿CBS | -5.912* | -5.830* |
| ⊿SLOPE2 | -10.238* | -9.432* |
| ⊿SLOPE3 | -9.525* | -9.032* |
| ⊿SLOPE4 | -9.022* | -8.549* |
| ⊿SLOPE5 | -8.920* | -8.537* |
| ⊿SLOPE7 | -8.432* | -7.832* |
| ⊿SLOPE10 | -7.939* | -7.219* |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(with Trend) .

Sample B

| Variable | Without Trend | With Trend |
|---|---|---|
| ⊿SY2 | -3.633* | -3.995* |
| ⊿SY3 | -5.183* | -6.035* |
| ⊿SY4 | -5.316* | -5.694* |
| ⊿SY5 | -5.493* | -6.381* |
| ⊿SY7 | -5.186* | -6.596* |
| ⊿SY10 | -6.333* | -7.758* |
| ⊿TED | -7.087* | -7.651* |
| ⊿CBS | -13.862* | -11.229* |
| ⊿SLOPE2 | -6.969* | -6.241* |
| ⊿SLOPE3 | -7.409* | -7.225* |
| ⊿SLOPE4 | -6.798* | -6.774* |
| ⊿SLOPE5 | -6.419* | -6.169* |
| ⊿SLOPE7 | -6.494* | -5.722* |
| ⊿SLOPE10 | -6.698* | -5.546* |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(With Trend) .

**Table 3.6 KPSS Test - Series with First Difference**

Sample A

| | Lag=0 | | Lag=6 | |
|---|---|---|---|---|
| Variable | $\eta_\mu$ | $\eta_\tau$ | $\eta_\mu$ | $\eta_\tau$ |
| ⊿SY2 | 0.158 | 0.049 | 0.162 | 0.053 |
| ⊿SY3 | 0.130 | 0.057 | 0.111 | 0.050 |
| ⊿SY4 | 0.086 | 0.060 | 0.077 | 0.053 |
| ⊿SY5 | 0.075 | 0.076 | 0.067 | 0.068 |
| ⊿SY7 | 0.078 | 0.077 | 0.109 | 0.104 |
| ⊿SY10 | 0.094 | 0.101 | 0.099 | 0.103 |
| ⊿TED | 0.017 | 0.014 | 0.071 | 0.061 |
| ⊿CBS | 0.022 | 0.096 | 0.022 | 0.096 |
| ⊿SLOPE2 | 0.049 | 0.094 | 0.034 | 0.067 |
| ⊿SLOPE3 | 0.086 | 0.131 | 0.051 | 0.081 |
| ⊿SLOPE4 | 0.123 | 0.063 | 0.157 | 0.087 |
| ⊿SLOPE5 | 0.174 | 0.074 | 0.220 | 0.107 |
| ⊿SLOPE7 | 0.159 | 0.076 | 0.202 | 0.110 |
| ⊿SLOPE10 | 0.168 | 0.079 | 0.201 | 0.108 |

Sample B

| | Lag=0 | | Lag=6 | |
|---|---|---|---|---|
| Variable | $\eta_\mu$ | $\eta_\tau$ | $\eta_\mu$ | $\eta_\tau$ |
| ⊿SY2 | 0.134 | 0.122 | 0.140 | 0.131 |
| ⊿SY3 | 0.209 | 0.201* | 0.137 | 0.131 |
| ⊿SY4 | 0.262 | 0.266* | 0.142 | 0.143 |
| ⊿SY5 | 0.312 | 0.320* | 0.152 | 0.155* |
| ⊿SY7 | 0.272 | 0.275* | 0.151 | 0.156* |
| ⊿SY10 | 0.351 | 0.327* | 0.185 | 0.154* |
| ⊿TED | 0.021 | 0.014 | 0.100 | 0.069 |
| ⊿CBS | 0.013 | 0.013 | 0.091 | 0.089 |
| ⊿SLOPE2 | 0.036 | 0.032 | 0.095 | 0.082 |
| ⊿SLOPE3 | 0.070 | 0.045 | 0.121 | 0.097 |
| ⊿SLOPE4 | 0.086 | 0.054 | 0.123 | 0.076 |
| ⊿SLOPE5 | 0.089 | 0.058 | 0.118 | 0.075 |
| ⊿SLOPE7 | 0.082 | 0.060 | 0.096 | 0.067 |
| ⊿SLOPE10 | 0.069 | 0.055 | 0.085 | 0.064 |

* indicates significance at the 5 % level.

5% critical values are 0.463 (trend stationary) 、 0.146(level stationary) .

$\eta_\mu$ indicates trend stationarity. $\eta_\tau$ indicates level stationarity.

**Table 3.7 Johansen Cointegration Test**

Maximal Eigen Value Test - Sample A

| | r = 0 | r≦1 | r≦2 | r≦3 |
|---|---|---|---|---|
| SY2,TED,CBS,SLOPE2 | 21.82 | 20.15 | 12.73 | 1.36 |
| SY3,TED,CBS,SLOPE3 | 25.64 | 20.38 | 14.85 | 1.28 |
| SY4,TED,CBS,SLOPE4 | 24.00 | 18.05 | 12.52 | 2.26 |
| SY5,TED,CBS,SLOPE5 | 24.53 | 14.98 | 9.00 | 2.04 |
| SY7,TED,CBS,SLOPE7 | 19.12 | 15.84 | 8.50 | 9.93 |
| SY10,TED,CBS,SLOPE10 | 26.51 | 16.11 | 8.11 | 1.11 |

Trace Test - Sample A

| | r = 0 | r≦1 | r≦2 | r≦3 |
|---|---|---|---|---|
| SY2,TED,CBS,SLOPE2 | 56.06* | 34.24 | 14.09 | 1.36 |
| SY3,TED,CBS,SLOPE3 | 62.14* | 36.5* | 16.13 | 1.28 |
| SY4,TED,CBS,SLOPE4 | 56.83* | 32.83 | 14.78 | 2.26 |
| SY5,TED,CBS,SLOPE5 | 50.55 | 26.02 | 11.04 | 2.04 |
| SY7,TED,CBS,SLOPE7 | 44.90 | 25.78 | 9.93 | 1.43 |
| SY10,TED,CBS,SLOPE10 | 51.85 | 25.33 | 9.22 | 1.11 |

Maximal Eigen Value Test - Sample B

| | r = 0 | r≦1 | r≦2 | r≦3 |
|---|---|---|---|---|
| SY2,TED,CBS,SLOPE2 | 24.41 | 17.51 | 11.40 | 3.76 |
| SY3,TED,CBS,SLOPE3 | 21.07 | 12.14 | 10.61 | 4.12 |
| SY4,TED,CBS,SLOPE4 | 22.35 | 11.99 | 9.58 | 3.74 |
| SY5,TED,CBS,SLOPE5 | 23.63 | 11.65 | 8.29 | 3.65 |
| SY7,TED,CBS,SLOPE7 | 19.95 | 11.65 | 7.13 | 3.56 |
| SY10,TED,CBS,SLOPE10 | 26.51 | 16.11 | 8.11 | 1.11 |

Trace Test - Sample B

| | r = 0 | r≦1 | r≦2 | r≦3 |
|---|---|---|---|---|
| SY2,TED,CBS,SLOPE2 | 57.08* | 32.66 | 15.16 | 3.76 |
| SY3,TED,CBS,SLOPE3 | 47.96 | 26.88 | 14.74 | 4.12 |
| SY4,TED,CBS,SLOPE4 | 47.66 | 25.31 | 13.32 | 3.74 |
| SY5,TED,CBS,SLOPE5 | 47.22 | 23.59 | 11.94 | 3.65 |
| SY7,TED,CBS,SLOPE7 | 42.30 | 22.35 | 10.69 | 3.56 |
| SY10,TED,CBS,SLOPE10 | 51.85 | 25.35 | 9.22 | 1.11 |

*indicates significance at the 5 % level.

### *5.3 VAR (Vector AutoRegression) Analysis*

Since there is no cointegration found for both Sample A and Sample B, *VAR* is estimated without error correction terms. The ordering of the variables is TED,CBS and SLOPE. I estimated this four variable system and then computed a 20- day-ahead forecast error variance decomposition. The results of Sample A and Sample B are shown in Table 3.8.

As for the TED in Sample A except for 10 Year Spread, the impacts of TED on spreads are stronger in the longer maturities. In Sample B, the impacts of TED are stronger in the shorter maturities.

As for the CBS in Sample A, the impacts are stronger in the mid term zones such as 4 year and 5 year. In Sample B, the impacts are stronger in the shorter terms. When the comparison is made between Sample A and Sample B, the impacts are stronger in all maturities of Sample A. Thus it's assumed that swap spreads in Sample A are influenced more by credit risk than in Sample B. As for the SLOPE, both in Sample A and Sample B, the impacts are stronger in the shorter maturities.

**Table 3.8 Variance Decomposition**

Sample A

| | ⊿TED | ⊿CBS | ⊿SLOPE |
|---|---|---|---|
| ⊿SY2 | 5.389 | 9.465 | 16.384 |
| ⊿SY3 | 6.379 | 8.789 | 19.718 |
| ⊿SY4 | 8.459 | 14.901 | 18.100 |
| ⊿SY5 | 11.979 | 20.087 | 18.996 |
| ⊿SY7 | 15.840 | 9.916 | 9.205 |
| ⊿SY10 | 7.157 | 11.121 | 18.343 |

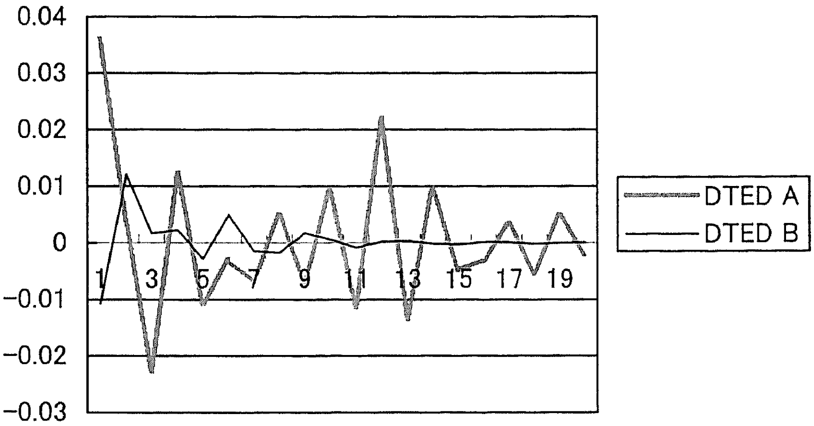
Sample B

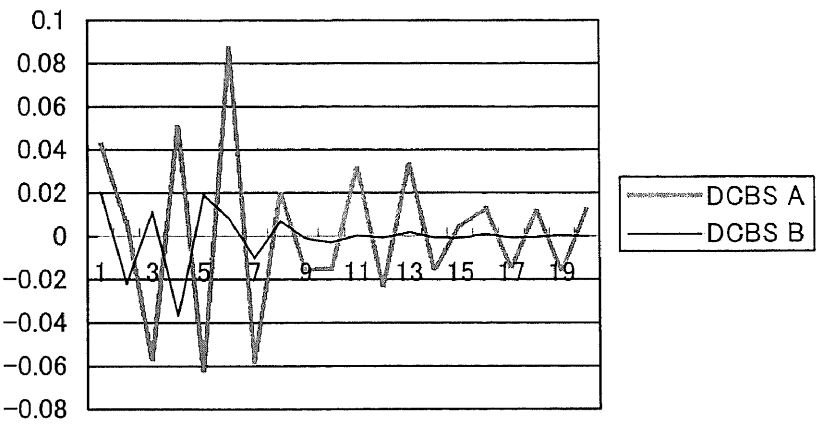
| | ⊿TED | ⊿CBS | ⊿SLOPE |
|---|---|---|---|
| ⊿SY2 | 20.579 | 7.053 | 19.626 |
| ⊿SY3 | 10.591 | 5.686 | 17.982 |
| ⊿SY4 | 7.900 | 6.151 | 12.705 |
| ⊿SY5 | 5.065 | 1.985 | 9.832 |
| ⊿SY7 | 7.997 | 1.496 | 13.202 |
| ⊿SY10 | 1.523 | 4.814 | 3.259 |

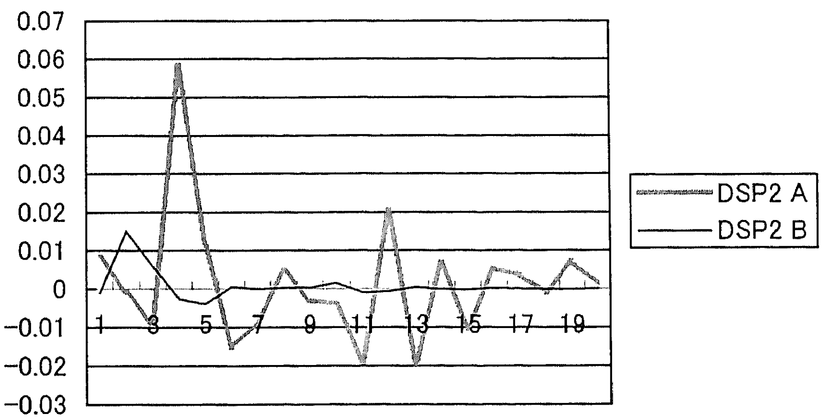
VAR System is SPREAD-TED-CBS -SLOPE.
The rows gives the variance decomposition for the variable in the first column.

The results of impulse response functions are shown in Figure 3.1 through Figure 3.6. As for TED, in shorter terms, shocks of TED are greater in Sample A. But in mid and long terms, the sizes of shocks are almost same. As for the CBS, the sizes of shocks are greater in Sample A. As for the SLOPE, the sizes of shocks are greater in Sample A.

## Figure3.1 Impulse Response Function - 2 Year Spread

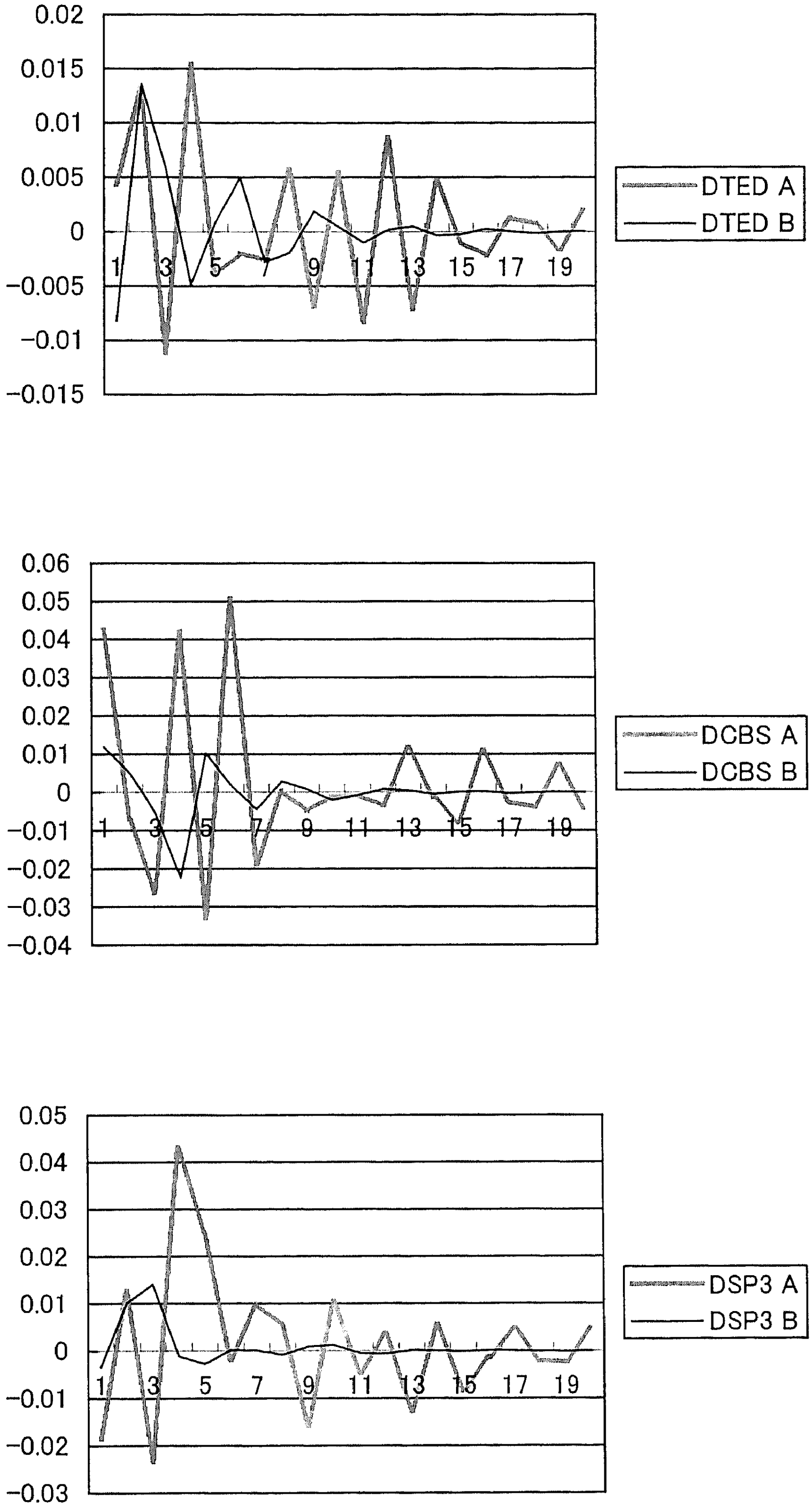


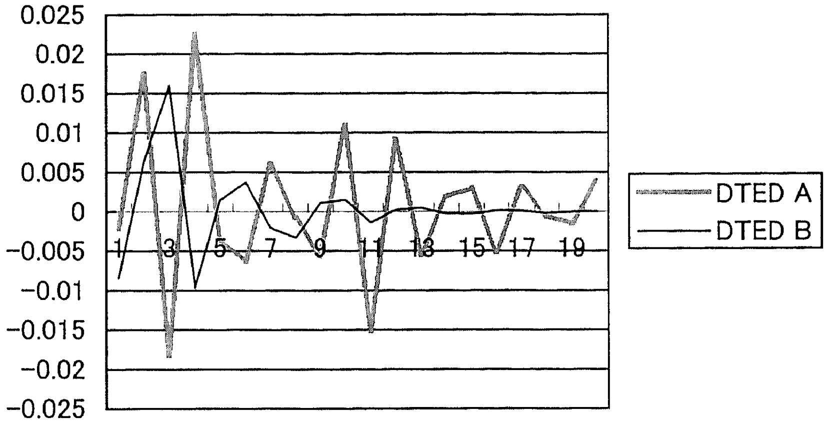

Sample A is from January, 1994 through January, 1999.
Sample B is from February, 1999 through July, 2004.
TED = TED Spread,CBS = Corporate Bond Spread
SP = SLOPE

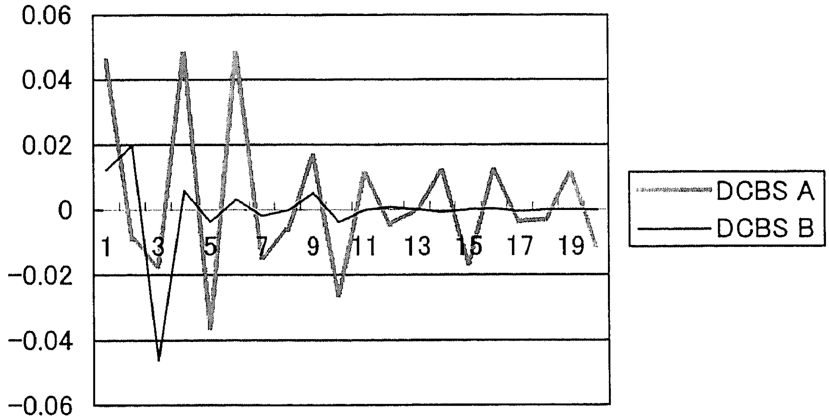
## Figure 3.2 Impulse Response Function - 3 Year Spread

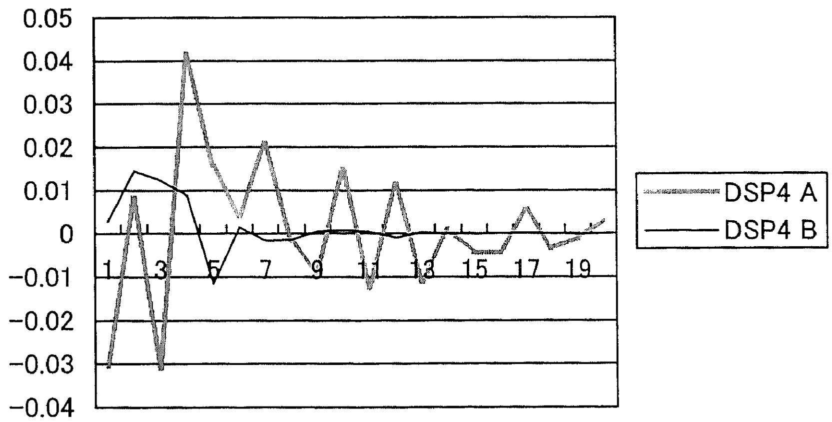



Sample A is from January, 1994 through January, 1999.
Sample B is from February, 1999 through July, 2004.
TED = TED Spread,CBS = Corporate Bond Spread
SP = SLOPE

## Figure 3.3 Impulse Response Function - 4 Year Spread

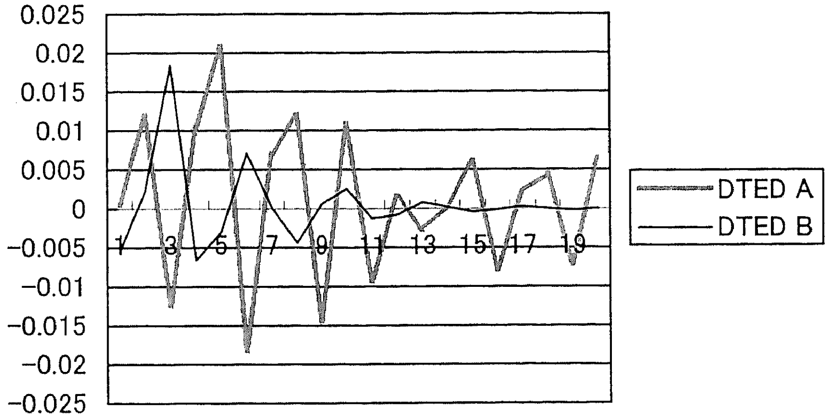


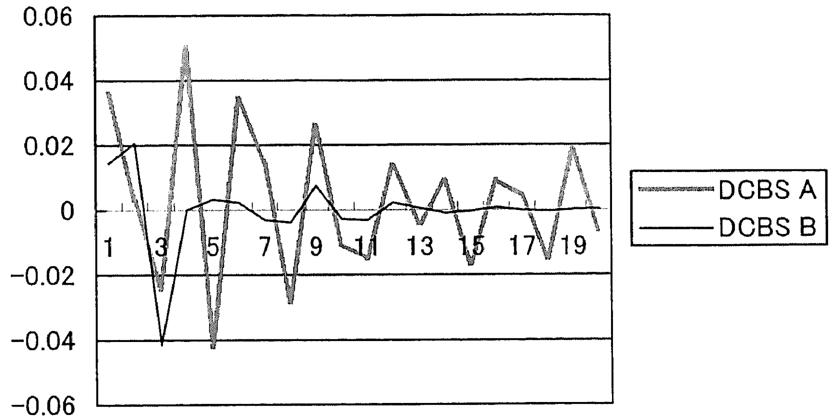



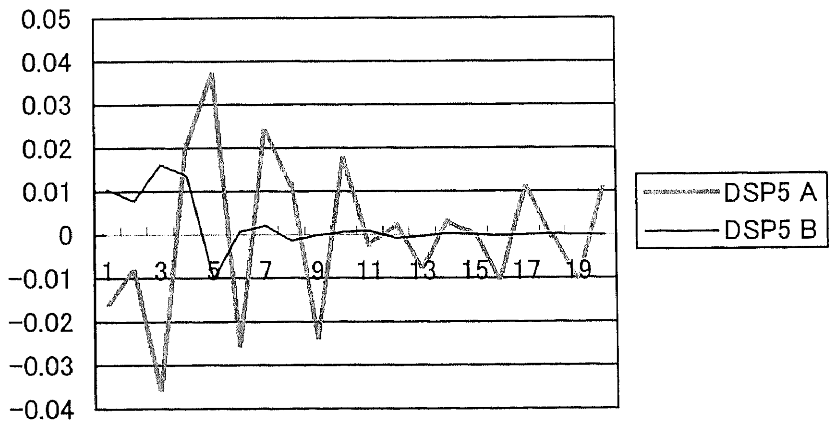




Sample A is from January, 1994 through January, 1999.
Sample B is from February, 1999 through July, 2004.
TED = TED Spread,CBS = Corporate Bond Spread
SP = SLOPE

## Figure 3.4 Impulse Response Function - 5 Year Spread

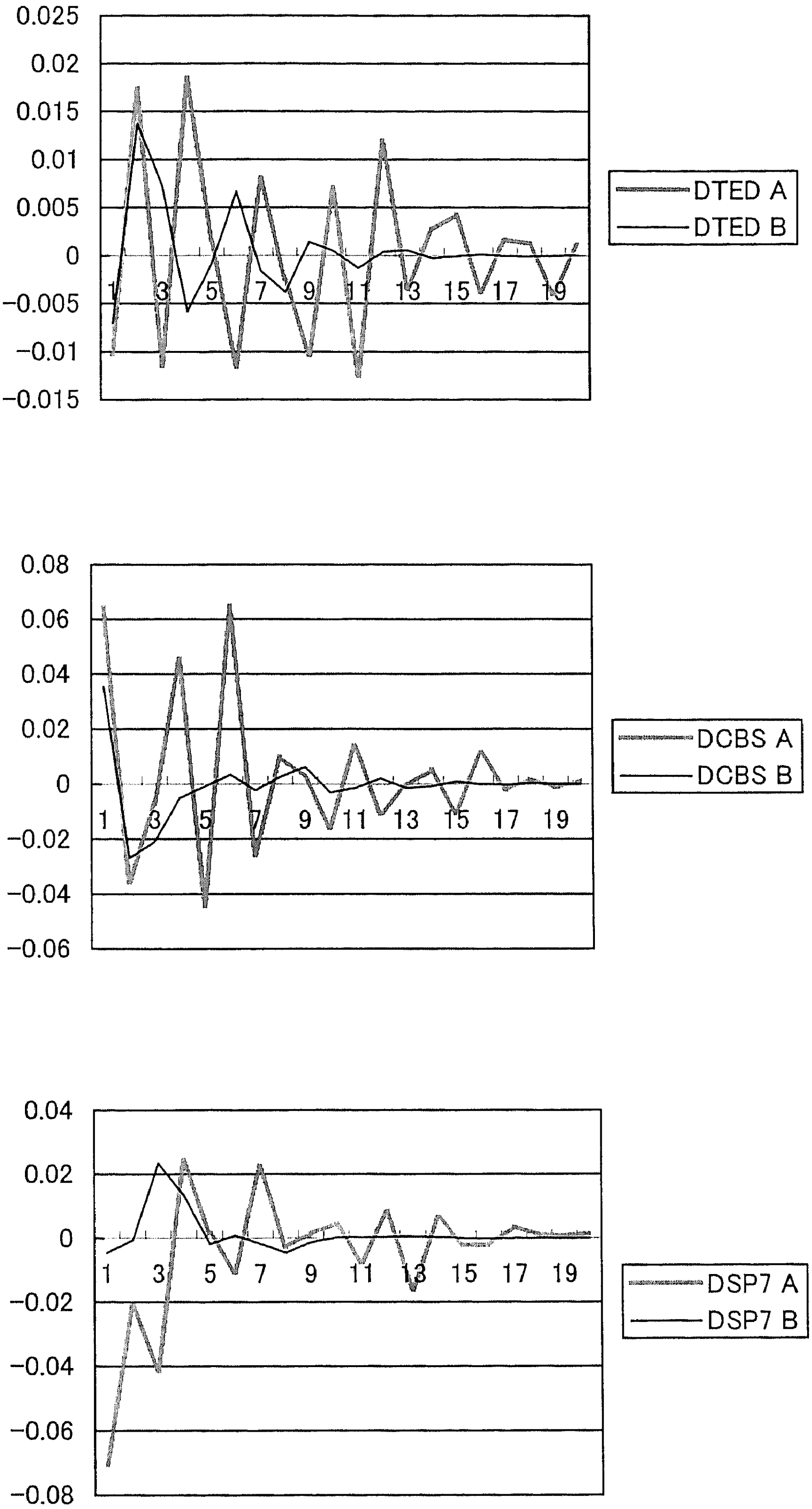


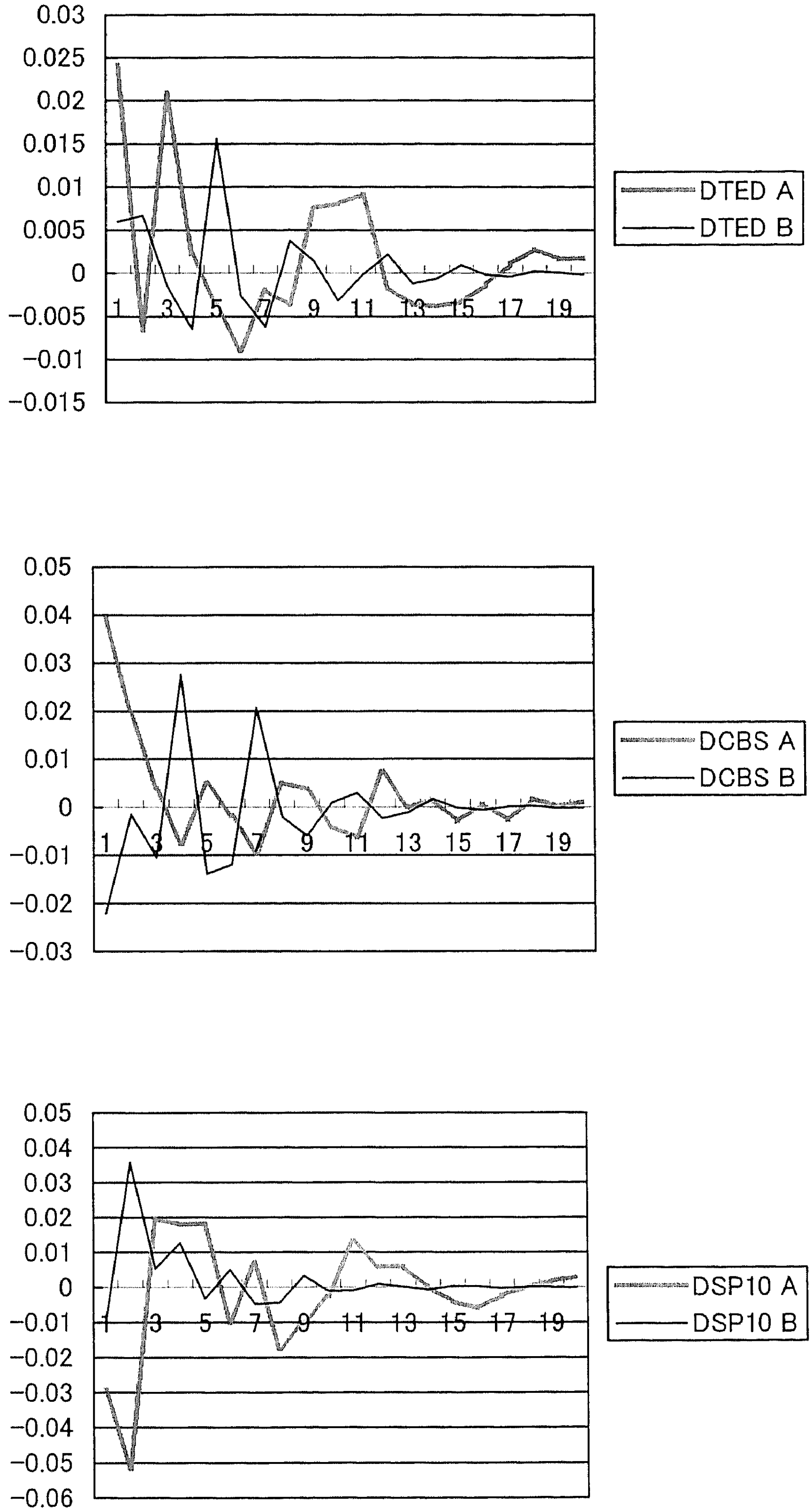

Sample A is from January, 1994 through January, 1999.
Sample B is from February, 1999 through July, 2004.
TED = TED Spread,CBS = Corporate Bond Spread
SP = SLOPE

## Figure 3.5 Impulse Response Function - 7 Year Spread




Sample A is from January, 1994 through January, 1999.
Sample B is from February, 1999 through July, 2004.
TED = TED Spread,CBS = Corporate Bond Spread
SP = SLOPE

## Figure 3.6 Impulse Response Function - 10 Year Spread




Sample A is from January, 1994 through January, 1999.
Sample B is from February, 1999 through July, 2004.
TED = TED Spread,CBS = Corporate Bond Spread
SP = SLOPE

## 6. Concluding Remarks

In this chapter variance decomposition and impulse response function are investigated with the estimation of *VAR* model. First, I report the results of variance decomposition. As for the TED in Sample A except for 10 Year Spread, the impacts of TED on spreads are stronger in the longer maturities. In Sample B, the impacts of TED are stronger in the shorter maturities.

As for the CBS in Sample A, the impacts are stronger in the mid term zones such as 4 year and 5 year. In Sample B the impacts are stronger in the shorter terms. When the comparison is made between Sample A and Sample B, the impacts are stronger in all maturities of Sample A. As for the slope, both in Sample A and Sample B, the impacts are stronger in the shorter maturities.

Next, I report the results of impulse response function. As for TED, in shorter terms, shocks of TED are greater in Sample A. But in mid and longer terms, the sizes of shocks are almost same. As for the CBS, the sizes of shocks are greater in Sample A. As for the SLOPE, the sizes of shocks are greater in Sample A.

When I consider the results of both variance decomposition and impulse response function, the major structural difference of Japanese yen interest rate swap spreads in Sample A and Sample B is the influence of credit risk. Swap spreads in Sample A are more influenced than those in Sample B. Especially in mid term such as 4 year and 5 year, the impacts of credit risk are very strong in Sample A.

Chapter 4

# Analyzing Super Long Zone*

## 1. Introduction

In this chapter a consideration is given to common trends underlying the term structure of Japanese Yen yield curve up to 15 year. We have known that the yield curve is usually driven by 3 common trends - level, slope and curvature. But especially in the Japanese yen market, it's believed that yield curve over 10 year has another driving force since the number of participants is limited and the motive for the transaction is very special. Most of the players in the super long zone are foreign security houses and banks.

Thus I assume that super long zones are driven by fourth trend distinguishing the super long zone from the entire yield curve. The purpose of this chapter is to investigate the existence of fourth trend by using the cointegration test and principal component analysis.

There are two previous studies applying cointegration test to Japanese yen term structure of interest rates. Hiraki/Shiraishi/Takezawa (1997) used the 13 series of data from 1988 through 1995. They conducted the unit root test and Johansen cointegration test. As for the daily data, they got a conclusion that the entire series has 11 cointagration vectors and 2 common trends. Ito (2000) used the cointegration test for 19 series of daily data from 1993 through 1998. They got a conclusion that the entire yield curve is driven by 3 common trends.

Hall/Anderson/Granger (1992) conducted Johansen cointegration test by using the US treasury bill monthly data (11 series: 1 month through 11 month) from 1970 through 1988. They found that the entire series are comprised of 10 cointegration vectors and 1 common

* This chapter is based on Ito (2005c).

trend.

Bradley/Lumpkin (1992) used the monthly US Treasury data (3 month, 1 year, 3 year, 5 year, 7 year, 10 year and 30 year) from 1972 through 1988. They found that there is a long term relationship between each series of the data. They only tested the data series in a pair since they use the Engle/Granger cointegration test.

Engsted/Tanggaard (1994) conducted the Johansen cointegration test by using 4 series of US Treasury data (3 month, 1 year, 10 year and 30 year). They find that the entire series has 3 cointegration vectors and 1 common trend. Mougoue (1992) analyzed the monthly data Euro interest rates (Canada,Germany,Japan, Swiss, United Kingdon,and USA) from 1980 through 1990 (1 month, 2 month,3 month and 6 month).They get a conclusion by Johansen cointegration test that each series has 3 cointegration vectors and 1 common trend.

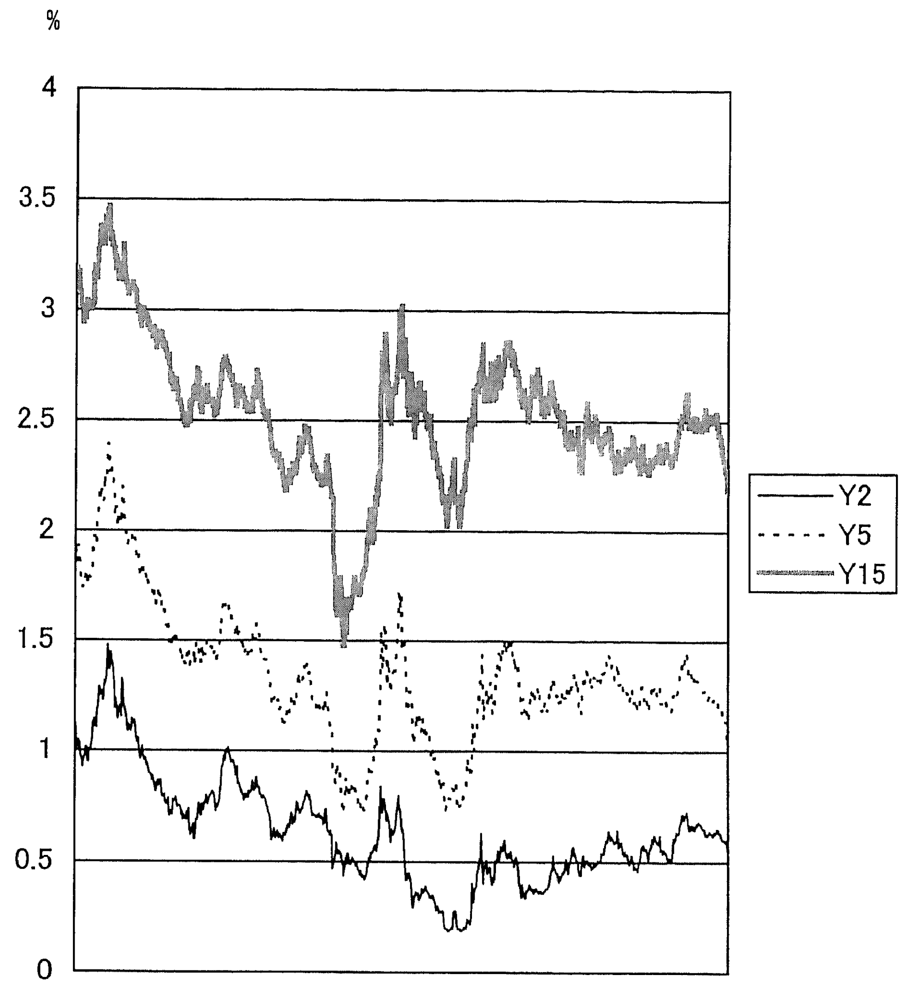
Zhang (1993) conducted the unit root test and Johansen cointegration test by using the 19 series of monthly US treasury data from February 1964 through November 1986. They conclude that the entire series has 16 cointegraton vectors and 3 common trends.

The remainder of this chapter is as follows. Section 2 describes the data. Section 3 discusses the framework of the analysis. Section 4 presents the results. Section 5 concludes.

## 2. Data

The 11 series of Japanese yen swap rate at 3 pm local time (from 2 year through 10 year, 12 year and 15 year) are used on a daily basis from March 1997 through November 2000. Figure 4.1 shows the movement of 3 series of data ( 2 year, 5 year, and 15 year).

**Figure 4.1 The Movement of Japanese Yen Swap Rate**




From March 24,1997 through November 30,2000

## 3. Framework of Analysis

### *3.1 Unit Root Test*

Since the empirical analysis from mid-1980's through mid-1990's show that such data as interest rates, foreign exchange and stocks are non-stationary[1], it's necessary to check if the

[1] Generally OLS method is used to analyze the relationships among the variables. However when the non-stationary variables are included, ordinary hypothesis test tends to draw the mistaken results since the coefficient of determination and t-statistics do not follow the simple distribution. Granger/Newbold (1974) called this problem 'Spurious Regression'. Phillips (1986) pointed out two points as to the analysis of non-stationary data—(1)the coefficient of determination tend not to measure the relationship among variables,(2)estimated equation with low Durbin-Watson ratio can possibly have a problem of spurious regression.

data used in this chapter contain unit roots. The ADF (Augmented Dickey Fuller) test and the KPSS (Kwiatowski, Phillips, Schmidt and Shin) test are used. AIC standard is used for the determination of lag length in the ADF Test.

The ADF test defines null hypothesis as 'unit roots exist' and alternative hypothesis as 'unit roots don't exist'. On the other hand, KPSS test defines null hypothesis as 'unit roots don't exist' and alternative hypothesis as 'unit roots exist'.

### *3.2 Cointegration Test of Johansen and Common Trend*

There are mainly two types of cointegration test - (1) Engle/Granger (1987), (2) Johansen (1988). The most difficult part of cointegration analysis starting from *VAR* model is how to decide the number of cointegration relationship. When 3 variables are analyzed, the number of cointegration relationship may be 1 or 2. Engle/Granger can't cope with this problem, but Johansen is able to decide the number of cointegration relationship and to get a MLE of unknown parameters. Johansen methodology is used in this chapter since the number of data series is 11.

Osterwald-Lenum (1992) provides the table for maximal eigenvalue test and trace test. Here the cointegration test is applied to analyze the structural changes derived by subtracting points of yield curve as Ito (2000). Stock/Watson (1988) draws the conclusion that the number of common trend is decided by subtracting the number of cointegration vector from the number of the entire time series.

### *3.3 Principal Component Analysis*

The Johansen cointegration test provides us with the number of common trends for the entire term structure, 5-10 year of the structure, 2-3 year of the structure. As Litterman/Scheinkman (1991), I apply principal component analysis to the whole term structure with the assumption that entire term structure has 4 trends, 5-10 year of the structure has 3 trends, and 2-4 year of the structure has 2 trends. The cointegration test considers the time series property of the term structure data, but principal component analysis doesn't consider it. Thus it's logical to use the number of common trends derived from the cointegartion test.

## 4. Result

### *4.1 Unit Root Test*

There is no denying that all the variables are no-stationary. The results are shown on Table 4.1 and Table 4.2. The data with first difference from original data are analyzed by ADF and KPSS Test. It's possible to conclude that all the variables are $I\,(1)$, results are shown on Table 4.3 and Table 4.4.

**Table 4.1 ADF Test - Original Series**

| Variable | Without Trend | With Trend |
|---|---|---|
| Y2 | -1.931 | -1.979 |
| Y3 | -2.032 | -2.145 |
| Y4 | -2.025 | -2.139 |
| Y5 | -2.090 | -2.111 |
| Y6 | -2.026 | -2.071 |
| Y7 | -2.055 | -2.068 |
| Y8 | -2.061 | -2.058 |
| Y9 | -2.071 | -2.061 |
| Y10 | -2.104 | -2.087 |
| Y12 | -2.188 | -2.174 |
| Y15 | -2.268 | -2.261 |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(With Trend) .

**Table 4.2 KPSS Test - Original Series**

| | Lag=4 | | Lag=12 | |
|---|---|---|---|---|
| Variable | $\eta_\mu$ | $\eta_\tau$ | $\eta_\mu$ | $\eta_\tau$ |
| ⊿Y2 | 9.884* | 2.862* | 3.881* | 1.137* |
| ⊿Y3 | 8.815* | 2.846* | 3.473* | 1.131* |
| ⊿Y4 | 7.816* | 2.828* | 3.082* | 1.122* |
| ⊿Y5 | 9.731* | 2.748* | 2.655* | 1.089* |
| ⊿Y6 | 5.805* | 2.648* | 2.291* | 1.048* |
| ⊿Y7 | 5.196* | 2.541* | 2.052* | 1.005* |
| ⊿Y8 | 4.862* | 2.473* | 1.921* | 0.979* |
| ⊿Y9 | 4.662* | 2.414* | 1.842* | 0.955* |
| ⊿Y10 | 4.540* | 2.353* | 1.795* | 0.932* |
| ⊿Y12 | 4.326* | 2.182* | 1.714* | 0.866* |
| ⊿Y15 | 4.274* | 1.952* | 1.696* | 0.776* |

* indicates significance at the 5 % level.
5% critical values are 0.463 (trend stationary) 、0.146(level stationary) .
$\eta_\mu$indicates trend stationarity. $\eta_\tau$ indicates level stationarity.

**Table 4.3 ADF Test with a first difference**

| Variable | Without Trend | With Trend |
|---|---|---|
| ⊿Y2 | -22.535* | -22.214* |
| ⊿Y3 | -22.331* | -22.197* |
| ⊿Y4 | -22.575* | -22.482* |
| ⊿Y5 | -22.747* | -22.713* |
| ⊿Y6 | -22.874* | -22.824* |
| ⊿Y7 | -23.063* | -23.009* |
| ⊿Y8 | -22.993* | -22.924* |
| ⊿Y9 | -23.047* | -22.966* |
| ⊿Y10 | -22.971* | -22.888* |
| ⊿Y12 | -22.871* | -22.787* |
| ⊿Y15 | -22.910* | -22.806* |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(with Trend) .

**Table 4.4 KPSS Test - Series with First Difference**

| | Lag=4 | | Lag=12 | |
|---|---|---|---|---|
| Variable | $\eta_\mu$ | $\eta_\tau$ | $\eta_\mu$ | $\eta_\tau$ |
| Y2 | 0.114 | 0.026 | 0.106 | 0.025 |
| Y3 | 0.087 | 0.031 | 0.080 | 0.029 |
| Y4 | 0.078 | 0.039 | 0.071 | 0.036 |
| Y5 | 0.075 | 0.047 | 0.068 | 0.043 |
| Y6 | 0.077 | 0.052 | 0.070 | 0.048 |
| Y7 | 0.078 | 0.055 | 0.071 | 0.051 |
| Y8 | 0.081 | 0.057 | 0.073 | 0.052 |
| Y9 | 0.082 | 0.058 | 0.075 | 0.053 |
| Y10 | 0.081 | 0.057 | 0.075 | 0.053 |
| Y12 | 0.076 | 0.054 | 0.072 | 0.051 |
| Y15 | 0.075 | 0.051 | 0.072 | 0.049 |

* indicates significance at the 5 % level.
5% critical values are 0.463 (trend stationary) 、 0.146(level stationary) .
$\eta_\mu$indicates trend stationarity. $\eta_\tau$ indicates level stationarity.

*4.2 Cointegration Test of Johansen and Common Trend*

It's found that the entire term structure is driven by 4 common trends. The result is consistent with the recognition held by the market participants that the term structure over 10 year is driven by a special fourth trend. The 5-10 year of swap have 3 common trends. The 2-4 year is driven by 2 common trends. The entire term structure is divided into three parts - (1)middle term (from 2 year through 4 year-two common trends),(2)long term (from 5 year through 10 year –two common trends),(5)super long term(from 12 year through 15 year-four common trends). The results are shown on Table 4.5 through Table 4.13.

**Table 4.5 Cointegration Test - 11 Series**

| Null | Alternative | Test Statistics | 5% Critical Value | 1% Critical Value |
|---|---|---|---|---|
| Maximal Eigenvalue Test | | | | |
| r = 0 | r = 1 | 290.82** | 69.74 | 76.63 |
| r ≦1 | r = 2 | 278.63** | 63.57 | 69.94 |
| r ≦2 | r = 3 | 173.88** | 57.42 | 63.71 |
| r ≦3 | r = 4 | 104.11** | 52 | 57.95 |
| r ≦4 | r = 5 | 86.14** | 46.45 | 51.91 |
| r ≦5 | r = 6 | 64.30** | 40.3 | 46.82 |
| r ≦6 | r = 7 | 58.38** | 34.4 | 39.79 |
| r ≦7 | r = 8 | 26.38 | 28.14 | 33.24 |
| r ≦8 | r = 9 | 12.09 | 22 | 26.81 |
| r ≦9 | r = 10 | 6.73 | 15.67 | 20.2 |
| r ≦10 | r = 11 | 4.91 | 9.24 | 12.97 |
| Trace Test | | | | |
| r = 0 | r = 1 | 1106.38** | 291.4 | 307.64 |
| r ≦1 | r = 2 | 815.56** | 244.15 | 257.68 |
| r ≦2 | r = 3 | 536.93** | 202.92 | 215.74 |
| r ≦3 | r = 4 | 363.05** | 165.58 | 177.2 |
| r ≦4 | r = 5 | 258.94** | 131.7 | 143.09 |
| r ≦5 | r = 6 | 172.8** | 102.14 | 111.01 |
| r ≦6 | r = 7 | 108.49** | 76.07 | 84.45 |
| r ≦7 | r = 8 | 50.11 | 53.12 | 60.16 |
| r ≦8 | r = 9 | 23.73 | 34.91 | 41.07 |
| r ≦9 | r = 10 | 11.64 | 19.96 | 24.6 |
| r ≦10 | r = 11 | 4.91 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 11 series.
The number of cointegration vector is 7. The number of common trend is 4.
The entire term structure is driven by 4 common trends.
** indicates signigicance at the 1 % level.
* indicates significance at the 5 % level.
Critical values are from Osterwald-Lenum(1992).

**Table 4.6 Cointegration Test - 10 Series**

| Null | Alternative | Test Statistics | 5% Critical Value | 1% Critical Value |
|---|---|---|---|---|
| Maximal Eigenvalue Test | | | | |
| r = 0 | r = 1 | 288.39** | 63.57 | 69.94 |
| r ≦1 | r = 2 | 266.62** | 57.42 | 63.71 |
| r ≦2 | r = 3 | 162.57** | 52 | 57.95 |
| r ≦3 | r = 4 | 100.54** | 46.45 | 51.91 |
| r ≦4 | r = 5 | 83.23** | 40.3 | 46.82 |
| r ≦5 | r = 6 | 60.22** | 34.4 | 39.79 |
| r ≦6 | r = 7 | 27.95 | 28.14 | 33.24 |
| r ≦7 | r = 8 | 12.33 | 22 | 26.81 |
| r ≦8 | r = 9 | 6.45 | 15.67 | 20.2 |
| r ≦9 | r = 10 | 4.95 | 9.24 | 12.97 |
| Trace Test | | | | |
| r = 0 | r = 1 | 1013.26** | 244.15 | 257.68 |
| r ≦1 | r = 2 | 724.87** | 202.92 | 215.74 |
| r ≦2 | r = 3 | 458.25** | 165.58 | 177.2 |
| r ≦3 | r = 4 | 295.68** | 131.7 | 143.09 |
| r ≦4 | r = 5 | 195.13** | 102.14 | 111.01 |
| r ≦5 | r = 6 | 111.90** | 76.07 | 84.45 |
| r ≦6 | r = 7 | 51.68 | 53.12 | 60.16 |
| r ≦7 | r = 8 | 23.73 | 34.91 | 41.07 |
| r ≦8 | r = 9 | 11.4 | 19.96 | 24.6 |
| r ≦9 | r = 10 | 4.95 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 10 series.
The number of cointegration vector is 6. The number of common trend is 4.
The term structure up to 12 year is driven by 4 common trends.

### Table 4.7 Cointegration Test- 9 Series

| Null | Alternative | Test Statistics | 5% Critical Value | 1% Critical Value |
|---|---|---|---|---|
| Maximal Eigenvalue Test | | | | |
| r = 0 | r = 1 | 275.93** | 57.42 | 63.71 |
| r ≦1 | r = 2 | 240.68** | 52 | 57.95 |
| r ≦2 | r = 3 | 150.61** | 46.45 | 51.91 |
| r ≦3 | r = 4 | 100.51** | 40.3 | 46.82 |
| r ≦4 | r = 5 | 63.33** | 34.4 | 39.79 |
| r ≦5 | r = 6 | 30.28* | 28.14 | 33.24 |
| r ≦6 | r = 7 | 12.65 | 22 | 26.81 |
| r ≦7 | r = 8 | 7.66 | 15.67 | 20.2 |
| r ≦8 | r = 9 | 3.82 | 9.24 | 12.97 |
| Trace Test | | | | |
| r = 0 | r = 1 | 855.47** | 202.92 | 215.74 |
| r ≦1 | r = 2 | 609.54** | 165.58 | 177.2 |
| r ≦2 | r = 3 | 368.86** | 131.7 | 143.09 |
| r ≦3 | r = 4 | 218.25** | 102.14 | 111.01 |
| r ≦4 | r = 5 | 117.74** | 76.07 | 84.45 |
| r ≦5 | r = 6 | 54.41* | 53.12 | 60.16 |
| r ≦6 | r = 7 | 24.13 | 34.91 | 41.07 |
| r ≦7 | r = 8 | 11.48 | 19.96 | 24.6 |
| r ≦8 | r = 9 | 3.82 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 9 series.
The number of cointegration vector is 6. The number of common trends is 3.
The term structure up to 10 year is driven by 3 common trend.
** indicates signigicance at the 1 % level.
* indicates significance at the 5 % level.
Critical values are from Osterwald-Lenum(1992).

**Table 4.8 Cointegration Test - 8 series**

| Null | Alternative | Test Statistics | 5% Critical Value | 1% Critical Value |
|---|---|---|---|---|
| Maximal Eigenvalue Test | | | | |
| r = 0 | r = 1 | 258.60** | 52 | 57.95 |
| r ≦1 | r = 2 | 224.62** | 46.45 | 51.91 |
| r ≦2 | r = 3 | 98.75** | 40.3 | 46.82 |
| r ≦3 | r = 4 | 71.34** | 34.4 | 39.79 |
| r ≦4 | r = 5 | 32.58* | 28.14 | 33.24 |
| r ≦5 | r = 6 | 12.61 | 22 | 26.81 |
| r ≦6 | r = 7 | 7.66 | 15.67 | 20.2 |
| r ≦7 | r = 8 | 3.82 | 9.24 | 12.97 |
| Trace Test | | | | |
| r = 0 | r = 1 | 709.98** | 165.58 | 177.2 |
| r ≦1 | r = 2 | 451.39** | 131.7 | 143.09 |
| r ≦2 | r = 3 | 226.76** | 102.14 | 111.01 |
| r ≦3 | r = 4 | 128.01** | 76.07 | 84.45 |
| r ≦4 | r = 5 | 56.68* | 53.12 | 60.16 |
| r ≦5 | r = 6 | 24.09 | 34.91 | 41.07 |
| r ≦6 | r = 7 | 11.48 | 19.96 | 24.6 |
| r ≦7 | r = 8 | 3.82 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 8 series.
The number of cointegration vector is 5. The number of common trend is 3.
The term structure up to 9 year is driven by 3 common trends.
** indicates signigicance at the 1 % level.
* indicates significance at the 5 % level.
Critical values are from Osterwald-Lenum(1992).

**Table 4.9 Cointegration Test - 7 series**

| Null | Alternative | Test Statistics | 5% Critical Value | 1% Critical Value |
|---|---|---|---|---|
| Maximal Eigenvalue Test | | | | |
| r = 0 | r = 1 | 242.71** | 46.45 | 51.91 |
| r ≦1 | r = 2 | 131.40** | 40.3 | 46.82 |
| r ≦2 | r = 3 | 79.15** | 34.4 | 39.79 |
| r ≦3 | r = 4 | 35.05** | 28.14 | 33.24 |
| r ≦4 | r = 5 | 13.43 | 22 | 26.81 |
| r ≦5 | r = 6 | 7.5 | 15.67 | 20.2 |
| r ≦6 | r = 7 | 3.83 | 9.24 | 12.97 |
| Trace Test | | | | |
| r = 0 | r = 1 | 513.06** | 131.7 | 143.09 |
| r ≦1 | r = 2 | 270.35** | 102.14 | 111.01 |
| r ≦2 | r = 3 | 138.95** | 76.07 | 84.45 |
| r ≦3 | r = 4 | 59.80** | 53.12 | 60.16 |
| r ≦4 | r = 5 | 24.76 | 34.91 | 41.07 |
| r ≦5 | r = 6 | 11.33 | 19.96 | 24.6 |
| r ≦6 | r = 7 | 3.83 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 7 series.
The number of cointegration vector is 4. The number of common trend is 3.
The term structure up to 8 year is driven by 3 common trends.
** indicates signigicance at the 1 % level.
* indicates significance at the 5 % level.
Critical values are from Osterwald-Lenum(1992).

**Table 4.10 Cointegration Test- 6 Series**

| Null | Alternative | Test Statistics | 5% Critical Value | 1% Critical Value |
|---|---|---|---|---|
| Maximal Eigenvalue Test | | | | |
| r = 0 | r = 1 | 196.22** | 40.3 | 46.82 |
| r ≦1 | r = 2 | 93.7** | 34.4 | 39.79 |
| r ≦2 | r = 3 | 42.04** | 28.14 | 33.24 |
| r ≦3 | r = 4 | 15.59 | 22 | 26.81 |
| r ≦4 | r = 5 | 6.76 | 15.67 | 20.2 |
| r ≦5 | r = 6 | 3.67 | 9.24 | 12.97 |
| Trace Test | | | | |
| r = 0 | r = 1 | 357.98** | 102.14 | 111.01 |
| r ≦1 | r = 2 | 161.76** | 76.07 | 84.45 |
| r ≦2 | r = 3 | 68.06** | 53.12 | 60.16 |
| r ≦3 | r = 4 | 26.02 | 34.91 | 41.07 |
| r ≦4 | r = 5 | 10.43 | 19.96 | 24.6 |
| r ≦5 | r = 6 | 3.67 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 6 series.
The number of cointegration vector is 3. The number of common trend is 3.
The term structure up to 7 year is driven by 3 common trends.
** indicates signigicance at the 1 % level.
* indicates significance at the 5 % level.
Critical values are from Osterwald-Lenum(1992).

**Table 4.11 Cointegration Test -5 series**

| Null | Alternative | Test Statistics | 5% Critical Value | 1% Critical Value |
|---|---|---|---|---|
| Maximal Eigenvalue Test | | | | |
| r = 0 | r = 1 | 144.00** | 34.4 | 39.79 |
| r ≦1 | r = 2 | 59.67** | 28.14 | 33.24 |
| r ≦2 | r = 3 | 17.35 | 22 | 26.81 |
| r ≦3 | r = 4 | 5.83 | 15.67 | 20.2 |
| r ≦4 | r = 5 | 3.55 | 9.24 | 12.97 |
| Trace Test | | | | |
| r = 0 | r = 1 | 230.40** | 76.07 | 84.45 |
| r ≦1 | r = 2 | 86.40** | 53.12 | 60.16 |
| r ≦2 | r = 3 | 26.73 | 34.91 | 41.07 |
| r ≦3 | r = 4 | 9.38 | 19.96 | 24.6 |
| r ≦4 | r = 5 | 3.55 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 5 series.
The number of cointegration vector is 2. The number of common trend is 3.
The term structure up to 6 year is driven by 3 common trends.
** indicates signigicance at the 1 % level.
* indicates significance at the 5 % level.
Critical values are from Osterwald-Lenum(1992).

**Table 4.12 Cointegration Test - 4 series**

| Null | Alternative | Test Statistics | 5% Critical Value | 1% Critical Value |
|---|---|---|---|---|
| Maximal Eigenvalue Test | | | | |
| r ≦0 | r = 1 | 101.98** | 28.14 | 33.24 |
| r ≦1 | r = 2 | 18.05 | 22 | 26.81 |
| r ≦2 | r = 3 | 5.62 | 15.67 | 20.2 |
| r ≦3 | r = 4 | 3.68 | 9.24 | 12.97 |
| Trace Test | | | | |
| r ≦0 | r = 1 | 129.33** | 53.12 | 60.16 |
| r ≦1 | r = 2 | 27.35 | 34.91 | 41.07 |
| r ≦2 | r = 3 | 9.3 | 19.96 | 24.6 |
| r ≦3 | r = 4 | 3.68 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 4 series.
The number of cointegration vector is 1. The number of common trend is 3.
The term structure up to 5 year is driven by 3 common trends.
** indicates signigicance at the 1 % level.
* indicates significance at the 5 % level.
Critical values are from Osterwald-Lenum(1992).

**Table 4.13 Cointegration Test - 3 series**

| Null | Alternative | Test Statistics | 5% Critical Value | 1% Critical Value |
|---|---|---|---|---|
| Maximal Eigenvalue Test | | | | |
| r ≦0 | r = 1 | 25.14** | 22 | 26.81 |
| r ≦1 | r = 2 | 5.55 | 15.67 | 20.2 |
| r ≦2 | r = 3 | 3.83 | 9.24 | 12.97 |
| Trace Test | | | | |
| r ≦0 | r = 1 | 34.52** | 34.91 | 41.07 |
| r ≦1 | r = 2 | 9.38 | 19.96 | 24.6 |
| r ≦2 | r = 3 | 3.83 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 3 series.
The number of cointegration vector is 1. The number of common trend is 2.
The term structure up to 4 year is driven by 2 common trends.
** indicates signigicance at the 1 % level.
* indicates significance at the 5 % level.
Critical values are from Osterwald-Lenum(1992).

**Table 4.14 - Factor Loading**

| Maturity | Factor One | Factor Two | Factor Three | Factor Four |
|---|---|---|---|---|
| Y2 | 0.82385 | 0.55263 | - | - |
| Y3 | 0.90060 | 0.43220 | - | - |
| Y4 | 0.95462 | 0.29615 | -0.01195 | - |
| Y5 | 0.98516 | 0.16242 | -0.04909 | - |
| Y6 | 0.99662 | 0.04584 | -0.06685 | - |
| Y7 | 0.99720 | -0.04240 | -0.06061 | - |
| Y8 | 0.99391 | -0.09931 | -0.04516 | - |
| Y9 | 0.98981 | -0.13880 | -0.02533 | - |
| Y10 | 0.98575 | -0.16698 | -0.00309 | - |
| Y12 | 0.97595 | -0.21173 | 0.04987 | -0.00083 |
| Y15 | 0.95888 | -0.24834 | 0.13524 | 0.02335 |

The First factor explains 94.02% of the yield (Y2 through Y15) change.
The Second factor explains 5.51% of the yield (Y2 through Y15) change.
The Third factor explains 0.42% of the yield (Y4 through Y15) change.
The Fourth factor explains 0.04% of the yield (Y12 through Y15) change.
The number of factors is decided by the Johansen cointegration test.

### *4.3 Principal Component Analysis*

The factor loadings are shown in Table 4.14. The first factor shows positive associations between the factor and each interest rate roughly the equal magnitude. This factor can be characterized as a shift factor. The second factor can be interpreted as a slope factor. The third factor seems to represent the curvature of the term structure. The fourth factor is considered to be a special factor for the structure over 12 year. Especially 15 year has positive third factor and fourth factor distinguishing the super long zone from the entire curve.

**5. Concluding Remarks**

In this chapter, statistical analyses are organized to avoid spurious regression due to non-stationarity of financial time series. First I use unit root analysis to confirm the non-stationarity of the data. Then I draw the common trends by using cointegration analysis. This is tested by using not only the whole term structure but also parts of the term structure with the sequential subtraction of the data from longer maturities. Finally the principal component analysis is conducted.

From empirical analysis, I can conclude that the whole term structure from 2 year through 15 year is driven by 4 common trends. The result is consistent with the recognition held by the market participants that the term structure over 10 year is driven by a special trend. This special trend can be called a foreign factor deciding the movement of the super long structure of the Japanese Yen swap since most of the participants are non-Japanese investment houses and banks.

The term structure from 2 year through 10 year is driven by 3 common trends. The term structure from 2 year through 4 year is driven by two common trends. Thus the entire term structure is divided into three parts- (1) middle term (from 2 year through 4 year-two common trends), (2) long term (from 5 year through 10 year –two common trends), (5) superlong term (from 12 year through 15 year-four common trends).

Chapter 5

# The Interest Rate Linkage between Japan and US*

## 1. Introduction

This chapter analyzes the relationship of interest rates between Japan and US from October 1990 through August 2000 in the framework of uncovered interest rate parity relationship (UIP). Under floating exchange rate, interest rates differ across countries because the existing pressures on financial markets are absorbed by movements in the exchange rates or expected exchange rate development.

The international integration of financial markets has increased dramatically since the beginning of 1980's[1]. The development and increase of new financial instruments such as currency and interest rate swaps have stimulated international financial integration by giving investors a wider range of choices than previously available in domestic markets. However the international integration of financial markets does not necessarily work to equalize interest rates among different countries.

Bank for International Settlements (1989) provides wide range of survey and empirical result to conclude generally that the correlations of long-term interest rates among the three major economies were higher on average in the 1980's than during the 1970's. Frankel (1989) supports this view by Bank for International Settlements (1989). But Christiansen/Pigott (1997) point out that there seems to have been no further increase in the synchronization of long-term interest rates since the early 1980's. Kasman/Pigott (1988) reports that the increase

* This chapter is based on Ito (2005d).

1 Blundell-Wignall/Browne (1991),Frankel (1992) ,Goldstein/Mussa (1993) and Pigott (1993) show that the globalization of financial markets increased markedly.

of international integration in financial markets doesn't necessarily lead to the convergence of nominal interest rates.

Throop (1994) and Christiansen/Pigott (1997) apply non-stationary time series methods such as unit root test and cointegration. Throop (1994) finds that in the 1980's there was no measurable tendency for real short and long-term interest rates between US and the major industrial counties to converge. Christiansen/ Pigott (1997) conclude that bilateral co-variation of long-term interest rates has gone up in the 1990's among some European counties, but there is no evidence of any substantial increase for counties with floating exchange rates such as Japan and US.

Berk (2001) provides extensive studies on international co-movement of long term bonds from international business cycles and inflation expectations to find that there seems no to be any convincing evidence toward a particular direction of causality among major 6 industrialized nations. McCallum (1994) concludes that there are reasons for reviewing UIP relationship as more important than the unbiasedness of forward rates as predictors of future spot exchange rates.

In view of these previous studies, the following features characterize this chapter. First, this chapter uses the whole term structure of JP yen and US dollar interest rates from 1 month through 10 year. In this way, whether the whole term structure between JP and US has a long run relationship or some parts of the yield curves are in the long run equilibriums. Second, the whole sample period is divided into two based upon the monetary policy regimes. Thus investigating the interest rate linkages in different monetary policy regimes can be possible.

The remainder of this chapter is as follows. Section 2 describes the data. Section 3 discusses the framework of the analysis. Section 4 presents the results. Section 5 concludes.

## 2. Data

### 2.1 *JPY Interest Rates*

The 11 series of data-LIBOR (London Interbank Offered Rate-1 month, 3 month, 6 month, 9 month, 12 month) and interest rate swap rate[2] (2 year, 3 year, 4 year, 5 year, 7 year and 10

2 So far the issuances of JGB (Japanese Government Bond) are centered on 10 year. The most of trading

year) as of 5 pm in New York time are used on a daily basis from October 2,1990 through August 11, 2000.

### 2.2 *US Interest Rates*

The 11 series of data - LIBOR (London Interbank Offered Rate-1 month, 3 month, 6 month, 9 month, 12 month) and interest rate swap rate (2 year, 3 year, 4 year, 5 year, 7 year and 10 year) as of 5 pm New York time are used on a daily basis from October 2,1990 through August 11, 2000.

### 2.3 *Foreign Exchange Rate Expectation*

If realized values of foreign exchange rate change are *I* (1), the innovation will influence the future change of foreign exchange rates. When the expected values of foreign exchange rate change , $E_t\ (S_{t+j})/k$ , are defined as *j* term forward expectation of foreign exchange rate based on the period of *t* are random walk, it follows that $S_{t+1} = S_t + \varepsilon_{t+1}$ ( $\varepsilon_{t+1}$ is an innovation of value of foreign exchange rate change) .

Accordingly as for the expected value of foreign exchange rate change at the future time of *j*, equation (5.5) holds true. Thus realized values of foreign exchange rate at the time of *t* indicate the future expectation of foreign exchange rates.

$$E_t(S_{t+j}) = S_t \qquad (5.5)$$

In this chapter, the realized values of foreign exchange rate are calculated for the periods of 1 month, 3 month, 6 month, 9 month and 12 month. For the actual analysis, realized rates are used to match the maturities of interest rates. But for the maturities longer than 2 year, the realized data for the period of 12 month are used.

### 2.4 *Sample Period*

The whole sample is divided into two sub periods. The first sub period, named Sample A, is

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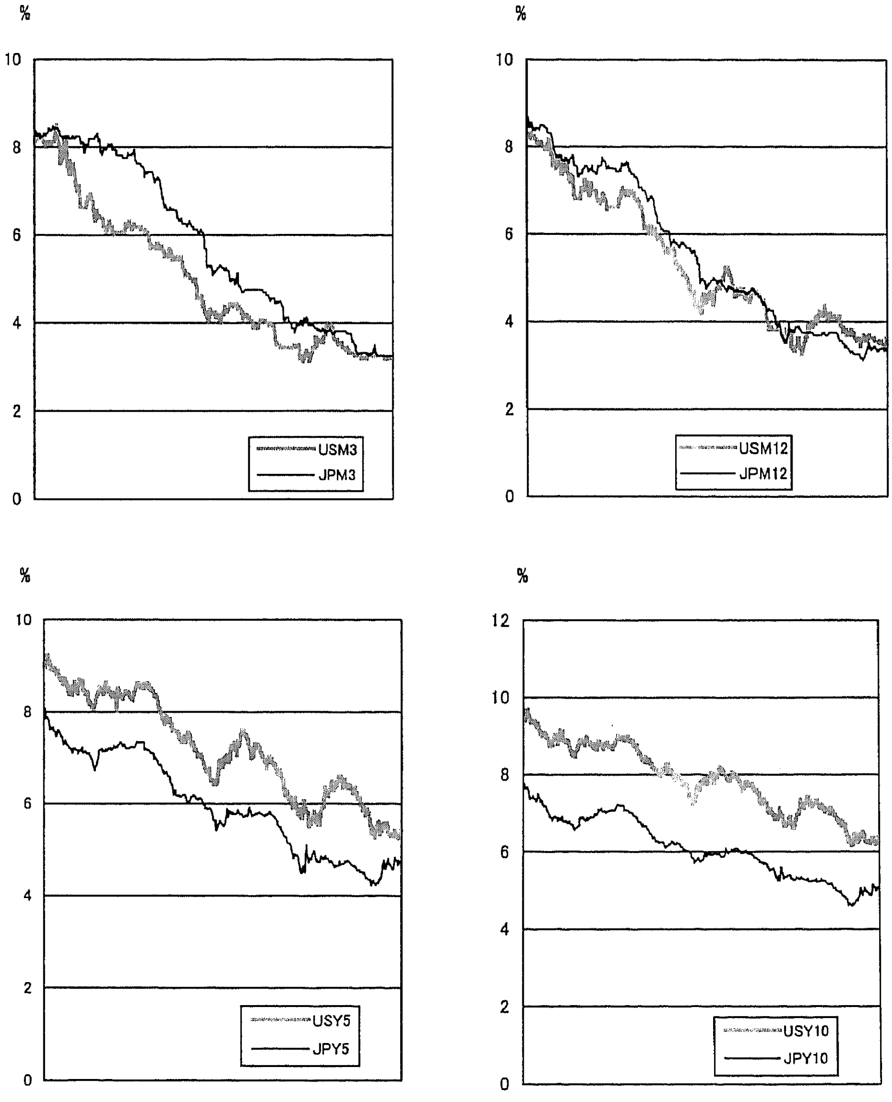
activities are made on 10 year JGB. Therefore it's very difficult to draw a proper yield curve by using the actual JGB data. On the other hand, actual transactions of interest rate swaps are conducted on the yield curve of 2 year through 10 year. Since swap data are used for Japanese yen, swap data are also used for U.S market.

from October2,1990 through May 17,1993. In Sample A the monetary policy regimes both in Japan and US are easing. The second sub period, named Sample B, is from May 18,1993 through August 11,2000.[3]

In Sample B the monetary policy regime in Japan is easing, but in US it's tightening. In figure 5.1 the comparison of 4 series (3 month, 12 month, 5 year, 10 year) in Sample A is shown. In figure 5.2 the comparison of 4 series (3 month, 12 month, 5 year, 10 year) in Sample B is indicated.

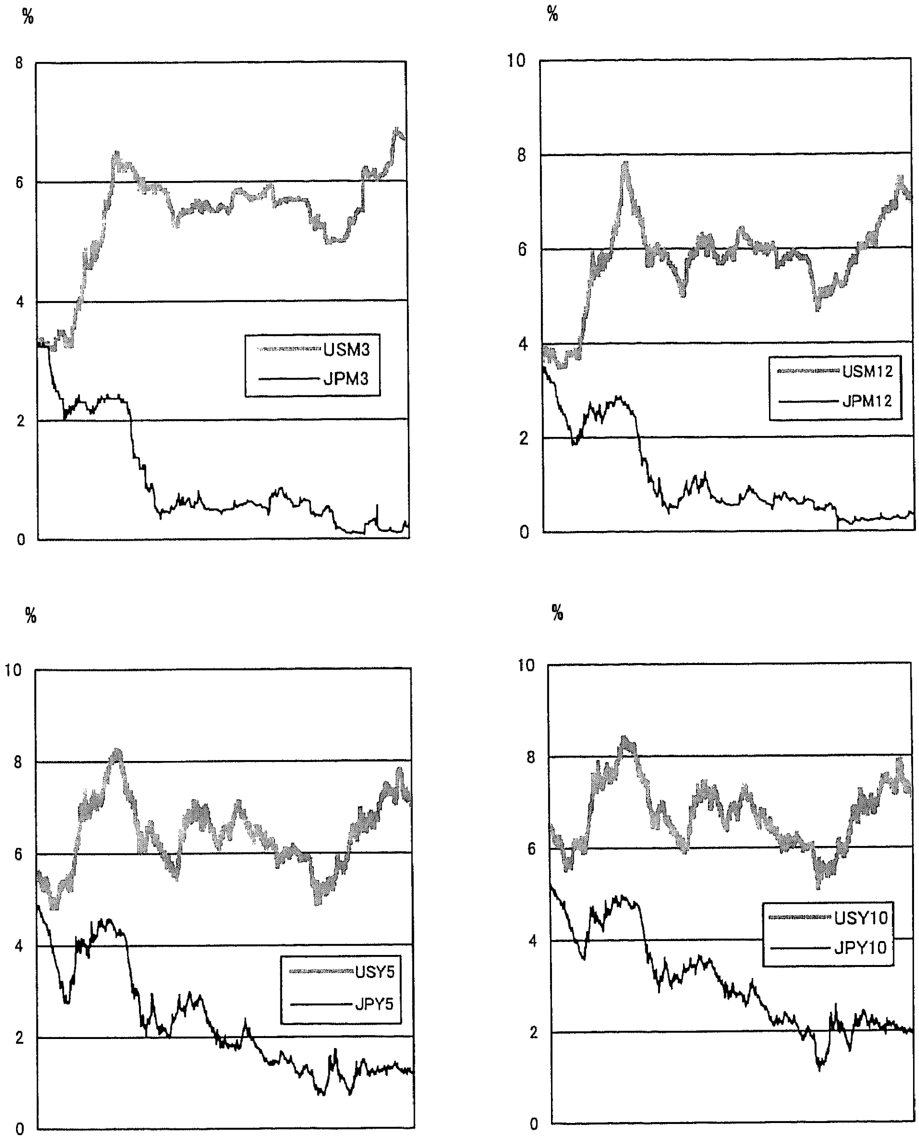
**Figure 5.1 The Movement of 4 Series (90.10.2～93.5.17)**




US=US Interest Rates
JP=Japanese Interest Rates

3 The Federal Open Market Committee (FOMC) changed monetary policy bias from neutral to tightening on May18,1993. The Bank of Japan lifted zero interest rate policy on August 11,2000.

**Figure 5.2 The Movement of 4 Series(93.5.18～00.8.11)**




US=US Interest Rates
JP=Japanese Interest Rates

## 3. Framework of Analysis

3.1 *Unit Root Test*

Since the empirical analysis from mid-1980 through mid-1990's show that such data as interest rates, foreign exchange and stocks are non-stationary, it's necessary to check if the data used in this chapter contain unit roots. The KPSS (Kwiatowski/Phillips/Schmidt/Shin) test is used. KPSS test defines null hypothesis as 'unit roots don't exist' and alternative hypothesis as 'unit roots exist'[4]. The KPSS test is considered to have more statistical power than other unit root tests such as ADF (Augmented Dickey/Fuller) and PP (Phillips Perron) tests[5].

3.2 *Cointegration Test*

The effects of exchange rate movements on interest rate relations can be described in terms of uncovered interest rate parity (UIP) relation. According to Blundell-Wignall/Brown (1991), UIP defines that the difference between any two countries' nominal interest rate equals the expected depreciation of the first country's currency against second's (over the life of the instrument).

$$i(k)_t - i(k)^*_t = E_t\,(S_{t+j})/k \qquad (5.1)$$

where $i(k)_t$ and $i(k)^*_t$ are respectively the interest rates on foreign currency and home currency denominated assets of a given maturity, $E_t\,(S_{t+j})/k$ is the expected (annualized) rate of home currency depreciation to maturity.

Generally OLS method is used to analyze the relationships among the variables. However when the non-stationary variables are included, ordinary hypothesis test tends to draw the mistaken results since the coefficient of determination and $t$-statistics do not follow the simple distribution.

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4 See Kwiatowski/Phillips/Scmidt/Shin (1992).

5 For the details of methods, see Dickey/Fuller (1979), Dickey/Fuller (1981) and Phillips/Perron (1988).

Granger/Newbold (1974) called this problem 'Spurious Regression'. Phillips (1986) pointed out two points as to the analysis of non-stationary data - (1) the coefficient of determination tend not to measure the relationship among variables,(2) estimated equation with low Durbin-Watson ratio can possibly have a problem of spurious regression.

Non-stationary time series wander widely with their own short-run dynamics, but a linear combination of the series can sometimes be stationary so that they show co-movement with long-run dynamics. This is called as cointegration by Engle/Granger (1987). In the test of cointegration, Equation (5.2) is estimated by OLS to find if residual contains unit root.

$$i(k)_t - i(k)_t^* = \alpha + \beta E_t(S_{t+k})/k + \varepsilon_t \tag{5.2}$$

When series $i(k)_t - i(k)_t^*$ and $E_t(S_{t+k})/k_t$ are both non-stationary $I$ (1), they are called to be in a relationship of cointegration if their linear combination is stationary $I$ (0).

3.3 *Granger Causality*

The Granger causality test checks whether $i(k)_t$ affects $i(k)_t^*$ or $i(k)_t^*$ affects $i(k)_t$ or $i(k)_t$ and $i(k)_t^*$ affect mutually in the time series model with regard to variables $i(k)_t$ and $i(k)_t^*$. The original data are usually transformed into the change ratio to avoid a problem of spurious regression. But using these data is considered to cause an error. Toda/Yamamoto (1995) developed the Granger causality test in which non-stationary data are directly used.

According to their method, the null hypothesis $H_0$ is tested as for the influence from $i(k)_t^*$ on $i(k)_t$ and for the influence from $i(k)_t$ on $i(k)_t^*$. But trend term $t$ and $p$ + *1* (original lag plus one) are added for the estimation.

$$i(k)_t^* = \kappa_0 + \lambda t + \sum_{i=1}^{p+1} \alpha_i i(k)_{t-i}^* + \sum_{i=1}^{p+1} \beta_i i(k)_{t-i} + u_t \tag{5.3}$$

$$H_0 : \beta_1 = \beta_2 = \cdots \beta_p = 0$$

$$H_1 : \text{Either } \beta_i \neq 0 \quad (i = 1,2,\cdots,p)$$

$$i(k)_t = \varsigma_0 + \eta t + \sum_{i=1}^{p+1} \gamma_i i(k)_{t-i} + \sum_{i=1}^{p+1} \delta_i i(k)_{t-i}^* + v_t \tag{5.4}$$

$H_0 : \delta_1 = \delta_2 = \cdots \delta_p = 0$

$H_1$ : Either $\gamma_i \neq 0 \quad (i = 1,2,\cdots,p)$

The $F$ test is conducted by estimating (5.3) and (5.4) through OLS and summing the squared error. If the null hypothesis of $H_0$ in the equation (5.3) is rejected, $i(k)_t$ is considered to explain $i(k)_t^*$. If the null hypothesis of $H_0$ in the formula (5.4) is rejected, $i(k)_t^*$ is considered to explain $i(k)_t$.

## 4. Result

### 4.1 *Unit Root Test*

KPSS test is conducted both for trend stationarity and level statinarity. The critical point of 5% is 0.463 (trend stationary) and 0.146 (level stationary) respectively. The results are shown on Table 5.1. There is no denying that all the variables are no stationary both in Sample A and Sample B.

**Table 5.1 KPSS Test -Original Series**

Sample A

| | Lag=4 | | Lag=12 | |
|---|---|---|---|---|
| Variable | $\eta_\mu$ | $\eta_\tau$ | $\eta_\mu$ | $\eta_\tau$ |
| USM1-JPM1 | 3.070* | 1.636* | 1.244* | 0.669* |
| USM3-JPM3 | 4.789* | 1.663* | 1.908* | 0.671* |
| USM6-JPM6 | 5.890* | 1.499* | 2.356* | 0.613* |
| USM9-JPM9 | 6.399* | 1.322* | 2.590* | 0.553* |
| USM12-JPM12 | 6.834* | 1.059* | 2.771* | 0.447* |
| USY2-JPY2 | 4.139* | 0.901* | 1.718* | 0.383* |
| USY3-JPY3 | 2.390* | 0.670* | 1.008* | 0.287* |
| USY4-JPY4 | 0.987* | 0.538* | 0.418* | 0.229* |
| USY5-JPY5 | 0.523* | 0.364* | 0.224* | 0.156* |
| USY7-JPY7 | 1.646* | 0.517* | 0.702* | 0.223* |
| USY10-JPY10 | 1.323* | 0.269* | 0.571* | 0.117* |
| E1 | 0.616* | 0.169* | 0.116* | 0.076* |
| E3 | 0.623* | 0.576* | 0.252* | 0.233* |
| E6 | 1.704* | 1.160* | 0.677* | 0.461* |
| E9 | 2.456* | 1.462* | 0.969* | 0.579* |
| E12 | 2.158* | 0.980* | 0.877* | 0.403* |

Sample B

| | Lag=4 | | Lag=12 | |
|---|---|---|---|---|
| Variable | $\eta_\mu$ | $\eta_\tau$ | $\eta_\mu$ | $\eta_\tau$ |
| USM1-JPM1 | 23.804* | 7.549* | 9.218* | 2.919* |
| USM3-JPM3 | 23.306* | 7.281* | 9.031* | 2.817* |
| USM6-JPM6 | 22.994* | 6.994* | 8.916* | 2.709* |
| USM9-JPM9 | 22.712* | 6.685* | 8.812* | 2.591* |
| USM12-JPM12 | 23.539* | 5.837* | 9.149* | 2.273* |
| USY2-JPY2 | 24.910* | 5.338* | 9.688* | 2.085* |
| USY3-JPY3 | 25.909* | 4.931* | 10.077* | 1.931* |
| USY4-JPY4 | 26.494* | 4.525* | 10.305* | 1.775* |
| USY5-JPY5 | 27.242* | 3.793* | 10.598* | 1.495* |
| USY7-JPY7 | 25.790* | 3.233* | 10.050* | 1.278* |
| USY10-JPY10 | 247.158* | 7.788* | 9.356* | 3.015* |
| E1 | 24.158* | 0.639* | 0.282* | 0.281* |
| E3 | 0.639* | 1.735* | 0.700* | 0.690* |
| E6 | 1.760* | 3.932* | 1.303* | 1.250* |
| E9 | 3.328* | 4.898* | 2.281* | 1.911* |
| E12 | 5.849* | 5.577* | 2.992* | 2.170* |

* indicates significance at the 5 % level.
5% critical values are 0.463 (trend stationary) 、 0.146(level stationary) .
$\eta_\mu$ indicates trend stationarity. $\eta_\tau$ indicates level stationarity.
E is expectation of foreign exchage rates.
For example, E1 is expectation of 1 month ahead.

**Table 5.2 KPSS Test - Series with a Fisrt Difference**

Sample A

| | Lag=4 | | Lag=12 | |
|---|---|---|---|---|
| Variable | ημ | ητ | ημ | ητ |
| ⊿(USM1-JPM1) | 0.151 | 0.038 | 0.230 | 0.060 |
| ⊿(USM3-JPM3) | 0.182 | 0.048 | 0.205 | 0.055 |
| ⊿(USM6-JPM6) | 0.099 | 0.034 | 0.111 | 0.038 |
| ⊿(USM9-JPM9) | 0.047 | 0.022 | 0.051 | 0.026 |
| ⊿(USM12-JPM12) | 0.028 | 0.022 | 0.032 | 0.024 |
| ⊿(USY2-JPY2) | 0.022 | 0.023 | 0.026 | 0.028 |
| ⊿(USY3-JPY3) | 0.031 | 0.027 | 0.039 | 0.033 |
| ⊿(USY4-JPY4) | 0.045 | 0.034 | 0.048 | 0.037 |
| ⊿(USY5-JPM5) | 0.056 | 0.034 | 0.064 | 0.038 |
| ⊿(USY7-JPY7) | 0.045 | 0.030 | 0.056 | 0.037 |
| ⊿(USY10-JPY10) | 0.049 | 0.027 | 0.059 | 0.032 |
| ⊿E1 | 0.087 | 0.082 | 0.100 | 0.094 |
| ⊿E3 | 0.093 | 0.076 | 0.100 | 0.076 |
| ⊿E6 | 0.147 | 0.070 | 0.148 | 0.072 |
| ⊿E9 | 0.151 | 0.056 | 0.157 | 0.059 |
| ⊿E12 | 0.032 | 0.022 | 0.037 | 0.025 |

Sample B

| | Lag=4 | | Lag=12 | |
|---|---|---|---|---|
| Variable | ημ | ητ | ημ | ητ |
| ⊿(USM1-JPM1) | 0.352 | 0.092 | 0.671* | 0.124 |
| ⊿(USM3-JPM3) | 0.911* | 0.202* | 0.882* | 0.199* |
| ⊿(USM6-JPM6) | 0.807* | 0.213* | 0.756* | 0.203* |
| ⊿(USM9-JPM9) | 0.563* | 0.183* | 0.540* | 0.175* |
| ⊿(USM12-JPM12) | 0.415 | 0.155* | 0.408 | 0.154* |
| ⊿(USY2-JPY2) | 0.194 | 0.097 | 0.200 | 0.100 |
| ⊿(USY3-JPY3) | 0.130 | 0.075 | 0.138 | 0.080 |
| ⊿(USY4-JPY4) | 0.094 | 0.059 | 0.103 | 0.064 |
| ⊿(USY5-JPM5) | 0.073 | 0.049 | 0.081 | 0.054 |
| ⊿(USY7-JPY7) | 0.043 | 0.034 | 0.050 | 0.039 |
| ⊿(USY10-JPY10) | 0.038 | 0.033 | 0.044 | 0.038 |
| ⊿E1 | 0.120 | 0.045 | 0.120 | 0.045 |
| ⊿E3 | 0.090 | 0.038 | 0.100 | 0.042 |
| ⊿E6 | 0.049 | 0.039 | 0.047 | 0.037 |
| ⊿E9 | 0.027 | 0.026 | 0.028 | 0.027 |
| ⊿E12 | 0.009 | 0.008 | 0.009 | 0.008 |

* indicates significance at the 5 % level.

5% critical values are 0.463 (trend stationary) 、 0.146(level stationary) .

ημ indicates trend stationarity. ητ indicates level stationarity.

E is expectation of foreign exchage rates.

For example, E1 is expectation of 1 month ahead.

Next, the data with first difference from original data are analyzed by KPSS test. There is no denying that all the variables are $I$ (1) in Sample A. But in Sample B,⊿ (USM3-JPM3),⊿ (USM6-JPM6) and ⊿(USM9-JPM9) are considered to contain unit roots. Results are shown on the Table 5.2.

4.2 *Cointegration Test*

Even though (USM3-JPM3),(USM6-JPM6) and (USM9-JPM9) are possibly to be $I$ (2) in Sample B, Engle /Granger cointegration test is conducted in accordance with Lukepohl (1991)[6]. In Sample A, UIP holds true in the term structure from 2 year through 10 year. In other words, we find evidence for closer long-run international linkage between JP and US in the term structure over 3 month from October 2,1990 through May 17,1993. The results are shown on Table 5.3.

On the other hand, in Sample B, we find no evidence of UIP in the entire term structure. Thus we find no evidence for long–run international linkages between JP and US from May 18,1993 and August 11,2000 .The results are shown on Table 5.3.

4.3 *Granger Causality*

In Sample A the influences of JP interest rates on US interest are confirmed in the entire structure except for 3 month and 6 month. The influences of US interest rates on JP interest rates are not confirmed in the entire term structure. The results are shown on Table 5.4.

On the other hand, in Sample B the influences of JP interest rates on US interest rates are confirmed in the entire term structure except for 6 month, 9 month and 12 month. The influences of US interest rates on JP interest rates are confirmed in the entire term structure. The results are shown on Table 5.5.Thus it can be concluded that during Sample B, JP interest rates and US interest rates influenced mutually.

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6 Lukepohl (1991) avoids distinguishing between variables with different order of integration.

## Table 5.3 Cointegration Test

Sample A

| Variables | Test Statistics |
|---|---|
| (USM1-JPM1),E1 | -2.8280 |
| (USM3-JPM3),E3 | -2.2490 |
| (USM6-JPM6),E6 | -2.1860 |
| (USM9-JPM9),E9 | -2.3870 |
| (USM12-JPM12),E12 | -2.3940 |
| (USY2-JPY2),E12 | -3.494* |
| (USY3-JPY3),E12 | -4.106* |
| (USY4-JPY4),E12 | -4.052* |
| (USY5-JPY5),E12 | -4.214* |
| (USY7-JPY7),E12 | -3.441* |
| (USY10-JPY10),E12 | -4.031* |

Sample B

| Variables | Test Statistics |
|---|---|
| (USM1-JPM1),E1 | -2.476 |
| (USM3-JPM3),E3 | -2.297 |
| (USM6-JPM6),E6 | -2.390 |
| (USM9-JPM9),E9 | -1.936 |
| (USM12-JPM12),E12 | -1.799 |
| (USY2-JPY2),E12 | -1.724 |
| (USY3-JPY3),E12 | -1.653 |
| (USY4-JPY4),E12 | -1.594 |
| (USY5-JPY5),E12 | -1.591 |
| (USY7-JPY7),E12 | -1.529 |
| (USY10-JPY10),E12 | -1.772 |

Critical value is -3.3377(5%) MacKinnon(1991).
* indicates significant at the 5% level.
E is expectation of foreign exchage rates.
For example, E1 is expectation of 1 month ahead.

## Table 5.4 Granger Causality -Sample A

From JP on US

| Variables | Lag | Test Statistics |
|---|---|---|
| JP M1 → US M1 | 11 | 3.051* |
| JP M3 → US M3 | 11 | 1.456 |
| JP M6 → US M6 | 2 | 1.605 |
| JP M9 → US M9 | 2 | 8.235* |
| JP M12 → US M12 | 2 | 10.000* |
| JP Y2 → US Y2 | 2 | 7.379* |
| JP Y3 → US Y3 | 3 | 5.146* |
| JP Y4 → US Y4 | 2 | 15.065* |
| JP Y5 → US Y5 | 2 | 13.253* |
| JP Y7 → US Y7 | 2 | 15.043* |
| JP Y10 → US Y10 | 6 | 8.247* |

From US on JP

| Variables | Lag | Test Statistics |
|---|---|---|
| US M1→JP M1 | 11 | 0.593 |
| US M3 →JP M3 | 11 | 0.819 |
| US M6 →JP M6 | 2 | 2.795 |
| US M9 → JP M9 | 2 | 0.853 |
| US M12 → JP M12 | 2 | 0.783 |
| US Y2 → JP Y2 | 2 | 0.358 |
| US Y3 →JP Y3 | 3 | 0.801 |
| US Y4 →JP Y4 | 2 | 0.553 |
| US Y5 →JP Y5 | 2 | 0.540 |
| US Y7 →JP Y7 | 2 | 0.712 |
| US Y10 → JP Y10 | 6 | 0.522 |

* indicates significant at the 5% level.
Original lag is chosen by AIC standard.
The method by Toda /Yamamoto(1995) is used.

**Table 5.5 Granger Causality -Sample B**

From JP on US

| Variables | Lag | Test Statistics |
|---|---|---|
| JP M1 → US M1 | 3 | 8.749* |
| JP M3 → US M3 | 12 | 4.266* |
| JP M6 → US M6 | 12 | 0.876 |
| JP M9 → US M9 | 12 | 1.388 |
| JP M12 → US M12 | 12 | 1.570 |
| JP Y2 → US Y2 | 13 | 3.497* |
| JP Y3 → US Y3 | 13 | 3.712* |
| JP Y4 → US Y4 | 13 | 4.226* |
| JP Y5 → US Y5 | 13 | 4.405* |
| JP Y7 → US Y7 | 5 | 9.576* |
| JP Y10 → US Y10 | 13 | 3.756* |

From US on JP

| Variables | Lag | Test Statistics |
|---|---|---|
| US M1→JP M1 | 3 | 6.589* |
| US M3 →JP M3 | 10 | 2.255* |
| US M6 →JP M6 | 12 | 2.571* |
| US M9 → JP M9 | 12 | 3.065* |
| US M12 →JP M12 | 12 | 2.643* |
| US Y2 → JP Y2 | 13 | 2.934* |
| US Y3 →JP Y3 | 13 | 2.577* |
| US Y4 →JP Y4 | 13 | 2.128* |
| US Y5 →JP Y5 | 13 | 2.386* |
| US Y7 →JP Y7 | 5 | 2.152* |
| US Y10 → JP Y10 | 13 | 1.876* |

* indicates significant at the 5% level.
Original lag is chosen by AIC standard.
The method by Toda /Yamamoto(1995) is used.

## 5. Concluding Remarks

This chapter examines the international linkage of interest rates between JP and US in the framework of UIP by using the data from 1 month through 10 year. The whole sample from

October 2,1990 through August 8,2000 is divided into two sub periods. The first sub period, named Sample A, is from October2,1990 through May 17,1993. In Sample A the monetary policy regimes both in Japan and US are easing. From a view point of economic cycles, in Sample A, both Japan and US are downtrend. The second sub period, named Sample B, is from May 17,1993 through August 11,2000. In Sample B the monetary policy regime in Japan is easing, but in US it's tightening. From a view point of economic cycles, in Sample B, Japan is downtrend, but US is uptrend.

In Sample A, UIP holds true in the term structure from 2 year through 10 year. In other words, we find evidence for closer long-run international linkage between JP and US in the term structure from 2 year through 10 year in the period from October 2,1990 through May 17,1993. The influences of JP interest rates on US interest rates are confirmed in the entire structure except for 3 month and 6 month. The influences of US interest rates on JP interest rates are not confirmed in the entire term structure.

On the other hand, in Sample B, we find no evidence of UIP in the entire term structure. Thus we find little evidence for long-run international linkages between JP and US in the entire term structure from May 18,1993 and August 11,2000 .

From October 2,1990 through May 17,1993, monetary policies both in Japan and US are in easing phase. Thus it's considered that economic cycles both in Japan and US during that period are in downtrend. When the FRB changed monetary policy stance from neutral to tightening on May18,1993, the divergence of JP and US interest rates over 2 year started.

The influences of JP interest rates on US interest rates are confirmed in the entire term structure except for 6 month,9 month and 12 month. The influences of US interest rates on JP interest rates are confirmed in the entire term structure.

The results of this chapter show that only when economic cycles are generally coincided between Japan and US, long term interest rates (from 2 year through 10 year) were in the long term equilibrium through the expectation of foreign exchange rates. Thus domestic factors are considered to exert an important influence on short and long term interest rates.

As for the remaining topics, (1) to investigate the reasons why US interest rates didn't influence JP interest rates in Sample A, (2) to estimate the error correction models and impulse response function, (3) to add Euro interest rates to check the relationship of interest rates among US, Japan, and EU —these three points are to be pointed out.

Chapter 6

# Comparing Yield Curves in Japan and US*

## 1. Introduction

The Bank of Japan (hereinafter BOJ) and the Federal Reserve Board (hereinafter FRB) conduct open market operations such as the purchase and sales of government bills to adjust the overnight interest rates within target ranges[1]. The overnight rates are considered to be the only benchmarks the BOJ and the FRB can be responsible in the interest rate targeting procedures.

The effects of the monetary policy can exert an influence on the shapes of the Japanese yen and US dollar yield curve respectively. The purpose of this chapter is to compare the number of common trends that explain the dynamics of the term structure of interest rates by analyzing the interest rate swap yield curves in Japan and US.

In this chapter, Johansen cointegration tests are conducted by using not only the whole term structure but also parts of the term structure with the sequential subtraction of the data from longer maturities to find the areas where a single common trend is a driving force. No previous study compares the yield curves of Japan and US as in this chapter.

There are numbers of previous studies in which cointegration are applied for the analysis of term structure of interest rates.

Hall/Anderson/Granger (1992) conducted Johansen cointegration test by using the US

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* This chapter is based on Ito (2005e).

[1] Starting in March 21,2001, BOJ changed their operating target from uncollateralized overnight call rate to current account balance held by financial institutions with the introduction of quantitative easing. In this paper, sample period ends on March 30,1999.

Treasury bill monthly data (11 series: 1 month through 11 month) from 1970 through 1988. They found that the entire series are comprised of 10 cointegration vectors and 1 common trend. Then they divided the entire sample period into three: one from March 1970 through September 1979, one from October 1979 through September 1982 and one from October 1982 through December 1988.

They conducted Johansen cointegration test by using the 4 series of data (1 month,2 month,3 month and 4 month) for each sub-period of the entire sample. They get a conclusion that there is a single common trend in the era (from March 1970 through September 1979 and from October 1982 through December 1988) when FRB took a policy of stabilized monetary policy. On the other hand they find that there are more than two common trends in the period from October 1979 through September 1982 when FRB emphasized the control of money supply.

Karfakis/Moschos (1995) tested the expectations theory of interest rates by analyzing the Australian monthly and quarterly domestic interest rates (overnight, 3 month, 2 year, 5 year and 10 year). They concluded that the spread between 3 months data and long-term interest rate could predict the change of 3-month interest rate. They also got a conclusion to support the expectations hypothesis that the spread between overnight and 3 month rate can forecast the overnight rate. Finally they conducted the Granger causality test to get a result that overnight interest rate controlled by the RBA (Reserve Bank of Australia) can influence the long term interest rates.

Hiraki/Takezawa/Shiraishi (1996) applied cointegration analysis to Japanese data. They use the 13 series of data from 1988 through 1995. They conducted the unit root test and Johansen cointegration test. As for the daily data, they get a conclusion that the entire series has 11 cointagration vectors and 2 common trends. Bradley/Lumpkin (1992) used the monthly US Treasury data (3 month,1 year,3 year,5 year,7 year,10 year and 30 year) from 1972 through 1988.They find that there is a long term relationship between each series of the data. They only test the data series in a pair since they use the Engle/Granger cointegration test.

Engsted/Tanggaard (1994) conducted the Johansen cointegration test by using 4 series of US Treasury data (3 month, 1 year,10 year and 30 year). They find that the entire series has 3 cointegration vectors and 1 common trend.

Mougoue (1992) analyzed the monthly a Euro interest rates (Canada, Germany, Japan, Swiss, United Kingdom, and US) from 1980 through 1990 (1 month, 2 month, 3 month and 6 month). They got a conclusion by Johansen cointegration test that each series has 3 cointegration vectors and 1 common trend. Then they conducted the same analysis by using the series of same maturities cross-sectionally to find that data series of same maturity has 1 cointegration vector. They suggested that there exists a weak form of efficient market hypothesis.

Zhang (1993) conducted the unit root test and Johansen cointegration test by using the 19 series of monthly US treasury data from February 1964 through December 1986. They concluded that the entire series has 16 cointegraton vectors and 3 common trends in the term structure from 1 month through 10 year.

The remainder of this chapter is as follows. Section 2 describes the data. Section 3 discusses the framework of the analysis. Section 4 presents the results. Section 5 concludes.

## 2. Data

### *2.1 Japan*

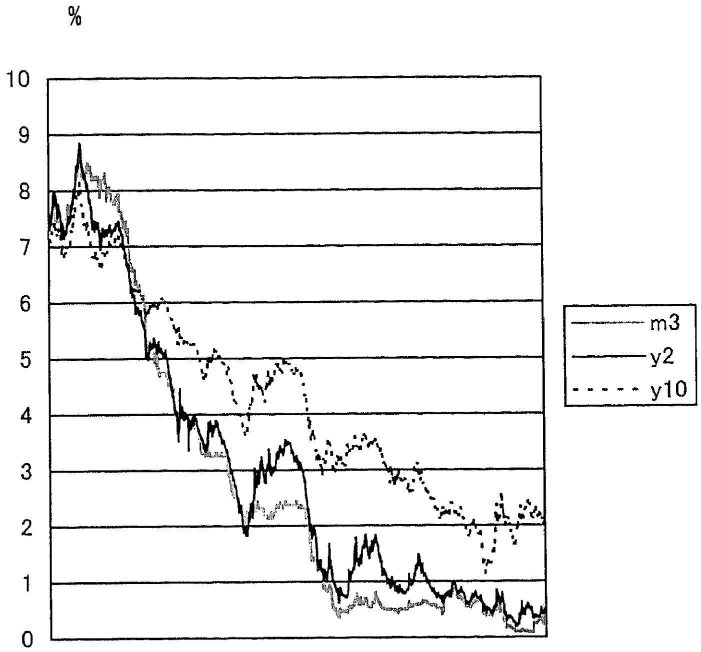
The 11 series of data - uncollateralized overnight call rate, LIBOR (London Interbank Offered Rate-3 month,6 month,9 month,12 month), interest rate swap rate[2] (2 year, 3 year, 4 year, 5 year, 7 year and 10 year) are used on a daily basis from February,8 1990 through March 30,1999. Figure 6.1 shows the movement of 4 series of data (3 month LIBOR, swap rate 2 year, and 10 year).

### *2.2 US*

The 11 series of data- overnight FF (Federal Funds) rate, LIBOR (London Interbank Offered Rate-3 month, 6 month, 9 month, 12 month), interest rate swap rate (2 year, 3 year, 4 year, 5 year,7 year and 10 year) are used on a daily basis from February,8 1990 through March 30,1999. Figure 6.2 shows the movement of 4 series of data (3 month LIBOR, swap rate 2 year, and 10 year).

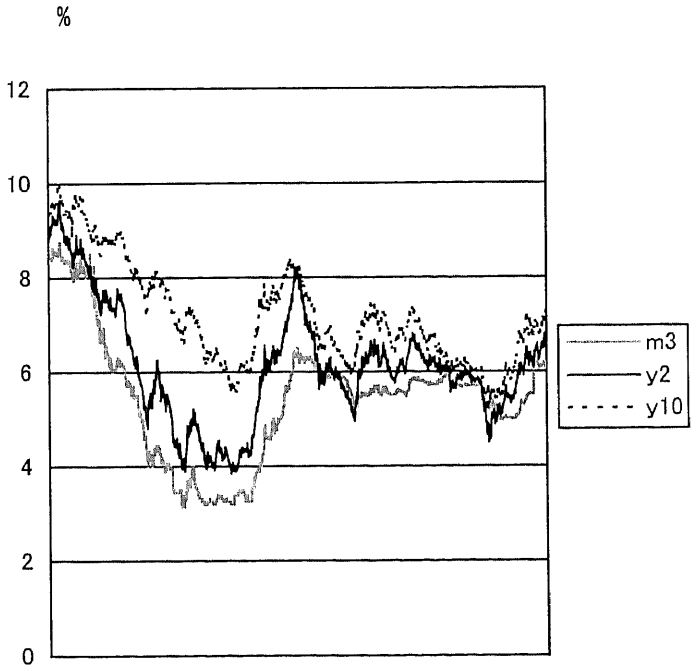
2 So far the issuances of JGB (Japanese Government Bond) are centered on 10 year. The most of trading activities are made on 10 year JGB. Therefore it's very difficult to draw a proper yield curve by using the actual JGB data. On the other hand, actual transactions of interest rate swaps are conducted on the yield curve of 2 year through 10 year.

**Figure 6.1 The Movement of Japanese Yen Rate**




(From Feburay 8,1990 through March 30,1999)

**Figure 6.2 the Movement of US dollar Rate**




(From Feburay 8,1990 through March 30,1999)

## 3. The Framework of Analysis

### *3.1 Unit Root Test*

Since the empirical analysis from mid-1980's through mid-1990's show that such data as interest rates, foreign exchange and stocks are non-stationary, it's necessary to check if the data used in this paper contain unit roots[3]. The ADF (Augmented Dickey Fuller) test and the PP (Phillips Perron) test are used[45]. Both the ADF and PP tests define null hypothesis as 'unit roots exist' and alternative hypothesis as 'unit roots don't exist'. Fuller (1976) provides the table for ADF and PP test.

### *3.2 Cointegration Test of Johansen and Common Trend*

There are mainly two types of cointegration test- (1) Engle/Granger(1987), (2) Johansen (1988)[6]. The most difficult part of cointegration analysis starting from *VAR* model is how to decide the number of cointegration relationship. When 3 variables are analyzed, the number of cointegration relationship may be 1 or 2. Engle/Granger can't cope with this problem, but Johansen is able to decide the number of cointegration relationship and to get a MLE of unknown parameters.

Johansen suggested the analysis with the *k* order *VAR* mode. Here *VAR* model is presented with *k* order against vector $X_t$ with *p* variables.

$$X_t = \Pi_1 X_{t-1} + \ldots + \Pi_k X_{t-k} + \lambda + u_t \qquad (6.1)$$

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[3] Generally OLS method is used to analyze the relationships among the variables. However when the non-stationary variables are included, ordinary hypothesis test tends to draw the mistaken results since the coefficient of determination and t-statistics do not follow the simple distribution. Granger/Newbold(1974) call this problem 'Spurious Regression'. Phillips(1986) points out two things as to the analysis of non-stationary data—(1) the coefficient of determination tend not to measure the relationship among variables,(2) the estimated equation with low Drubin-Watson ratio can possibly have a problem of spurious regression. Nelson/Plosser(1982) get a conclusion that there is no denying the existence of unit root in the macro economic variables of US.

[4] See Dickey/Fuller(1979) and Dickey/Fuller(1981).

[5] See Phillips/Perron(1988).

[6] The test of expectations hypothesis is conducted by applying the Johansen method to the term structure of interest rates. As for the theoretical framework, Hall/Anderson/Granger(1992) and Engsted/ Tannggaard (1994) are referred. When the expectations hypothesis holds true, the term structure is driven by a single common trend. Based upon the analysis in this paper, the expectations hypothesis dose not hold true in either Japan or in US.

All the p elements of $X_t$ is considered to be $I$ (1) variables. $u_t$ is an error term with zero mean. λ is a constant term. The equation (6.1) is expressed by using a first difference.

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi \Delta X_{t-k} + \lambda + u_t \qquad (6.2)$$

Here

$$\Gamma_I = -I + \Pi_1 + \ldots + \Pi_i, \quad (i = 1, \ldots, k-1)$$
$$\Pi = -I + \Pi_1 + \ldots + \Pi_k$$

Under the assumption that all the elements of $X_t$ are $I$ (1), $\Pi X_{t-1}$ needs to be $I$ (0). This means the rank of matrix $\Pi$ satisfies $0 \le rank(\Pi) < p$. When the elements of $X_t$ are in the relationship of cointegration, $0 < rank(\Pi) < p$ is established. Thus matrix $\Pi$ can be expressed as $\Pi = \alpha\beta'$ by using the $\alpha$ and $\beta$ of $p$ x $r$ matrix $\Pi$. Finally the equation (6.2) can be expressed as follows.

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} \ldots + \Gamma_{t-k} \Delta X_{t-k+1} + \alpha\beta' \Delta X_{t-k} + \lambda + u_t \qquad (6.3)$$

$\beta'$ is a cointegration vector and $\beta' X_{t-k}$ is an error correction term. The Johansen methodology tests $r$ consecutively by comparing the likelihood ratio of model estimated to have $r$ number of cointegration under null hypothesis with the likelihood ratio of model under the alternative hypothesis. The alternative hypothesis has two types mentioned below.

(1) Type not considering the number of cointegration (trace test).
(2) Type increasing the number of cointegration by one to ask for the redundancy of the model (maximum eigenvalue test).

Johansen methodology is used in this chapter since the number of dada series is 11. Osterwald-Lenum (1992) provides the table for maximal eigen value test and trace test.

An alternative interpretation of the cointegration between yields of different maturities arises from the relationship between cointegration and common trends. Stock/Watson (1988) show that when there are $(n-p)$ linearly independent cointegrating vectors for a set of n $I$

(1) variables, then each of these $n$ variables can be expressed as a linear combination of P $I$ (1) common trends and an $I$ (0) component[7].

Applying the result to this paper, we expect that there will be a couple of nonstationary common trend in the yields of different maturity[8]. Denoting the $I$ (1) common trends by $W(t_1) \ldots W(t_n)$, a simple representation of how it links the yield curve is given by

$$
\begin{aligned}
R(1,t) &= A(1,t) + b_1 W(t_1) \\
R(2,t) &= A(2,t) + b_2 W(t_1) + b_2 W(t_2) \\
&\ldots\ldots\ldots \\
R(n,t) &= A(n,t) + b_n W(t_1) + b_n W(t_2) \ldots b_n W(t_n)
\end{aligned}
$$

where $A(i,t)$ are $I$ (0) variables. Since $W(t_n)$ is $I$ (1) and $A(i,t)$ are $I$ (0), the observed long-run movement in each yield is mainly due to the common trends. Thus $W(t_n)$ drives the time series behavior of each yield and determines how the entire yield curve change over time. $W(t_n)$ are considered as something exogenous to the system of yield curve such as inflation, measures of monetary growth and etc.

Usually yield curve is supposed to have a couple of common trends (in other words, factors) - level, steepness and curvature. In this article, Johansen cointegration tests are conducted by using not only the whole term structure but also parts of the term structure with the sequential subtraction of the data from longer maturities to find the areas where only the level of overnight rates can influence.

## 4. Result

### *4.1 Unit Root Analysis*

The ADF and PP Tests are conducted both for with time trend and without time trend. AIC

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7 They draw the following conclusion. The multivariate time series in the cointegration relationship has at least one common trend. They test to extract common trends by using multivariate time series both with drift and without drift. Both types of test include the roots obtained by regressing the time series into the 1st lag. The critical values for test are calculated and the power is investigated by Monte Carlo method. Usually economic time series are modeled as having a unit root or a common trend. They also get a conclusion from an empirical analysis that the time series with three variables (federal funds rate, 90 day US Treasury bills,1 year US Treasury bills) has 2 cointegration vectors and a common factor.

8 Hall/Anderson/Granger(1992) is referred for this part.

standard is used for the determination of lag length in the ADF Test. The results are shown on Table 6.1 through Table 6.4.

Even though the results of PP tests for US FF rate and 7 year rate show that they don't have unit roots, but all the results of ADF tests show that all the data have unit root. Thus the doubt that none of the variables is not stationary can't be excluded. It's proper to think that non-stationary time series models are to be used to avoid the problem of spurious regression.

**Table 6.1 ADF Test - JPY Original Series**

| Variable | Without Trend | With Trend |
|---|---|---|
| O/N Call | -1.115 | -0.457 |
| M3 | -1.180 | -0.324 |
| M6 | -1.908 | -0.498 |
| M9 | -1.857 | -0.692 |
| M12 | -1.855 | -0.823 |
| Y2 | -1.497 | -0.993 |
| Y3 | -1.350 | -1.329 |
| Y4 | -1.251 | -1.571 |
| Y5 | -1.157 | -1.732 |
| Y7 | -1.226 | -2.649 |
| Y10 | -0.980 | -2.161 |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(With Trend) .

**Table 6.2 ADF Test - US Original Series**

| Variable | Without Trend | With Trend |
|---|---|---|
| O/N FF | -2.289 | -2.068 |
| M3 | -2.261 | -1.920 |
| M6 | -2.233 | -1.926 |
| M9 | -2.199 | -1.906 |
| M12 | -2.212 | -1.958 |
| Y2 | -2.223 | -1.856 |
| Y3 | -2.224 | -1.889 |
| Y4 | -2.207 | -1.758 |
| Y5 | -2.193 | -1.723 |
| Y7 | -2.138 | -1.553 |
| Y10 | -2.036 | -1.583 |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(With Trend) .

**Table 6.3 PP Test- JPY Original Series**

| Variable | Without Trend | With Trend |
|---|---|---|
| O/N Call | -1.296 | -2.420 |
| M3 | -1.612 | -0.060 |
| M6 | -1.573 | -0.468 |
| M9 | -1.650 | -0.509 |
| M12 | -1.657 | -0.614 |
| Y2 | -1.546 | -0.852 |
| Y3 | -1.386 | -1.185 |
| Y4 | -1.267 | -1.470 |
| Y5 | -1.195 | -1.574 |
| Y7 | -1.036 | -1.987 |
| Y10 | -1.013 | -2.256 |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(With Trend) .

**Table 6.4 PP Test - US Original Series**

| Variable | Without Trend | With Trend |
|---|---|---|
| O/N FF | -5.557* | -5.556* |
| M3 | -2.207 | -1.835 |
| M6 | -2.226 | -1.865 |
| M9 | -2.270 | -1.898 |
| M12 | -2.267 | -1.897 |
| Y2 | -2.338 | -1.970 |
| Y3 | -2.357 | -1.973 |
| Y4 | -2.251 | -1.708 |
| Y5 | -2.258 | -1.759 |
| Y7 | -3.637* | -4.437* |
| Y10 | -2.117 | -1.817 |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(With Trend) .

Next, the data with a first difference are analyzed by ADF and PP Tests. It's possible to conclude that all the original variables are *I* (1), results are shown on the Table 6.5 through Table 6.8.

**Table 6.5 ADF Test - JPY Series with First Difference**

| Variable | Without Trend | With Trend |
|---|---|---|
| ⊿O/N Call | -16.963* | -16.991* |
| ⊿M3 | -13.617* | -13.744* |
| ⊿M6 | -12.762* | -12.900* |
| ⊿M9 | -11.281* | -11.404* |
| ⊿M12 | -12.158* | -12.272* |
| ⊿Y2 | -46.471* | -46.397* |
| ⊿Y3 | -46.493* | -46.403* |
| ⊿Y4 | -47.457* | -47.363* |
| ⊿Y5 | -46.369* | -46.260* |
| ⊿Y7 | -35.824* | -35.741* |
| ⊿Y10 | -37.008* | -36.866* |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41 (With Trend) .

**Table 6.6 ADF Test - US Series with First Difference**

| Variable | Without Trend | With Trend |
|---|---|---|
| ⊿O/N FF | -25.540* | -25.625* |
| ⊿M3 | -13.444* | -13.749* |
| ⊿M6 | -13.374* | -13.611* |
| ⊿M9 | -12.758* | -12.940* |
| ⊿M12 | -47.752* | -47.707* |
| ⊿Y2 | -26.996* | -27.036* |
| ⊿Y3 | -55.947* | -55.845* |
| ⊿Y4 | -26.481* | -26.511* |
| ⊿Y5 | -13.271* | -13.345* |
| ⊿Y7 | -26.287* | -24.062* |
| ⊿Y10 | -22.601* | -22.657* |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(With Trend) .

**Table 6.7 PP Test - JPY Series with Difference**

| Variable | Without Trend | With Trend |
|---|---|---|
| ⊿O/N Call | -72.916* | -72.908* |
| ⊿M3 | -47.222* | -47.269* |
| ⊿M6 | -59.880* | -59.938* |
| ⊿M9 | -58.787* | -58.848* |
| ⊿M12 | -58.266* | -58.322* |
| ⊿Y2 | -46.471* | -46.492* |
| ⊿Y3 | -46.492* | -46.503* |
| ⊿Y4 | -47.457* | -46.369* |
| ⊿Y5 | -46.368* | -46.369* |
| ⊿Y7 | -47.588* | -47.583* |
| ⊿Y10 | -48.480* | -48.474* |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(with Trend) .

**Table 6.8 PP Test - US Series with First Difference**

| Variable | Without Trend | With Trend |
|---|---|---|
| ⊿O/N FF | -71.353* | -71.345* |
| ⊿M3 | -46.781* | -46.924* |
| ⊿M6 | -46.860* | -46.982* |
| ⊿M9 | -47.090* | -47.186* |
| ⊿M12 | -47.752* | -47.831* |
| ⊿Y2 | -57.336* | -57.380* |
| ⊿Y3 | -55.947* | -55.978* |
| ⊿Y4 | -47.382* | -47.411* |
| ⊿Y5 | -48.545* | -48.569* |
| ⊿Y7 | -76.912* | -76.911* |
| ⊿Y10 | -48.755* | -48.769* |

* indicates significance at the 5 % level.
5% critical values are -2.86(Without Trend)-3.41(with Trend) .

*4.2 Cointegration Test - Japan*

(1) From uncollateralized overnight call rate through 10 year swap rate (11 data series)

The number of cointegration vector is 8. The number of common trend is 3. The whole term structure is driven by 3 common trends. The result is shown on the Table 6.9.

**Table 6.9 Cointegration Test -Japan ( 11 series -from ON through 10Y)**

| Hypothesis | λmax | 5% Value | 1% Value | λtrace | 5% Value | 1% Value |
|---|---|---|---|---|---|---|
| r = 0 | 409.97** | 69.74 | 76.63 | 1584.07** | 291.40 | 307.64 |
| r≦1 | 294.94** | 63.57 | 69.94 | 1174.1** | 244.15 | 257.68 |
| r≦2 | 252.85** | 57.42 | 63.71 | 879.16** | 202.92 | 215.74 |
| r≦3 | 219.93** | 52.00 | 57.95 | 626.32** | 165.58 | 177.20 |
| r≦4 | 182.14** | 46.45 | 51.91 | 406.39** | 131.70 | 143.09 |
| r≦5 | 89.52** | 40.30 | 46.82 | 224.25** | 102.14 | 111.01 |
| r≦6 | 63.92** | 34.40 | 39.79 | 134.74** | 76.07 | 84.45 |
| r≦7 | 41.49** | 28.14 | 33.24 | 70.82** | 53.12 | 60.16 |
| r≦8 | 17.67 | 22.00 | 26.81 | 29.32 | 34.91 | 41.07 |
| r≦9 | 7.22 | 15.67 | 20.20 | 11.65 | 19.96 | 24.60 |
| r≦10 | 4.44 | 9.24 | 12.97 | 4.44 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 11 series of Japanese data.
The number of cointegration vector is 8. The number of common trend is 3.
The entire term structure is driven by 3 common trends.
**,* indicates signigicance at the 1 % and 5 % level respectively.
Critical Values are from Osterwald-Lenum(1992).

(2) From uncollateralized overnight call rate through 7 year swap rate (10 data series)

The number of cointegration vector is 8. The number of common trend is 2. The term structure up to the 7 year is driven by 2 common trends. The result is shown on Table 6.10.

**Table 6.10 Cointegration Test -Japan ( 10 series -from ON through 7Y)**

| Hypothesis | λmax | 5% Value | 1% Value | λtrace | 5% Value | 1% Value |
|---|---|---|---|---|---|---|
| r = 0 | 409.08** | 63.57 | 69.94 | 1519.62** | 244.15 | 257.68 |
| r≦1 | 290.76** | 57.42 | 63.71 | 1110.54** | 202.92 | 215.74 |
| r≦2 | 247.91** | 52.00 | 57.95 | 819.78** | 165.58 | 177.20 |
| r≦3 | 219.94** | 46.45 | 51.91 | 571.87** | 131.70 | 143.09 |
| r≦4 | 178.74** | 40.30 | 46.82 | 351.92** | 102.14 | 111.01 |
| r≦5 | 81.91** | 34.40 | 39.79 | 173.19** | 76.07 | 84.45 |
| r≦6 | 48.17** | 28.14 | 33.24 | 91.28** | 53.12 | 60.16 |
| r≦7 | 31.50** | 22.00 | 26.81 | 43.11** | 34.91 | 41.07 |
| r≦8 | 7.26 | 15.67 | 20.20 | 11.6 | 19.96 | 24.60 |
| r≦9 | 4.34 | 9.24 | 12.97 | 4.34 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 10 series of Japanese data.
The number of cointegration vector is 8. The number of common trend is 2.
The term structure up to 7 year is driven by 2 common trends.
**,* indicates signigicance at the 1 % and 5 % level respectively.
Critical Values are from Osterwald-Lenum(1992).

(3) From uncollateralized overnight call rate through 5 year swap rate (9 data series)

The number of cointegration vector is 7. The number of common trend is 2. The term structure up to the 5 year is driven by 2 common trends. The result is shown on the Table 6.11.

**Table 6.11 Cointegration Test -Japan ( 9 series -from ON through 5 Y)**

| Hypothesis | λmax | 5% Value | 1% Value | λtrace | 5% Value | 1% Value |
|---|---|---|---|---|---|---|
| r = 0 | 409.95** | 57.42 | 63.71 | 1444.64** | 202.92 | 215.74 |
| r≦1 | 288.74** | 52.00 | 57.95 | 1034.69** | 165.58 | 177.20 |
| r≦2 | 242.19** | 46.45 | 51.91 | 745.95** | 131.70 | 143.09 |
| r≦3 | 219.71** | 40.30 | 46.82 | 503.77** | 102.14 | 111.01 |
| r≦4 | 165.28** | 34.40 | 39.79 | 284.06** | 76.07 | 84.45 |
| r≦5 | 62.22** | 28.14 | 33.24 | 118.78** | 53.12 | 60.16 |
| r≦6 | 44.81** | 22.00 | 26.81 | 56.56** | 34.91 | 41.07 |
| r≦7 | 7.32 | 15.67 | 20.20 | 11.75 | 19.96 | 24.60 |
| r≦8 | 4.43 | 9.24 | 12.97 | 4.43 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 9 series of Japanese data.
The number of cointegration vector is 7. The number of common trend is 2.
The term structure up to 5 year is driven by 2 common trend.
**,* indicates signigicance at the 1 % and 5 % level respectively.
Critical Values are from Osterwald-Lenum(1992).

(4) From uncollateralized overnight call rate through 4 year swap rate (8 data series)

The number of cointegration vector is 6. The number of common trends is 2. The term structure up to the 4 year is driven by 2 trends. The result is shown on the Table 6.12.

**Table 6.12 Cointegration Test -Japan ( 8 series -from ON through 4 Y)**

| Hypothesis | λmax | 5% Value | 1% Value | λtrace | 5% Value | 1% Value |
|---|---|---|---|---|---|---|
| r = 0 | 404.66** | 52.00 | 57.95 | 1295.56** | 165.58 | 177.20 |
| r≦1 | 286.26** | 46.45 | 51.91 | 890.9** | 131.70 | 143.09 |
| r≦2 | 241.77** | 40.30 | 46.82 | 604.64** | 102.14 | 111.01 |
| r≦3 | 186.98** | 34.40 | 39.79 | 362.87** | 76.07 | 84.45 |
| r≦4 | 110.68** | 28.14 | 33.24 | 175.89** | 53.12 | 60.16 |
| r≦5 | 53.13** | 22.00 | 26.81 | 65.21** | 34.91 | 41.07 |
| r≦6 | 7.29 | 15.67 | 20.20 | 12.08 | 19.96 | 24.60 |
| r≦7 | 4.79 | 9.24 | 12.97 | 4.79 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 8 series of Japanese data.
The number of cointegration vector is 6. The number of common trend is 2.
The term structure up to 4 year is driven by 2 common trend.
**,* indicates signigicance at the 1 % and 5 % level respectively.
Critical Values are from Osterwald-Lenum(1992).

(5) From uncollateralized overnight call rate through 3 year swap rate (7 data series)

The number of cointegration vector is 5. The number of common trend is 2. The term structure up to the 3 year is driven by 2 trends. The result is shown on the Table 6.13.

**Table 6.13 Cointegration Test -Japan ( 7 series -from ON through 3 Y)**

| Hypothesis | λmax | 5% Value | 1% Value | λtrace | 5% Value | 1% Value |
|---|---|---|---|---|---|---|
| r = 0 | 391.14** | 46.45 | 51.91 | 1098.64** | 131.70 | 143.09 |
| r≦1 | 244.79** | 40.30 | 46.82 | 707.5** | 102.14 | 111.01 |
| r≦2 | 236.41** | 34.40 | 39.79 | 462.72** | 76.07 | 84.45 |
| r≦3 | 155.85** | 28.14 | 33.24 | 226.3** | 53.12 | 60.16 |
| r≦4 | 55.49** | 22.00 | 26.81 | 70.45** | 34.91 | 41.07 |
| r≦5 | 8.62 | 15.67 | 20.20 | 14.96 | 19.96 | 24.60 |
| r≦6 | 6.34 | 9.24 | 12.97 | 6.34 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 7 series of Japanese data.
The number of cointegration vector is 5. The number of common trend is 2.
The term structure up to 3 year is driven by 2 common trend.
**,* indicates signigicance at the 1 % and 5 % level respectively.
Critical Values are from Osterwald-Lenum(1992).

(6) From uncollateralized overnight call rate through 2 year swap rate (6 data series)

The number of cointegration vector is 5. The number of common trend is 1. The term structure up to the 2 year is driven by a single trend. The result is shown on the Table 6.14.

**Table 6.14 Cointegration Test -Japan ( 6 series -from ON through 2 Y)**

| Hypothesis | λmax | 5% Value | 1% Value | λtrace | 5% Value | 1% Value |
|---|---|---|---|---|---|---|
| r = 0 | 378.50** | 40.30 | 46.82 | 940.47** | 102.14 | 111.01 |
| r≦1 | 236.31** | 34.40 | 39.79 | 561.97** | 76.07 | 84.45 |
| r≦2 | 228.70** | 28.14 | 33.24 | 325.66** | 53.12 | 60.16 |
| r≦3 | 70.64** | 22.00 | 26.81 | 96.97** | 34.91 | 41.07 |
| r≦4 | 19.41* | 15.67 | 20.20 | 26.33** | 19.96 | 24.60 |
| r≦5 | 6.92 | 9.24 | 12.97 | 6.92 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 6 series of Japanese data.
The number of cointegration vector is 5. The number of common trend is 1.
The term structure up to 2 year is driven by a single common trend.
**,* indicates signigicance at the 1 % and 5 % level respectively.
Critical Values are from Osterwald-Lenum(1992).

(7) From uncollateralized overnight call rate through 12 month LIBOR rate (5 data series)

The number of cointegration vector is 4. The number of common trend is 1. The term structure up to the 12 month is driven by a single trend. The result is shown on the Table 6.15.

**Table 6.15 Cointegration Test -Japan ( 5 series -from ON through 12M)**

| Hypothesis | λmax | 5% Value | 1% Value | λtrace | 5% Value | 1% Value |
|---|---|---|---|---|---|---|
| r = 0 | 576.81** | 34.40 | 39.79 | 758.97** | 76.07 | 84.45 |
| r≦1 | 234.58** | 28.14 | 33.24 | 382.17** | 53.12 | 60.16 |
| r≦2 | 98.42** | 22.00 | 26.81 | 147.59** | 34.91 | 41.07 |
| r≦3 | 41.44** | 15.67 | 20.20 | 49.17** | 19.96 | 24.60 |
| r≦4 | 7.74 | 9.24 | 12.97 | 7.74 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 5 series of Japanese data.
The number of cointegration vector is 4. The number of common trend is 1.
The term structure up to 12 month is driven by a single common trend.
**,* indicates signigicance at the 1 % and 5 % level respectively.
Critical Values are from Osterwald-Lenum(1992).

It's found that the term structure up to the 2 year is driven by a single common trend. The result is consistent with the recognition held by the market participants that the term structure up to 2 year forms a single group as a short term interest rate.

In terms of the organization of financial institutions, the operations of FRA (Forward Rate Agreement) and IMM (International Monetary Market) swap belong to money market section. Since FRA and IMM swap are traded up to 2 year, thus making their arbitrage with 2 year swap rate possible. This is why the term structure up to 2 year is considered to form a group as a short term money market.

The 3 - 7 year of swap is often used for the hedge operations by major Japanese banks and for the speculation by Japanese and foreign financial institutions. The 10 year swap is traded in relation with the issuance of bonds.

The entire term structure is divided into three parts-(1)short term (up to 2 year- a single common trend),(2)middle term (from 3 year through 7 year – 2 common trends),(5)long term (10 year- 3 common trends). Thus market segmentation where participants and purposes of transactions are different, depending on the zones of the yield curve is observed in the Japanese yen yield curve.

### *4.3 Cointegration Test-US*

(1) From overnight FF rate through 10 year swap rate (11 data series)

The number of cointegration vector is 9. The number of common trend is 2. The whole term structure is driven by 2 common trends. The result is shown on the Table 6.16.

**Table 6.16 Cointegration Test -US ( 11 series -from ON through 10Y)**

| Hypothesis | λmax | 5% Value | 1% Value | λtrace | 5% Value | 1% Value |
|---|---|---|---|---|---|---|
| r = 0 | 957.02** | 69.74 | 76.63 | 3812.10** | 291.40 | 307.64 |
| r≦1 | 904.49** | 63.57 | 69.94 | 2855.08** | 244.15 | 257.68 |
| r≦2 | 699.66** | 57.42 | 63.71 | 1950.59** | 202.92 | 215.74 |
| r≦3 | 465.14** | 52.00 | 57.95 | 1250.93** | 165.58 | 177.20 |
| r≦4 | 371.03** | 46.45 | 51.91 | 785.80** | 131.70 | 143.09 |
| r≦5 | 200.13** | 40.30 | 46.82 | 414.76** | 102.14 | 111.01 |
| r≦6 | 102.59** | 34.40 | 39.79 | 214.64** | 76.07 | 84.45 |
| r≦7 | 67.87** | 28.14 | 33.24 | 112.05** | 53.12 | 60.16 |
| r≦8 | 35.76** | 22.00 | 26.81 | 44.18** | 34.91 | 41.07 |
| r≦9 | 5.85 | 15.67 | 20.20 | 8.42 | 19.96 | 24.60 |
| r≦10 | 2.57 | 9.24 | 12.97 | 2.57 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 11 series of US data.
The number of cointegration vector is 9. The number of common trend is 2.
The entire term structure is driven by 2 common trends.
**,* indicates signigicance at the 1 % and 5 % level respectively.
Critical Values are from Osterwald-Lenum(1992).

(2) From overnight FF rate through 7 year swap rate (10 data series)

The number of cointegration vector is 8. The number of common trend is 2. The term structure up to the 7 year is driven by 2 common trends. The result is shown on the Table 6.17.

**Table 6.17 Cointegration Test -US ( 10 series -from ON through 7Y)**

| Hypothesis | λmax | 5% Value | 1% Value | λtrace | 5% Value | 1% Value |
|---|---|---|---|---|---|---|
| r = 0 | 904.56** | 63.57 | 69.94 | 3532.38** | 244.15 | 257.68 |
| r≦1 | 853.93** | 57.42 | 63.71 | 2627.82** | 202.92 | 215.74 |
| r≦2 | 646.78** | 52.00 | 57.95 | 1773.89** | 165.58 | 177.20 |
| r≦3 | 450.97** | 46.45 | 51.91 | 1127.11** | 131.70 | 143.09 |
| r≦4 | 342.62** | 40.30 | 46.82 | 676.14** | 102.14 | 111.01 |
| r≦5 | 187.13** | 34.40 | 39.79 | 333.51** | 76.07 | 84.45 |
| r≦6 | 91.15** | 28.14 | 33.24 | 146.38** | 53.12 | 60.16 |
| r≦7 | 46.56** | 22.00 | 26.81 | 55.23** | 34.91 | 41.07 |
| r≦8 | 5.69 | 15.67 | 20.20 | 8.67 | 19.96 | 24.60 |
| r≦9 | 2.97 | 9.24 | 12.97 | 2.97 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 10 series of US data.
The number of cointegration vector is 8. The number of common trend is 2.
The term structure up to 7 year is driven by 2 common trends.
**,* indicates signigicance at the 1 % and 5 % level respectively.
Critical Values are from Osterwald-Lenum(1992).

(3) From overnight FF rate through 5 year swap rate (9 data series)

The number of cointegration vector is 7. The number of common trend is 2. The term structure up to the 5 year is driven by 2 common trends. The result is shown on the Table 6.18.

**Table 6.18 Cointegration Test -US ( 9 series -from ON through 5Y)**

| Hypothesis | λmax | 5% Value | 1% Value | λtrace | 5% Value | 1% Value |
|---|---|---|---|---|---|---|
| r = 0 | 899.60** | 57.42 | 63.71 | 2710.12** | 202.92 | 215.74 |
| r≦1 | 669.87** | 52.00 | 57.95 | 1810.52** | 165.58 | 177.20 |
| r≦2 | 458.05** | 46.45 | 51.91 | 1140.65** | 131.70 | 143.09 |
| r≦3 | 347.57** | 40.30 | 46.82 | 682.60** | 102.14 | 111.01 |
| r≦4 | 188.38** | 34.40 | 39.79 | 335.03** | 76.07 | 84.45 |
| r≦5 | 91.53** | 28.14 | 33.24 | 146.65** | 53.12 | 60.16 |
| r≦6 | 46.61** | 22.00 | 26.81 | 55.30** | 34.91 | 41.07 |
| r≦7 | 5.68 | 15.67 | 20.20 | 8.69 | 19.96 | 24.60 |
| r≦8 | 3.01 | 9.24 | 12.97 | 3.01 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 9 series of US data.
The number of cointegration vector is 7. The number of common trend is 2.
The term structure up to 5 year is driven by 2 common trend.
**,* indicates signigicance at the 1 % and 5 % level respectively.
Critical Values are from Osterwald-Lenum(1992).

(4) From overnight FF rate through 4 year swap rate (8 data series)

The number of cointegration vector is 6. The number of common trend is 2. The term structure up to the 4 year is driven by 2 common trends. The result is shown on the Table 6.19.

**Table 6.19 Cointegration Test -US ( 8 series -from ON through 4Y)**

| Hypothesis | λmax | 5% Value | 1% Value | λtrace | 5% Value | 1% Value |
|---|---|---|---|---|---|---|
| r = 0 | 888.65** | 52.00 | 57.95 | 2233.33** | 165.58 | 177.20 |
| r≦1 | 554.94** | 46.45 | 51.91 | 1344.68** | 131.70 | 143.09 |
| r≦2 | 431.86** | 40.30 | 46.82 | 789.74** | 102.14 | 111.01 |
| r≦3 | 209.79** | 34.40 | 39.79 | 357.87** | 76.07 | 84.45 |
| r≦4 | 91.40** | 28.14 | 33.24 | 148.08** | 53.12 | 60.16 |
| r≦5 | 47.44** | 22.00 | 26.81 | 56.68** | 34.91 | 41.07 |
| r≦6 | 5.67 | 15.67 | 20.20 | 9.24 | 19.96 | 24.60 |
| r≦7 | 3.57 | 9.24 | 12.97 | 3.57 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 8 series of US data.
The number of cointegration vector is 6. The number of common trend is 2.
The term structure up to 4 year is driven by 2 common trend.
**,* indicates signigicance at the 1 % and 5 % level respectively.
Critical Values are from Osterwald-Lenum(1992).

(5) From overnight FF rate through 3 year swap rate (7 data series)

The number of cointegration vector is 5. The number of common trend is 2. The term structure up to the 3 year is driven by 2 common trends. The result is shown on the Table 6.20.

**Table 6.20 Cointegration Test -US ( 7 series -from ON through 3Y)**

| Hypothesis | λmax | 5% Value | 1% Value | λtrace | 5% Value | 1% Value |
|---|---|---|---|---|---|---|
| r = 0 | 742.91** | 46.45 | 51.91 | 1548.08** | 131.70 | 143.09 |
| r≦1 | 435.52** | 40.30 | 46.82 | 805.18** | 102.14 | 111.01 |
| r≦2 | 211.52** | 34.40 | 39.79 | 369.65** | 76.07 | 84.45 |
| r≦3 | 92.67** | 28.14 | 33.24 | 158.13** | 53.12 | 60.16 |
| r≦4 | 50.66** | 22.00 | 26.81 | 65.46** | 34.91 | 41.07 |
| r≦5 | 9.59 | 15.67 | 20.20 | 14.81 | 19.96 | 24.60 |
| r≦6 | 5.21 | 9.24 | 12.97 | 5.21 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 7 series of US data.
The number of cointegration vector is 5. The number of common trend is 2.
The term structure up to 3 year is driven by 2 common trend.
**,* indicates signigicance at the 1 % and 5 % level respectively.
Critical Values are from Osterwald-Lenum(1992).

(6) From overnight FF rate through 2 year swap rate (6 data series)

The number of cointegration vector is 5. The number of common trend is 1. The term structure up to the 2 year is driven by a single trend. The result is shown on the Table 6.21.

**Table 6.21 Cointegration Test -US ( 6 series -from ON through 2Y)**

| Hypothesis | λmax | 5% Value | 1% Value | λtrace | 5% Value | 1% Value |
|---|---|---|---|---|---|---|
| r = 0 | 434.57** | 40.30 | 46.82 | 862.64** | 102.14 | 111.01 |
| r≦1 | 220.67** | 34.40 | 39.79 | 428.07** | 76.07 | 84.45 |
| r≦2 | 109.53** | 28.14 | 33.24 | 207.40** | 53.12 | 60.16 |
| r≦3 | 73.12** | 22.00 | 26.81 | 97.87** | 34.91 | 41.07 |
| r≦4 | 19.52* | 15.67 | 20.20 | 24.75** | 19.96 | 24.60 |
| r≦5 | 5.23 | 9.24 | 12.97 | 5.23 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 6 series of US data.
The number of cointegration vector is 5. The number of common trend is 1.
The term structure up to 2 year is driven by a single common trend.
**,* indicates signigicance at the 1 % and 5 % level respectively.
Critical Values are from Osterwald-Lenum(1992).

(7) From overnight FF rate through 12 month LIBOR rate (5 data series)

The number of cointegration vector is 4. The number of common trend is 1. The term structure up to the 12 month is driven by a single common trend. The result is shown on the Table 6.22.

**Table 6.22 Cointegration Test -US ( 5 series -from ON through 12M)**

| Hypothesis | λmax | 5% Value | 1% Value | λtrace | 5% Value | 1% Value |
|---|---|---|---|---|---|---|
| r = 0 | 576.81** | 34.40 | 39.79 | 758.97** | 76.07 | 84.45 |
| r≦1 | 234.58** | 28.14 | 33.24 | 382.17** | 53.12 | 60.16 |
| r≦2 | 98.42** | 22.00 | 26.81 | 147.59** | 34.91 | 41.07 |
| r≦3 | 41.44** | 15.67 | 20.20 | 49.17** | 19.96 | 24.60 |
| r≦4 | 7.74 | 9.24 | 12.97 | 7.74 | 9.24 | 12.97 |

The Johansen cointegration test is conducted using 5 series of US data.
The number of cointegration vector is 4. The number of common trend is 1.
The term structure up to 12 month is driven by a single common trend.
**,* indicates signigicance at the 1 % and 5 % level respectively.
Critical Values are from Osterwald-Lenum(1992).

It's found that the term structure up to the 2 year is driven by a single common trend. As in the case of Japan, the result is consistent with the recognition held by the market participants that the term structure up to 2 year forms a single group as a short term interest rate. In terms of the organization of financial institutions, the operations of FRA (Forward Rate Agreement) and IMM (International Monetary Market) swap belong to the money market section. Since FRA and IMM swap are traded up to 2 year, thus making their arbitrage with 2 year swap rate possible. This is why the term structure up to 2 year is considered to form a group as a short term money market.

The zone from 2 year through 10 year is driven by a single common trend. This point is totally different from Japanese yen swap yield curve. Two reasons cited below are considered to support this phenomenon. (1) US dollar swap transactions were started as a spread to US Treasury markets. In US, swap rates indicate credit spread for financial sectors. Thus there is little room for swap characteristics to be incorporated in the market. (2)The fact that not only banks but also other investors participate actively even in the middle zone makes the swap market more liquid compared with Japanese yen swap. Therefore US dollar swap yield curve is less likely to be influenced by particular participants.

The entire term structure is divided into two parts- (1) short term (up to 2 year — a single common trend), (2) middle and long term (from 3 year through 10 year – 2 common trends). The market segmentation is not observed in US dollar yield curve over the structure of 2 year as in Japanese yen yield curve[9].

## 5. Concluding Remarks

In Japan, the entire term structure is driven by 3 common trends. The term structure up to 2 year is driven by a single trend. The entire term structure is divided into three parts-(1)short term (up to 2 year- a single common trend),(2)middle term (from 3 year through 7 year - 2 common trends),(5)long term (10 year - 3 common trends). Thus market segmentation where participants and purposes of transactions are different depending on the zones of the yield curve is observed in the Japanese yen yield curve.

In US, the entire term structure is driven by 2 common trends. The term structure up to 2 year is driven by a single common trend. The entire term structure is divided into two parts-

[9] Zhang (1993) use the term structure up to 30 year and get a conclusion that US term structure of treasury securities is driven by 3 common trends. In US swap market, there is a possibility that market segmentation exists over the zone of 10 year. Since the purpose of this paper is the comparison of swap yield curves in Japan and US, the zone over 10 year isn't tested. In the Japanese swap market, the zone over 10 year is illiquid and it's very difficult to get the proper data especially before 1998.

(1) short term (up to 2 year —single common trend), (2) middle and long term (from 3 year through 10 year – 2 common trends). The market segmentation is not observed in US dollar yield curve over the structure of 2 year as in Japanese yen yield curve.

From this analysis, it's important to consider the third trend when we analyze the Japanese yen swap curve especially in the zone over 7 year. But in the case of US swap yield curve from 2 year through 10 year, we need to pay attention to 2 common trends.

Chapter 7

## Conclusion

### 1. Summary of Each Chapter

This thesis deals with empirical analysis on the long term interest rates in Japan. It can be divided into two parts. Chapters from 2 through 4 deal with the structure of long term interest markets in Japan. Chapters from 5 through 6 covers Japanese and US interest rates.

**At Chapter 2** I investigated Japanese Government Bond yields and Japanese interest rate swap rates. The whole sample is divided into two sub periods. The first sub period, named Sample A, is from January 4,1994 through February 12,1999. The second sub period, named Sample B, is from February 15,1999 through July 30,2003 .

In Sample A, Japanese Yen Interest Rate Swap rates are in the long run equilibrium with Japanese Government Bond yield in the structure from 2 year through 10 year. On the other hand, in Sample B, Japanese Yen Interest Rate Swap rates are in the long run equilibrium with Japanese Government Bond yield only in the structure from 2 year through 4 year. Thus it's considered that market segmentation in the structure from 5 year through 10 year between Japanese Government Bond and Japanese Yen Interest Rate Swap became apparent in sample B.

In Sample A, a 1 % increase (a decrease) in Japanese Government Bond yields lead to a 1 % increase (decrease) in Japanese Yen Interest Rate swap rate in the structure of 2 year, 3 year, 4 year, 5 year , and 7 year. A 1 % increase in Japanese Government Bond yields lead to a less than 1 % increase in Japanese Yen Interest Rate swap rate in 10 year. In other words, a rise (a decline) in Japanese Government Bond yield is associated with a decline (a rise) in the swap spread in 10 year.

On the other hand, in Sample B, a 1 % increase in Japanese Government Bond yields lead to a more than 1 % increase in Japanese Yen Interest Rate swap rate in the structure of 2 year, 3 year, 4 year, 5 year , 7 year and 10 year. In other words, a rise (a decline) in Japanese Government Bond yield is associated with a rise (a decline) in the swap spread.

As for the comparison of causality impacts made between Sample A and Sample B, in Sample A Japanese Government Bond yield is stronger than Japanese Yen Interest Rate swap rate, but in Sample B Japanese Yen Interest Rate swap rate is stronger than Japanese Government Bond yield. Thus it's considered that in Sample A Japanese Government Bond market possibly lead interest rate swap market, but in sample B interest rate swap market led Japanese Government Bond market.

**At Chapter 3** I investigated the determinants of Japanese swap spreads. The whole sample is divided into two sub periods. The first sub period, named Sample A, is from January,1994 through January, 1999. The second sub period, named Sample B, is from February,1999 through July, 2003 .

As for the TED (TED spread) in Sample A except for 10 Year Spread, the impacts of TED on spreads are stronger in the longer maturities. In Sample B, the impacts of TED are stronger in the shorter maturities.

As for the CBS (Corporate Bond Spread) in Sample A the impacts are stronger in the mid term zones such as 4 year and 5 year. In Sample B the impacts are stronger in the shorter terms. When the comparison is made between Sample A and Sample B, the impacts are stronger in all maturities of Sample A. As for the SLOPE (slope of the yield curve), both in Sample A and Sample B, the impacts are stronger in the shorter maturities.

Next, I report the results of impulse response function. As for TED, in shorter terms, shocks of TED are greater in Sample A. But in mid and longer terms, the sizes of shocks are almost same. As for the CBS, the sizes of shocks are greater in Sample A. As for the Slope, the sizes of shocks are greater in Sample A.

When I consider the results of both variance decomposition and impulse response function, the major structural difference of Japanese yen interest rate swap spread in Sample A and Sample B is the influence of credit risk. Swap spreads in sample A are more influenced than those in Sample B. Especially in mid term such as 4 year and 5 year, the impacts of credit risk are very strong in Sample A.

**At chapter 4** I analyzed the super long zone (over 10 year) of Japanese interest rate swap. The statistical analyses are organized to avoid spurious regression due to non-stationarity of financial time series. First I use unit root analysis to confirm the non-stationarity of the data. Then I draw the common trends by using cointegration analysis. This is tested by using not only the whole term structure but also parts of the term structure with the sequential subtraction of the data from longer maturities. Finally the principal component analysis is conducted.

From empirical analysis, I can conclude that the whole term structure from 2 year through 15 year is driven by 4 common trends. The result is consistent with the recognition held by the market participants that the term structure over 10 year is driven by a special trend. This special trend can be called a foreign factor deciding the movement of the super long structure of the Japanese Yen swap since most of the participants are non-Japanese investment houses and banks.

The term structure from 2 year through 10 year is driven by 3 common trends. The term structure from 2 year through 4 year is driven by two common trends. Thus the entire term structure is divided into three parts- (1) middle term (from 2 year through 4 year - two common trends), (2) long term (from 5 year through 10 year - two common trends), (5) superlong term (from 12 year through 15 year-four common trends).

**At chapter 5** I examined the international linkage of interest rates between JP and US in the framework of UIP by using the data from 1 month through 10 year. The whole sample from October 2,1990 through August 8,2000 is divided into two sub periods. The first sub period, named Sample A, is from October2,1990 through May 17,1993. In Sample A the monetary policy regimes both in Japan and US are easing. From a view point of economic cycles, in Sample A, both Japan and US are downtrend. The second sub period, named

Sample B, is from May 17,1993 through August 11,2000. In Sample B the monetary policy regime in Japan is easing, but in US it's tightening. From a view point of economic cycles, in Sample B, Japan is downtrend, but US is uptrend.

In Sample A, UIP holds true in the term structure from 2 year through 10 year. In other words, we find evidence for closer long-run international linkage between JP and US in the term structure from 2 year through 10 year in the period from October 2,1990 through May 17,1993. The influences of JP interest rates on US interest rates are confirmed in the entire structure except for 3 month and 6 month. The influences of US interest rates on JP interest rates are not confirmed in the entire term structure.

On the other hand, in Sample B, we find no evidence of UIP in the entire term structure. Thus I find little evidence for long-run international linkages between JP and US in the entire term structure from May 18,1993 and August 11,2000 .

From October 2,1990 through May 17,1993, monetary policies both in Japan and US are in easing phase. Thus it's considered that economic cycles both in Japan and US during that period are in downtrend. When the FRB changed monetary policy stance from neutral to tightening on May18,1993, the divergence of JP and US interest rates over 2 year started.

The influences of JP interest rates on US interest rates are confirmed in the entire term structure except for 6 month, 9 month and 12 month. The influences of US interest rates on JP interest rates are confirmed in the entire term structure.

The results show that only when economic cycles are generally coincided between Japan and US, long term interest rates (from 2 year through 10 year) were in the long term equilibrium through the expectation of foreign exchange rates. Thus domestic factors are considered to exert an important influence on short and long term interest rates.

**At chapter 6** I conducted a comparative analysis of the yield curves in Japan and US. The entire term structure is driven by 3 common trends in Japan. The term structure up to 2 year is driven by a single trend. The entire term structure is divided into three parts - (1)short term (up to 2 year- a single common trend), (2)middle term (from 3 year through 7 year - 2 common trends), (5)long term (10 year - 3 common trends). Thus market segmentation where participants and purposes of transactions are different depending on the zones of the yield curve is observed in the Japanese yen yield curve.

The entire term structure is driven by 2 common trends in US. The term structure up to 2 year is driven by a single common trend. The entire term structure is divided into two parts - (1) short term (up to 2 year - single common trend), (2) middle and long term (from 3 year through 10 year - 2 common trends). The market segmentation is not observed in US dollar yield curve over the structure of 2 year as in Japanese yen yield curve.

From this analysis, it's important to consider the third trend when we analyze the Japanese yen swap curve especially in the zone over 7 year. But in the case of US swap yield curve from 2 year through 10 year, we need to pay attention to 2 common trends.

## 2. Implications for Market

As I have already indicated, this thesis includes a lot of newly found results. From these results, I would like to point out 4 major implications for the long term interest rate market in Japan.

(1) The structural change of the market was confirmed after the Bank of Japan introduced zero interest rate policy in February, 1999. For example, Japanese Yen Interest Rate Swap rates were in the long run equilibrium with Japanese Government Bond yield in the structure from 2 year through 10 year before the introduction of zero interest rate policy. On the other hand, Japanese Yen Interest Rate Swap rates are in the long run equilibrium with Japanese Government Bond yield only in the structure from 2 year through 4 year after the introduction of zero interest rate policy.

(2) The recognition that we need to pay attention to 3 common trends in the analysis of the yield curve can't be applied when we analyze the yield curve over 10 year. This is because I could confirm the existence of the fourth common trend in the 12 year and 15 year of Japanese Interest Rate Swap yield curve.

(3) The perception that the linkage of global financial market has been strengthened with the

worldwide integration of the market can't be applicable to the relationship between Japanese and US interest rates after May, 1993. Before May, 1993 long term interest rates in Japan and US were in the long term equilibrium.

(4)The structural difference of yield curve is found between Japan and US. Japanese yield curve is driven by 3 common trends, but US yield curve is driven by 2 common trends. This is mainly due to the difference in the development of interest rate swap market.

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