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The Comparison of Yield Curves in Japan and US-Analysis of Common Trends

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Abstract

The purpose of this paper 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 Japan, the entire term structure is driven by 3 common trends. 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). On the other hands, in US the entire term structure is driven by 2 common trends. 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.

JEL Classification : C32, E43, E52

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Common Trend, Market Segmentation

1. Introduction

The Bank of Japan (hereinafter BOJ) and the Federal Reserve Board (hereinafter

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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 paper 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 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 a single common trend is a driving force. No previous study compares the yield curves of Japan and US as in this paper.

There are numbers of previous studies in which cointegration are applied for the analysis of term structure of interest rates. Hall/Anderson/Granger (1992) conduct Johansen cointegration test by using the US Treasury bill monthly data (11 series: 1 month through 11 month) from 1970 through 1988. They find that the entire series are comprised of 10 cointegration vectors and 1 common trend. Then they divide 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 depending on the monetary policy regimes.

They also conduct 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) test the expectations theory of interest rates by analyzing the Australian monthly and quarterly domestic interest rates (overnight, 3 month, 2

[1] Starting in March 21, 2001, BOJ changed their operating target from unsecured 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.

year, 5 year and 10 year). They conclude that the spread between 3 month data and long-term interest rate could predict the change of 3 month interest rate. They also get a conclusion to support the expectations hypothesis that the spread between overnight and 3 month rate can forecast the overnight rate. Finally they conduct 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) apply cointegration analysis to Japanese data. They use the 13 series of data from 1988 through 1995. They conduct 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) use 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) conduct 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) analyze the monthly 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 get a conclusion by Johansen cointegration test that each series has 3 cointegration vectors and 1 common trend. Then they conduct 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 suggest that there exists a weak form of efficient market hypothesis.

Zhang (1993) conducts 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 conclude that the entire series has 16 cointegraton vectors and 3 common trends in the term structure from 1 month through 10 year.

2. The Framework of the 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[2]. The ADF (Augmented Dickey Fuller) test and the PP (Phillips Perron) test are used[3,4]. 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.

2．2 *Cointegration Test of Johansen and Common Trend*

There are mainly two types of cointegration test-(1) Engle/Granger(1987), (2) Johansen (1988)[5]. The most difficult part of cointegration analysis starting from VAR model is how to decide the number of cointegration relationships. When 3 variables are analyzed, the number of cointegration relationships may be 1 or 2. Engle/Granger can't cope with this problem, but Johansen is able to decide the number of cointegration relationships 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.

$$X_t = \Pi_1 X_{t-1} + \ldots + \Pi_k X_{t-k} + \lambda + u_t \tag{1}$$

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

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \Pi \Delta X_{t-k} + \lambda + u_t \tag{2}$$

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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).

[4] See Phillips/Perron (1988).

[5] 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/Tanggaard (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.

Here

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

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 $0 \leqq rank(\Pi) < p$. When the elements of X_t are in the relationship of cointegration, $0 \leqq rank(\Pi) < p$ 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 formula (2) can be expressed as follows.

$$\Delta X_t = \Gamma_1 \Delta X_{t-1} ... + \Gamma_{t-k} \Delta X_{t-k+1} + \alpha\beta' \Delta X_{t-k} + \lambda + u_t \quad (3)$$

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[6].

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[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.

Applying the result to this paper, we expect that there will be a couple of nonstationary common trends in the yields of different maturity[7]. Denoting the $I(1)$ common trends by $W(t_1)...W(t_n)$, a simple representation of how it links the yield curve is given by

$$R(1,t)=A(1,t)+b_1W(t_1)$$
$$R(2,t)=A(2,t)+b_2W(t_1)+b_2W(t_2)$$
$$\cdots\cdots$$
$$R(n,t)=A(n,t)+b_nW(t_1)+b_nW(t_2)...b_nW(t_n)$$

wher $A(i,t)$ eare $I(0)$ variables. Since $W(t_n)$ are $I(1)$ and $A(i,t)$ are $I(0)$, the observed long-run movement in each yield is mainly due to the common trends. Thus $W(t_n)$ drive the time series behavior of each yield and determines how the entire yield curve changes 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.

3. Data

3. 1 Japan

The 11 series of data- overnight unsecured call rate, LIBOR (London Interbank Offered Rate-3 month, 6 month, 9 month, 12 month), interest rate swap rate[8] (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 1 shows the movement of 4 series of data (3 month LIBOR, 2 year swap rate, and 10 year swap rate).

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

[8] In the 1990's the issuances of JGB (Japanese Government Bond) were centered on 10 year. The 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 were conducted on the yield curve of 2 year through 10 year.

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

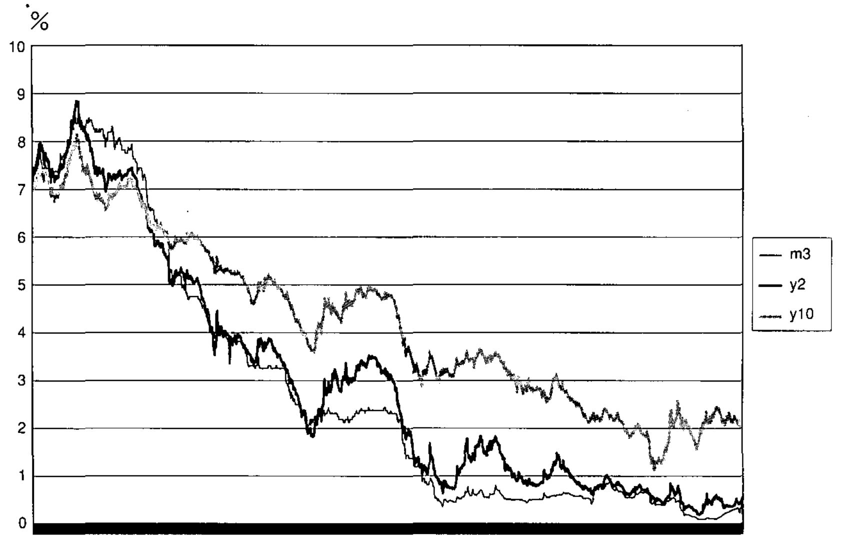

Figure 1 The Movement of Japanese Yen Rate (From Feburay 8, 1990 through March 30, 1999)

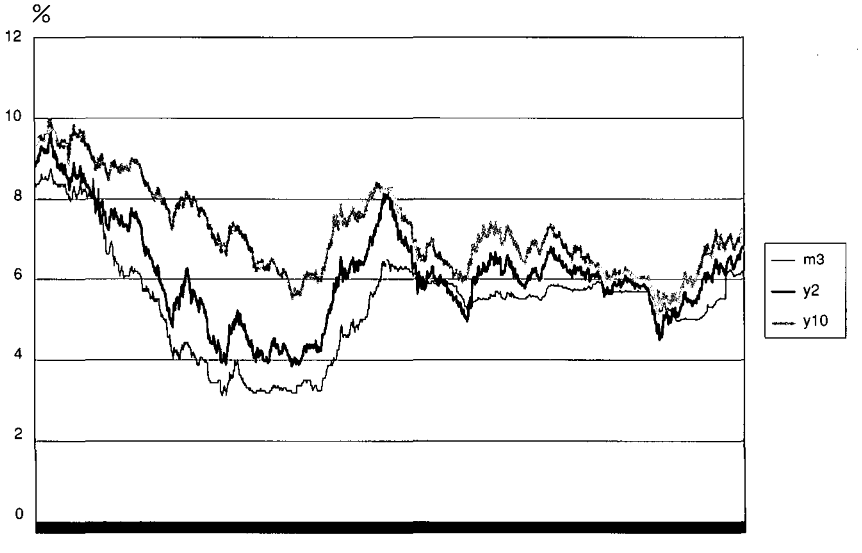

Figure 2 The Movement of US Dollar Rate (From Feburay 8, 1990 through March 30, 1999)

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 results are shown on Table 1 through Table 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 roots.

Table 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 -2.89(Without Trend)-3.45(with Trend).

Table 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 -2.89(Without Trend)-3.45(with Trend).

Table 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 -2.89(Without Trend)-3.45(with Trend).

Table 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	-3.367*	-4.437*
Y10	-2.117	-1.817

* indicates significance at the 5 % level.
5 % critical values are -2.89(Without Trend)-3.45(with Trend).

Thus the doubt that none of the variables is 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. 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 5 through Table 8.

Table 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 -2.89(Without Trend)-3.45(with Trend).

Table 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 -2.89(Without Trend)-3.45(with Trend).

Table 7 PP Test -JPY Series with First 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 -2.89(Without Trend)-3.45(with Trend).

Table 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 -2.89(Without Trend)-3.45(with Trend).

4. 2 Cointegration Test-Japan

(1) From overnight unsecured 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 9.

Table 9 Cointegration Test-Japan(11 series-from ON through 10 Y)

Hypothesis	λ max	5% Value	1% Value	λ trace	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% level.
* indicates significance at the 5% level.
Test statictics are from Osterwald-Lenum(1992).

(2) From overnight unsecured 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 the Table 10.

Table10 Cointegration Test-Japan (10 series-from ON through 7 Y)

Hypothesis	λ max	5 % Value	1 % Value	λ trace	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 % level.
* indicates significance at the 5 % level.
Test statictics are from Osterwald-Lenum (1992).

(3) From overnight unsecured 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 11.

Table11 Cointegration Test-Japan (9 series-from ON through 5 Y)

Hypothesis	λ max	5 % Value	1 % Value	λ trace	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 trends.
** indicates signigicance at the 1 % level.
* indicates significance at the 5 % level.
Test statictics are from Osterwald-Lenum (1992).

(4) From overnight unsecured 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 12.

Table12 Cointegration Test-Japan(8 series-from ON through 4 Y)

Hypothesis	λ max	5 % Value	1 % Value	λ trace	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	890.90**	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 trends.
** indicates signigicance at the 1 % level.
* indicates significance at the 5 % level.
Test statictics are from Osterwald-Lenum(1992).

(5) From overnight unsecured 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 13.

Table13 Cointegration Test-Japan(7 series-from ON through 3 Y)

Hypothesis	λ max	5 % Value	1 % Value	λ trace	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	707.50**	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	226.30**	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 trends.
** indicates signigicance at the 1 % level.
* indicates significance at the 5 % level.
Test statictics are from Osterwald-Lenum(1992).

(6) From overnight unsecured 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 14.

Table14 Cointegration Test-Japan(6 series-from ON through 2 Y)

Hypothesis	λ max	5 % Value	1 % Value	λ trace	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 % level.
* indicates significance at the 5 % level.
Test statictics are from Osterwald-Lenum(1992).

(7) From overnight unsecured 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 15.

Table15 Cointegration Test-Japan(5 series-from ON through 12M)

Hypothesis	λ max	5 % Value	1 % Value	λ trace	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 % level.
* indicates significance at the 5 % level.
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 16.

Table16 Cointegration Test-US(11 series-from ON through 10 Y)

Hypothesis	λ max	5% Value	1% Value	λ trace	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% level.
* indicates significance at the 5% level.
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 17.

Table17 Cointegration Test-US(10 series-from ON through 7 Y)

Hypothesis	λ max	5% Value	1% Value	λ trace	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% level.
* indicates significance at the 5% level.
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 18.

Table18 Cointegration Test-US(9 series-from ON through 5 Y)

Hypothesis	λ max	5% Value	1% Value	λ trace	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 trends.
** indicates signigicance at the 1% level.
* indicates significance at the 5% level.
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 19.

Table19 Cointegration Test-US(8 series-from ON through 4 Y)

Hypothesis	λ max	5 % Value	1 % Value	λ trace	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 trends.
** indicates signigicance at the 1 % level.
* indicates significance at the 5 % level.
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 20.

Table20 Cointegration Test-US(7 series-from ON through 3 Y)

Hypothesis	λ max	5 % Value	1 % Value	λ trace	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 trends.
** indicates signigicance at the 1 % level.
* indicates significance at the 5 % level.
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 21.

Table21 Cointegration Test-US(6 series-from ON through 2 Y)

Hypothesis	λ max	5％ Value	1％ Value	λ trace	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％ level.
* indicates significance at the 5％ level.
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 22.

Table22 Cointegration Test-US(5 series-from ON through 12M)

Hypothesis	λ max	5％ Value	1％ Value	λ trace	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％ level.
* indicates significance at the 5％ level.
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 a 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.

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[9] Zhang (1993) uses 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.

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.

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