Interest Rates and Monetary Policy in Japan

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Sciences and technology made remarkable progress in the 20th Century, which was at the same time the century of war and upheaval. Wars of a global scale broke out twice. The number of local wars and upheavals is too numerous to be counted.

On the threshold of the 21st century we cannot see any sign that things will take a favorable turn. In parallel with the process that various places of the world are becoming more closely linked by markets and information, friction in the social and cultural spheres is becoming more and more obvious. We are now being pressed by necessity to construct a system for creating peace and prosperity, in other words, a system of '*kyohsei*' in which human beings and nature live together side by side.

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March 2005
Niigata University, Graduate School of Modern Society and Culture
Dean, Professor
FUJII Takashi, Ph.D.

ITO Takayasu

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Preface

This book provides readers with empirical analysis on the term structure of interest rates mainly in Japan. There are three parts in this book. Part I provides the empirical analysis concerning the monetary policy and yield curve. Part II deals with interest rate swap market. Part III covers Japanese and US interest rates.

Part I is based on my PhD dissertation submitted to the University of Tsukuba. I would like to express thanks to Professor TSUBAKI Hiroe, Professor KATO Hideaki and Associate Professor MAKIMOTO Naoki who were my advisors. Part II and III are based on the articles presented at academic meetings and published on the journals.

I'm also grateful to professors who gave me useful comments at the academic meetings and seminars. They are ABIKO Yuichi (Kinki University), UEDA Kazuo (Bank of Japan), OSAWA Makoto (Bank of Japan), OKABE Mitsuaki (Keio University), KASUYA Munehisa (Bank of Japan), KIMURA Takeshi (Bank of Japan), KOBAYASHI Masahito (Yokohama National University), KOMAGATA Kokichi (Mitsubishi Securities), SHIKANO Yoshiaki (Doshisha Univeristy), SHIMIZU Yoshinori (Hitotsubashi University), SHIRAKAWA Masaaki (Bank of Japan), SOEJIMA Yutaka (Bank of Japan), TAKATA Hajime (Mizuho Securities), TATSUMI Kenichi (Gakusyhuin University), TSUTSUI Yoshiro (Osaka University), HONDA Yuzo (Osaka University), MIYAKOSHI Tatsuyoshi (Tohoku University), YONEZAWA Yasuhiro (Waseda University). Chapter 6 and 7 are supported by a grant-in-aid from the Zengin Foundation for Studies on Economics and Finance.

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March, 2005 ITO Takayasu

Chapter 1

Introduction

1 Background

The Bank of Japan (hereinafter BOJ) conducts its monetary policy by adjusting the uncollateralized overnight call rate. It's considered to be the only benchmark the BOJ can be responsible. The effects of the monetary policy can exert an influence on the shape of the Japanese yen yield curve.

But there is a room for discussion as to the range of the yield curve the BOJ can control. The BOJ has means to provide money into the market through the operation of buying the long term Japanese Government Bonds up to the maturities and so on in addition to the control of uncollateralized overnight call rate. But the buying operation does not have a meaning of controlling long-term interest rates, but it just provides liquidity in accordance with the growth of money supply.

The monetary policy operation targeting at a short term interest rate is called interest rate targeting[1]. Since the BOJ introduced lowering the target of short term interest rates in March 1995, more significance as a benchmark of monetary policy operation has been given to uncollateralized overnight call

[1] The change of official discount rate was the most important measure of monetary policy by the mid 1990's.But market operations have become central measures and the role of official discount rate declined. The uncollateralized call rate was around 0.02 - 0.03% starting in March 1999 and 0.02-0.03% means a virtually zero interest rate with the introduction of zero interest rate policy by the BOJ. The BOJ lifted it in August 2000.

rate[2]. The effects of target changes at uncollateralized overnight call rate are researched from 3 points, - (1) the yield curve analysis, (2) the relationship between interest rates and macro economy, (3) the function of financial intermediary. In this book, I focus on (1) the yield curve analysis[3]. I provide the results of empirical analysis mainly from the data in 1990's when the BOJ took a policy of interest rate targeting.

The relationship between yield cure and monetary policy can be analyzed from 2 points,- (1) transmission mechanism and (2) information function[4]. The transmission function refers to influence from short term interest rates on long term interest rates. If targeting changes of short term interest rates can be transmitted to long term interest rates, gross expenditure in macro economy can be influenced. By analyzing transmission mechanism, I can investigate the effects and limits of monetary policy in yield curve.

Information function means the information contained in the yield curve. Especially it refers to inflation information. Fisher (1930) maintains that the expected rate of inflation is reflected in the nominal interest rates and the real interest rates are constant. This relationship between the expected rate of inflation and the nominal interest rates is called 'Fisher Hypothesis'. By investigating the validity of the Fisher Hypothesis, I can judge if the interest rate levels contain the future information of inflation.

The analysis on the spreads of interest rates is also important. When the spreads can predict the future of inflation, I can say that the spreads contain

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[2] The BOJ introduced policy of quantitative easing as of March 21, 2001. The target of monetary operation was changed from interest rate to current account balance held by private financial institutions. But the BOJ announced on March 19,2001 that should there be a risk of financial market instability, e.g., a rapid surge in liquidity demand, the Bank will provide ampler liquidity irrespective of the guideline above. From this announcement the BOJ made it clear that it will pay attention to uncollateralized overnight call rate even under the reserve targeting.

[3] In Japan, Kuroda (1982) is the first empirical analysis of yield curve. Nagayasu (2004) mentions that traditional theory of yield curve can't be used for the analysis of interest rates in the periods of zero interest rate and quatitative easing.

[4] Angeloni/Rovelli (1998) covers the relationship between the yield curve and monetary policy. Angeloni/Rovelli (1998) divides the topic into 3 parts; (1) transmission mechanism, (2) information function, (3) policy indicator function. Part I of this book covers former two points, but adds consideration from the third point.

the information of future inflation. I can also conclude that the spreads of interest rates can be used as an information variable in the pursuit of monetary policy.

The importance of yield curve has been increasing in many countries, but the role of monetary aggregate indicators has been decreasing. This is because newly developed financial techniques have diluted the relationship between monetary aggregate indicators and GDP (Gross Domestic Product).

Central banks have been able to access the market information because of the development of fixed income and derivatives market. Under these circumstances, the central banks of major countries can easily get interest rate information from overnight through 10 year and utilize them for the conduct of monetary policy[5].

The stance of monetary policy in developed countries has been forward looking and prioritized the prevention of inflation. Prior to the foundation of ECB (European Central Bank), BOE (Bank of England) and RiksBank of Sweden introduced the inflation targeting so that they started to pay more attention to the information contained in the yield curve.

Thus the yield curve has been used as an indicator of monetary policy in various countries. But it's a future task in Japan. Since the BOJ introduced quantitative easing policy, uncollateralized overnight call rate has been moving around 0.001 – 0.002 % and the slope of Japanese yield curve has been flat because the amount of the BOJ current account balance exceed remarkably the amount necessary for the market[6].

The BOJ seems to be considering the introduction of inflation as a long term objective. But inflation rate is under 0 % and the importance of forward looking monetary policy has just begun to be recognized. When the BOJ changes monetary policy from monetary targeting to interest rate targeting

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[5] In major countries interest rate information up to 30 year is provided, but the zone over 10 year has less liquidity.

[6] The commitment by the BOJ that quantitative easing policy will be in place until the consumer price index (excluding perishables, on a nationwide statistics) registers stably a zero percent or an increase year on year also contributed to flattening of Japanese yield curve.

with the lifting of quantitative easing policy, the shape of Japanese yield curve will be normalized gradually. Thus the BOJ will pay more attention to the yield curve.

As for the previous works analyzing the yield curve, the number is many in US, but it's very limited in Japan. Three reasons can be cited in Japan,-(1) Researchers in finance analyzed the yield curve in no relation to monetary policy, (2) Researchers in monetary economics rarely considered the yield and analyzed mainly the relationship between an interest rate and macro economy. (3) Researchers have difficulty in obtaining data of market interest rates.

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).

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 of Japan, 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.

In relation with the BOJ, it's necessary for them to grasp the movements of mid and long term interest rates from viewpoints of both interest rate swaps and Japanese Government Bonds.

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. 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. In terms of monetary policy, the BOJ needs to know the relationship between Japanese yield curve and foreign yield curve.

2 Structure

Part I (from Chapter 2 through Chapter 5) provides the empirical analysis concerning the monetary policy and yield curve. Part II (from Chapter 6 through Chapter 8) deals with interest rate swap market. Part III (from Chapter 9 through Chapter 10) covers Japanese and US interest rates. Finally chapter 11 concludes.

Part I (from Chapter 2 through Chapter 5) provides the empirical analysis concerning the monetary policy and yield curve. At Chapter 2, I investigate the influence of monetary policy on interest rates by estimating the effect of changes in the uncollateralized overnight call rate - the Bank of Japan's policy instrument- on market interest rates in the 1990's in accordance with the method by Cook/Hahn (1989). I use OLS and method in White (1980) to correct heteroscedasticity. I also get rid of first autocorrelation as described in Cochrane/Orcutt (1949).

At Chapter 3, I investigate the effects and limits of the monetary policy by the BOJ by analyzing the term structure of Japanese yen open interest market from a view point of long run. 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. Finally I use Granger causality test by Toda/Yamamoto (1995) to check whether uncollateralized overnight call rate affects yield curve and vice versa.

At Chapter 4, I investigate the validity of the Fisher Hypothesis by using the Japanese yen interest rate data in 1990's. I use the whole term structure to investigate the validity of the hypothesis. Thus it's possible to test where in the term structure, the hypothesis is established. First, I use unit root tests of ADF and KPSS to confirm if the data contain unit root. Next, I use Engle/Granger (1987) cointegration test between the expected rate of inflation and the nominal interest rate. Finally, I use Granger causality test by Toda/Yamamoto (1995) to check if the expected rates of inflation influenced the nominal interest rates and vice versa.

At Chapter 5, I investigate whether interest rate spreads can predict the future inflation as in Mishkin (1990a). I use OLS with heteroscedasticity and serial correlation adjusted by Newy/West (1987). Although I use entire yield curve, the main focus is mid term and long term zone which have never been wholly tested in Japan.

Part II (from Chapter 6 through Chapter 8) deals with interest rate swap market. At Chapter 6, 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 7, 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 8, a consideration is given to common trends underlying the term structure of Japanese en yield curve up to 15 year. The purpose of this chapter is to investigate the existence of forth 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.

Part III (from Chapter 9 through Chapter 10) covers Japanese and US interest rates. At Chapter 9, 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 10, 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 11, I provide concluding remarks.

Reference

In Japanese

Kuroda,A.(1982), "*Structure of Interest Rates in Japan,*" Toyokeizai.

In English

Angeloni,I. and R.Rovelli (1998), *Monetary Policy and Interest Rates*, Macmillan.

Cochrane,D. and G.H.Orcutt (1949), "Application of Least Squares Regression to Relationships Containing Autocorrelated Error Terms," *Journal of the American Statistical Asscociation*,Vol.44,pp.32-61.

Cook,T. and T.Hahn(1989), "The Effects of Changes in the Federal Funds Rate Target on Market Interest Rates in the 1970's," *Journal of Monetary Economics*, Vol.24,pp.331-351.

Economics, Vol.24,pp.331-351.

Engle,R.F. and C.W.J.Granger(1987), "Co-Integration and Error Correction: Representation,and Testing," *Econometrica*,Vol.55,pp.251-276.

Fisher,I.(1930), *The Theory of Interest*, Macmillan,New York.

Johansen,S.(1988), "Statistical Analysis of Cointegrated Vectors," *Journal of Economic Dynamics and Control*,Vol.12,pp.231-254.

Mishkin,S.F.(1990a), "What Does Term Structure Tell us about Future Inflation?" *Journal of Monetary Economics Economics*,Vol.25,pp.77-95.

Morris,C., R,Neal, and D.Rolph (1998), "Credit Spreads and Interest Rates : A Cointegration Approach," *Federal Reserve Bank of Kansas City Research Working Paper*, RWP 98-08.

Nagayasu,J. (2004), "The Term structure of Interest Rates and Monetary Policy during a zero-Interest-Rate Period," *IMES Discussion Paper Series*, No.2004-E-2.

Newey,W.K. and K.D.West(1987), "A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix," *Econometrica*, Vol.55,pp.703-708.

Thornton,D.L.(2004), "Testing the Expectaion Hypothesis: Some New evidence for Japan," *IMES Discussion Paper Series*,No.2004-E-3.

Toda,H.Y. and T.Yamamoto(1995), "Statistical Inference in Vector Autoregressions with Possibly Integrated Processes," *Journal of Econometrics*, Vol.66, pp.225-250.

White,H.(1980), "A Heteroskedasticity-Consistent Covariance Matrix Estimatimator and A Direct Test For Heterodkedasticity," *Econometrica,* Vol.48,pp.817-838.

Part Ⅰ Japanese Yield Curve and Monetary Policy

Chapter 2

The Reaction of Yield Curve at the Monetary Policy Change*

1 Introduction

1.1 The Purpose of this Chapter

The Bank of Japan (hereinafter BOJ) conducts its monetary policy by adjusting the uncollateralized overnight call rate. It's considered to be the only benchmark the BOJ can be responsible. The benchmark of uncollateralized overnight call rate as a target of monetary operation has been increasing since the BOJ introduced a policy of lowering short term interest rates in 1995.

The effects of the monetary policy can exert an influence on the shape of the Japanese Yen open interest rate market. But there is a room for discussion as to the range of the yield curve the BOJ can control. The BOJ has means to provide money into the market through the operation of buying the long term Japanese Government Bonds up to the maturities and so on in addition to the control of uncollateralized overnight call rate. But the buying operation does not have a meaning of controlling long-term interest rates, but it just provides

* This chapter is based on Ito (2003b). Prior to the publication of Ito (2003b) initial drafted was presented at symposium ' Frontier of Capital Market' at the University of Tukuba in March 2001.

liquidity in accordance with the growth of money supply.

The purpose of this chapter is to investigate the influence of monetary policy on interest rates by estimating the effect of changes in the uncollateralized overnight call rate target - the Bank of Japan's policy instrument - on market interest rates in the 1990's in accordance with the method by Cook/Hahn (1989). In Japan related studies are very limited to Kuroki/Honda (2001). But they compare the market data within a few days or a week. In this sense, their work is different from Cook/Hahn (1989) and this chapter. Thus this chapter is considered to be original.

The remainder of this chapter is as follows. In section 1.2 I summarize previous studies. In section 2 I explain the framework of the analysis. In section 3 I touch on the data. In section 4 I report the results of the empirical analysis. In section 5 I summarize the conclusion and the remaining issues.

1.2 Previous Studies

Cook/Hahn (1989) was the first previous study to investigate the impacts of the target changes of FF (Federal Fund) rate by the FRB (Federal Reserve Board) on market interest rates. They used FF rate and 3 month,6 month,12 month,3 year,5 year,7 year,10 year, 20 year interest rates in the 1970's. They found that FF rate changes significantly affected the market interest rates from 3 month through 20 year. The impacts were as follows; strong from 3 month through 12 month (0.50~0.55% change on 1 % change of FF rate), less strong from 3 year through 7 year (0.19~0.30% change), and weak (0.10~0.13%) over 10 year. They used the Wall Street Journal on next day to distinguish FF rate changes if they are monetary policy change or market transaction.

Other previous studies in US followed the suit of Cook/Hahn (1989). Roley/Sellon (1995) used FF rate and 12 month, 30 year interest rates from 1987 through 1995. They found that FF rate changes significantly affected the market interest rates. The impacts are as follows; strong at 12 month (0.26% change) and weak (0.04%) at 30 year.

Roley/Sellon (1996) used FF rate and 3 month,6 month,12 month,3 year,5 year,7 year,10 year interest rates in two periods; one from 1974 through 1979 and the other from 1987 through 1995. They found that FF rate changes significantly affected the market interest rates from 3 month through 20 year. The impacts are as follows; strong from 3 month through 12 month (0.42~0.45% change on 1 % change of FF rate), less strong from 3 year through 7 year (0.11~0.25% change), and weak (0.07%) at 10 year.

Thornton (1998) used FF (Federal Fund) rate and 3 month, 12 month, 10 year, 30 year interest rates from 1989 through 1997. They found that FF rate changes significantly affected the market interest rates from 3 month through 5 year. The impacts are as follows; strong from 3 month through 12 month (0.42~0.45% change on 1 % change of FF rate) and weak (0.03%~0.07%) at 10 year.

Nilsen (1998) used FF (Federal Fund) rate and 3 month,12 month,3 year,5 year,10 year ,30 year interest rates from 1985 through 1992. They found that FF rate changes significantly affected the market interest rates from 3 month through 20 year. The impacts are as follows; strong from 3 month through 12 month(0.27~0.31% change on 1 % change of FF rate), less strong from 3 year through 10 year (0.13~0.23% change), and weak (0.09%) at 30 year.

2 The Framework of Analysis

ΔR_t (market interest rate on the day of policy change — market interest rate on the previous business day of policy change) is regressed with OLS by

$\Delta ROUC$ (uncollateralized overnight call rate on the day of policy change —

uncollateralized overnight call rate on the previous business day of policy change). The estimation method is shown on equation (2.1). The data used for analysis is 37 days when monetary policy was changed.

$$\Delta R_t = \alpha \quad + \quad \beta \Delta ROUC_t \quad + \quad u_t \tag{2.1}$$

ΔR_t = market interest rate on the day of policy change − market interest rate on the previous business day of policy change

$\Delta ROUC$ = uncollateralized overnight call rate on the day of policy change − uncollateralized overnight call rate on the previous business day of policy change

u_t = error term

As for the error term, I use the method in White (1980) to correct heteroscedasticity[1]. I also get rid of first autocorrelation as described in Cochrane/Orcutt (1949)[2].

3 The Date of Monetary Policy Change and Data

3.1 The Day of Monetary Policy Change

As for the day of monetary policy change, I pick up the days when operating target of uncollateralized overnight call rate was changed. Market participants point out that they could find movement of uncollateralized overnight call rate as policy change or market transaction by looking at

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[1] White (1980) suggests that squared sum $\hat{u}_i^2$ will be used instead of error variance in $\mathrm{var}(\hat{\beta}) = \frac{\sum x_i^2 \sigma_i^2}{\left(\sum x_i^2\right)^2}$. Accordingly, we can get the unbiased estimation of $\mathrm{var}(\hat{\beta})$ without knowing the error variance.

[2] Cochrane/Orcutt (1949) suggests that OLS is used by doing two things.(1) Estimate the correlation relationship of errors between each period and a previous period by using the residual of regression equation,(2) Correct regression equation so that errors may not have serial correlation.

operations by the BOJ in the morning. Nihon Keizai Shimbun (Japan Economic Daily) and Nikkei Kinyu Shimbun (Japan Financial Daily) report monetary policy change.

In this chapter I choose the days of monetary policy change from Nihon Keizai Shimbun (Japan Economic Daily) and Nikkei Kinyu Shimbun (Japan Financial Daily) as Cook/Hahn (1989) used Wall Street Journal. The days are included when easing expectations got stronger because the BOJ lowered interest rates without the announcement of policy change.

The typical expressions are as follows. The expectation of interest rate hikes strengthened (March 16, 1990). The BOJ tolerated the decrease of short and long term interest rates (October 2, 1990). The BOJ made its stance clear that short term interest rates would decrease (October 17, 1991). The BOJ is taking tightening operation to decrease the amount of money in short term money market (February 3, 1992). The BOJ is further lowering the short term interest rates (March 2, 1994).

The first and last days of depositing reserves, the end of September and March are included in the analysis only when the policy changes are reported (March 16, 1990, August16, 1993, March 31, 1995, February 15, 1999, February 16, 1999).

Cook/Hahn (1989) excluded November 1, 1978 from the analysis when the intervention into foreign exchange market was executed. On this day the value of US dollar increased approximately 7 % with short term interest rates increased and long term interest rates decreased. According to the information released by the Ministry of Finance, foreign exchange intervention was made on 9 days of policy change. These 9 days (April 1, 1992, July 27, 1992, August 16, 1993, March 2, 1994, March 31, 1995, April 14, 1995, April 17, 1995, July 7, 1995, September 8, 1995) are included in this analysis because the impacts of intervention were small[3].

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[3] The dollar /yen exchange rates on the day and previous business day are reported as follows. These exchange rates are as of 5 pm Tokyo time reported in Nihon Keizai Shimbun.

1992/4/1 133.90 yen (previous business day 133.05yen)

When the announcements of policy change were made after 5 pm, the next business days are regarded as policy change dates (September 10, 1998, February 15, 1999).

The BOJ never announced the target ranges of uncollateralized overnight call rates except for September 10, 1998 and February 15, 1999[4]. The BOJ instead changed the levels of uncollateralized overnight call rates through daily operations. Accordingly I use central rates by May 15, 1995 and weighted averaged rates after May 16, 1995.

Table 2.1 shows the dates of monetary policy change, the levels of unsecured overnight call rates and official discount rates, the contents of policy change.

3.2 Data

The 18 series of data - uncollateralized overnight call rata, LIBOR (London InterBank Offered Rate) from 1 month through 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 April 30, 1999[5]. The data of 37 days are chosen for the analysis.

Figure 2.1 shows the movement of 4 series (uncollateralized overnight call

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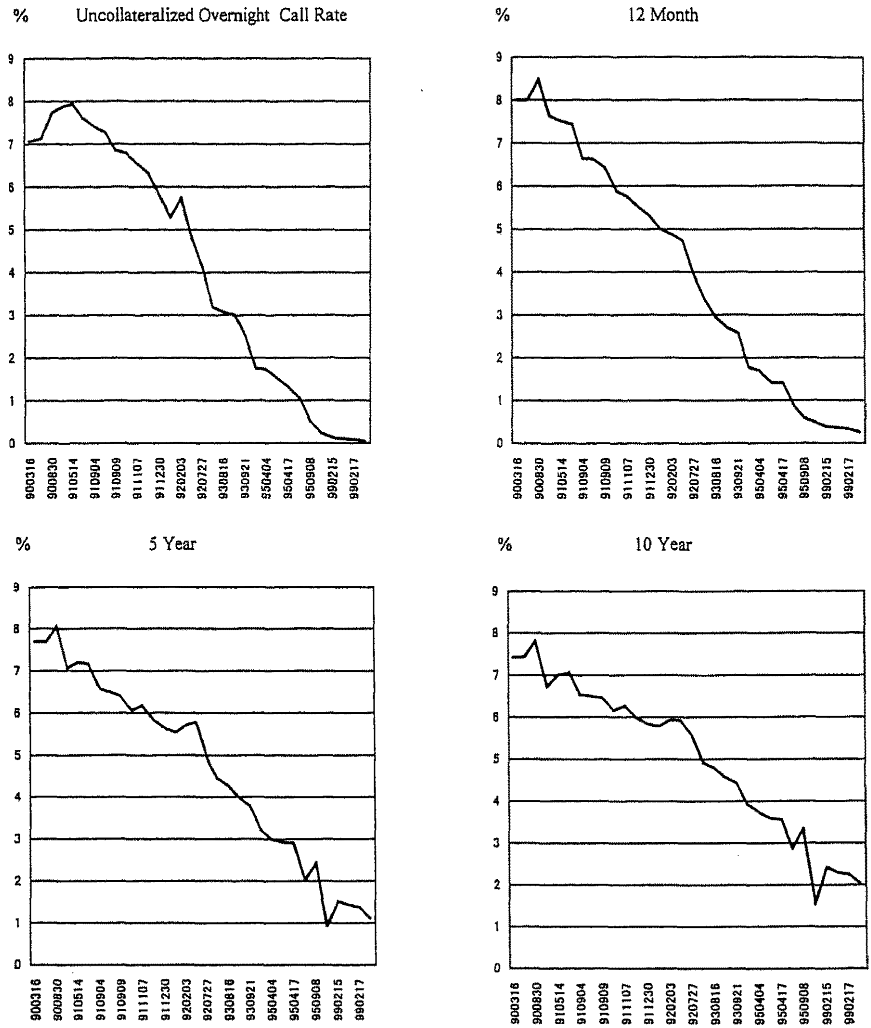
1992/7/27	128.17 yen (126.90yen)	1993/8/16	101.25yen (102.40yen)
1994/3/2	104.23yen (104.92)	1995/3/31	88.35yen (88.25yen)
1995/4/14	83.55yen (83.20yen)	1995/4/17	82.15yen (83.55yen)
1995/7/7	85.92yen (85.22yen)	1995/9/8	99.80yen (98.68yen)

4 The BOJ announced on September 9, 1998 that they will encourage the uncollateralized overnight call rate to move on average around 0.25%. The BOJ announced on February 12, 1999 that they will, by paying due consideration to maintaining market function, initially aim to guide the uncollateralized call rate to move around 0.15%, and subsequently induce further decline in view of the market developments.

5 As for uncollateralized overnight call rate, I use central rates before May 15,1995 and weighted averaged rates after May 16,1995. These rates are calculated by Association of Money Market. BBA (British Bankers' Association) publishes LIBOR as of 11 am London time. Interest rate swap rates as of 3 pm Japan time are provided by a major broker. In the 1990's the issuances of JGB (Japanese Government Bond) were centered on 10 year and most of trading activities were 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.

rate, 12 month interest rates, 10 year interest rates) based on 37 policy changes. Table 2.2 shows the difference of interest rates before and after policy changes.

Figure 2.1 The Movement of 4 Series



The movement of 4 series at the change of monetary policy from February 8, 1990 through April 30, 1999.

Table 2.1 The Date of Monetary Policy Change and Content

Date	ON	ODR	Content of Change
19900316	7.06250	4.25	ON rate increased with the anticipation of fourth ODR hike.
19900622	7.50000	5.25	BOJ made it clear that it will allow increase of interest rates.
19900830	7.71875	6.00	BOJ increased ODR to 6% to control inflation caused by soring oil price.
19901002	7.62500	6.00	BOJ allowed lowering interest rates and is to continue accomodative policy.
19910205	7.87500	6.00	ON rate decreased below 8 % and the anticipation of monetary easing spread.
19910514	7.93750	6.00	BOJ lowered ON rate and opened a way toward monetary operation.
19910701	7.59375	5.50	BOJ changed price prioriry policy and lowered ODR to 5.5%.
19910904	7.40625	5.50	BOJ made it clear that it allows lowering interest rates by easing monetary operation.
19910905	7.25000	5.50	Operation to ease disseminated and ON rate decreased to a new level.
19910909	6.84375	5.50	Stance to lower interest rate became clear and BOJ moved to another easing.
19911017	6.78125	5.50	BOJ made it clear again that it will lower interest rates against slowdown of business .
19911107	6.53125	5.50	Supply of money was more that usual. The policy easing is fully expected in the market.
19911224	6.31250	5.00	Anticipation of monetary easing in early stage is spread in the market against US easing.
19911230	5.78250	4.50	BOJ lowered ODR to 4.5% to support investment in the private sector.
19920106	5.28125	4.50	BOJ allowed lowering interest rates and ON rate decreased.
19920203	5.75000	4.50	BOJ tighted monetary operation to contain the expectation of lowering ODR.
19920401	4.81250	3.75	BOJ lowered ODR to 3.75% to simulate slumping business.
19920727	4.12500	3.25	BOJ lowred ODR to 3.25% out of consideration for sluggish loan demand.
19930204	3.18750	2.50	BOJ lowered ODR to 2.5% to support business activity.
19930816	3.06250	2.50	BOJ made it clear that it will lower interest rates by supplying more funds.
19930906	3.00000	2.50	The market interpreted that BOJ would allow the reduction of ODR.
19930921	2.50000	1.75	BOJ lowered ODR to 1.75% to strengthen the assistance to economy.
19940302	2.15625	1.75	BOJ expressed concern over increasing long term interest rates.
19940510	2.09375	1.75	BOJ judged that increasing long term interest rates would give a bad impact on business.
19940722	2.12500	1.75	BOJ slightly increased the level of ON rate.
19941011	2.25000	1.75	The expectation of increasing interest rates in the short term money market is getting stronger.
19950331	1.75000	1.75	BOJ decided to lower short term interest rates to maximize monetary easing.
19950404	1.71875	1.75	ON rate was lowered to below ODR by the operation to make a surplus on a large scale.
19950414	1.50000	1.00	BOJ lowered ODR to 1.00% to suport business activities.
19950417	1.31250	1.00	ON rate was lowest level because BOJ supplied more funds far more than expected.
19950707	1.05000	1.00	BOJ decided to lower shor term interest rates to support business from monetary side.
19950908	0.51000	0.50	BOJ decided to lower ODR to 0.5% and to lower short term interest rates.
19980910	0.23000	0.50	ON rate decreased against the policy easing by Meeting of Monetary Policy Committee.
19990215	0.12000	0.50	BOJ lowered the target of ON rate at the Meeting of Monetary Policy Committee heln on 10 th.
19990216	0.10000	0.50	Fund Surplus was 800 billion yen. ON rate decreased to 0.1%.
19990217	0.08000	0.50	ON rate decreased against the statement by BOJ governor that ON rate may drecerse to zero %.
19990303	0.04000	0.50	Fund Surplus was 18000billion yen. ON rate decreased to 0.4%.

ON = Over Night , ODR = Official Discount Rate

Table 2.2 The Chage of Interest Rates on the Day of Policy Change

Date	ON	3M	6M	12M	3Y	5Y	7Y	10Y
19900316	0.4063	0.0792	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
19900622	0.0625	0.0634	0.0000	0.0158	0.0800	0.0850	0.0600	0.0600
19900830	0.0938	-0.1267	-0.1267	-0.1267	0.0300	0.0050	0.0050	-0.0350
19901002	-0.1563	-0.0317	-0.1267	-0.0792	-0.0200	0.0150	-0.1600	-0.1300
19910205	-0.0938	-0.0634	-0.0792	-0.0634	-0.0900	-0.0450	-0.0400	-0.0550
19910514	-0.1250	0.0000	0.0000	0.0000	0.0250	0.0100	0.0250	0.0050
19910701	-0.5000	-0.2535	-0.2535	-0.1901	-0.1600	-0.1750	-0.1600	-0.1350
19910904	-0.0313	-0.1267	-0.1267	-0.1109	-0.0500	-0.0400	-0.0200	-0.0400
19910905	-0.1563	0.0000	0.0000	-0.0158	-0.0750	-0.0750	-0.0600	-0.0350
19910909	-0.3438	-0.0634	-0.0792	-0.0634	-0.0300	-0.0450	-0.0100	-0.0100
19911017	-0.1250	-0.1267	-0.1743	-0.1743	-0.0750	-0.0800	-0.0400	-0.0450
19911107	-0.1875	0.0000	0.0000	-0.0634	-0.0150	-0.0100	-0.0050	0.0000
19911224	-0.1875	0.0000	-0.0634	-0.1267	-0.0700	-0.0600	-0.0350	-0.0400
19911230	-0.7175	-0.2535	-0.3010	-0.1901	-0.0950	-0.0900	-0.0500	-0.0400
19920106	-0.5013	-0.3802	-0.3802	-0.3168	-0.1350	-0.1050	-0.0750	-0.0550
19920203	0.1250	0.0634	0.0634	0.0000	0.0700	0.0550	0.0300	0.0200
19920401	-0.7500	0.0317	-0.0158	-0.0317	0.0500	0.0500	0.0500	0.0400
19920727	-0.4688	-0.3168	-0.2376	-0.1901	-0.0600	-0.0550	-0.0300	-0.0350
19930204	-0.6875	-0.0158	-0.0158	-0.0158	-0.0450	-0.0750	-0.0750	-0.0600
19930816	-0.1563	-0.0634	-0.0634	-0.0634	-0.0400	-0.0300	0.0000	0.0100
19930906	-0.0313	-0.0634	-0.0634	-0.0634	-0.0700	-0.0600	-0.0700	-0.0700
19930921	-0.4375	0.0000	0.0000	0.0000	-0.1000	-0.0600	-0.0700	-0.0600
19940302	-0.0313	-0.0634	-0.0634	-0.1267	0.2000	0.2000	0.2100	0.1800
19940510	-0.0625	-0.0634	-0.0634	-0.0158	-0.1060	-0.0530	-0.0380	-0.0460
19940722	0.0313	0.0000	0.0475	0.0475	0.0000	0.0010	0.0030	0.0090
19941011	0.0313	0.0634	0.0317	0.0634	0.0300	-0.0060	-0.0100	-0.0110
19950331	-0.5000	-0.2931	-0.2376	-0.1743	-0.0630	-0.0570	-0.0660	-0.0710
19950404	-0.1563	-0.0634	-0.0475	0.0000	-0.0320	-0.0320	-0.0330	-0.0070
19950414	-0.2813	-0.2535	-0.1901	-0.1584	-0.0900	-0.1050	-0.1450	-0.1460
19950417	-0.1875	0.0000	0.0000	0.0000	-0.0320	-0.0280	-0.0360	-0.0260
19950707	-0.1900	-0.3802	-0.2535	-0.1901	-0.1770	-0.1880	-0.1660	-0.1810
19950908	-0.3900	-0.0317	0.0000	0.0158	-0.1070	-0.0170	0.0100	0.0110
19980910	-0.2200	-0.1861	-0.1545	-0.1426	-0.1610	-0.1750	-0.1890	-0.1980
19990215	-0.1600	-0.0242	-0.0242	-0.0168	-0.0500	-0.0010	0.0350	0.0560
19990216	-0.0200	-0.0241	-0.0291	-0.0277	-0.0600	-0.0900	-0.1110	-0.1290
19990217	-0.0200	-0.0154	-0.0166	-0.0269	-0.0600	-0.0620	-0.0660	-0.0420
19990303	-0.0300	-0.0436	-0.0475	-0.0421	-0.0830	-0.0960	-0.1060	-0.1120

The chage of interest rates on the policy change day over previous business day was calculated.
ON = Over Night

4 The Result of Empirical Analysis

I investigated the impacts of the target changes of uncollateralized overnight call rates as in Cook/Hahn (1989). I found that unsecured overnight call rate changes significantly affected the market interest rates from 1 month through

5 year. I couldn't find the statistical significance over 7 year zone. The impacts are as follows; 0.52~0.17% change on 1 % change of uncollateralized overnight call rate from 1 month through 12 month, 0.16~0.09% change from 3 year through 5 year, and 0.06~0.04% change from 7 year through 10 year.

This result as for interest rates reaction over 2 year is similar to Cook/Hahn (1989), Roley/Sellon (1995), Roley/Sllon (1996), Thornton (1998). In Japan the impacts on 1 month and 2 month interest rates are very strong in comparison with the impacts on 3 month through 12 month. In US the impacts on 3 month through 12 month are almost equal, but in Japan the impacts are diminishing in accordance with the length of maturity.

The coefficients of determination are 0.46 (1 month) through 0.09 (10 year), which are small in comparison with US previous cases. As for the coefficient of determination in the case of Cook/Hahn (1989), 0.59 at 6 month is the largest and 0.29 at 20 year is the smallest.

5 Concluding Remarks

Uncollateralized overnight call rate changes significantly affected the market interest rates from 1 month through 5 year. I couldn't find the statistical significance over 7 year zone. The impacts are as follows; 0.52~0.17% change on 1 % change of uncollateralized overnight call rate from 1 month through 12 month, 0.16~0.09% change from 3 year through 5 year,0.06~0.04%, and 0.06~0.04% change from 7 year through 10 year.

From this analysis, I can conclude that the changes of monetary policy by the BOJ gave more impacts on interest rates with shorter maturities. I can also say that the impacts on over 3 year interest rates are limited.

Table 2.3 The Effects of Policy Change over Previous Business Day

ΔR_t	α	β	R^2	SER	DW
1M	0.004	0.518	0.460	0.129	2.037
	(0.159)	(6.385)***			
2M	-0.024	0.377	0.384	0.112	2.081
	(-1.211)	(5.339)***			
3M	-0.030	0.267	0.309	0.105	2.054
	(-1.630)	(4.017)***			
4M	-0.029	0.292	0.337	0.096	2.033
	(-1.705)*	(4.745)***			
5M	-0.026	0.174	0.171	0.091	1.921
	(-1.194)	(2.487)**			
6M	-0.039	0.226	0.274	0.092	2.070
	(-2.182)**	(3.620)***			
7M	-0.027	0.211	0.252	0.085	2.068
	(-1.650)	(3.626)***			
8M	-0.029	0.224	0.310	0.081	2.029
	(-1.911)*	(4.165)***			
9M	-0.032	0.180	0.289	0.073	2.010
	(-2.418)**	(3.778)***			
10M	-0.029	0.191	0.306	0.074	2.002
	(-2.203)**	(3.972)***			
11M	-0.036	0.176	0.278	0.073	1.940
	(-5.330)***	(3.760)***			
12M	-0.038	0.174	0.258	0.074	1.952
	(-2.757)***	(3.592)***			
2Y	-0.039	0.106	0.137	0.067	1.906
	(-2.822)***	(2.296)**			
3Y	-0.023	0.110	0.120	0.072	1.888
	(-3.625)***	(2.112)**			
4Y	-0.024	0.095	0.103	0.071	1.850
	(-1.616)	(1.875)*			
5Y	-0.021	0.099	0.105	0.071	1.819
	(-1.379)	(1.952)*			
7Y	-0.027	0.058	0.048	0.075	1.863
	(-1.820)*	(1.114)			
10Y	-0.031	0.038	0.094	0.071	1.765
	(-2.311)**	(0.796)			

OLS is used between the changes of ON call rates and the changes of market interest rates. White (1980) is used to corrext heteroscedasticity. The first serial correlation is erased by the method by Cochrane/Orcutt (1949).
The insides of parenthesis ( ) indictae t statistics.
,,* indicate the siginificance at 1%, 5%, 10%.
DW = Durbin-Watson ratio, SER = Standard Error

As for the remaining topics, (1) Conduct the empirical analysis in the latter part of Roley/Sellon (1995), and Roley/Sellon (1996), Nilsen (1998) by considering the forecast on monetary policy[6], (2) Analyze the relationship between monetary policy change and the change of yield curve by incorporating the expectation on monetary policy as mentioned in Balduzzi/ Bertola/Silverio/Klapper (1998), McCallum (1994), Rudebush (1995).

References

In Japanese

Ito,T. (2003b), "The Analysis of Monetary Policy by the Bank of Japan," *Review of Monetary and Financial Studies*, Vol.20,pp.53-63.

Kuroki,Y. and Y.Honda (2001), 「Monetary Policy and Financial System」 *Paper presented at 39th Conference on Econometrics (Lake Biwa Conferenc)*

Nikkei Kinyu Shimbun (Japan Financial Daily).

Nihon Keizai Shimbun (Japan Economic Daily).

In English

Balduzzi,P.,G.Bertola,S.Foresi and L.Klapper (1998), "Interest Rate Targeting and the Dynamics of Sort-Term Rates," *Journal of Money,Credit, and Banking*,Vol.30. pp.26-50.

Cochrane,D. and G.H.Orcutt (1949), "Application of Least Squares Regression to Relationships Containing Autocorrelated Error Terms," *Journal of the American Statistical Asscociation*,Vol.44,pp.32-61.

Cook,T. and T.Hahn (1989), "The Effects of Changes in the Federal Funds Rate Target on Market Interest Rates in the 1970's," *Journal of Monetary Economics*, Vol.24,pp.331-351.

6 According to Roley/Sellon (1995), Roley/Sellon (1996), Thornton (1998), Nilesen (1998), unexpected changes of monetary policy five more impacts on market interests than expected policy change.

McCallum,B.T.(1994), "Monetary Policy and the Term Structure of Interest Rates," *National Bureau of Economic Research, Working Paper* No.4938.

Nilesen,J.(1998), "Borrowed Reserves, Fed Funds Rate Targets and the Term Structure," in Angeloni,I and R.Rovelli(ed),*Monetary Policy and Interest Rates*, Macmillan,pp.80-120.

Roley,V.V. and G.H.Sellon,Jr (1995), "Monetary Policy Actions and Long-Term Interest Rates," *Federal Reserve Bank of Kansas City, Economic Review,* Fourth Quarter,pp.73-89.

Roley,V.V. and G.H.Sellon,Jr (1996), "The Response of the Term Structure of Interest Rates To Federal Funds Rate Target changes," *Federal Reserve Bank of Kansa City Research Working Paper*,pp.96-08.

Rudebush,G.D.(1995), "Federal Reserve Interest Rate Targeting, Rational Expectations ,and the Term Structure," *Journal of Monetary Economics*, Vol.35,pp.245-274.

Thornton,D.L.(1998), "Tests of the Market's Reaction to Federal Funds Rate Target Changes," *Federal Reserve Bank of St.Louis Review*, November/ December, pp.25-36.

White,H.(1980), "A Heteroskedasticity-Consistent Covariance Matrix Estimator and A Direct Test For Heteroskedasticity," *Econometrica*, Vol.48, pp.817-838.

Chapter 3

The Effects of Monetary Policy from Long Term*

1 Introduction

1.1 The Purpose of this Chapter

The Bank of Japan (hereinafter BOJ) conducts its monetary policy by adjusting the uncollateralized overnight call rate[1]. It's considered to be the only benchmark the BOJ can be responsible. The effects of the monetary policy can exert an influence on the shape of the Japanese term structure of interest rates.

But there is a room for discussion as to the range of the yield curve the BOJ can control. The BOJ has means to provide money into the market through the operation of buying the long term Japanese Government Bonds up to the maturities and so on in addition to the control of uncollateralized overnight call rate. But the buying operation does not have a meaning of controlling long-term interest rates, but it just provides liquidity in

* This chapter is based on Ito (2000). Prior to the publication of Ito (2000), initial drafted was submitted as a thesis of Master's degree at the University of Tukuba in March 19999.

[1] The change of official discount rate was the most important measure of monetary policy by the mid 1990's.But market operations have become central measures and the role of official discount rate declined. The uncollateralized overnight call rate was around 0.02 - 0.03% starting in March 1999 and 0.02- 0.03% means a virtually zero interest rate with the introduction of zero interest rate policy by the BOJ. The BOJ lifted it in August 2000. The sample of this chapter ends at the end of March, 1999. On March 3 1999, Mr.Kazuo Ueda, a member of the BOJ monetary policy committee expressed his opinion that short term interest rates such as 1 week and 1 month can be a target of monetary policy by the BOJ.

accordance with the growth of money supply.

From a point of economic policy, it is important to know whether the uncollateralized overnight call rate can control the long term interest rates which influence housing and equipment investment. If the uncollateralized overnight call rate can influence the interest rate up to the 10 year, the control of long term interest rates can be possible within the current framework. If not, we need to consider the introduction of measures to control them.

The purpose of this chapter is to investigate the effects and limits of the monetary policy by the BOJ by analyzing the term structure of Japanese interest rates. The remainder of this chapter is as follows. In section 1.2 I summarize previous studies. In section 2 I explain the framework of the analysis. In section 3 I touch on the data. In section 4 I report the results of the empirical analysis. In section 5 I summarize the conclusion and the remaining issues.

1.2 Previous Studies

There are two previous studies in which cointegration is applied for the analysis of term structure of interest rates and monetary policy. 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 month 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.

Hall/Andersen/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 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 got a conclusion that there is a single common trend in the era (one from March 1970 through September 1979 and one from October 1982 through December 1988) when FRB (Federal Reserve Board) took a policy of stabilized monetary policy. On the other hand they found that there are more than two common trends in the period from October 1979 through September 1982 when the FRB emphasized the control of money supply.

Hiraki/Shiraishi/Takezawa (1997) applied cointegration test to Japanese data. They 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.

Let me quote the other works using cointagration test for the analysis of the term structure of interest rates. 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 used the Engle/Grager cointegration test.

Engsted/Anggaard (1994) conducted the Johansen cointegration test by using 4 series of US Treasury data (3 month, 1 year, 10 year and 30 year). They found that the entire series has 3 cointegration vectors and 1 common factor. Mougoue (1992) analyzed the monthly Euro interest rates data (Canada, Germany,Japan,Swiss,United Kingdon,and USA) 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.

Here I would like to mention an important point to be improved as to the previous works. All of the previous works analyze only the entire term structure. None of them considers the structural change derived from the analysis by subtracting points of yield curve. When the entire yield curve is driven by more than 2 trends, it's worth trying to know the range in the entire yield curve which is drive by a single trend.

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[2]. The ADF (Augmented Dickey Fuller) test and the PP (Phillips Perron) test are used. Both the ADF and PP tests define null hypothesis as 'unit roots exist' and alternative hypothesis as 'unit roots don't exist'[3]. Fuller (1976) provides the table for ADF and PP test.

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[2] 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.

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

3.2 Cointegration Test of Johansen and Common Trend

There are mainly two types of cointegration test- (1)Engle/Granger(1987), (2) Johansen(1988)[4]. 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.

$$X_t = \Pi_1 X_{t-1} + \ldots + \Pi_k X_{t-k} + \lambda + u_t \qquad (3.1)$$

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 (3.1) is expressed by using a first difference.

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi \Delta X_{t-k} + \lambda + u_t \qquad (3.2)$$

Here

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

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

[4] 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 chapter, the expectations hypothesis dose not hold true in Japan.

β of p x r matrix Π. Finally equation (3.2) can be expressed as follows.

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} \ldots + \Gamma_{t-k} \Delta X_{t-k+1} + \alpha\beta' \Delta X_{t-k} + \lambda + u_t \qquad (3.3)$$

β' is a cointegration vector and $\beta' X_{t-k}$ is an error correction term. In this chapter I use Johansen (1988) cointegration test since the number of cointegration vector is not known. For the hypothesis test, I use trace test and test statistics provided by Zhang (1988)[5].

An alternative interpretation of the cointegration among 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 I (0) component[6].

Applying the result to this chapter, we expect that there will be a couple of non-stationary common trend in the yields of different maturities[7]. 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

$$R(1,t) = A(1,t) + b_1 W(t_1)$$
$$R(2,t) = A(2,t) + b_2 W(t_1) + b_2 W(t_2)$$

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[5] 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).

[6] 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.

[7] Hall/Anderson/Granger(1992) is referred for this part.

....

$$R(n,t) = A(n,t) + b_n W(t_1) + b_n W(t_2) .... b_n W(t_n)$$

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. $W(t_n)$ drives the time series behavior of each yield and determines how the entire yield curve change over time. $W(t_n)$ is considered as something exogenous to the system of yield curve such as inflation, measures of monetary growth and so on.

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.

3.3 The Granger Causality Test

The Granger causality test checks whether x (uncollateralized overnight call rate) affects y (market interest rate) or y affects x or x and y affects mutually in the time series model with regard to variables x and y. The original data are 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 to the influence from y to x and the influence from x to y. But trend term t and $p + 1$ (original lag plus one) are added for the estimation.

$$x_t = u_0 + u_t + \sum_{i=1}^{p+1} \alpha_i x_{t-i} + \sum_{i=1}^{p+1} \beta_i y_{t-i} + u_t \qquad (3.3)$$

$$H_0 : \beta_1 = \beta_2 = \cdots \beta_p = 0$$
$$H_1 : \text{Either } \beta_i \neq 0 \quad (i = 1,2,\cdots,p)$$

$$y_t = v_0 + v_t + \sum_{i=1}^{p+1} \gamma_i x_{t-i} + \sum_{i=1}^{p+1} \delta_i y_{t-i} + v_t \tag{3.4}$$

$$H_0 : \gamma_1 = \gamma_2 = \cdots \gamma_p = 0$$
$$H_1 : \text{ Either } \gamma_i \neq 0 \quad (i = 1,2,\cdots,p)$$

The F test is conducted by estimating (3.3) and (3.4) through OLS and summing the squared error. If the null hypothesis of H_0 in the formula (3.3) is rejected, y is considered to explain y. If the null hypothesis of H_0 in the formula (3.4) is rejected, x is considered to explain y.

3 Data

The 19 series of data - uncollateralized overnight call rate , LIBOR (London InterBank Offered rate)from 1 month through 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 March 1993 through March 1998[8]. Figure 3.1 shows the movement of 4 series of data (overnight unsecured call rate, swap rate 2 year,5 year, and 10 year).

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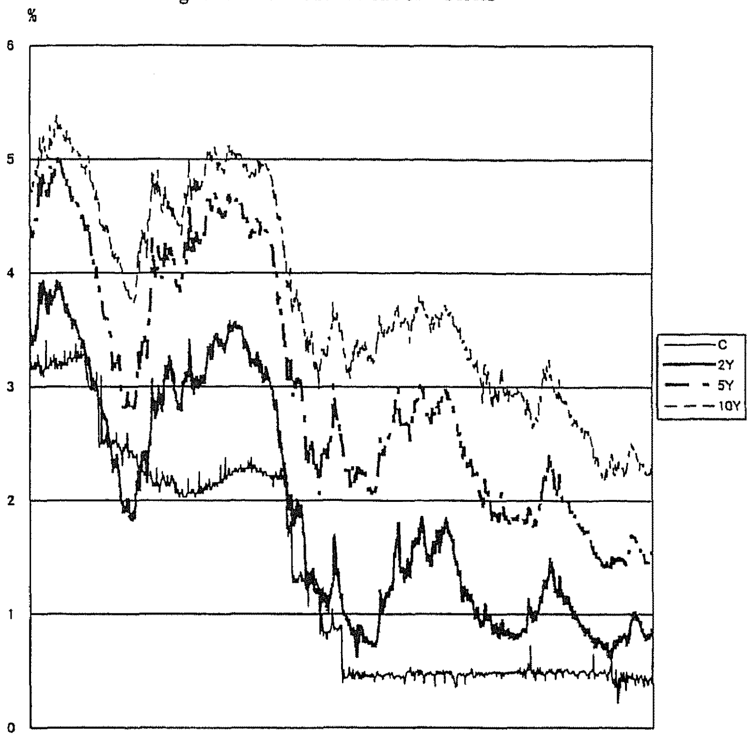
[8] As for uncollateralized overnight call rate, I use central rates before May 15,1995 and weighted averaged rates after May 16,1995. These rates are calculated by Association of Money Market. BBA (British Bankers' Association) publishes LIBOR as of 11 am London time. Interest rate swap rates as of 3 pm Japan time are provided by a major broker. In 1990's the issuances of JGB (Japanese Government Bond) were centered on 10 year and most of trading activities were 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 3.1 The Movement of 4 Series



Daily base from March 1,1993 through March 31,1998.

C = Uncollateralized Over Night Call Rate
2Y = 2 Year Swap Rate
5Y = 5 Year Swap Rate
10Y = 10 Year Swap Rate

4 The Result of Empirical Analysis

4.1 Unit Root Analysis

The 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).

The results are shown on Table 3.1. There is no denying that all the variables 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 are $I(1)$, results are shown on the Table 3.2.

Table 3.1 The Result os Unit Root Test (Original Series)

Variable	Test	Without Trend	With Trend
ON	ADF	-1.7386*	-0.7214*
	PP	-2.3934*	-4.8189
1M	ADF	-2.0493*	-1.0712*
	PP	-2.0926*	-0.9643*
2M	ADF	-1.9357*	-0.8009*
	PP	-2.1087*	-0.6083*
3M	ADF	-2.0251*	-0.6087*
	PP	-2.0251*	-0.6134*
4M	ADF	-1.8416*	-0.7513*
	PP	-2.0161*	-0.6457*
5M	ADF	-1.8652*	-0.7592*
	PP	-1.8804*	-0.6346*
6M	ADF	-1.7923*	-0.8688*
	PP	-1.8693*	-0.6501*
7M	ADF	-1.7759*	0.7664*
	PP	-1.8172*	-0.6840*
8M	ADF	-1.6720*	-1.0053*
	PP	-1.7687*	-0.7178*
9M	ADF	-1.5219*	-1.2288*
	PP	-1.6681*	-0.8386*
10M	ADF	-1.5794*	-1.0404*
	PP	-1.6120*	-0.8935*
11M	ADF	-1.4367*	-1.2501*
	PP	-1.5527*	-0.9479*
12M	ADF	-1.4044*	-1.3240*
	PP	-1.5061*	-0.9851*
2Y	ADF	-1.2430*	-1.7974*
	PP	-1.1765*	-1.4453*
3Y	ADF	-1.1673*	-1.9131*
	PP	-1.0514*	-1.5781*
4Y	ADF	-0.9680*	-1.7728*
	PP	-0.9082*	-1.6389*
5Y	ADF	-0.8098*	-1.8864*
	PP	-0.8043*	-1.7593*
7Y	ADF	-0.6212*	-2.0262*
	PP	-0.6212*	-2.0657*
10Y	ADF	-0.4468*	-2.1167*
	PP	-0.6290*	-2.3797*

* indicates significance at the 5 % level.
5% critical values are -2.86 (Without Trend)-3.41(With Trend) .
ADF = Augmented Dickey Fuller.
PP = Phillips Perron.

Table 3.2 The Result os Unit Root Test (First Difference)

Variable	Test	Without Trend	With Trend
⊿ON	ADF	-12.3565	-12.6646
	PP	-40.4241	-40.4166
⊿1 M	ADF	-15.5194	-15.5344
	PP	-33.0924	-33.1065
⊿2M	ADF	-10.4637	-10.5080
	PP	-31.3366	-31.3562
⊿3M	ADF	-18.2882	-18.2245
	PP	-31.9763	-31.9946
⊿4M	ADF	-10.5976	-10.6356
	PP	-31.5447	-31.5587
⊿5M	ADF	-15.3895	-15.3630
	PP	-31.4128	-31.4221
⊿6M	ADF	-10.1895	-10.2200
	PP	-30.6881	-30.6963
⊿7M	ADF	-21.5851	-21.4938
	PP	-30.5614	-30.5661
⊿8M	ADF	-10.1313	-10.1395
	PP	-30.2280	-30.2297
⊿9M	ADF	-20.7743	-20.6880
	PP	-30.8279	-30.8265
⊿10M	ADF	-21.5914	-21.5001
	PP	-30.6490	-30.6461
⊿11M	ADF	-29.7089	-29.5360
	PP	-29.7089	-29.7040
⊿12M	ADF	-29.3513	-29.1786
	PP	-29.3513	-29.3452
⊿2Y	ADF	-10.7969	-10.7730
	PP	-33.1958	-33.1828
⊿3Y	ADF	-10.6365	-10.6167
	PP	-33.6286	-33.6153
⊿4Y	ADF	-19.0334	-18.9311
	PP	-34.2436	-34.2315
⊿5Y	ADF	-15.4694	-15.3987
	PP	-35.0774	-35.0678
⊿7Y	ADF	-15.3987	-19.9380
	PP	-36.4446	-36.4417
⊿10Y	ADF	-27.2113	-27.0366
	PP	-37.7109	-37.7102

* indicates significance at the 5 % level.
5% critical values are -2.86 (Without Trend) -3.41(With Trend) .
ADF = Augmented Dickey Fuller.
PP = Phillips Perron.

Table 3.3 The Result of Cointegration Analysis (19 Series)

Null	Alternative	Test Statisitcs	5% Value	1% Value
r = 0	r = 1	3142.72**	666.8	689.8
r ≦1	r = 2	2662.15**	601.1	623.1
r ≦2	r = 3	2285.48**	538.9	559.7
r ≦3	r = 4	1946.06**	480.1	499.7
r ≦4	r = 5	1646.06**	424.6	443.1
r ≦5	r = 6	1386.19**	372.6	389.9
r ≦6	r = 7	1130.57**	323.6	339.7
r ≦7	r = 8	901.58**	276.4	293.4
r ≦8	r = 9	721.55**	236.6	250.4
r ≦9	r = 10	556.78**	198.0	210.6
r ≦10	r = 11	404.76**	162.8	172.3
r ≦11	r = 12	295.96**	131.1	141.4
r ≦12	r = 13	207.69**	103.1	112.7
r ≦13	r = 14	139.94**	78.1	86.6
r ≦14	r = 15	80.28**	57.2	63.9
r ≦15	r = 16	48.49**	38.6	44.5
r ≦16	r = 17	20.76	23.8	28.5
r ≦17	r = 18	7.74	12.0	15.6
r ≦18	r = 19	2.19	4.2	5.2

The Johansen cointegration test is conducted using 19 series data.
The number of cointegration vector is 16. The number of common trend is 3.
The entire term structure is driven by 3 common trends.
** indicates significance at the 1 % level.

4.2 Cointegration Test

Since all the variables are non-stationary, cointegration test needs to be done to analyze the term structure and draw out common trends. Johansen methodology is used since the number of cointegration vector in the 19 series of data is not known in advance. For the test, distribution table by Zhang (1993) is used. A point in the yield curve is found where a single common trend drives the series.

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

(19 data series)

The number of cointegration vector is 16. The number of common trend is 3. The whole term structure is driven by three trends. The result is shown on the Table 3.3.

Table 3.4 The Result of Cointegration Test (18 Series)

Null	Alternative	Test Statisitcs	5% Value	1% Value
r = 0	r = 1	3063.12**	601.1	623.1
r ≦1	r = 2	2587.97**	538.9	559.7
r ≦2	r = 3	2211.57**	480.1	499.7
r ≦3	r = 4	1874.18**	424.6	443.1
r ≦4	r = 5	1575.14**	372.6	389.9
r ≦5	r = 6	1316.33**	323.6	339.7
r ≦6	r = 7	1061.35**	276.4	293.4
r ≦7	r = 8	841.47**	236.6	250.4
r ≦8	r = 9	664.64**	198.0	210.6
r ≦9	r = 10	504.06**	162.8	172.3
r ≦10	r = 11	355.06**	131.1	141.4
r ≦11	r = 12	257.23**	103.1	112.7
r ≦12	r = 13	170.33**	78.1	86.6
r ≦13	r = 14	104.47**	57.2	63.9
r ≦14	r = 15	59.66**	38.6	44.5
r ≦15	r = 16	28.80**	23.8	28.5
r ≦16	r = 17	7.56	12.0	15.6
r ≦17	r = 18	2.22	4.2	5.2

The Johansen cointegration test is conducted using 18 series data.
The number of cointegration vector is 16. 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 % level.

(2) From uncollateralized overnight call rate through 7 year swap rate (18 data series)

The number of cointegration vector is 16. The number of common trend is

2. The term structure up to the 7 year is driven by two trends. The result is shown on the Table 3.4.

Table 3.5 The Result of Cointegration Test (17 Series)

Null	Alternative	Test Statisitcs	5% Value	1% Value
r = 0	r = 1	2963.61**	538.9	559.7
r ≦1	r = 2	2488.08**	480.1	499.7
r ≦2	r = 3	2113.66**	424.6	443.1
r ≦3	r = 4	1780.00**	372.6	389.9
r ≦4	r = 5	1486.27**	323.6	339.7
r ≦5	r = 6	1231.86**	276.4	293.4
r ≦6	r = 7	986.19**	236.6	250.4
r ≦7	r = 8	768.37**	198.0	210.6
r ≦8	r = 9	598.20**	162.8	172.3
r ≦9	r = 10	439.07**	131.1	141.4
r ≦10	r = 11	305.57**	103.1	112.7
r ≦11	r = 12	209.74**	78.1	86.6
r ≦12	r = 13	126.66**	57.2	63.9
r ≦13	r = 14	69.63**	38.6	44.5
r ≦14	r = 15	30.12**	23.8	28.5
r ≦15	r = 16	7.96	12.0	15.6
r ≦16	r = 17	2.24	4.2	5.2

The Johansen cointegration test is conducted using 17 series data.
The number of cointegration vector is 15. The number of common trend is 2.
The term structure up to 5 year is driven by 2 common trends.
** indicates signigicance at the 1 % level.

(3) From uncollateralized overnight call rate through 5 year swap rate (17 data series)

The number of cointegration vector is 15. The number of common trend is 2. The term structure up to the 5 year is driven by two trends. The result is shown on the Table 3.5.

(4) From uncollateralized overnight call rate through 4 year swap rate (16 data series)

The number of cointegration vector is 14. The number of common trend is 2. The term structure up to the 4 year is driven by two trends. The result is shown on the Table 3.6.

Table 3.6 The Result of Cointegration Test (16 Series)

Null	Alternative	Test Statisitcs	5% Value	1% Value
r = 0	r = 1	2835.22**	480.1	499.7
r ≦1	r = 2	2363.33**	424.6	443.1
r ≦2	r = 3	1993.28**	372.6	389.9
r ≦3	r = 4	1664.72**	323.6	339.7
r ≦4	r = 5	1374.50**	276.4	293.4
r ≦5	r = 6	1122.29**	236.6	250.4
r ≦6	r = 7	879.89**	198.0	210.6
r ≦7	r = 8	665.80**	162.8	172.3
r ≦8	r = 9	496.58**	131.1	141.4
r ≦9	r = 10	338.70**	103.1	112.7
r ≦10	r = 11	226.34**	78.1	86.6
r ≦11	r = 12	142.35**	57.2	63.9
r ≦12	r = 13	73.89**	38.6	44.5
r ≦13	r = 14	30.98**	23.8	28.5
r ≦14	r = 15	9.23	12.0	15.6
r ≦15	r = 16	2.22	4.2	5.2

The Johansen cointegration test is conducted using 16 series data.
The number of cointegration vector is 14. 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.

(5) From uncollateralized overnight call rate through 3 year swap rate (15 data series)

The number of cointegration vector is 13. The number of common trend is 2. The term structure up to the 3 year is driven by two trends. The result is shown on the Table 3.7.

Table 3.7 The Result of Cointegration Test (15 Series)

Null	Alternative	Test Statisitcs	5% Value	1% Value
r = 0	r = 1	2717.29**	424.6	443.1
r ≦1	r = 2	2251.18**	372.6	389.9
r ≦2	r = 3	1882.20**	323.6	339.7
r ≦3	r = 4	1553.40**	276.4	293.4
r ≦4	r = 5	1285.42**	236.6	250.4
r ≦5	r = 6	1035.49**	198.0	210.6
r ≦6	r = 7	794.84**	162.8	172.3
r ≦7	r = 8	594.33**	131.1	141.4
r ≦8	r = 9	428.06**	103.1	112.7
r ≦9	r = 10	284.38**	78.1	86.6
r ≦10	r = 11	173.96**	57.2	63.9
r ≦11	r = 12	91.55**	38.6	44.5
r ≦12	r = 13	34.28**	23.8	28.5
r ≦13	r = 14	11.03	12.0	15.6
r ≦14	r = 15	2.56	4.2	5.2

The Johansen cointegration test is conducted using 15 series data.
The number of cointegration vector is 13. The number of common trend is 2.
The term structure up to 3 year is driven by 2 common trends.
** indicates signigicance at the 1 % level.

(6) From uncollateralized overnight call rate through 2 year swap rate (14 data series)

The number of cointegration vector is 13. 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 3.8.

Table 3.8 The Result of Cointegration Test (14 Series)

Null	Alternative	Test Statisitcs	5% Value	1% Value
r = 0	r = 1	2571.78**	372.6	389.9
r ≦1	r = 2	2105.58**	323.6	339.7
r ≦2	r = 3	1738.05**	276.4	293.4
r ≦3	r = 4	1428.56**	236.6	250.4
r ≦4	r = 5	1164.41**	198.0	210.6
r ≦5	r = 6	921.87**	162.8	172.3
r ≦6	r = 7	708.60**	131.1	141.4
r ≦7	r = 8	536.63**	103.1	112.7
r ≦8	r = 9	378.82**	78.1	86.6
r ≦9	r = 10	247.55**	57.2	63.9
r ≦10	r = 11	138.39**	38.6	44.5
r ≦11	r = 12	64.51**	23.8	28.5
r ≦12	r = 13	19.02**	12.0	15.6
r ≦13	r = 14	3.14	4.2	5.2

The Johansen cointegration test is conducted using 14 series data.
The number of cointegration vector is 13. 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 % level.

(7) From uncollateralized overnight call rate through 12 month swap rate (13 data series)

The number of cointegration vector is 12. 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 3.9.

Table 3.9 The Test of Cointegration Test (13 Series)

Null	Alternative	Test Statisitcs	5% Value	1% Value
r = 0	r = 1	2415.43**	323.6	339.7
r ≦1	r = 2	1955.91**	276.4	293.4
r ≦2	r = 3	1588.47**	236.6	250.4
r ≦3	r = 4	1278.85**	198.0	210.6
r ≦4	r = 5	1018.88**	162.8	172.3
r ≦5	r = 6	780.81**	131.1	141.4
r ≦6	r = 7	571.87**	103.1	112.7
r ≦7	r = 8	409.61**	78.1	86.6
r ≦8	r = 9	257.93**	57.2	63.9
r ≦9	r = 10	148.32**	38.6	44.5
r ≦10	r = 11	71.66**	23.8	28.5
r ≦11	r = 12	22.32**	12.0	15.6
r ≦12	r = 13	3.72	4.2	5.2

The Johansen cointegration test is conducted using 13 series data.
The number of cointegration vector is 12. 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 % level.

It's found that the term structure up to 2 year is driven by a single 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 the money market section. Since FRA and IMM swap are traded up to 2 years, 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 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

Table 3.10 The Rsult of Granger Causality Test

F Statistics concerning Over Night rate and Market Rates			
Causality of Over Night Rate on Market Rates		Causality of Market Rates onOver Night Rate	
1M	43.5812**	1M	1.7510
2M	44.2975**	2M	0.6905
3M	34.4583**	3M	0.3504
4M	27.9616**	4M	1.1915
5M	25.2642**	5M	2.0007
6M	18.0453**	6M	0.2721
7M	16.6261**	7M	0.3208
8M	15.5283**	8M	0.2537
9M	11.9445**	9M	2.4076
10M	13.2363**	10M	0.4635
11M	10.4806**	11M	2.2146
12M	9.5269**	12M	2.6391
2Y	4.1209**	2Y	1.2059
3Y	3.0043	3Y	0.4027
4Y	2.5349	4Y	0.2143
5Y	2.2718	5Y	0.1222
7Y	1.3617	7Y	0.3223
10Y	1.4760	10Y	0.6813

** indicates signigicance at the 1 % level.

year - single common trend), (2) middle term(from 3 year through 7 year - two common trends), (3) long term (10 year-three common trends).

From a viewpoint of monetary policy, it can be assumed that the uncollateralized overnight call rate is deeply connected with the term structure up to 2 year.

4.3 Granger Causality

When the influences of uncollateralized overnight call rate on the each interest rate of the entire term structure are investigated, it influences the term structure up to the 2 year. The uncollateralized overnight call rate is judged to give the shorter period of interest rate more influence since F-statistics increases as the maturities of the interest rate get shorter except for the case of 9 month and 1 month. The results are shown on the Table 3.10.

Next, the influences of each interest rate of the entire term structure on the uncollateralized overnight call rate are checked. None of the interest rate is found to influence uncollateralized overnight call rate. Accordingly it's assumed that the BOJ could influence the term structure up to 2 year independently by its monetary policy and the BOJ never followed the change of the market. The results are shown on the Table 3.10.

5 Conclusion

The entire term structure is driven by 3 common trends. The term structure up to 2 year is driven by a single trend. By the Granger causality test, it's found that the uncollateralized overnight call rate influence the term structure up 2 year.

Thus the conclusion is that the BOJ can control the term structure up to 2 year by the adjustment of the uncollateralized overnight call rate. Accordingly it's necessary for us to consider the introduction of market management policy to control the long term interest rates.

As for remaining topics, (1) Conduct principal component analysis using the number of trends,(2) Regress uncollateralized overnight call rate with stock prices, foreign exchange rates and etc, (3) Introduce structural change into the analysis of cointegration, (4) Compare Japanese data with US data,--these four points are pointed out.

References

In Japanese

Ito.T.(2000) "The Analysis on the Term Structure of Interest Rates – The Effects and Limits of Monetary Policy by the Bank of Japan," *Modern Finance*,No.7,pp75-90.

In English

Bradley,M.G. and S.A.Lumpkin(1992), "The Treasury Yield Curve as a Cointegrated System," *Journal of Financial and Quantitative Analysis*, Vol.27,pp.449-463.

Dickey,D.A. and W.Fuller(1979), "Distribution of the Estimators for Autoregressive Time Series With a Unit Root," *Journal of the American Statistical Association*, Vol.74,pp.427-431.

Dickey,D.A. and W.Fuller(1981), "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root," *Econometrica*, Vol.49, pp.107-1072.

Engle,R.F. and C.W.J.Granger(1987), "Co-Integration and Error Correction: Representation,and Testing," *Econometrica*, Vol.55, pp.251-276.

Engsted,T. and C.Tanggaard(1994), "Cointegration and the US Term Structure," *Journal of Banking and Finance*,Vol.18,pp.167-181.

Fuller,W.A.(1976), *Introduction to Statistical Time Series*, John Wiley & Sons,Inc

Hall,A.D.,H.M.Anderson and C.W.J.Granger(1992), "A Cointegration Analysis of Treasury Bill Yields," *Review of Economics and Statistics*, Vol.74, pp.116-126.

Hiraki,T.,N.Shiraishi and N.Takezawa(1996), "Cointegration, Common Factors, and the Term Structure of Yen Offshore Interest Rates," *Journal of Fixed Income*, December,pp.69-75.

Johansen,S.(1988), "Statistical Analysis of Cointegrated Vectors," *Journal of Economic Dynamics and Control*,Vol.12,pp.231-254.

Karfakis,C. and D.M.Moschos(1995), "The Information Content of the Yield Curve in Australia," *Journal of Macroeconomics*, Vol.17,pp.93-109.

Mougoue,M.(1992), "The Term Structure of Interest Rates as a Cointegrated System: Empirical Evidence from The Eurocurrency Market, *Journal of Financial Research*,Vol.15,pp.285-296.

Phillips,P.C.B.(1986), "Understanding Spurious Regressions in Econometrics," *Journal of Econometrics*,Vol.33,pp.311-340.

Phillips,P.C.B. and P.Perron(1988), "Testing for a Unit Root in Time Series Regression," *Biometrica*,Vol.75,pp.335-46.

Stock,J.H. and M.W.Watson(1988), "Testing for Common Trends," *Journal of the American Statistical Association*, Vol.83,pp.1097-1107.

Toda,H.Y. and T.Yamamoto(1995), "Statistical Inference in Vector Autoregressions With Possibly Integrated Processes," *Journal of Econometrics*, Vol.66, pp.225-250.

Zhang,H.(1993), "Treasury Yield Curves and Cointegration," *Applied Econometrics*, Vol.25,pp.361-367.

Chapter 4

Fisher Hypothesis*

1 Inrodcution

1.1 The purpose of this Chapter

Fisher (1930) maintains that the expected rate of inflation is reflected in the nominal interest rates and the real interest rates are constant. This relationship between the expected rate of inflation and the nominal interest rates is called Fisher Hypothesis. The purpose of this chapter is to investigate the validity of the Fisher Hypothesis by using the Japanese yen interest rate data in 1990's.

In this chapter, I will use the whole term structure to investigate the validity of the hypothesis. Thus it's possible to test where in the term structure the hypothesis is established. The data used in this chapter is likely to contain the non-stationary process called unit root. I will use non-stationary time series model to cope with a problem of unit root.

This chapter is considered to be original in the following two points. First, Fisher Hypothesis is never tested by using the whole term structure either in Japan or in the rest of the world. Second, the number of previous studies using the non-stationary times series model in Japan is very small.

First, the non-stationarity of the data is confirmed by the unit root tests. Next, the cointegration test is applied between the expected rate of inflation and the nominal interest rates. Finally, Granger causality tests are used to

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* This chapter is based on Ito (2003a).

check if the expected rates of inflation influenced the nominal interest rates and vice versa.

The remainder of this chapter are as follows. In section 1.2 I summarize previous studies. In section 2 I explain the framework of the analysis. In section 3 I touch on the data. In section 4 I report the results of the empirical analysis. In section 5 I summarize the conclusion and the remaining issues.

1.2 Previous Studies

There are no unified conclusions as to the Fisher Hypothesis. The conclusions are different depending on countries, period, interest rates and the definition of expected inflation. In Japan, the number of previous studies using non-stationary times series is limited. Kamae (1999) conducted empirical analysis using Japanese Government Bond (4 Year,6 Year,8 Year). He estimated expected inflation from CPI (Consumer Price Index) by using Kalman Filter. The period is from 1977 through 1995. He conducted Engle/Granger (1987) cointegration test to find that the Fisher hypothesis holds true.

Inder/Silvapulle (1993) used Engle/Granger cointegration test between bankers acceptance rates and CPI in Australia. They concluded that the Fisher hypothesis doesn't hold true. MacDonald/Murphy (1989) conducted Engle/ Granger cointegration test by using 3 month treasury bills and CPI in US and Canada, UK, Belgium from 1955 through 1973. They found that the Fisher hypothesis is effective in 4 countries.

Then they divided the whole sample into two. The first sub sample is from 1955 through 1973 (second quarter) - fixed exchange regime. The second sub sample is from 1973 (third quarter) through 1986. Their conclusions are that the Fisher hypothesis holds true in US and Canada in the first sub sample, but the validity of the hypothesis can't be found in 4 countries in the second sub sample.

Bonham (1991) utilized Engle/Granger cointegration test by using 3 month treasury bills and CPI in US from 1955 through 1986. He found that the Fisher hypothesis holds true. Atkins (1989) conducted Engle/Granger cointegraion test by using CPI and 90 day interest rates in USA and Australia from 1953 through 1971. He found that the Fisher hypothesis holds true in US and Australia. He also conducted Granger causality test to find CPI influenced nominal interest rates.

Wallace /Warner (1993) tested the Fisher hypothesis by using 3 month treasury bills, 10 year treasury bonds and CPI. They conducted Johansen cointegration test. They concluded that the Fisher hypothesis doesn't hold true from 1953 through 1979, but it doesn't from 1982 through 1990.

2 The Framework of Analysis

2.1 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 paper contain unit roots.

Here I use ADF (Augmented Dickey/Fuller) test and KPSS (Kwiatowski/ Phillips/ Schmidt/Shin) test. The ADF test defines null hypothesis as 'unit roots exist' and alternative hypothesis as 'unit roots don't exist'. Fuller (1976) provides the table for ADF test. The KPSS test defines null hypothesis as 'unit roots don't exist' and alternative hypothesis as 'unit roots exist'.

2.2 Cointegration

A cointegration framework is presented to analyze the relation between nominal interest rate and expected inflation. 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.

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 the Fisher hypothesis by cointegration, the equation (4.1) is estimated by OLS to find if residual contains unit root.

$$i_t = \alpha + \beta E_t(\pi_{t+j}) + u_t \quad (4.1)$$

i_t = nominal interest rates

$E_t(\pi_{t+j})$ = expected inflation rate

When series i_t and $E_t(\pi_{t+j})$ 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 i_t and $E_t(\pi_{t+j})$ implies that nominal interest rates and expected inflation rates move together in the long run equilibrium.

In addition to testing if nominal interest rates and expected inflation rates are in a relationship of cointegration, cointegration vector (1,-1), β in the equation (4.1), is checked with the method of dynamic OLS by Stock/ Watson (1993). The equation (4.2) is used to test if $\beta = 1$ can be rejected. Δjy_{t-i} is lead and lag variables of expected inflation rates[1]. If $\beta = 1$ can't be rejected, nominal interest rates changes with the equivalent degree of expected inflation rates.

1 As for the number of lead and lag terms, 12 is used. In the case of 6 and 9, the results are the same. Hirayama/Kasuya (1996) provides empirical analysis using Rats procedure SWDYNAMIC.PRG.

$$y_t = \alpha + \beta j y_t + \sum_{i=-p}^{p} b_i \Delta j y_{t-i} + u_t \qquad (4.2)$$

2.3 Granger Causality Test

The Granger causality test checks whether nominal interest rates i_t affects expected inflation rate or expected inflation rates $E_t(\pi_{t+j})$ affects nominal interest rates or nominal interest rates and expected inflation rates affect mutually in the time series model. 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_t to $E_t(\pi_{t+j})$ and for the influence $E_t(\pi_{t+j})$ from i_t. But trend term t and $p+1$ (original lag plus one) are added for the estimation.

$$i_t = \kappa_0 + \lambda t + \sum_{i=1}^{p+1} \alpha_i i_{t-i} + \sum_{i=1}^{p+1} \beta_i E_{t-i}(\pi_{t+j-i}) + u_t \qquad (4.3)$$

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

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

$$E_t(\pi_{t+j}) = \varsigma_0 + \eta t + \sum_{i=1}^{p+1} \gamma_i i_{t-i} + \sum_{i=1}^{p+1} \delta_i E_{t-i}(\pi_{t+j-i}) + v_t \qquad (4.4)$$

$$H_0 : \gamma_1 = \gamma_2 = \cdots \gamma_p = 0$$

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

The F test is conducted by estimating (4.3) and (4.4) through OLS and summing the squared error. If the null hypothesis of H_0 in the formula (4.3) is rejected, $E_t(\pi_{t+j})$ is considered to explain i_t. If the null hypothesis of H_0 in the equation (4.4) is rejected, i_t is considered to explain $E_t(\pi_{t+j})$.

3 Data

3.1 The Expected Inflation Rate

As for the expected inflation rate, Kamae (1999) estimated it by the Kalman filter. Kuroda (1982) calculated it by the ARIMA model, but he warns that the estimated values don't necessarily reflect the expectation of people. Woodward (1992) estimated the expected inflation rate from the Inflation Indexed British Government Bonds, but this method can't be used since inflation indexed government bonds are not issued in Japan[2].

On the other hand, Shimizu (1978) and others didn't calculate the expected inflation rates. Shimizu (1978) mentions that the results of the Fisher hypothesis test depend on the estimated values of expected inflation rate.

The formulation process of inflation expectation is complex and no consensus exists. According to Higo/Nakata (2000), there are two formulation processes as to the inflation expectation; Phillips and NAIRU (Non- Accelerating Inflation Rate of Unemployment). Phillips presupposes that the expected inflation follows within a certain value. NAIRU defines that expected inflation is corrected in accordance with realized inflation and realized inflation rates are random walk process called unit root.

According to Wallace /Warner (1993), if realized rates of inflation rates are $I(1)$, the innovation will influence the future change of inflation rates. When the expected rates of inflation rate change, $E_t(S_{t+j})/k$, defined as j term forward expectation of inflation rate based on the period of t are random walk it follows that $S_{t+1} = S_t + \varepsilon_{t+1}$ (ε_{t+1} is an innovation of inflation rate change).

Accordingly as for the expected rates of inflation at the future time of j, equation (4.5) holds true. Thus realized values of inflation at the time of t indicate the future expectation of inflation rates.

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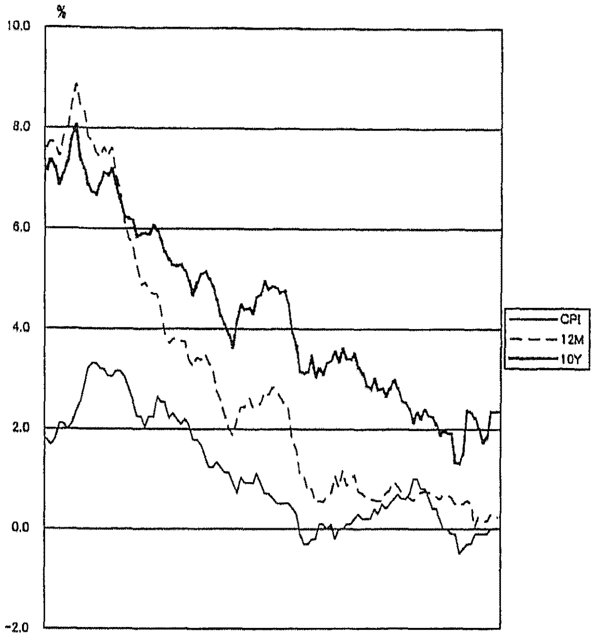
2 The Ministry of Finance started to issue 10-Year Inflation-Indexed JGB from March 10,2004.

$$E_t(S_{t+j}) = S_t \tag{4.5}$$

Thus realized inflation rates are used as inflation expectation after confirming that they are I (1) process in accordance with Shimizu (1978) and other previous studies. Annualized rate of inflation is calculated by using monthly CPI data (excluding perishables, on a nationwide statistics) . The effects of consumption tax introduction and increase are excluded[3].

Figure 4.1The Movement of 3 Series



CPI = change of consumer price index (excluding perishables on a nationwide statistics on a year base)
12M = 12 Month LIBOR
10Y = 10 Year Swap Rate

3 As for the CPI 1.3 point which is the increase of March seasonally adjusted number over April in 1989 is subtracted from the data after April 1989. The purpose of doing this is to remove the impacts of consumption tax introduction. In the same way, 1.4 point is subtracted from the data after April 1997 to remove the impacts of the consumption tax increase.

3.2 Nominal Interest Rates

The 18 series of data - LIBOR (London InterBank Offered rate) from 1 month through 12 month and interest rate swap rate (2 year,3 year,4 year,5 year,7 year and 10 year) are used on a monthly basis from February 1990 through August 1999[4]. Figure 4.1 shows the movement of 3 series of data (annualized CPI change, LIBOR 12 month, interest rate swap 10 year).

4 The Results of Empirical Analysis

4.1 Unit Root Test

The 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 4.1 through Table 4.2. The results of ADF and KPSS tests show that all the data have unit root. Next, the data with a first difference are analyzed by ADF and KPSS tests. It's possible to conclude that all the original variables are I (1), results are shown on the Table 4.3 through Table 4.4.

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4 BBA (British Bankers' Association) publishes LIBOR as of 11 am London time. Interest rate swap rates as of 3 pm Japan time are provided by a major broker. 2. So far the issuances of JGB (Japanese Government Bond) are centered on 10 year. Thus 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.

Table 4.1 Result of ADF Test (Original Series)

Variable	Lag	Without Trend	With Trend
CPI(t)	12	-1.7326	-1.0632
1M	12	-3.7773*	-2.1978
2M	1	-1.5207	-1.7322
3M	2	-1.5564	-2.0634
4M	2	-1.6565	-1.8290
5M	2	-1.6965	-1.8217
6M	2	-1.6778	-1.8626
7M	2	-1.6667	-1.9111
8M	2	-1.7237	-1.9097
9M	12	-3.0620*	-1.6018
10M	12	-3.0192*	-1.6039
11M	12	-2.8978*	-1.5586
12M	2	-1.7455	-2.0099
2Y	2	-1.5890	-2.1739
3Y	2	-1.4593	-2.5486
4Y	2	-1.3814	-2.8864
5Y	3	-1.1230	-2.6643
7Y	3	-1.0184	-2.6335
10Y	3	-1.0321	-2.5937

* indicates significance at the 5 % level.
5% critical values are -2.89(Without Trend)-3.45(With Trend) .
CPI = change of consumer price index (excluding perishables, on a nationwide statistics) on a year basis.

Table 4.2 The Result of KPSS Test (Original Series)

	Lag = 4		Lag = 12	
Variable	η_μ	η_τ	η_μ	η_τ
CPI(t)	1.9055*	0.2877*	0.7937*	0.1425
M1	2.1008*	0.4971*	0.8694*	0.2188*
M2	2.0870*	0.5027*	0.8645*	0.2215*
M3	2.0849*	0.5026*	0.8663*	0.2213*
M4	2.0834*	0.5046*	0.8671*	0.2225*
M5	2.0804*	0.5064*	0.8673*	0.2236*
M6	2.0788*	0.5057*	0.8673*	0.2239*
M7	2.0804*	0.5042*	0.8689*	0.2240*
M8	2.0819*	0.5045*	0.8703*	0.2246*
M9	2.0842*	0.5028*	0.8722*	0.2246*
M10	2.0855*	0.5009*	0.8732*	0.2243*
M11	2.0867*	0.4986*	0.8746*	0.2241*
M12	2.0877*	0.4950*	0.8757*	0.2232*
Y2	2.1364*	0.4527*	0.8992*	0.2169*
Y3	2.1807*	0.3964*	0.9189*	0.2048*
Y4	2.2190*	0.3332*	0.9349*	0.1901*
Y5	2.2430*	0.2924*	0.9436*	0.1785*
Y7	2.2738*	0.2113*	0.9533*	0.1466*
Y10	2.2784*	0.2145*	0.9537*	0.1508*

* indicates significance at the 5 % level.
5% critical values are 0.463 (trend stationary) 、 0.146(level stationary) .
η_μ indicates trend stationarity. η_τ indicates level stationarity.
CPI = change of consumer price index (excluding perishables, on a nationwide statistics) on a yearly basis.

Table 4.3 The Result of ADF Test (First Difference)

Variable	Lag	Without Trend	With Trend
ΔCPI(t)	11	-4.9279*	-4.9530*
ΔM1	12	-2.8835	-3.9861*
ΔM2	0	-10.7011*	-11.9021*
ΔM3	1	-4.6714*	-5.3765*
ΔM4	1	-4.7546*	-5.2526*
ΔM5	1	-4.6520*	-5.1113*
ΔM6	1	-4.8346*	-5.2522*
ΔM7	1	-4.8156*	-5.1424*
ΔM8	1	-4.7569*	-5.2098*
ΔM9	11	-2.9769*	-3.9865*
ΔM10	11	-2.9750*	-3.9586*
ΔM11	11	-2.9861*	-3.8981*
ΔM12	1	-5.0335*	-5.2335*
ΔY2	2	-5.6808*	-5.3646*
ΔY3	2	-6.0390*	-5.6260*
ΔY4	2	-4.1226*	-4.6383*
ΔY5	2	-6.5230*	-6.2404*
ΔY7	2	-7.3265*	-6.9044*
ΔY10	2	-7.4332*	-7.0833*

* indicates significance at the 5 % level.
5% critical values are -2.89(Without Trend)-3.45 (with Trend) .
CPI = change of consumer price index (excluding perishables, on a nationwide statistics) on a yearly basis.

Table 4.4 The Result of KPSS Test (First Difference)

	Lag = 4		Lag = 12	
Variable	η_μ	η_τ	η_μ	η_τ
ΔCPI(t)	0.1182	0.1208	0.1015	0.1038
ΔM1	0.2657	0.1149	0.1777	0.0826
ΔM2	0.2815	0.1108	0.1874	0.0802
ΔM3	0.2896	0.1037	0.1960	0.0771
ΔM4	0.3064	0.0947	0.2153	0.0744
ΔM5	0.3085	0.0874	0.2247	0.0721
ΔM6	0.2970	0.0830	0.2238	0.0712
ΔM7	0.2911	0.0771	0.2280	0.0693
ΔM8	0.2852	0.0729	0.2316	0.0684
ΔM9	0.2772	0.0685	0.2333	0.0671
ΔM10	0.2686	0.0663	0.2315	0.0665
ΔM11	0.2624	0.0639	0.2303	0.0655
ΔM12	0.2567	0.0610	0.2305	0.0640
ΔY2	0.1718	0.0430	0.2040	0.0590
ΔY3	0.1260	0.0370	0.1712	0.0561
ΔY4	0.0982	0.0335	0.1494	0.0556
ΔY5	0.0923	0.0332	0.1471	0.0574
ΔY7	0.0822	0.0382	0.1297	0.0640
ΔY10	0.0840	0.0340	0.1323	0.0669

* indicates significance at the 5 % level.
5% critical values are 0.463 (trend stationary) 、 0.146(level stationary) .
η_μ indicates trend stationarity. η_τ indicates level stationarity.
CPI = change of consumer price index (excluding perishables, on a nationwide statistics) on a yearly basis.

4.2 Cointegration Test

18 series of nominal interest rates are in the relationship of cointegration with expected rates of inflation[5]. The results are shown on Table 4.5. As for the results of cointegration vector test, β = 1 can't be rejected in the term structure from 3 year through 10 year. The results are shown on Table 4.6.

5 I also conducted cointegration test with time trend. Test statistics are almost same as without time trend. But significance disappeared since critical values increased. This is because statistical power declined by getting rid of trend.

Table 4.5 The Result of Coitegration Test

Variable	CPI(t)
M1	-3.0553**
M2	-3.0688**
M3	-3.0944**
M4	-3.1451**
M5	-3.1911**
M6	-3.2263**
M7	-3.2508**
M8	-3.2585**
M9	-3.2721**
M10	-3.2969**
M11	-3.3062**
M12	-3.2926**
Y2	-3.4857*
Y3	-3.4038*
Y4	-3.3260**
Y5	-3.2200**
Y7	-3.1240**
Y10	-3.0887**

* indicates significance at 5% level.
5% critical value is -3.3377 from MacKinnon(1991).
** indicates significance at 10% level.
10% ciritical value is -3.0462 from MacKinnon(1991).
CPI = change of consumer price index (excluding perishables on a nationwide statistics) on a yearly basis.

From the tests of cointegration and cointegration vector, I can conclude that the Fisher hypothesis holds true in the term structure from 3 year through 10 year.

This result that the Fisher hypothesis holds true in the mid and long term zones of Japanese yen interest rates are consistent with Kamae (1999). In comparison with the overseas previous studies, Wallace/Warner (1993) shares the same result as this chapter.

In addition to cointegration and cointegration vector tests, I checked the stationarity of the real interest rates with unit root test. The results were

Table 4.6The Result of Cointegration Vector Test

Variable	β	Modified SE	Modified t Value
M1	2.3589	0.4223	3.2179
M2	2.3124	0.4363	3.0080
M3	2.2703	0.4206	3.0202
M4	2.2301	0.4370	2.8149
M5	2.2010	0.4387	2.7376
M6	2.1579	0.4347	2.6637
M7	2.1362	0.4268	2.6621
M8	2.1151	0.4220	2.6424
M9	2.1060	0.4161	2.6580
M10	2.1060	0.4161	2.6580
M11	2.0857	0.4122	2.6339
M12	2.0764	0.4146	2.5962
Y2	1.9331	0.4225	2.2085
Y3	1.8351	0.4474	1.8666*
Y4	1.7396	0.4506	1.6414*
Y5	1.6553	0.4575	1.4323*
Y7	1.5045	0.4772	1.0572*
Y10	1.3908	0.4285	0.9120*

* means that β= 1 can't be rejected since modified t value is smller than 5 critical value (1.96).
CPI = change of consumer price index (excluding perishables, on a nationwaide statistics) on a yearly basis.

mixed and I couldn't get clear results[6]. According to ADF test without time trend, real interest rates from 5 month through 12 month are stationary. On ADF test with time trend, real interest rates are stationary from 3 year and 4 year. According to KPSS test with level stationarity, all real interests are not stationary. On KPSS test with trend stationarity, real interest rates are stationary from 6 month through 10 year.

6 The relationship among real interest rates $i(r)_t$, nominal interest rates i_t, realized inflation are expressed as $i(r)_t = i_t - \pi_t$. According to Kasuya (2000), there are two types of real interest rates – ex ante real interest rate and ex post real interest. Here I test the stationarity of ex post real interest rates.

4.3 Ganger Causality

Causalities from expected inflation rate on nominal interest rates in all term structures are fund to be significant. On the other hand, causalities from nominal interest rates on expected inflation rate are fund to be insignificant. The results are shown on Table 4.7 and Table 4.8.

Table 4.7 The result of Granger Causality Test (1)

Interest Rate	Lag	CPI(t)
M1	13	7.3903*
M2	2	8.4306*
M3	3	8.6578*
M4	3	8.4333*
M5	3	8.4314*
M6	3	8.7580*
M7	3	8.5396*
M8	3	8.6795*
M9	13	8.7287*
M10	13	8.5461*
M11	13	8.1339*
M12	3	10.6764*
Y2	3	7.9839*
Y3	3	6.3586*
Y4	3	5.5479*
Y5	4	4.7838*
Y7	4	3.9066*
Y10	4	5.0011*

* indicates significance at 5 % level.
As for the number of lags, one ia added to AIC selection.
CPI = change of consumer price index (excluding perishables, on a nationwaide statistics) on a yearly basis.

Table 4.8 The result of Granger Causality Tes (2)

Interest Rate	Lag	CPI(t)
M1	13	1.8903
M2	2	1.8342
M3	3	1.7831
M4	3	1.3046
M5	3	1.0560
M6	3	1.0126
M7	3	0.9428
M8	3	0.8220
M9	13	0.7600
M10	13	0.6922
M11	13	0.6805
M12	3	0.5187
Y2	3	0.0350
Y3	3	0.0361
Y4	3	0.0872
Y5	4	0.1211
Y7	4	0.1970
Y10	4	0.0988

* indicates significance at 5 % level.
As for the number of lags, one ia added to AIC selection.
CPI = change of consumer price index (excluding perishables, on a nationwaide statistics) on a yearly basis.

5 Concluding Remarks

The Fisher hypothesis is tested by using the Japanese yen interest rates (18 series from 1 month through 10 year). 18 series of nominal interest rates are in the relationship of cointegration with expected rates of inflation.

As for the results of cointegration vector test, $\beta = 1$ can't be rejected in the term structure from 3 year through 10 year. From the tests of cointegration and cointegration vector, I can conclude that the Fisher hypothesis holds true in the term structure from 3 year through 10 year.

In addition to cointegration and cointegration vector tests, I checked the stationarity of the real interest rates with unit root test. The results are mixed and I couldn't get clear results. Finally Granger causality tests by Toda /Yamamoto (1995) are conducted. Causalities from expected inflation rate on nominal interest rates in all term structures are fund to be significant. On the other hand, causalities from nominal interest rates on expected inflation rate are fund to be insignificant.

As for the remainig topics, (1) Deepen the understanding as to why clear conclusions were not drawn from unit root tests of real interest rates, (2) Add consideration from view point of monetary policy, (3) Investigate the Fisher hypothesis by using the Johansen cointegration, (4) Add macroeconomic variables to 2 system VAR, (5) Investigate why the impacts of expected inflation on nominal interest rates are more than 1—these five points are indicated.

References

In Japanese

Ito,T.(2003a), "The Empirical Analysis on the Fisher Hypothesis" *Review of Monetary and Financial Studies*, Vol.19,pp.1-14.

Kasuya.M. (2000), "Price Trend Variable and Inflation targeting – Reconsideration on the Selection of Trend Variable and Real Interest Rates" *Journal of Economics & Business Administration*,Vol.81, pp.106-123.

Kamae,H.(1999), "*Efficiency of Japanese Security and Financial Market,*" Yuhikaku.

Kuroda,A.(1982), "*Structure of Interest Rates in Japan,*" Toyokeizai.

Shimiz,Y.(1978), "System of Interest Rates and Inflation" *Hitotsubashi University Annual Report Research on Commerce*, Vol.20, pp.113-181.

Bank of Japan (1994), "Inflationary Indicator of Interest Rates Spreads," *Bank of Japan Monthly Bulletin*, July, pp.61-81.

In English

Atkins,F.J.(1989), "Co-integration,Error Correction and the Fisher Effect," *Applied Economics*,Vol.21,pp.1611-1620.

Bonham,C.S.(1991), "Correct Cointegration Tests of the Long-Run Relationship Between Nominal Interest and Inflation," *Applied Economics*,Vol.23, pp.1487-1492.

Cheung,Y. and K.S.Lai(1993), "Finite-Sample Sizes of Johansen's Likelihood Ratio Tests for Cointegration," *Oxford Bulletin of Economics and Statistics*,Vol.55, pp.313-328.

Dickey,D.A. and W.Fuller(1979), " Distribution of the Estimators for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association*, Vol.74,pp.427-431.

Dickey,D.A. and W.Fuller(1981), "Likelihood Ratio Statistics For Autoregressive Time Series with a Unit Root," *Econometrica*, Vol.49, pp.107-1072.

Engle,R.F. and C.W.J.Granger(1987), "Co-Integration and Error Correction: Representation,and Testing," *Econometrica*,Vol.55,pp.251-276.

Fisher,I.(1930), *The Theory of Interest*, Macmillan,New York.

Hirayama,K. and M.Kasuya(1996), "Financial Deregulation and Divisia Monetary Aggregates in Japan," Mullineux,A (eds) '*Financial Innovation, Banking and Monetary Aggregates*,' Edward Elgar, pp.104-130.

Inder,B. and P.Silvapulle(1993), "Does the Fisher Effect Apply in Australia?" *Applied Economics*,Vol.25,pp.839-843.

Kwiatkowski,D.,P.C.B.Phillips,P.Schmidt and Y.Shin(1992), "Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root," *Journal of Econometrics*,Vol.54,pp.159-178.

MacDonald,R. and P.D.Murphy(1989), "Testing for the Long Run Relationship between Nominal Interest Rates and Inflation using Cointegration Techniques," *Applied Economics*,Vol.21,pp.439-447.

MacKinnon,J.(1991), "Critical Values for Cointegration Tests," Engle,R.F and C.W.J.Granger ed '*Long-Run Economic Relationships:Readings in*

Cointegration,' Oxford University Press,pp.267-276.

Mishkin,S.F.(1992), "Is the Fisher Effect For Real? " *Journal of Monetary Economics"*, Vol.30, pp.195-215.

Stock,J.H. and M.W.Watson(1993), "A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems," *Econometrica*, Vol.61, pp.783-820.

Toda,H.Y. and T.Yamamoto(1995), "Statistical Inference in Vector Autoregressions with Possibly Integrated Processes," *Journal of Econometrics*, Vol.66, pp.225-250.

Wallace,M.S. and J.T.Warner,(1993) "The Fisher Effect and the Term Structure of Interest Rates : Tests of Cointegration," *Review of Economics and Statistics*,pp.320-324.

Woodward,G.T.(1992), "Evidence of the Fisher Effect From U.K Indexed Bonds," *Review of Economics and Statistics*,pp.315-320.

Chapter 5

The Inflationary Indicator of Interest Rate Spreads*

1 Introduction

1.1 The Purpose of this Chapter

The discussion on information variables as intermediate targets in the operation of monetary policy is going on[1]. The intermediate target is set as a one step before the final target set by a central bank. It refers to economic variables which can be a target within a certain rage.

As one of these variables, interest rate spreads have been pointed out. Two reasons are cited. First interest rates which can be observed in the market are superior in terms of objectiveness. Second the theoretical basis can be drawn.

The purpose of this chapter is to investigate whether interest rates spreads can predict the future inflation. The strong point of this chapter is to check mid and long term interest rates which have never been fully investigated.

The remainder of this chapter is as follows. Section 1.2 refers to previous studies. Section 2 explains the framework of analysis. Section 3 touches upon data. Section 4 reports the empirical analysis. Section 5 summarizes the conclusion and remaining issues.

1.2 Previous Study

Mishkin (1990a, 1990b) started the empirical analysis using the inflation

* This chapter is based on Ito (2002).

1 As for the information variables as intermediate targets in the operation of monetary policy, Kato (1990) and Komaki/Yajima (2001) can be referred.

prediction equation and other works followed. The results are different depending on the nations or sample periods. Mishkin (1990a) concluded that spread between 6 month interest rates and 12 month interest rates and spread between 9 month and 12 month interest rates have an inflationary indicator.

According to Mishkin (1990b), spreads among 1 year through 5 year interest rates include expectation on future inflation and the spread between 1 year interest rate and 5 year interest rate contain the most information.

Jorion/Mishkin (1991) investigated interest rates from 1 year through 5 year in U.K, West Germany, and Switzerland. They conclude that longer interest rates contain more information on future inflation. Frankel/Lowen (1994) reports that spread between US 3 month and 12 month interest rates and spread between FF (Federal Fund) and 5 year interest rates contain information of future information.

Gerlach (1995) concluded that interest rate spreads contain the information of future inflation. He also maintains that the spread between 2 year and 6 year interest rates is the strongest indicator of future inflation. According to Koedijk/Kool (1995), spreads between long term interest rates don't contain the information of future inflation in US, Japan, Germany, France, Switzerland, Belgium and Holland.

Tzavalis/Wickens (1996) concluded that the spreads between short term interest rates contain less information of future inflation by using recent US data. According to Day/Lange (1997), the spreads between Canadian interest rates from 1 year through 5 year can predict the future inflation.

Estrella/Mishkin (1997) conducted the empirical analysis on quarterly data of France, Germany, Italy, UK and US from 1973 through 1994. They concluded that the spreads of Germany, Italy, UK and US contain the information, but the spread of France doesn't.

As for the empirical analysis on Japanese interest rates, I cite Yamada (1991) and the Bank of Japan (194). But analysis on mid term and long term interest rates are not enough. According to Yamada (1991), the spreads between 1 month and 2 month interest rates, 1 month and 3 month can predict the future inflation.

But spreads between interest rates over 6 month can't predict the future inflation. The Bank of Japan concludes that only spreads between 1 month and 2 month interest rates, between 5 year and 10 year contain the information of future inflation.

2 The Framework of Analysis

I conduct the empirical analysis based on Mishkin (1990a) . According to Fisher hypothesis, the expected rate of inflation at *m* period can be drawn by subtracting real term interest rate from nominal interest rate at *m* period.

$$E_t \pi_t^m = i_t^m - rr_t^m \qquad (5.1)$$

$E_t \pi_t^m$ = expected rate of inflation from *t* period through *m* period
i_t^m = nominal interest rate of *m* periods at *t* period
rr_t^m = real interest rate of *m* periods from at *t* period

The realized rate of inflation in *m* period can be expressed as expected rate of inflation and forecast error.

$$\pi_t^m = E_t \pi_t^m + e_t^m \qquad (5.2)$$

The equation (5.3) can be drawn by substituting the equation (5.1) into the equation (5.2).

$$\pi_t^m = i_t^m - rr_t^m + e_t^m \qquad (5.3)$$

Here I convert the equation (5.3) into the equation (5.4) to introduce the inflation rate of *n* periods.

$$\pi_t^m - \pi_t^n = i_t^m - i_t^n - rr_t^m + rr_t^n + e_t^m - e_t^n \qquad (5.4)$$

Mishkin (1990a) introduced the equation (5.5) to investigate whether the interest rate spreads can predict the future inflation[2].

$$\pi_t^m - \pi_t^n = \alpha_{m,n} + \beta_{m,n}[i_t^m - i_t^n] + e_t^{m,n} \qquad (5.5)$$

$\pi_t^m - \pi_t^n$ = π_t^n (annualized rate of inflation from period t through period n) is subtracted from π_t^m (annualized rate inflation from period t through period m)

$i_t^m - i_t^n$ = i_t^n (nominal interest rate form period t through period n) is subtracted from i_t^m (nominal interest rate from period t through period m)

I estimate the equation (5.5) by OLS and conduct statistical test as to $\beta = 0$ and $\beta = 1$. The results of the test can be interpreted as follows.

(1) *$\beta = 0$ and $\beta = 1$ are rejected.*
The interest rate spreads contain the information of future inflation significantly, but the changes of nominal interest rate are connected with the change of expected inflation and real interest rates.

(2) *$\beta = 0$ is rejected, but $\beta = 1$ isn't rejected.*
The interest rate spreads respond almost equally to the change of future inflation and they are effective as inflation indicator.

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[2] I checked level stationarity of ($rr_t^n - rr_n^m$) which corresponds to α of formula (5.5) by KPSS (Kwiatowski, Phillips, Schmidt and Shin) test. The result is that null hypothesis 'unit roots don't exist' can't be rejected at the 5 % level of significance. Thus all the spreads are considered to be moving around a certain level. As for KPSS test, Kwiatkowski/ Phillips/ Schmidt/Shin (1992) can be referred. $\alpha = rr_t^n - rr_n^m$ ($m > n$) can be either positive or negative because it depends on the sizes of future inflation rate and nominal interest rate.

(3) $\beta = 0$ isn't rejected, but $\beta = 1$ is rejected.
The interest rate spreads don't contain the information of future inflation significantly.

(4) $\beta = 0$ and $\beta = 1$ aren't rejected.
It's impossible to judge from this analysis

But the statistical problem in the estimation of the equation (5.5) is the existence of serial correlation in $e_t^{m,n}$. The serial correlation occurs from the overlapping monthly data. Thus I use the method by Newey/West (1987) to get rid of the serial correlation. I use 12 lag periods for the analysis within 1 year and 24 lag periods for the analysis over 1 year.

3 Data

3.1 Expected Inflation

I use CPI (excluding perishables, on a nationwide statistics) data. The effects of consumption tax introduction and increase are excluded[3]. The inflation spread is calculated by subtracting annualized inflation (period t through period n) from annualized inflation (period t through period m)

3.2 Nominal Interest Rate

The 17 series of LIBOR (London Interbank Offered rate) from 1 month through 12 month, interest rate swap rate (2 year, 3 year, 4 year, 5 year, and 7 year) are used on a monthly basis from February 1990 through August 1999. Figure 5.1 shows the movement of 3 series of data (LIBOR 3 month, interest rate swap 2 year, interest rate swap 5 year).

As for the spread of interest rate, nominal interest rate from period t through period n is subtracted from nominal interest rate from period t

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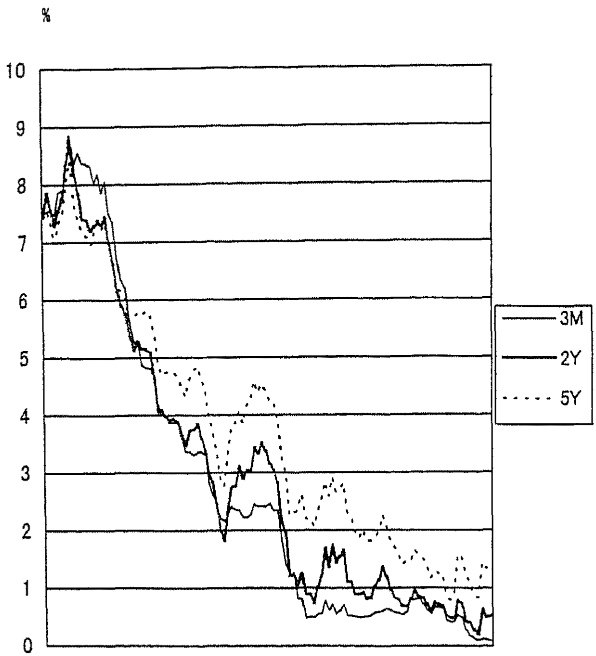
[3] As for the CPI 1.3 point which is the increase of March seasonally adjusted number over April in 1989 is subtracted from the data after April 1989. The purpose of doing this is to remove the impacts of consumption tax introduction. In the same way, 1.4 point is subtracted from the data after April 1997 to remove the impacts of the consumption tax increase.

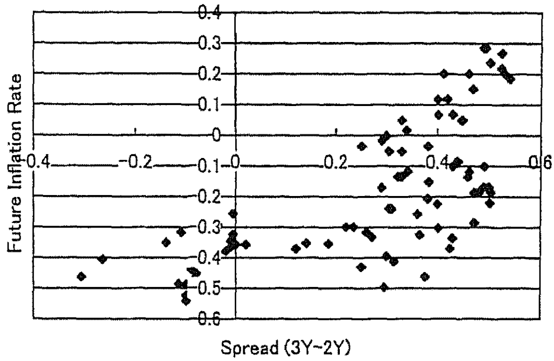
through period m. Figure 5.2 through Figure 5.5 show the relation between nominal interest rate spreads and future inflation

Figure 5.1 The Movement of 3 Series



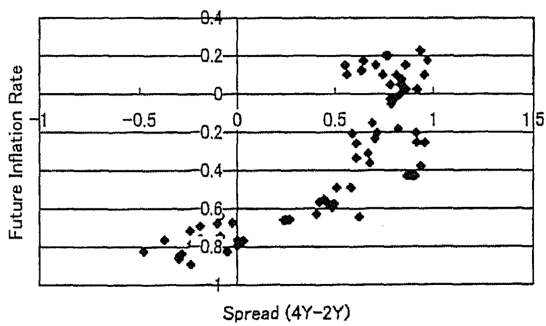
Monthly base from Feburuary 1990 through August 1999
3M=LIBOR3M
2Y=SWAP2Y
5Y=SWAP5Y

Figure 5.2 Scatter Plots



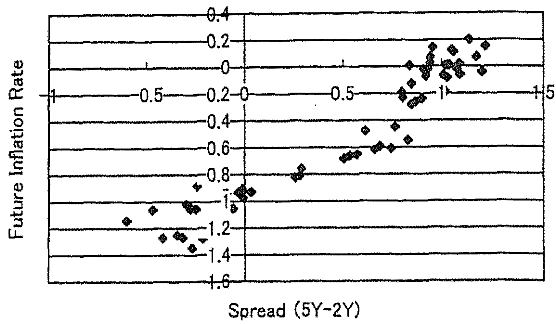
Spread (3Y - 2Y) and CPI increase are shown.

Figure 5.3 Scatter Plots



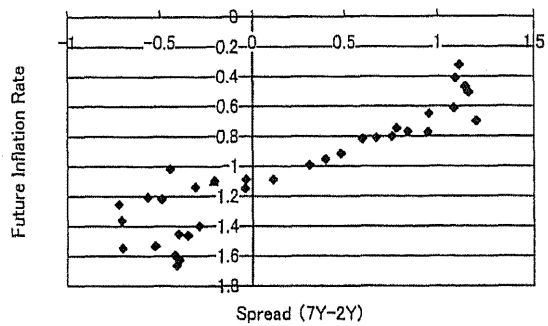
Spread (4Y - 2Y) and CPI increase are shown.

Figure 5.4 Scatter Plots



Spread (5Y - 2Y) and CPI increase are shown.

Figure 5.5 Scatter Plots



Spread (7Y - 2Y) and CPI increase are shown.

4 The Result

4.1 The Analysis within 1 Year Interest Rate

(1) 1 Month Interest Rate and Other Interest Rates

In the analysis of spread between 1 month interest rate and 3 month or 6 month or 9 month or 12 month interest rates, $\beta=0$ and $\beta=1$ are rejected. Thus I can judge that spreads contain the information of future inflation. But the coefficient of determination is very small (0.0268~0.0983) . Table 5.1 shows the result.

Table 5.1 The Spread between 1 Month and Other Rates

Spread	α	β	R^2	SE	t value (β=0)	t value (β=1)
3M-1M	-0.1267	-3.9022	0.0268	3.0660	-3.6440***	4.5776***
	(0.1687)	(1.0709)				
6M-1M	0.7106	-3.6447	0.0473	3.2846	-2.1873**	3.0041***
	(0.3817)	(1.5461)				
9M-1M	1.6640	-4.3480	0.0983	3.8755	-2.0368**	2.5053**
	(0.6745)	(2.1347)				
12M-1M	2.5401	-4.3374	0.0965	4.7644	-2.1985**	2.7542***
	(0.894)	(1.9729)				

***,**,* indicates siginificance at 1%、5%、10% level.
Value inside parenthesis is standard error.

(2) 3 Month Interest Rate and Other Interest Rates

In the analysis of spread between 3 month interest rate and 6 month or 9 month or 12 month interest rates, $\beta=0$ and $\beta=1$ can't be rejected. Thus I can't judge whether spreads contain the information of future inflation from the analysis. But the coefficient of determination is very small (0.0204~0.0356) . Table 5.2 shows the result.

Table 5.2 The Spread between 3 Month and Other Rates

Spread	α	β	R^2	SE	t value (β=0)	t value (β=1)
6M-3M	-1.4684	-8.5642	0.0204	6.5341	-1.2241	1.3670
	(0.62227)	(6.9964)				
9M-3M	-0.5588	-4.8554	0.0328	4.9465	-1.8266*	2.2029**
	(0.4329)	(2.6581)				
12M-3M	0.4112	-5.3328	0.0356	6.6206	-5.3328***	4.5170***
	(0.3476)	(1.4020)				

***,**,* indicates siginificance at 1%、5%、10% level.
Value inside parenthesis is standard error.

(3) 6 Month Interest Rate and Other Interest Rates

In the analysis of spread between 6 month interest rate and 9 month or 12 month interest rates, $\beta=0$ and $\beta=1$ are rejected. Thus I can judge that spreads contain the information of future inflation from the analysis. But the coefficient of determination is very small (0.0454～0.0483). Table 5.3 shows the result.

Table 5.3 The Spread between 6 Month and Other Rates

Spread	α	β	R^2	SE	t value (β=0)	t value (β=1)
9M-6M	-2.7911	12.2824	0.0483	4.7427	2.6154**	-2.4025**
	(12.2824)	(4.6962)				
12M-6M	-2.9075	7.4970	0.0454	4.7498	2.4306**	-2.1063**
	(0.9842)	(3.0845)				

***,**,* indicates siginificance at 1%、5%、10% level.
Value inside parenthesis is standard error.

(4) 9 Month Interest Rate and Other Interest Rates

In the analysis of spread between 9 month interest rate and 12 month interest rate, $\beta=0$ and $\beta=1$ are rejected. Thus I can judge that spreads contain the information of future inflation from the analysis. But the coefficient of determination is very small (0.0698). Table 5.4 shows the result.

Table 5.4 The Spread between 9 Month and Other Rates

Spread	α	β	R^2	SE	t value (β=0)	t value (β=1)
12M-9M	-6.9651	46.9352	0.0698	9.6135	3.0803***	-3.0147***
	(1.9656)	(15.2373)				

***,**,* indicates siginificance at 1%、5%、10% level.
Value inside parenthesis is standard error.

4.2 The Analysis over 1 Year Interest Rate

(1) 1 Year Interest Rate and Other Interest Rates

In the analysis of spread between 1 year interest rate and 2 year or 3 year or 4 year or 5 year or 7 year interest rate, $\beta=0$ and $\beta=1$ are rejected. Thus I can judge that spreads contain the information of future inflation from the analysis. The coefficient of determination is large (0.1257~0.7591). The coefficient is largest in the spread between 1 year and 5 year interest rates. Table 5.5 shows the result.

Table 5.5 The Spread between 12 Month and Other Rates

Spread	α	β	R^2	SE	t value (β=0)	t value (β=1)
2Y-12M	-0.2496	0.3635	0.1257	0.2809	2.5178**	4.4079***
	(0.0521)	(0.1444)				
3Y-12M	-0.6249	0.5330	0.4030	0.3380	3.4642***	3.0344***
	(0.0707)	(0.1539)				
4Y-12M	-0.8876	0.6239	0.6342	0.3439	6.0597***	3.6515***
	(0.0906)	(0.1030)				
5Y-12M	-1.1519	0.6456	0.7591	0.3130	6.8935***	3.7823***
	(0.0665)	(0.0937)				
7Y-12M	-1.4245	0.4949	0.7559	0.2814	7.1933***	7.3416***
	(0.0450)	(0.0688)				

***,**,* indicates siginificance at 1%、5%、10% level.
Value inside parenthesis is standard error.

(2) 2 Year Interest Rate and Other Interest Rates

In the analysis of spread between 2 year interest rate and 3 year or 4 year or 5 year or 7 year interest rate, $\beta=0$ and $\beta=1$ are rejected. Thus I can judge that spreads contain the information of future inflation from the analysis. The coefficient of determination is large (0.4714~0.8291). The coefficient is largest in the spread between 2 year and 5 year interest rates. Table 5.6 shows the result.

Table 5.6 The Spread between 2 Year and Other Rates

Spread	α	β	R^2	SE	t value (β=0)	t value (β=1)
3Y-2Y	-0.3686	0.6835	0.4714	0.1599	4.5395***	2.1016**
	(0.0231)	(0.1506)				
4Y-2Y	-0.6516	0.6845	0.6688	0.2098	7.2979***	3.3635***
	(0.0447)	(0.0938)				
5Y-2Y	-0.9105	0.8213	0.9102	0.1457	15.3863***	3.3464***
	(0.0284)	(0.0534)				
7Y-2Y	-1.1275	0.5040	0.8291	0.1533	10.2800***	10.1224***
	(0.0317)	(0.0490)				

***,**,* indicates siginificance at 1%、5%、10% level.
Value inside parenthesis is standard error.

(3) 3 Year Interest Rate and Other Interest Rates

In the analysis of spread between 3 year interest rate and 4 year or 5 year or 7 year interest rate, $\beta=0$ and $\beta=1$ are rejected. Thus I can judge that spreads contain the information of future inflation from the analysis. The coefficient of determination is large (0.6111～0.8365). The coefficient is largest in the spread between3 year and 5 year interest rates. Table 5.7 shows the result.

Table 5.7 The Spread between 3 Year and Other Rates

Spread	α	β	R^2	SE	t value (β=0)	t value (β=1)
4Y-3Y	-0.2866	0.6371	0.6111	0.1094	6.5269***	3.7182***
	0.0227	0.0976				
5Y-3Y	-0.5401	0.8245	0.8864	0.1007	14.4608***	2.8627***
	0.0136	0.0613				
7Y-3Y	-0.7317	0.6185	0.8365	0.1323	11.4839***	7.0779***
	0.0298	0.0539				

***,**,* indicates siginificance at 1%、5%、10% level.
Value inside parenthesis is standard error.

(4) 4 Year Interest Rate and Other Interest Rates

In the analysis of spread between 4 year interest rate and 5 year $\beta=0$ is rejected and $\beta=1$ isn't rejected. Thus I can judge that the spread and the information of future inflation are in the relationship of one to one. The spread is considered to be effective indicator of inflation. In the analysis of the spread between 4 year and 7 year, $\beta=0$ and $\beta=1$ aren't rejected. Thus I can judge that spreads contain the information of future information from the analysis. The coefficient of determination is large (0.5229～0.6538). The coefficient is largest in the spread between 4 year and 5 year interest rates. Table 5.8 shows the result.

Table 5.8 The Spread between 4 Year and Other Rates

Spread	α	β	R^2	SE	t value (β=0)	t value (β=1)
5Y-4Y	-0.2264	0.7515	0.5229	0.1016	4.1419***	1.3699
	(0.0409)	(0.1814)				
7Y-4Y	-0.4225	0.5827	0.6538	0.1361	7.3962***	5.2957***
	(0.0428)	(0.0788)				

***,**,* indicates siginificance at 1%、5%、10% level.
Value inside parenthesis is standard error.

(5) 5 Year Interest Rate and Other Interest Rates

In the analysis of spread between 5 year and 7 year, $\beta=0$ and $\beta=1$ aren't rejected. Thus I can judge that spreads contain the information of future information from the analysis. The coefficient of determination gets smaller (0.1050). Table 5.9 shows the result.

Table 5.9 The Spread between 5 Year and Other Rates

Spread	α	β	R^2	SE	t value (β=0)	t value (β=1)
7Y-5Y	-0.2157 (0.0253)	0.1356 (0.0666)	0.1050	0.0830	2.0346**	12.9790***

***,**,* indicates siginificance at 1%、5%、10% level.
Value inside parenthesis is standard error.

5 Concluding Remarks

I investigated the relationship between the spreads of Japanese interest rates and the future inflation. I find that almost all the spreads contain the information of future inflation. As for the analysis within 1 year interest rates, all the spreads except for one between 3 month and 6 month interest rates contain the information of future inflation. But the coefficient of determination is low(0.0204～0.0983) and the spreads of interest rate explain less future inflation. This point is consistent with Tzavalis/Wickens (1996) concluding that the spreads of short term interest rates contain less information of future inflation.

As for the analysis over 2 year, the spreads of interest rate contain the information of future inflation since $\beta=0$ and $\beta=1$ are rejected ($\beta=1$ is rejected at the spread between 5 year and 4 year interest rates). The coefficient of determination is 0.1050～0.9102 which is larger in comparison with the analysis within 1 year. The coefficient (0.9120) is the largest in the spread between 2 year and 5 year interest rates. Thus the spread between 2 year and 5 year spreads contain most information of future inflation. The spread between 4 year and 5 year interest rates is in the relationship of one to one and it's considered to be effective indicator of inflation.

When I look over the entire term structure, spreads over 1 year contain more information of future inflation than spreads within 1 year. This result is consistent with Mishkin (1990a), Mishkin (1990b) ,Jorion/Mishkin (1991) ,Gerlach (1995) and Day/Lange (1997). But it's different from Yamada(1991) concluding that spreads over 6 month interest rates don't contain the information of future inflation.

The result of this chapter coincides with Gerlach (1995) and Day/Lange (1997) maintaining that spreads between midterm interest rates contain much information of future inflation. Especially Gerlach (1995) concludes that the spread between 2 year and 6 year interest rates contain most information of future inflation. It's interesting that the result of this chapter coincides with that of Gerlach(1995).

From this chapter I can conclude that spreads between mid term and long term interest rates are effective information variable in the conduct of monetary policy. As for the remaining topics, (1)specify the factors why the spreads between mid term and long term interests contain much information of future inflation, (2)compare internationally,——2 points are pointed out.

References

In Japanese

Bank of Japan (1994), "The Inflationary Indicator in Interest Rate Spreads," *Bank of Japan Monthly Bulletin*, April,pp.1-29.

Ito,T. (2002), "The Analysis on the Inflationary Indicator of Interest Rate Spreads," Vol.37, *Annals of Society for the Economic Studies of Securities*,pp.25-34.

Kato,K.(1990), "The Intermediate Target in the Conduct of Monetary Policy and Information Variable," *Monetary and Economic Studies*,Vol.9,pp51-92.

Komaki,Y. and Y.Yajima (2001), "The measurement of monetary Policy Response Function – Validity of Information Variable and its Application," *NLI Report* ,Vol.19,pp.28-45.

Yamada,Y (1991), "The Possibility of Inflation Forecast by Interest Rates Spreads," *Financial Review*, March,pp129-145.

In English

Day,J. and R.Lange(1997), "The Structure of Interest Rates in Canada: Information Content About Medium-Trem Inflation," *Bank of*

Canada, Working Paper, 97-10.

Estrella,A. and F.S.Mishkin(1997), "The Predictive Power of the Term Structure of Interest Rates in Europe and the United States: Implictions for the European Central Bank," *European Economic Review*,Vol.41, pp.1375-1401.

Frankel,J.A. and C.S.Lown(1994), "An Indicator of Future Inflation Expected from the Steepness of the Interest Rate Yield Curve along its Entire length," *Quarterly Journal of Economics*, Vol.109,pp.517-530.

Gerlach,S.(1995), "The Information Content of the Term Structure :Evidence for Germany," *BIS Working Paper* No.29.

Jorion,P. and F.Mishkin(1991), "A Multi-Country Comparison of the Term Structure Forecasts at Long Horizon," *NBER Working Paper* No.3574.

Koedijk,K.G. and C.J.M.Kool(1995), "Future Inflation and the Information in the International Term Structures," *Empirical Economics*, Vol.20, pp.217-242.

Kwiatkowski,D.,P.C.B.Phillips,P.Schmidt and Y.Shin(1992), "Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root," *Journal of Econometrics*,Vol.54,pp.159-178.

Mishkin,S.F.(1990a), "What Does TermStucture Tell us about Future Inflation?," *Journal of Monetary Economics Economics*, Vol.25, pp.77-95.

Mishkin,S.F.(1990b), "The Information in the Longer Maturity Term Structure About Future Inflation," *Quarterly Journal of Economics*, Vol.105, pp.815-828.

Newey,W.K. and K.D.West(1987), "A Simple,Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix," *Econometrica*, Vol.55,pp.703-708.

Tzavalis,E. and M.R.Wickens(1996), "Forecasting Inflation from the Term Structure," *Journal of Empirical Finance*,Vol.3,pp.103-122.

Part Ⅱ Japanese Interest Rate Swap

Chapter 6

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].

* This chapter is based on Ito (2004).

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).

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. In this sense, credit risk in 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 paper, 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 (1971). Japanese Government Bond data of 10 year and 20 year are used from January 4, 1994 through July 30,2003[4].

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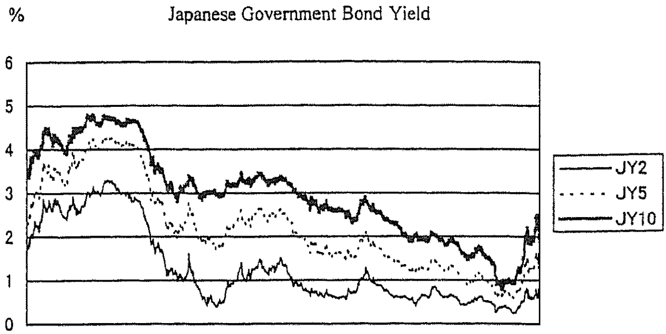
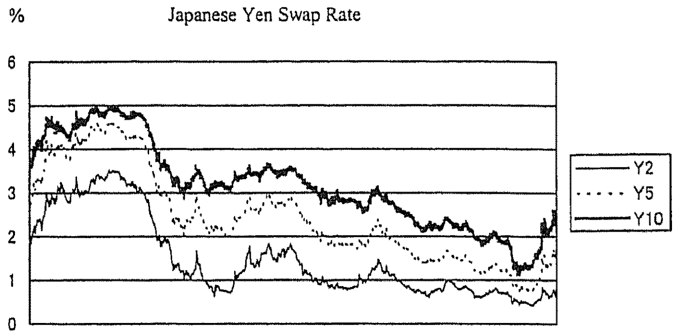
[2] Starting in March 21,2001, the BOJ changed their operating target from uncollateralized overnight call rate to current account balance held by financial institutions with the introduction of quantitative easing.

[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 6.1 Data in Sample A





Daily data from January 4, 1994 through Feburary 12, 1999. The number of sample is 1263.

2.2 Japanese Yen Interest Rate Swap Rate

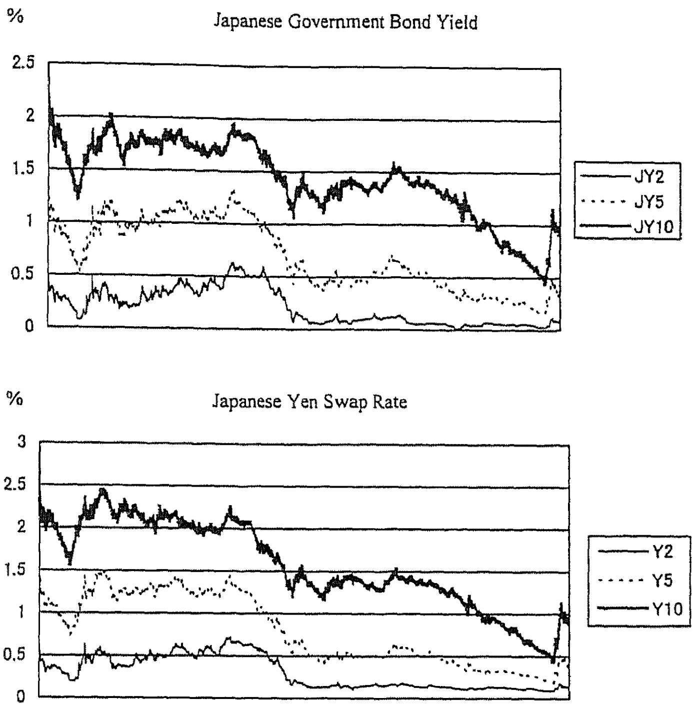
Japanese Yen Interest Rate Swap rates (2 year, 3 year, 4 year, 5 year, 7 year and 10 year) as of 3 pm at Tokyo time are used on a daily basis from January 4, 1994 through July 30,2003.

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 6.1 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 6.2 shows the data in Sample B.

Figure 6.2 Data in Sample B



Daily data from Feburary 15, 1999 through July 30 2003. The number of sample is 1099.

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. 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 (6.1) is estimated by OLS to find if residual contains unit root.

$$y_t = \alpha + \beta\, jy_t + u_t \qquad (6.1)$$

y_t = Japanese Yen Interest Rate Swap rate

jy_t = Japanese Government Bond yield

5 See Dickey/Fuller(1979) and Dickey/Fuller(1981).

6 See Phillips/Perron(1988).

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 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), β in the equation (6.1), is checked with the method of dynamic OLS by Stock/Watson (1993). The equation (6.2) is used to test if $\beta = 1$ can be rejected. Δjy_{t-i} is lead and lag variables of Japanese Government Bond yield[7].

$$y_t = \alpha + \beta jy_t + \sum_{i=-p}^{p} b_i \Delta jy_{t-i} + u_t \qquad (6.2)$$

When β is one, a 1 % increase in Japanese Government Bond yield wil lead to a 1% increase in Japanese Yen Interest Rate swap rate. When β 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.

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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.

3.3 Granger Causality

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.

$$y_t = \kappa_0 + \lambda t + \sum_{i=1}^{p+1} \alpha_i y_{t-i} + \sum_{i=1}^{p+1} \beta_i jy_{t-i} + u_t \tag{6.3}$$

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

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

$$jy_t = \varsigma_0 + \eta t + \sum_{i=1}^{p+1} \gamma_i jy_{t-i} + \sum_{i=1}^{p+1} \delta_i y_{t-i} + v_t \tag{6.4}$$

$H_0 : \gamma_1 = \gamma_2 = \cdots \gamma_p = 0$

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 (6.3) and equation (6.4) through OLS and summing the squared error. If the null hypothesis of H_0 in the equation (6.3) is rejected, jy_t is considered to explain y_t. If the null hypothesis of H_0 in the equation (6.4) is rejected, y_t is considered to explain jy_t.

Table 6.1 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

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].

Table 6.2 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

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

The results are shown on Table 6.1 and Table 6.2. 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 6.3 and 6.4.

Table 6.3 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 6.4 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 6.5. 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 6.5 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 5% and ** indicates significant 10%.

JY=Japanese Government Bond Yield

Y=Japanese Yen Interest Rate Swap Rate

Next, dynamic OLS by Stock/Watson (1993) are used to check if β indicated in the equation (6.1) is one. The results are shown on the table 6.6. In Sample A , β = 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 β 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 β 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 6.6 Test on the Cointegrating Vector

Sample A

Variables	β	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	β	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 6.7 and 6.8. 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 6.7 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 5%.
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 6.10 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 5%.
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.

References

In Japanese

Hamano,M. (1997), "Empirical Study of the Yen Interest Rate Swap Spread," *Gendai Finance (Modern Finance)*,No.1,pp.55-67.

In English

Bank for International Settlements (2003), *OTC Derivatives Market Activity in the first half of 2003.*

Bank for International Settlements (1998), *Global OTC Derivatives Market At the End – June 1998.*

Brown,K.,W.Harlow and D.J.Smith (1994) , "An Empirical Analysis of Interest Rate Swap Spreads," *Journal of Fixed Income*, March,pp.61-78.

Cossin,D. and H.Pirotte (1997), "Swap credit Risk : An Empirical Investigation on Transaction Data," *Journal of Banking &*

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

Finance,Vol.21,pp.1351-1373.

Dickey,D.A. and W.Fuller (1979), "Distribution of the Estimators for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association*,Vol.74, pp.427-431.

Dickey,D.A. and W.Fuller (1981), "Likelihood Ratio Statistics For Autoregressive Time Series with A Unit Root," *Econometrica*, Vol.49,pp.107-1072.

Duffie,D. and M.Huang (1996), "Swap Rates and Credit Quality," *Journal of Finance*, Vol.51, pp.921-949.

Engle,R.F. and C.W.J.Granger (1987), "Co-Integration and Error Correction: Representation, and Testing, "*Econometrica*,Vol.55,pp.251-276.

Eom,Y.H. M.G.Subrahmanyam and J.Uno (2000), "Credit Risk and the Yen Interest Rate swap market," Unpublished manuscript, Stern business School, New York..

Fuller,W.A. (1976), *Introduction to Statistical Time Series*, John Wiley & Sons,Inc.

Granger,C.W.J. and P.Newbold (1974), "Spurious Regressions in Econometrics," *Journal of Econometrics*,Vo.2,pp.111-120.

Hamano,M. (1997), "Empirical Study of the Yen Interest Rate Swap Spread," *Gendai Finance (Modern Finance)*,No.1,pp.55-67.

Ito,T. (2004) , "Japanese Yen Swap Spreads and Interest Rates," *Niigata University Working Paper* No.40

Lang,L.H.P.,R.H.Lizenberger, and L.A.Liu (1998), "Determinants of Interest Rate Swap Spreads," *Journal of Banking and Finance*, No.22, pp.1507-1532.

Lekkos,I. and C.Milas (2001), "Identifying the Factors that Affect Interest Rate Swap Spreads: Some Evidence from the United States and the United Kingdom," *Journal of Futures Markets*, Vol.21,pp.737-768.

MacKinnon,J.(1991), "Critical Values for Cointegration Tests," Engle,R.F. and C.W.J.Granger (ed.), *Long-Run Economic Relationships:Readings in Cointegration*, Oxford University Press, pp.267-276.

Minton,B.A. (1997), "An Empirical Examination of Basic Valuation Models for plain Vanilla U.S. Interest Rate Swaps," *Journal of Financial Economics*,No.44,pp.251-277.

Morris,C., R,Neal, and D.Rolph (1998), "Credit Spreads and Interest Rates : A Cointegration Approach," *Federal Reserve Bank of Kansas City Research Working Paper*, RWP 98-08.

McCulloch,H.J. (1971), "Measuring the Term Structure of Interest Rates," *Journal of Business*,Vo.44,pp.19-31.

Nelson,C.R. and C.I.Plosser (1982), "Trends and Random Walks in Macroeconomic Time Series," *Journal of Monetary Economics*,Vol.10,pp.139-162.

Phillips,P.C.B.(1986), "Understanding Spurious Regressions in Econometrics," *Journal of Econometrics*,Vol.33,pp.311-340.

Phillips,P.C.B. and P.Perron (1988), "Testing for a Unit Root in Time Series Regression," *Biometrica* Vol.75,pp.335-46.

Stock,J.H. and M.W.Watson(1993), "A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems," *Econometrica*, Vol.61, pp.783-820.

Sun,T., S.Sundaresan and C.Wang (1993), "Interest Rate Swaps : An Empirical Investigation," *Journal of Financial Economics*,No.34,pp.77-99.

Toda,H.Y .and T.Yamamoto (1995), "Statistical Inference in Vector Autoregressions with Possibly Integrated Processes," *Journal of Econometrics*,Vol.66,pp.225-250.

Chapter 7

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].

* This chapter is based on Ito (2005).

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.

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 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.

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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.

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 (7.1).

$$\frac{f_1}{(1+R_1)}+\frac{E(f_2)}{(1+R_2)^2}+\cdots+\frac{E(f_n)}{(1+R_n)^n}=\frac{C}{(1+R_1)}+\frac{C}{(1+R_2)^2}+\cdots+\frac{C}{(1+R_n)^n} \tag{7.1}$$

$E(\,)$ 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 (7.1), 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 (7.1) is redefined as the equation (7.2).

$$\frac{f_1+TED_1}{(1+R_1)}+\frac{E(f_2+TED_2)}{(1+R_2)^2}+\cdots+\frac{E(f_n+TED_n)}{(1+R_n)^n}=\frac{C+SS}{(1+R_1)}+\frac{C+SS}{(1+R_2)^2}+\cdots+\frac{C+SS}{(1+R_n)^n} \tag{7.2}$$

TED_n is TED spread, SS is swap spread.

Equation (7.2) can be rewritten into equation (7.3) to show that swap spread is a weighted average of present and future TED spreads.

$$\frac{TED_1}{(1+R_1)}+\frac{E(TED_2)}{(1+R_2)^2}+\cdots+\frac{E(TED_n)}{(1+R_n)^n}=SS(\frac{1}{(1+R_1)}+\frac{1}{(1+R_2)^2}+\cdots+\frac{1}{(1+R_n)^n}) \quad (7.3)$$

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 (1971). 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.

3.2 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 March1999 through July,2003.

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[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.

[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).

Sample B covers the period of zero interest rate policy and quantitative easing.

3.4 Summary Statistics

Table 7.1 provides the sample statistics of swap spreads, TED spread (TED), corporate bond spread (CBS) and slope (SLOPE) in sample period A. Table 7.2 provides swap spreads, TED spread, corporate bond spread and slope in sample period B.

Table 7.1 Summary Statistics of Data in Sample A

Variable	Mean	Standard Deviation	Kurtosis	Skewnwss
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. The number of sample is 61.

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 7.2 Summary Statistics of Data in Sample B

Variable	Mean	Standard Deviation	Kurtosis	Skewnwss
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 January, 1999 through July, 2004. The number of sample is 55.

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 The 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

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

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) 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.

$$X_t = \Pi_1 X_{t-1} + \ldots + \Pi_k X_{t-k} + \lambda + u_t \qquad (7.4)$$

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 (7.4) is expressed by using a first difference.

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi \Delta X_{t-k} + \lambda + u_t \qquad (7.5)$$

Here

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

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[7] See Dickey/Fuller(1979) and Dickey/Fuller(1981).
[8] See Kwiatowski/Phillips/Scmidt/Shin (1992).

$$\Pi = -I + \Pi_1 + \ldots + \Pi_k$$

Under the assumption that all the elements of X_t are I (1), ΠX_{t-1} needs to be I (0). This means the rank of matrix Π satisfies $0 \leq rank(\Pi) < p$. When the elements of X_t are in the relationship of cointegration, $0 < rank(\Pi) < p$ is established. Thus matrix Π can be expressed as $\Pi = \alpha\beta'$ by using the α and β of p x r matrix Π. Finally the equation (7.5) can be expressed as follows.

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} \ldots + \Gamma_{t-k} \Delta X_{t-k+1} + \alpha\beta' \Delta X_{t-k} + \lambda + u_t \qquad (7.6)$$

β' 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 (7.7). As for the length of lags, AIC standard is used.

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \lambda + u_t \qquad (7.7)$$

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* (∞) 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 7.3 and Table 7.4. 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 7.5 and 7.6.

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 7.7. 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 7.3 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 7.4 KPSS Test -Original Series

Sample A

	Lag=0		Lag=6	
Variable	η_μ	η_τ	η_μ	η_τ
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	η_μ	η_τ	η_μ	η_τ
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) .

η_μ indicates trend stationarity. η_τ indicates level stationarity.

Table 7.5 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 7.6 KPSS Test - Series with First Difference

Sample A

	Lag=0		Lag=6	
Variable	η_μ	η_τ	η_μ	η_τ
⊿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	η_μ	η_τ	η_μ	η_τ
⊿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) .

η_μ indicates trend stationarity. η_τ indicates level stationarity.

Table 7.7 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 7.8.

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 7.8 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

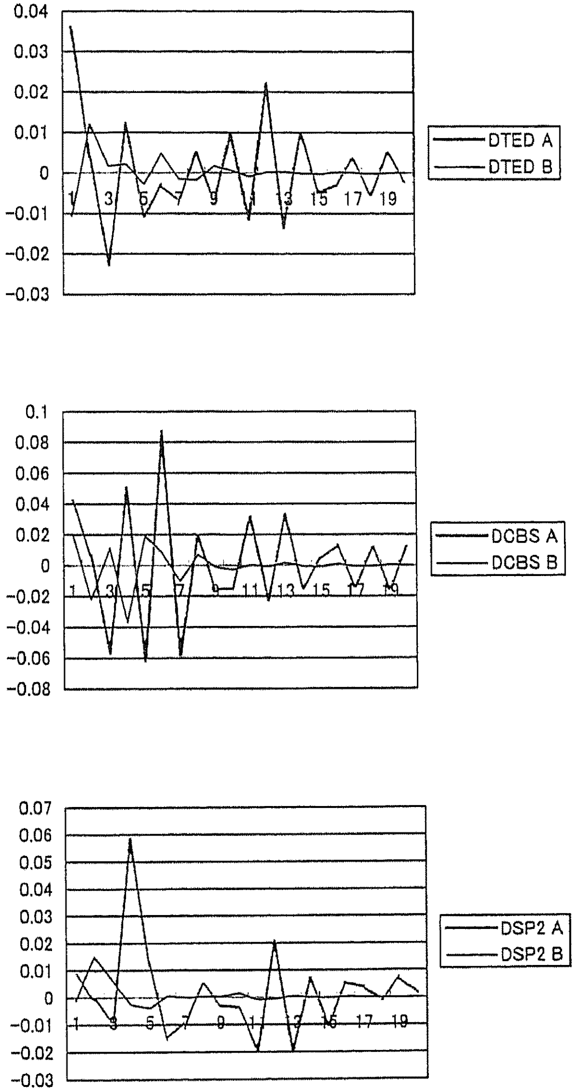
Sample B

	⊿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 columı

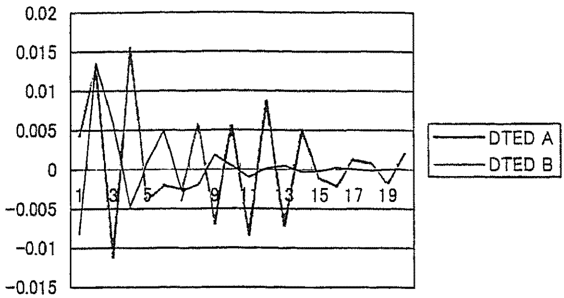
The results of impulse response functions are shown in Figure 7.1 through Figure 7.6. As for TED, in shorter terms, shocks of TED are greater in Sample A. But in mid and long terms, the sizes of shocks are almost same. As for the CBS, the sizes of shocks are greater in Sample A. As for the SLOPE, the sizes of shocks are greater in Sample A.

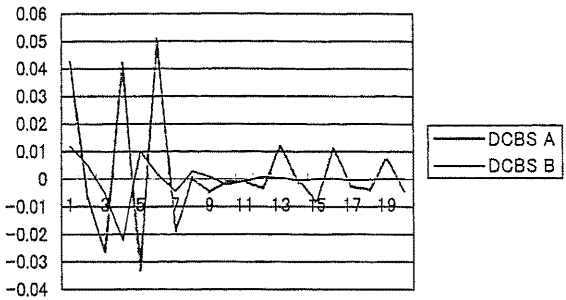
Figure7.1 Impulse Response Function - 2 Year Spread

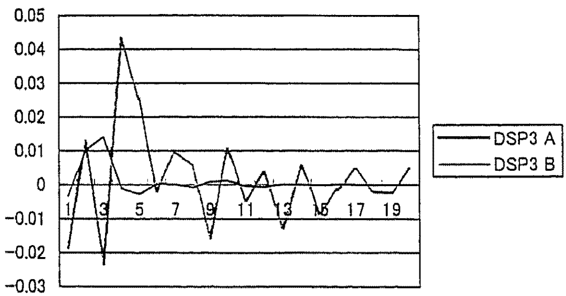


Sample A is from January, 1994 through January, 1999.
Sample B is from February, 1999 through July, 2004.
TED = TED Spread,CBS = Corporate Bond Spread
SP = SLOPE

Figure 7.2 Impulse Response Function - 3 Year Spread

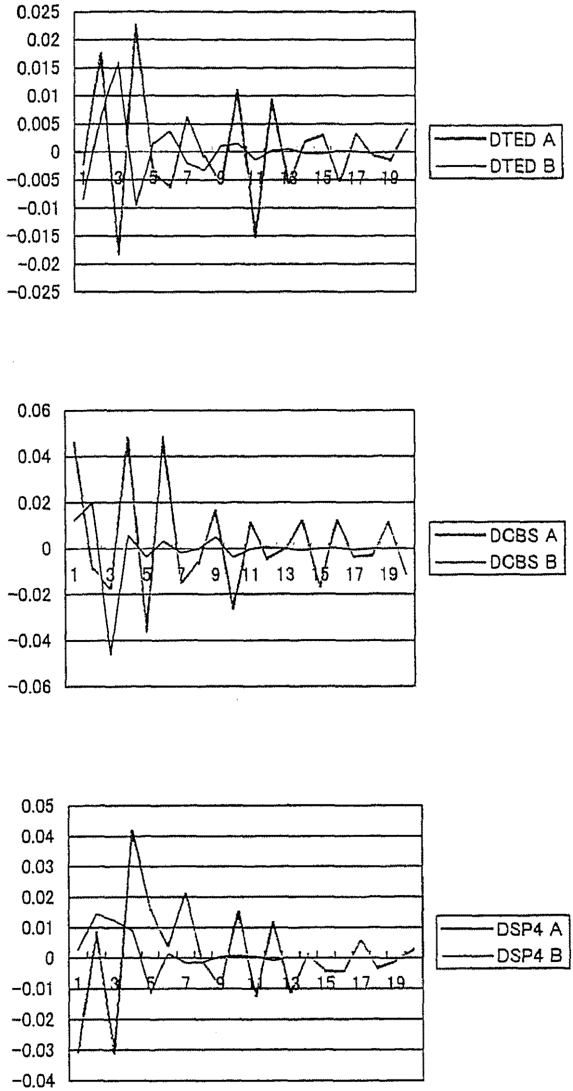






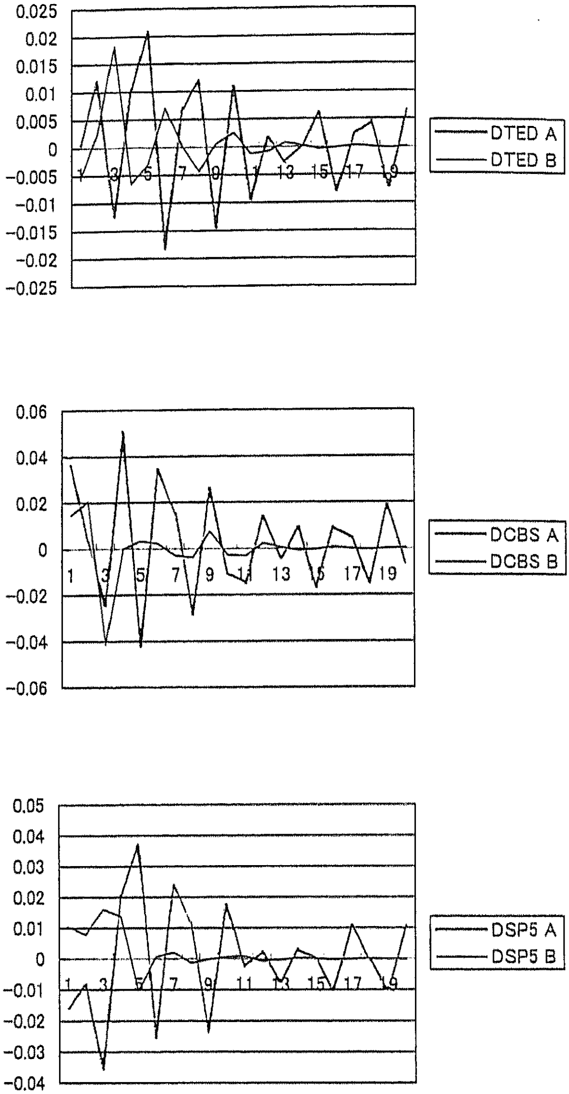
Sample A is from January, 1994 through January, 1999.
Sample B is from February, 1999 through July, 2004.
TED = TED Spread,CBS = Corporate Bond Spread
SP = SLOPE

Figure 7.3 Impulse Response Function - 4 Year Spread



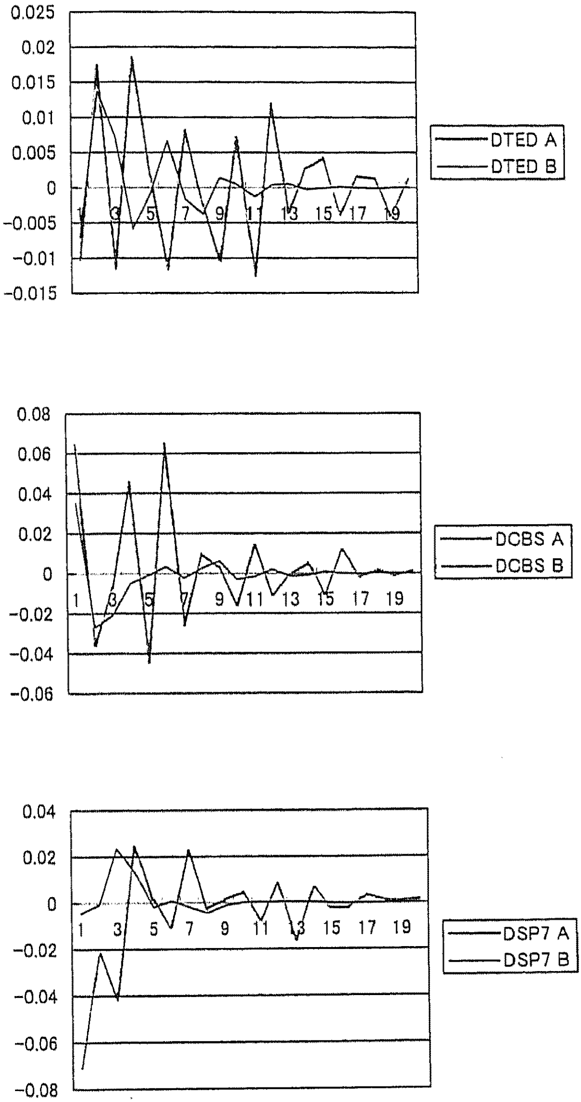
Sample A is from January, 1994 through January, 1999.
Sample B is from February, 1999 through July, 2004.
TED = TED Spread,CBS = Corporate Bond Spread
SP = SLOPE

Figure 7.4 Impulse Response Function - 5 Year Spread



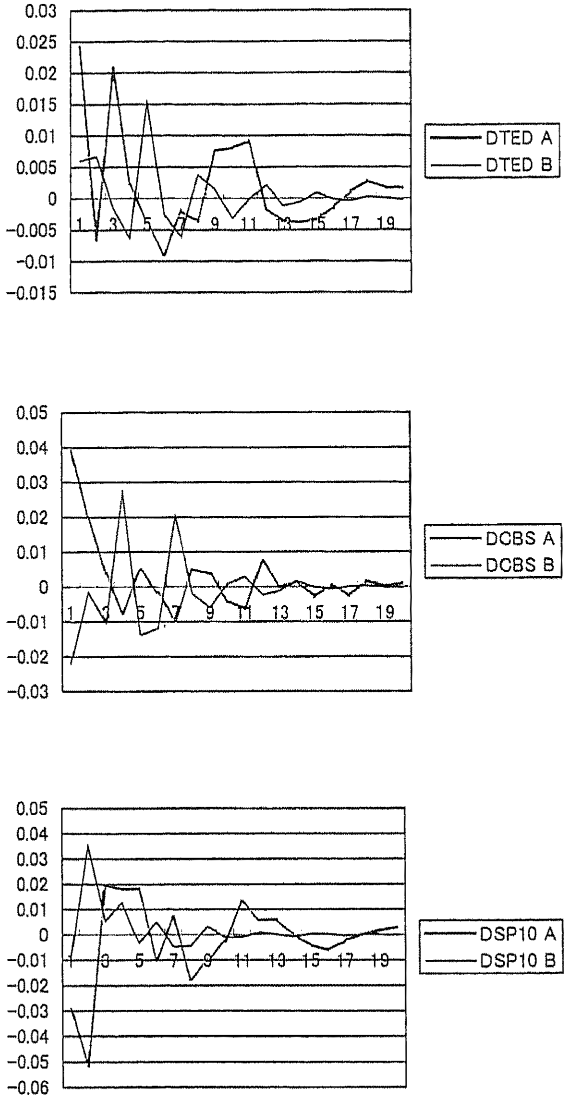
Sample A is from January, 1994 through January, 1999.
Sample B is from February, 1999 through July, 2004.
TED = TED Spread,CBS = Corporate Bond Spread
SP = SLOPE

Figure 7.5 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 7.6 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 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.

References

In Japanese

Hamano,M. (1997), "Empirical Study of the Yen Interest Rate Swap Spread," *Gendai Finance (Modern Finance)*,No.1,pp.55-67.

In English

Bank for International Settlements (2003), *OTC Derivatives Market Activity in the first half of 2003.*

Bank for International Settlements (1998), *Global OTC Derivatives Market At the End – June 1998.*

Brown,K.,W.Harlow and D.J.Smith (1994) , "An Empirical Analysis of Interest Rate Swap Spreads," *Journal of Fixed Income*, March,pp.61-78.

Cossin,D. and H.Pirotte (1997), "Swap credit Risk : An Empirical Investigation on Transaction Data," *Journal of Banking & Finance*,Vol.21,pp.1351-1373.

Dickey,D.A. and W.Fuller (1979), "Distribution of the Estimators for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association*,Vol.74, pp.427-431.

Dickey,D.A. and W.Fuller (1981), "Likelihood Ratio Statistics For Autoregressive Time Series with A Unit Root," *Econometrica*, Vol.49, pp.107-1072.

Engle,R.F. and C.W.J.Granger (1987), "Co-Integration and Error Correction: Representation, and Testing, "*Econometrica*,Vol.55,pp.251-276.

Eom,Y.H. M.G.Subrahmanyam and J.Uno (2000), "Credit Risk and the Yen Interest Rate swap market," Unpublished manuscript, Stern business School, New York..

Fuller,W.A. (1976), *Introduction to Statistical Time Series*, John Wiley & Sons,Inc.

Granger,C.W.J. and P.Newbold (1974), "Spurious Regressions in Econometrics," *Journal of Econometrics*,Vo.2,pp.111-120.

Ito,T. (2005), "Determinants of Japanese Yen Interest Rate Swap Spreads," *Journal of Economics Niigata University*,No.75,pp.1-23.

Johansen,S. (1988) "Statistical Analysis of Cointegrated Vectors," *Journal of Economic Dynamics and Control*,12,pp231-254.

Kwiatkowski,D., P.C.B.Phillips, P.Schmidt and Y.Shin (1992), "Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root," *Journal of Econometrics*,Vol.54,pp.159-178.

Lang,L.H.P.,R.H.Lizenberger, and L.A.Liu (1998), "Determinants of Interest Rate Swap Spreads," *Journal of Banking and Finance*, No.22, pp.1507-1532.

Lekkos,I. and C.Milas (2001), "Identifying the Factors that Affect Interest Rate Swap Spreads: Some Evidence From the United States and the United Kingdom," *Journal of Futures Markets*, Vol.21,pp.737-768.

Longstaff.E.A. and E.S.Schwartz (1995) "A Simple Approach to Valuing Risky Fixed and Floating Rate Debt," *Journal of Finance*, Vol.50,pp.811-830.

MacKinnon,J.(1991), "Critical Values for Cointegration Tests," Engle,R.F. and C.W.J.Granger (ed.), *Long-Run Economic Relationships:Readings in Cointegration*, Oxford University Press, pp.267-276.

Minton,B.A. (1997), "An Empirical Examination of Basic Valuation Models for plain Vanilla U.S. Interest Rate Swaps," *Journal of Financial Economics*,No.44,pp.251-277.

McCulloch,H.J. (1971), "Measuring the Term Structure of Interest Rates," Journal of Business,Vo.44,pp.19-31.

Nelson,C.R. and C.I.Plosser (1982), "Trends and Random Walks in Macroeconomic Time Series," *Journal of Monetary Economics*, Vol.10,pp.139-162.

Phillips,P.C.B.(1986), "Understanding Spurious Regressions in Econometrics," *Journal of Econometrics*,Vol.33,pp.311-340.

Phillips,P.C.B. and P.Perron (1988), "Testing for a Unit Root in Time Series Regression," *Biometrica* Vol.75,pp.335-46.

Sun,T., S.Sundaresan and C.Wang (1993), "Interest Rate Swaps : An Empirical Investigation," *Journal of Financial Economics*,No.34,pp.77-99.

Toda,H.Y .and T.Yamamoto (1995), "Statistical Inference in Vector Autoregressions with Possibly Integrated Processes," *Journal of Econometrics*,Vol.66,pp.225-250.

Chapter 8

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.

The remainder of this chapter is as follows. Section 2 explains previous studies. Section 3 describes the data. Section 4 discusses the framework of the analysis. Section 5 presents the results. Section 6 concludes.

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* This chapter is based on Ito (2001).

2 Preivous Study

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 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.

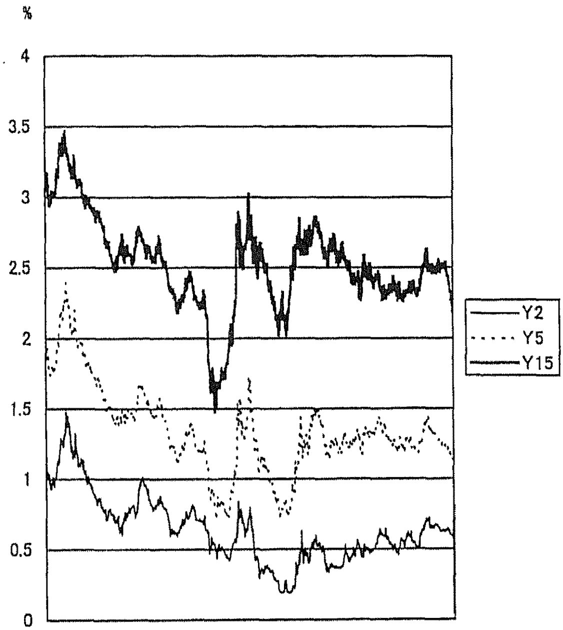
Mougoue (1992) analyzed the monthly data Euro interest rates (Canada,Germany,Japan, Swiss, United Kingdon,and USA) from 1980 through 1990 (1 month, 2 month,3 month and 6 month).They get a conclusion by Johansen cointegration test that each series has 3 cointegration vectors and 1 common trend.

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 vectórs and 3 common trends.

3 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 8.1 shows the movement of 3 series of data (2 year, 5 year, and 15 year).

Figure 8.1 The Movement of Japanese Yen Swap Rate



From March 24,1997 through November 30,2000

4 The 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[1], it's necessary to check if the 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'.

4.2 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

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[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.

of the entire time series.

4.3 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.

5 Result

5.1 Unit Root Test

There is no denying that all the variables are no-stationary. The results are shown on Table 8.1 and Table 8.2 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 8.3 and Table 8.4.

Table 8.1 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 8.2 KPSS Test - Original Series

	Lag=4		Lag=12	
Variable	ημ	ητ	ημ	ητ
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. η_τ indicates level stationarity.

Table 8.3 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 8.4 KPSS Test - Series with First Difference

	Lag=4		Lag=12	
Variable	η_μ	η_τ	η_μ	η_τ
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. η_τ indicates level stationarity.

5.2 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 8.5 through Table 8.13.

Table 8.5 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 8.6 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.
** indicates signigicance at the 1 % level.
* indicates significance at the 5 % level.
Critical Values are from Osterwald-Lenum(1992).

Table 8.7 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 8.8 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 8.9 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 8.10 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 8.11 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
$r \leqq 1$	$r = 2$	59.67**	28.14	33.24
$r \leqq 2$	$r = 3$	17.35	22	26.81
$r \leqq 3$	$r = 4$	5.83	15.67	20.2
$r \leqq 4$	$r = 5$	3.55	9.24	12.97
Trace Test				
$r = 0$	$r = 1$	230.40**	76.07	84.45
$r \leqq 1$	$r = 2$	86.40**	53.12	60.16
$r \leqq 2$	$r = 3$	26.73	34.91	41.07
$r \leqq 3$	$r = 4$	9.38	19.96	24.6
$r \leqq 4$	$r = 5$	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 8.12 Cointegration Test - 4 series

Null	Alternative	Test Statistics	5% Critical Value	1% Critical Value
Maximal Eigenvalue Test				
$r \leqq 0$	$r = 1$	101.98**	28.14	33.24
$r \leqq 1$	$r = 2$	18.05	22	26.81
$r \leqq 2$	$r = 3$	5.62	15.67	20.2
$r \leqq 3$	$r = 4$	3.68	9.24	12.97
Trace Test				
$r \leqq 0$	$r = 1$	129.33**	53.12	60.16
$r \leqq 1$	$r = 2$	27.35	34.91	41.07
$r \leqq 2$	$r = 3$	9.3	19.96	24.6
$r \leqq 3$	$r = 4$	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 8.13 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 8.14 - 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.

5.3 Principal Component Analysis

The factor loadings are shown in Table 8.14. 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.

6 Conclusion

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).

References

In Japanese

Ito,T. (2000) "The Analysis of the Term Structure of Interest Rate-the Effect and Limit of the Monetary Policy by BOJ," *Modern Finance* (In Japanese), No.7,pp75-90

In English

Bradley,M.G. and S.A.Lumpkin (1992) "The Treasury Yield Curve as a Cointegrated System," *Journal of Financial and Quantitative Analysis*, Vol.27,pp449-463.

Dickey,D.A. and W.Fuller (1979) "Distribution of the Estimators for Autoregressive Time Series With a Unit Root,"*Jouranal of the American Statistical Association*, Vol74,No.366,pp427-431.

Dickey,D.A. and W.Fuller (1981) "Likelihood Ratio Statistics For Autoregressive Time Series with A Unit Root," *Econometrica*, Vol.49,pp107-1072.

Engle,F. and C.W.J.Granger (1987) "Co-Integration and Error Correction: Representation, and Testing,"*Econometrica*,Vol.55,No.2,pp251-276.

Engsted,T. and C.Tanggard (1994) "Cointegration and the US Term Structure," *Jouranal of Banking and Finance*,Vol.18,pp167-181.

Fuller,W.A. (1976) *Introduction to Statistical Time Series*, John Wiley & Sons,Inc

Granger,C.W.J. and P.Newbold (1974). "Spurious Regressions in Econometrics," *Journal of Econometrics*,Vol.2, pp111-120.

Hall,A.D. ,H.M.Anderson and C.W.J.Granger (1992) "A Cointegration Analysis of Treasury Bill Yields," *Review of Economics and Statistics*, Vol.74,pp116-126.

Hiraki,T., N.Shiraishi and N.Takezawa (1996) "Cointegration,Common Factors, and the Term Structure of Yen Offshore Interest Rates," *Journal of Fixed Income*, December,pp.69-75.

Ito,T.(2001), "The Super Long Zone of Japanese Yen Yield Curve - Application of Cointegration Test," *Proceedings of JAFEE Summer Conference Proceedings*,pp.310-329.

Johansen,S. (1988) "Statistical Analysis of Cointegrated Vectors," *Journal of Economic Dynamics and Control*,Vo.12,pp231-254.

Karfakis,C. and D.M.Moschos (1995) "The Information Content of the Yield Curve in Australia," *Journal of Macroeconomics,* Vol.17,pp93-109.

Kwiatkowski,D.,P.C.B.Phillips,P.Schmidt and Y.Shin (1992) "Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root," *Journal of Econometrics*,Vol.54,pp.159-178.

Litterman,R. and J.Scheinkman (1991) "Common Factors Affecting Bond Returns," *Journal of Fixed Income*, June,pp54-61.

Mougoue,M. (1992) "The Term Structure of Interest Rates as a Cointegrated System: Empirical Evidence From The Eurocurrency Market, *Journal of Financial Research*,,No.3,pp285-296.

Nelson,C.R. and C.I.Plosser (1982) "Trends and Random Walks in Macroeconomic Time Series," *Journal of Monetary Economics*, Vo.10,pp139-162.

Osterwald-Lenum,M. (1992) "Practitioners' Corner A Note with Quantiles of the Asymptotic Distribution of the Maximum Likelihood Cointegration Rank Test Statistics," *Oxford Bulletin of Economics and Statistics*, Vol.54,3,pp169-210.

Stock,J.H. and M.W.Watson (1988) "Testing for Common Trends," *Journal of the American Statistical Association*,Dec,83,pp1097-1107.

Zang,H. (1993) "Treasury Yield Curves and Cointegration," *Applied Econometrics*,Vol. 25,pp361-367.

Part Ⅲ Japanese and US Interest Rates

Chapter 9

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

* This chapter is based on Ito (2004a).

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

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 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 Framework of Analysis

.1 *Unit Root Test*

ince the empirical analysis from mid-1980 through mid-1990's show that ıch data as interest rates, foreign exchange and stocks are non-stationary, it's ecessary to check if the data used in this chapter contain unit roots. The :PSS (Kwiatowski/Phillips/Schmidt/Shin) test is used. KPSS test defines ull hypothesis as 'unit roots don't exist' and alternative hypothesis as 'unit oots exist'[2]. The KPSS test is considered to have more statistical power than ther unit root tests such as ADF (Augmented Dickey/Fuller) and PP (Phillips 'erron) tests[3].

:.2 *Cointegration Test*

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

$$i(k)_t - i(k)_t^* = E_t\,(S_{t+j})/k \qquad (9.1)$$

where $i(k)_t$ and $i(k)_t^*$ are respectively the interest rates on foreign :urrency 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

2 See Kwiatowski/Phillips/Scmidt/Shin (1992).
3 For the details of methods, see Dickey/Fuller (1979), Dickey/Fuller (1981) and Phillips/Perron (1988).

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, Equation (9.2) is estimated by OLS to find if residual contains unit root.

$$i(k)_t - i(k)_t^* = \alpha + \beta E_t(S_{t+k}) / k + \varepsilon_t \qquad (9.2)$$

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).

2.3 *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.

$$i(k)_t^* = \kappa_0 + \lambda t + \sum_{i=1}^{p+1} \alpha_i i(k)_{t-i}^* + \sum_{i=1}^{p+1} \beta_i i(k)_{t-i} + u_t \quad (9.3)$$

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

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

$$i(k)_t = \varsigma_0 + \eta t + \sum_{i=1}^{p+1} \gamma_i i(k)_{t-i} + \sum_{i=1}^{p+1} \delta_i i(k)_{t-i}^* + v_t \quad (9.4)$$

$H_0 : \gamma_1 = \gamma_2 = \cdots \gamma_p = 0$

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

The F test is conducted by estimating (9.3) and (9.4) through OLS and summing the squared error. If the null hypothesis of H_0 in the equation (9.3) is rejected, $i(k)_t$ is considered to explain $i(k)_t^*$. If the null hypothesis of H_0 in the formula (9.4) is rejected, $i(k)_t^*$ is considered to explain $i(k)_t$.

3 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[4] (2 year, 3 year, 4 year, 5 year, 7 year and 10 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

4 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. Since swap data are used for Japanese yen, swap data are also used for U.S market.

on a daily basis from October 2,1990 through August 11, 2000.

3.3 *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 $S_{t+1} = S_t + \varepsilon_{t+1}$ (ε_{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 (9.5) holds true. Thus realized values of foreign exchange rate at the time of t indicate the future expectation of foreign exchange rates.

$$E_t(S_{t+j}) = S_t \qquad (9.5)$$

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.

3.4 *Sample Period*

The whole sample 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. The second sub period, named Sample B, is from May 18,1993 through August 11,2000.[5]

In Sample B the monetary policy regime in Japan is easing, but in US it's

5 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.

tightening. In figure 9.1 the comparison of 4 series (3 month, 12 month, 5 year, 10 year) in Sample A is shown. In figure 9.2 the comparison of 4 series (3 month, 12 month, 5 year, 10 year) in Sample B is indicated.

Figure 9.1 The Movement of 4 Series (90.10.2～93.5.17)

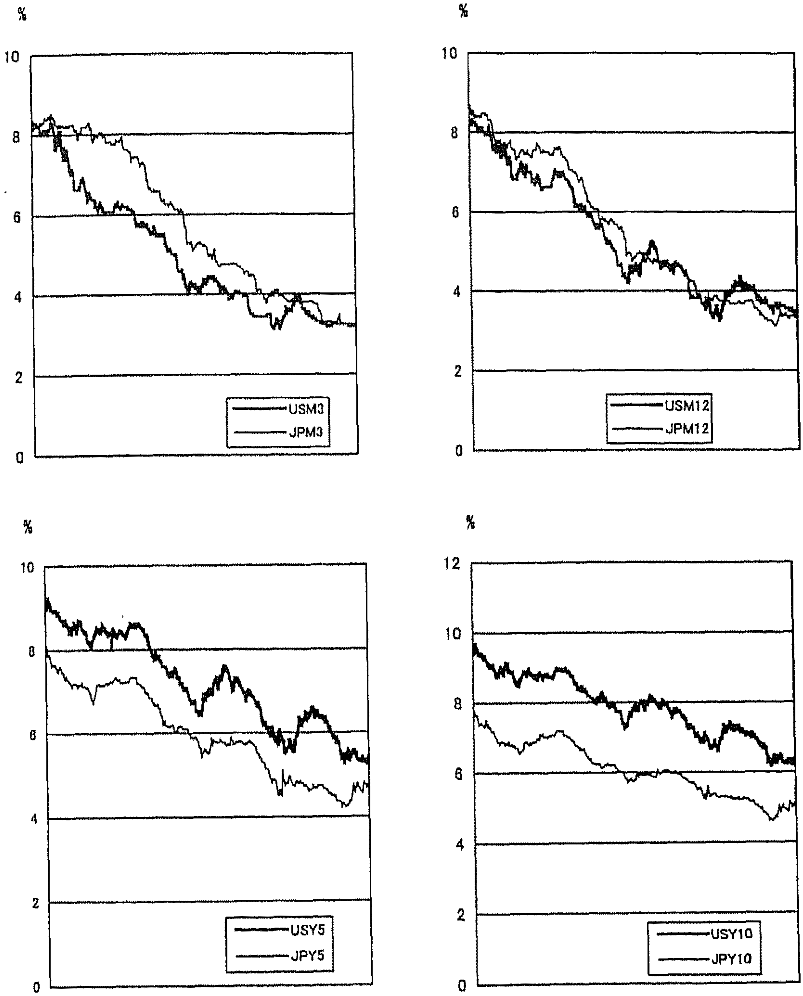
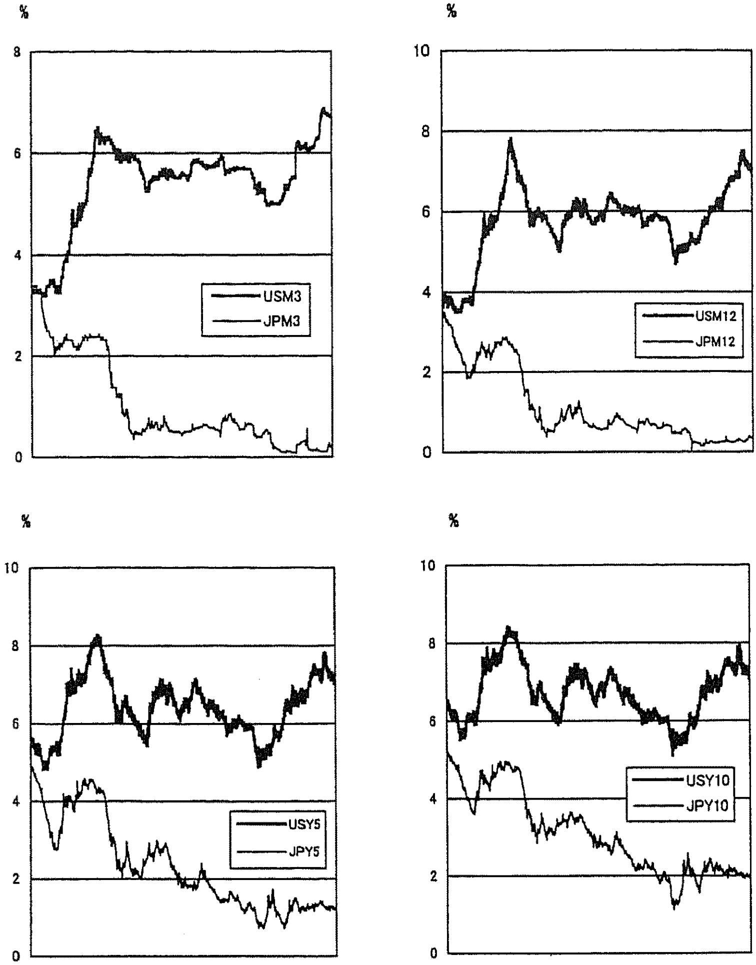


Figure 9.2 The Movement of 4 Series(93.5.18~00.8.11)



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 9.1. There is no denying that

Table 9.1 KPSS Test -Original Series

Sample A

	Lag=4		Lag=12	
Variable	η_μ	η_τ	η_μ	η_τ
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	η_μ	η_τ	η_μ	η_τ
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) .
η_μ indicates trend stationarity. η_τ indicates level stationarity.
E is expectation of foreign exchage rates.
For example, E1 is expectation of 1 month ahead.

Table 9.2 KPSS Test - Series with a Fisrt Difference

Sample A

	Lag=4		Lag=12	
Variable	η_μ	η_τ	η_μ	η_τ
⊿(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	η_μ	η_τ	η_μ	η_τ
⊿(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) .
η_μ indicates trend stationarity. η_τ indicates level stationarity.
E is expectation of foreign exchage rates.
For example, E1 is expectation of 1 month ahead.

all the variables are no stationary both in Sample A and Sample B.

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 9.2.

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 9.3.

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 9.3.

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 9.4.

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 9.5.Thus it can be concluded that during Sample B, JP interest rates and US

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

interest rates influenced mutually.

Table 9.3 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 5%.

E is expectation of foreign exchage rates.

For example, E1 is expectation of 1 month ahead.

Table 9.4 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 5%.
Original lag is chosen by AIC standard.
The method by Toda /Yamamoto(1995) is used.

Table 9.5 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 5%.
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.

References

Bank for International Settlements (1989), *International Interest Rate Linkages and Monetary Policy.*

Berk,M.J. (2001), *The Preparation of Monetary Policy*, Kluwer.

Blundell-Wignall,A. and F.Browne (1991), "Increasing Financial Markets Integration, Real Exchage Rates and Macroeconomic Adjustment," *OECD Department of Economic and Statistics Working Papers*,No.96.

Christiansen,H. and C.Pigott (1997), "Long-Term Interest Rates in Globalize Markets," *OECD Economics Department Working Papers*,No.175.

Dickey,D.A. and W.Fuller (1979), "Distribution of the Estimators for Autoregressive Time Series with a Unit Root," *Journal of the American Statistical Association*,Vol.74, pp.427-431.

Dickey,D.A. and W.Fuller (1981), "Likelihood Ratio Statistics For Autoregressive Time Series with A Unit Root,"*Econometrica*,Vol.49,pp.107-1072.

Engle,R.F. and C.W.J.Granger (1987), "Co-Integration and Error Correction: Representation, and Testing, "*Econometrica*,Vol.55,pp.251-276.

Frankel,J. (1989), "International Financial Integration, Relations among Interest Rates and Exchange Rates, and Monetary Indicators," in C.Pigott(ed), '*International Financial Integration and U.S Monetary*

Policy', FRBNY, October.

Frankel,J.(1992), "Measuring World Capital Mobility; a Review," *American Economic Review*, Vol.88,pp.197-202.

Fuller,W.A. (1976), *Introduction to Statistical Time Series*, John Wiley & Sons.

Goldstein,M. and M.Mussa (1993), "The Integration of World Capital Markets," in *'Changing Capital Markets'*, Proceedings of a Symposium sponsored by FRBKC.

Granger,C.W.J. and P.Newbold (1974), "Spurious Regressions in Econometrics," *Journal of Econometrics*, Vo.2,pp.111-120.

Ito,T. (2004a), "Financial Market Linkage between Japan and US: Investigation of Short and Long Term Interest Rates," *Annual Report of Economics Niigata University*, No.28,pp1-16.

Kasman,B. and C.Pigott (1988), "Interest Rate Divergences among the Major Industrial Nations," *FRBNY Quarterly Review*, Autumn,pp.28-44.

Kwiatkowski,D., P.C.B.Phillips, P.Schmidt and Y.Shin (1992), "Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root," *Journal of Econometrics*, Vol.54,pp.159-178.

Lukepohl,H. (1991), *Introduction to Multiple Time Series Analysis*, Springer Verlag.

MacKinnon,J.(1991), "Critical Values for Cointegration Tests," Engle,R.F. and C.W.J.Granger (ed.), *Long-Run Economic Relationships:Readings in Cointegration*, Oxford University Press,pp.267-276.

McCallum,B.T. (1994), "A Reconsideration of the Uncovered Interest Parity Relationship," *Journal of Monetary Economics*, Vol.33,pp.105-132.

Nelson,C.R. and C.I.Plosser (1982), "Trends and Random Walks in Macroeconomic Time Series," *Journal of Monetary Economics*, Vol.10,pp.139-162.

Phillips,P.C.B.(1986), "Understanding Spurious Regressions in Econometrics," *Journal of Econometrics*, Vol.33,pp.311-340.

Phillips,P.C.B. and P.Perron (1988), "Testing for a Unit Root in Time Series

Regression," *Biometrica* Vol.75,pp.335-46.

Pigott,C. (1993), "International Interest Rate Convergence : A Survey of the Issues and Evidence;" *FRBNY Quarterly Review*,Winter,pp.24-37.

Throop,A.W. (1994), "International Financial Market Integration and Linkages of National Interest Rates," *FRBSF Economic Review*,No.3,pp.3-18.

Toda,H.Y .and T.Yamamoto (1995), "Statistical Inference in Vector Autoregressions with Possibly Integrated Processes," *Journal of Econometrics*, Vol.66,pp.225-250.

Chapter 10

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.

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* This chapter is based on Ito (2004b).

[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.

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 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 6 concludes.

2 Data

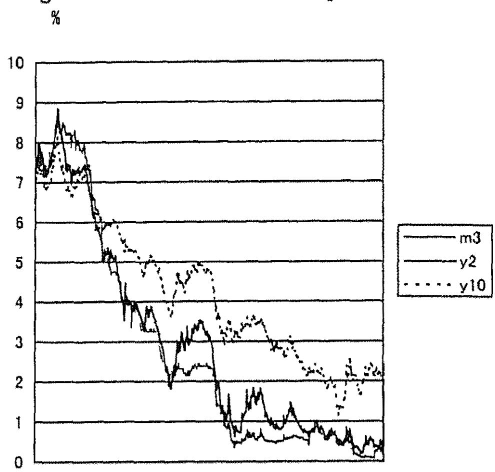
2.1 Japan

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

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

daily basis from February,8 1990 through March 30,1999. Figure 10.1 shows the movement of 4 series of data (3 month LIBOR, swap rate 2 year, and 10 year).

Figure 10.1 The Movement of Japanese Yen Rate



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

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 10.2 shows the movement of 4 series of data (3 month LIBOR, swap rate 2 year, and 10 year).

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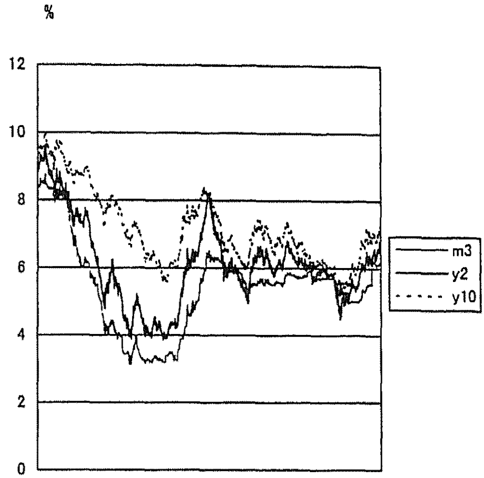
trading activities are made on 10 year JGB. Therefore it's very difficult to draw a proper yield curve by using the actual JGB data. On the other hand, actual transactions of interest rate swaps are conducted on the yield curve of 2 year through 10 year.

Figure 10.2 the Movement of US dollar Rate



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

3 The Framework of Analysis

2.1 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

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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 t hings 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).

alternative hypothesis as 'unit roots don't exist'. Fuller (1976) provides the table for ADF and PP test.

2.2 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.

$$X_t = \Pi_1 X_{t-1} + \ldots + \Pi_k X_{t-k} + \lambda + u_t \qquad (10.1)$$

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 (10.1) is expressed by using a first difference.

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi \Delta X_{t-k} + \lambda + u_t \qquad (10.2)$$

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 $I(1)$, ΠX_{t-1} needs to

[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.

be $I(0)$.

This means the rank of matrix Π 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 Π can be expressed as $\Pi = \alpha\beta'$ by using the α and β of p x r matrix Π. Finally the equation (10.2) can be expressed as follows.

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} \ldots + \Gamma_{t-k} \Delta X_{t-k+1} + \alpha\beta' \Delta X_{t-k} + \lambda + u_t \qquad (10.3)$$

β' 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 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].

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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

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

$$R(1,t) = A(1,t) + b_1 W(t_1)$$
$$R(2,t) = A(2,t) + b_2 W(t_1) + b_2 W(t_2)$$
$$\ldots\ldots$$
$$R(n,t) = A(n,t) + b_n W(t_1) + b_n W(t_2) \ldots b_n W(t_n)$$

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 The Result of Empirical Analysis

4.1 Unit Root Analysis

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

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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.

time trend. AIC standard is used for the determination of lag length in the ADF Test. The results are shown on Table 10.1 through Table 10.4.

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 10.1 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 10.2 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 10.3 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 10.4 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 10.5 through Table 10.8.

Table 10.5 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 10.6 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 10.7 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 10.8 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 10.9.

Table 10.9 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.
Test statictics 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 10.10.

Table 10.10 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.
Test statictics 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 10.11.

Table 10.11 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.
Test statictics 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 10.12.

Table 10.12 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.
Test statictics 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 10.13.

Table 10.13 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.
Test statictics 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 10.14.

Table 10.14 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.
Test statictics 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 10.15.

Table 10.15 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.
Test statictics 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 10.16.

Table 10.16 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.
Test statictics 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 10.17.

Table 10.17 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.
Test statictics 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 10.18.

Table 10.18 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.
Test statictics 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 10.19.

Table 10.19 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.
Test statictics 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 10.20.

Table 10.20 Cointegration Test -US (9 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.
Test statictics 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 10.21.

Table 10.21 Cointegration Test -US (9 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.
Test statictics 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 10.22.

Table 10.22 Cointegration Test -US (9 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.
Test statictics 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 Conclusion

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- (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

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[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.

pay attention to 2 common trends.

References

Bradley,M. and S.Lumpkin (1992) "The Treasury Yield Curve as a Cointegrated System," *Journal of Financial and Quantitative Analysis*, Vol.27, No.3, September, pp449-463.

Dickey,D.A. and W.A.Fuller (1979) "Distribution of the Estimators for Autoregressive Time Series With a Unit Root," *Journal of the American Statistical Association*, July Vol. 74,No.366,pp427-431.

Dickey,D.A. and W.A.Fuller (1981) "Likelihood Ratio Statistics For Autoregressive Time Series with A Unit Root," *Econometrica*, Vol.49,pp107-1072.

Engle,R.F and C.W.J.Granger (1991) "Long-Run Economic Relationships", *Readings in Cointegration* Oxford University Press.

Engsted,T .and C.Tanggard (1994) "Cointegration and the US Term Structure" *Journal of Banking and Finance*, 18,pp167-181.

Fuller,W.A. (1976) *Introduction to Statistical Time Series*, John Wiley & Sons,Inc

Granger,C.W.J. and P.Newbold (1974) "Spurious Regressions in Econometrics," *Journal of Econometrics*,2,pp111-120.

Hall,D.,H.M.Anderson and C.W.J.Granger (1992) " A Cointegration Analysis of Treasury Bill Yields," *Review of Economics and Statistics*, Vol.74,pp116-126.

Hiraki,T.,N.Shiraishi and N.Takezawa. (1996) "Cointegration, Common Factors, and the Term Structure of Yen Offshore Interest Rates," *Journal of Fixed Income*, December,pp.69-75.

Ito,T. (2004b) , "The Comparison of Yield Curves in Japan and US - Analysis of Coomon Trends," *Journal of Economics Niigata University*, No.75,pp.1-21.

Johansen,S. (1988) "Statistical Analysis of Cointegrated Vectors," *Journal of*

Economic Dynamics and Control,12,pp231-254

Karfakis,C. and D.M.Moschos (1995) "The Information Content of the Yield Curve in Australia ," *Journal of Macroeconomics*, Vol.17,No.1,pp93-109.

Mougoue,M. (1992) "The Term Structure of Interest Rates as a Cointegrated System: Empirical Evidence From The Eurocurrency Market," *Journal of Financial Research*,Fall,No.3,pp285-296.

Nelson,C.R. and C.I.Plosser (1982) "Trends and Random Walks in Macroeconomic Time Series," *Journal of Monetary Economics*, Vo.10,pp139-162.

Osterwald-Lenum,M. (1992) "Practitioners' Corner A Note with Quantiles of the Asymptotic Distribution of the Maximum Likelihood Cointegration Rank TestStatistics," *Oxford Bulletin of Economics and Statistics*,Vol. 54,pp169-210.

Phillips,P.C.B. and P.Perron (1988) "Testing for a Unit Root in Time Series Regression," *Biometrica* ,Vol.75,pp335-46.

Stock,J.H. and M.W.Watson (1988) "Testing for Common Trends," *Journal of the American Statistical Association*, Vol. 83, pp1097-1107.

Zhang,H. (1993) "Treasury Yield Curves and Cointegration," *Applied Econometrics*, Vo.25, pp361-367.

Conclusion

Chapter 11

Conclusion

At Chapter 2 I investigated the impacts of the target changes of uncollateralized overnight call rates. I found that uncollateralized overnight call rate changes significantly affected the market interest rates from 1 month through 5 year. I couldn't find the statistical significance over 7 year zone. The impacts are as follows; 0.52~0.17% change on 1 % change of unsecured overnight call rate from 1 month through 12 month and 0.16~0.09% change from 3 year through 5 year,0.06~0.04%.

This result as for interest rates reaction over 2 year is similar to previous studies in US. In Japan the impacts on 1 month and 2 month interest rates are very strong in comparison with the impacts on 3 month through 12 month. In US the impacts on 3 month through 12 month are almost equal, but in Japan the impacts are diminishing in accordance with the length of maturity.

The coefficients of determination are 0.46 (1 month) through 0.09 (10 year), which are small in comparison with US previous cases. In the case of a previous study in US, the coefficient of determination, 0.59 at 6 month, is the largest and 0.29 at 20 year is the smallest.

At chapter 3 I investigated the effects and limits of the monetary policy by the Bank of Japan by analyzing the term structure of Japanese Yen open interest market. It's found that the term structure up to the 2 year is driven by a single 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 the money market section. Since FRA and IMM swap are traded up to 2 years, 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 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 - single common trend),(2) middle term (from 3 year through 7 year - two common trends),(3) long term (10 year-three common trends).

From a viewpoint of monetary policy, it can be assumed that uncollateralized overnight call rate is deeply connected with the term structure up to 2 year.

When the influences of uncollateralized overnight call rate on the each interest rate of the entire term structure are investigated, it influences the term structure up to the 2 year. The uncollateralized overnight call rate is judged to give the shorter period of interest rate more influence since F-statistics increases as the maturities of the interest rate get shorter except for the case of 9 month and 1 month.

Next, the influences of each interest rate of the entire term structure on the uncollateralized overnight call rate are checked. None of the interest rate is found to influence uncollateralized overnight call rate.

Accordingly it's assumed that the BOJ could influence the term structure up to 2 year independently by its monetary policy and the BOJ never followed the change of the market.

At chapter 4 I investigated the Fisher Hypothesis by using the Japanese yen interest rates (18 series from 1 month through 10 year). 18 series of nominal interest rates are in the relationship of cointegration with expected rates of inflation. As for the results of cointegration vector test, $\beta = 1$ can't be rejected in the term structure from 3 year through 10 year. From the tests of cointegration and cointegration vector, I can conclude that the Fisher hypothesis holds true in the term structure from 3 year through 10 year.

In addition to cointegration and cointegration vector tests, I checked the stationarity of the real interest rates with unit root test. The results were mixed and I couldn't get clear results. Finally Granger causality tests are conducted. Causalities from expected inflation rate on nominal interest rates in all term structures are fund to be significant. On the other hand, causalities from nominal interest rates on expected inflation rate are fund to be insignificant.

At chapter 5 I investigated the relationship between the spreads of Japanese interest rates and the future inflation. I find that almost all the spreads contain the information of future inflation. As for the analysis within 1 year interest rates, all the spreads except for one between 3 month and 6 month interest rates contain the information of future inflation. But the coefficient of determination is low (0.0204～0.0983) and the spreads of interest rate explain less future inflation.

As for the analysis over 2 year, the spreads of interest rate contain the information of future inflation. The coefficient of determination is 0.1050～0.9102 which is larger in comparison with the analysis within 1 year. The coefficient (0.9120) is the largest in the spread between 2 year and 5 year interest rates. Thus the spread between 2 year and 5 year spreads contain most information of future inflation. The spread between 4 year and 5 year interest rates is in the relationship of one to one with the information of future inflation and it's considered to be effective indicator of inflation.

When I look over the entire term structure, spreads over 1 year contain more information of future inflation than spreads within 1 year. From this chapter I can conclude that spreads between mid term and long term interest rates are effective information variable in the conduct of monetary policy.

At Chapter 6 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

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 7 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 8 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 9 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 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 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 10 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.