When did the JGB market become efficient?

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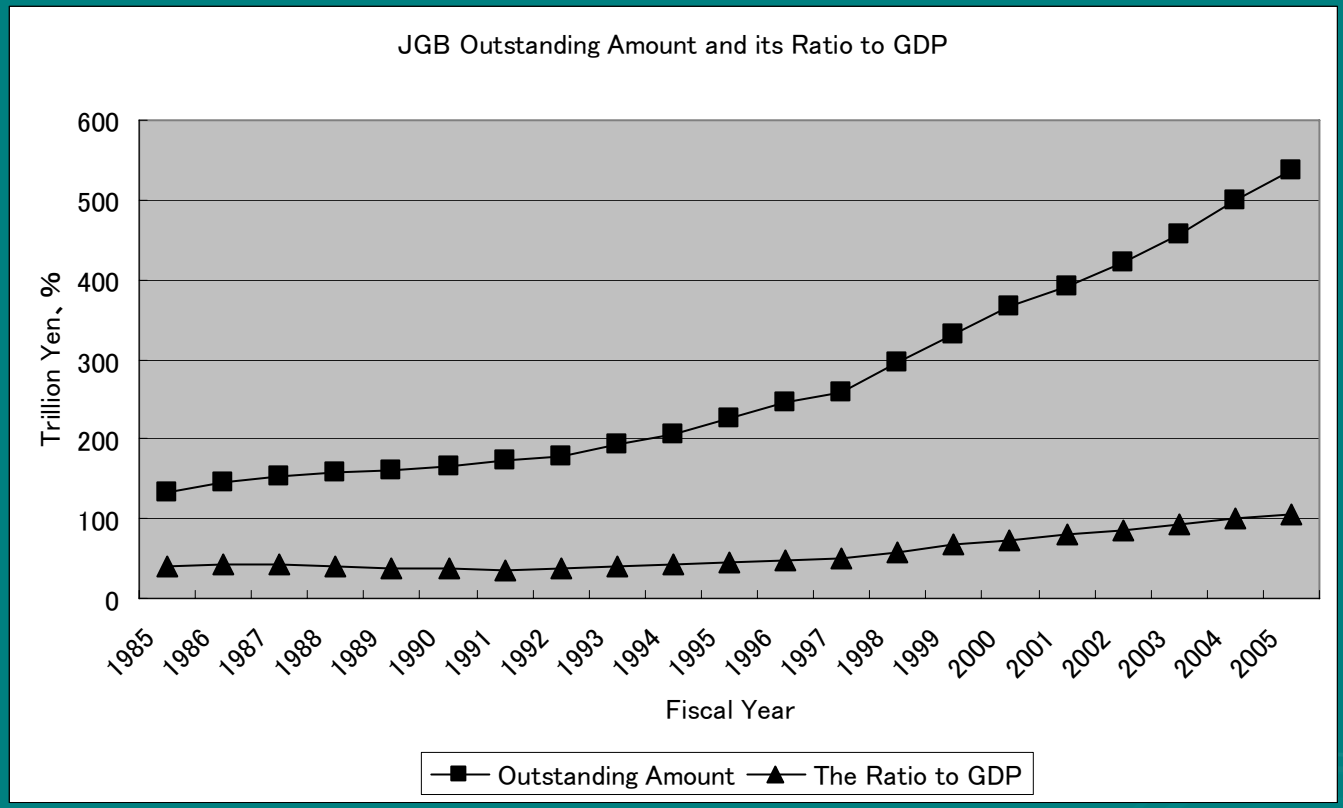
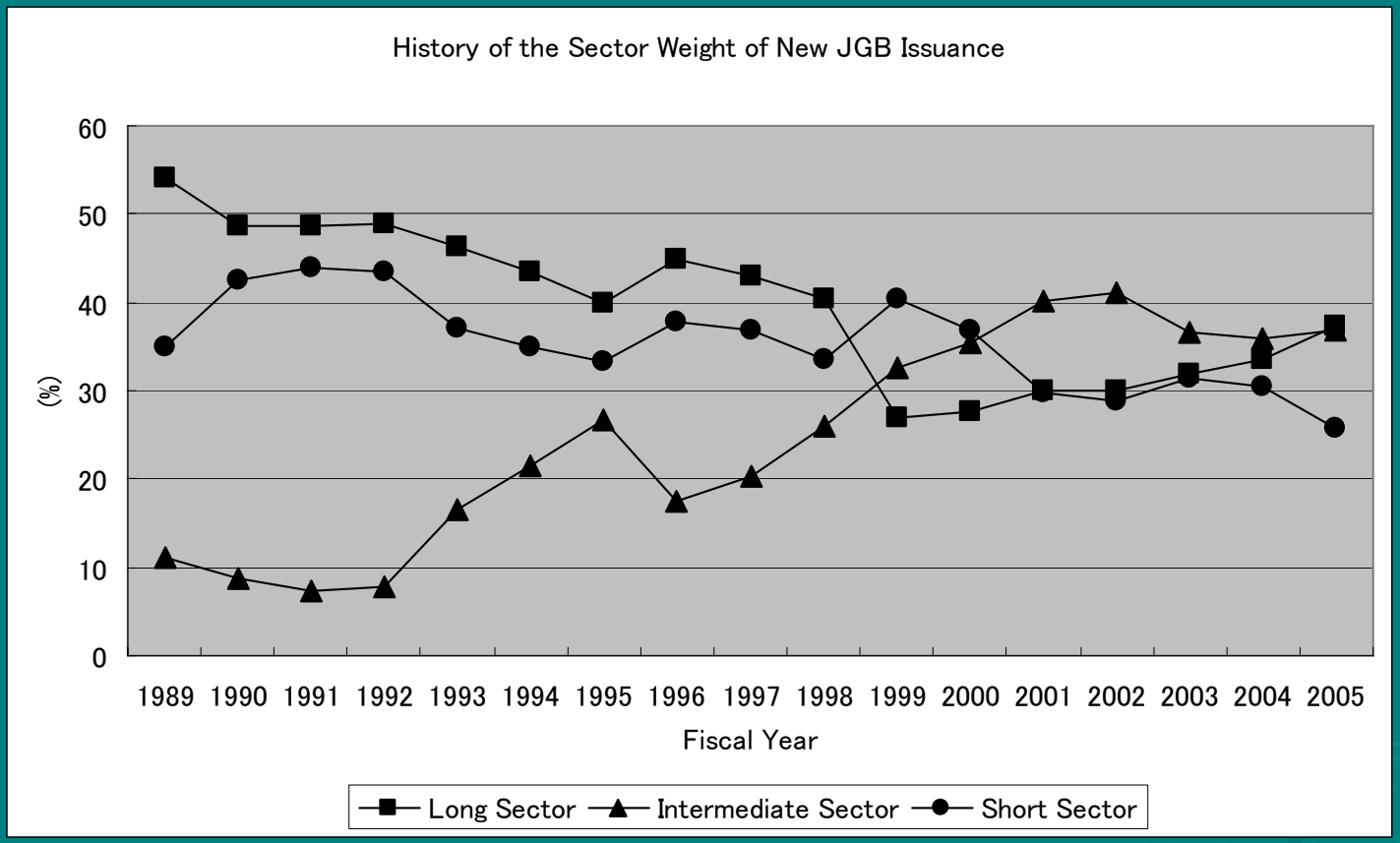
History of JGB Outstanding Amount and its Ratio to GDP



History of the Sector Weight of New JGB Issuance

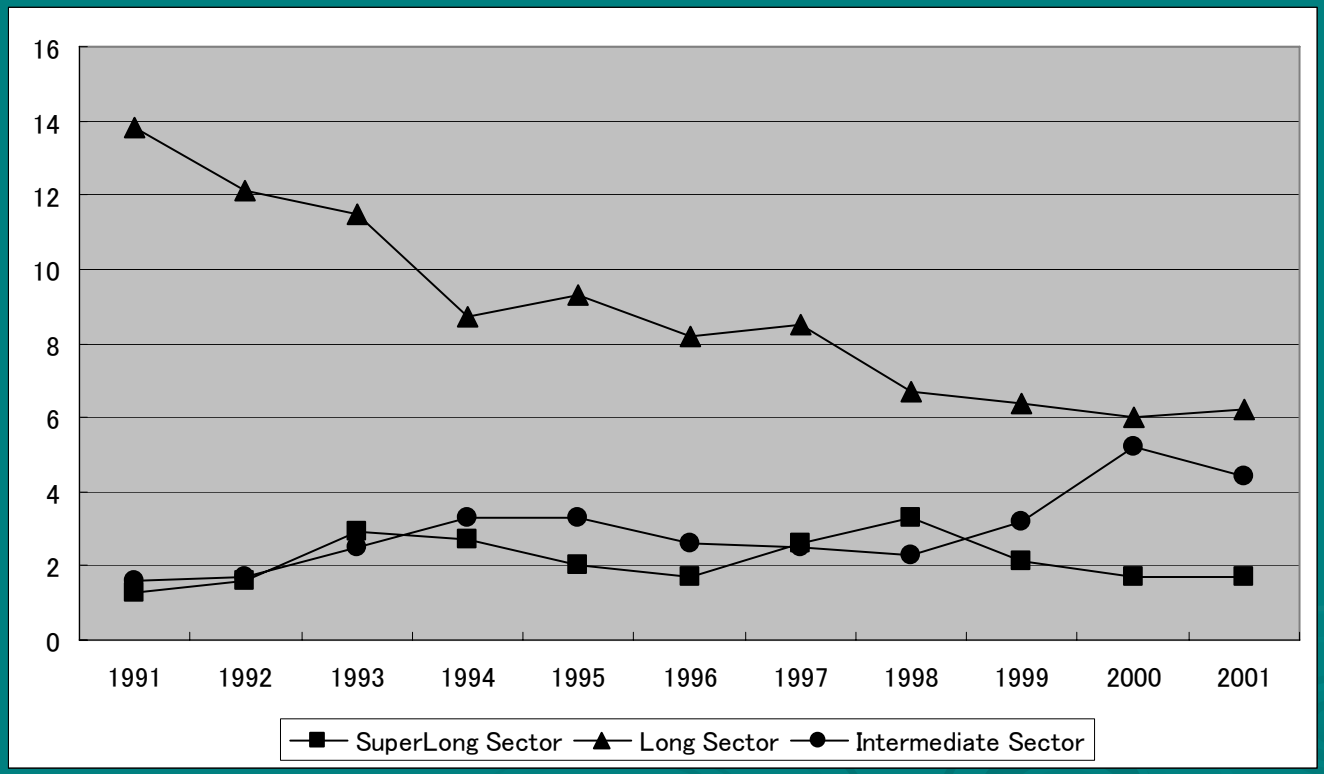


Preceding Research

- Efficiency～Liquidity is usual perception
- Annual Trading Frequency
- Bid/Ask Spread
- Existence Rate of Quoted Price
- Price Impact in the Execution
- Amount of the order around current execution price (板の厚さ)

Annual Trading Frequency

- Annual Trading Frequency＝Annual Trading Volume ÷ Fiscal Year End Outstanding Amount



Bid/Ask Spread

In Year 1998:

- Benchmark：0.5BP
- Maturity Over 10Y：2～4BP
- Maturity 7～10Y：0.5～1BP
- Maturity 2～7Y：2BP
- Maturity Less Than 2Y：2～4BP

When did the JGB become efficient?

Efficient: All the JGB sectors are fairly priced in the relative basis

Three Models to quantify the efficiency of the JGB market

- Model1

  Relative comparison of bond yields

- Model2

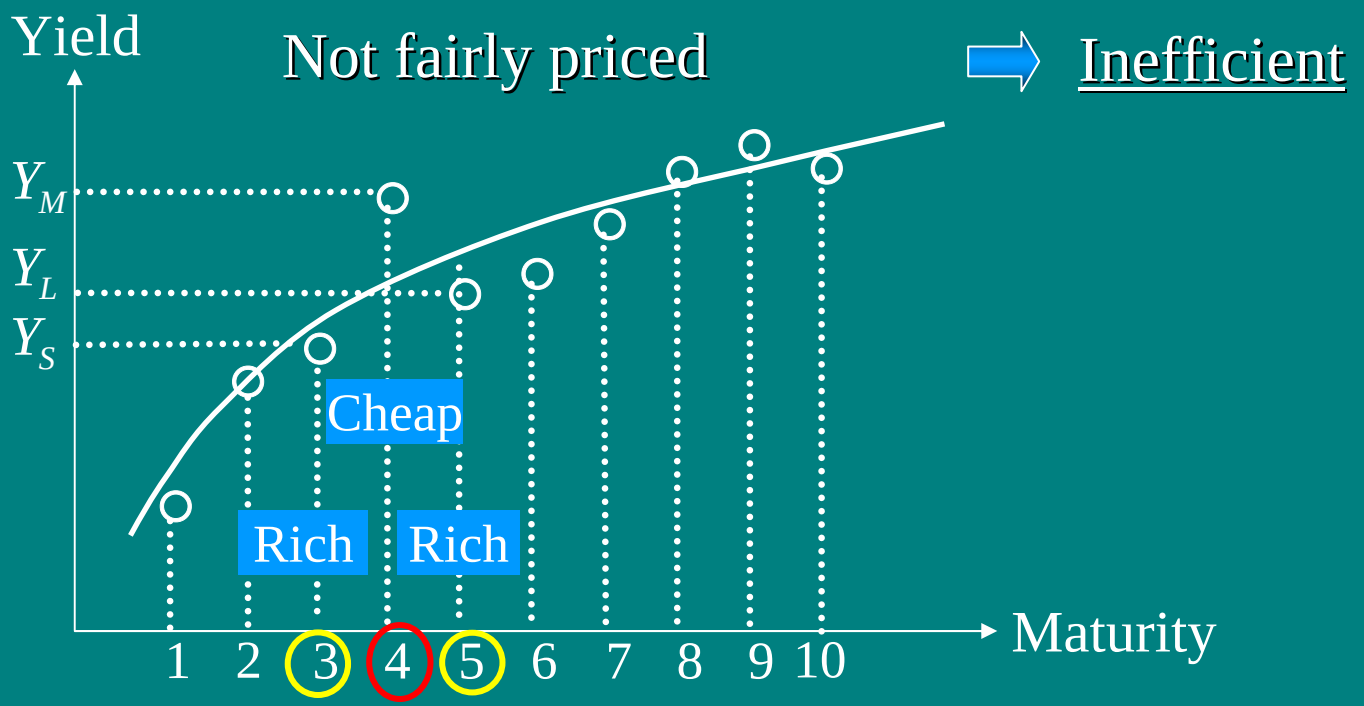
  Price correction speed of the bond

- Model3

  Timing of the change in efficiency

Model1

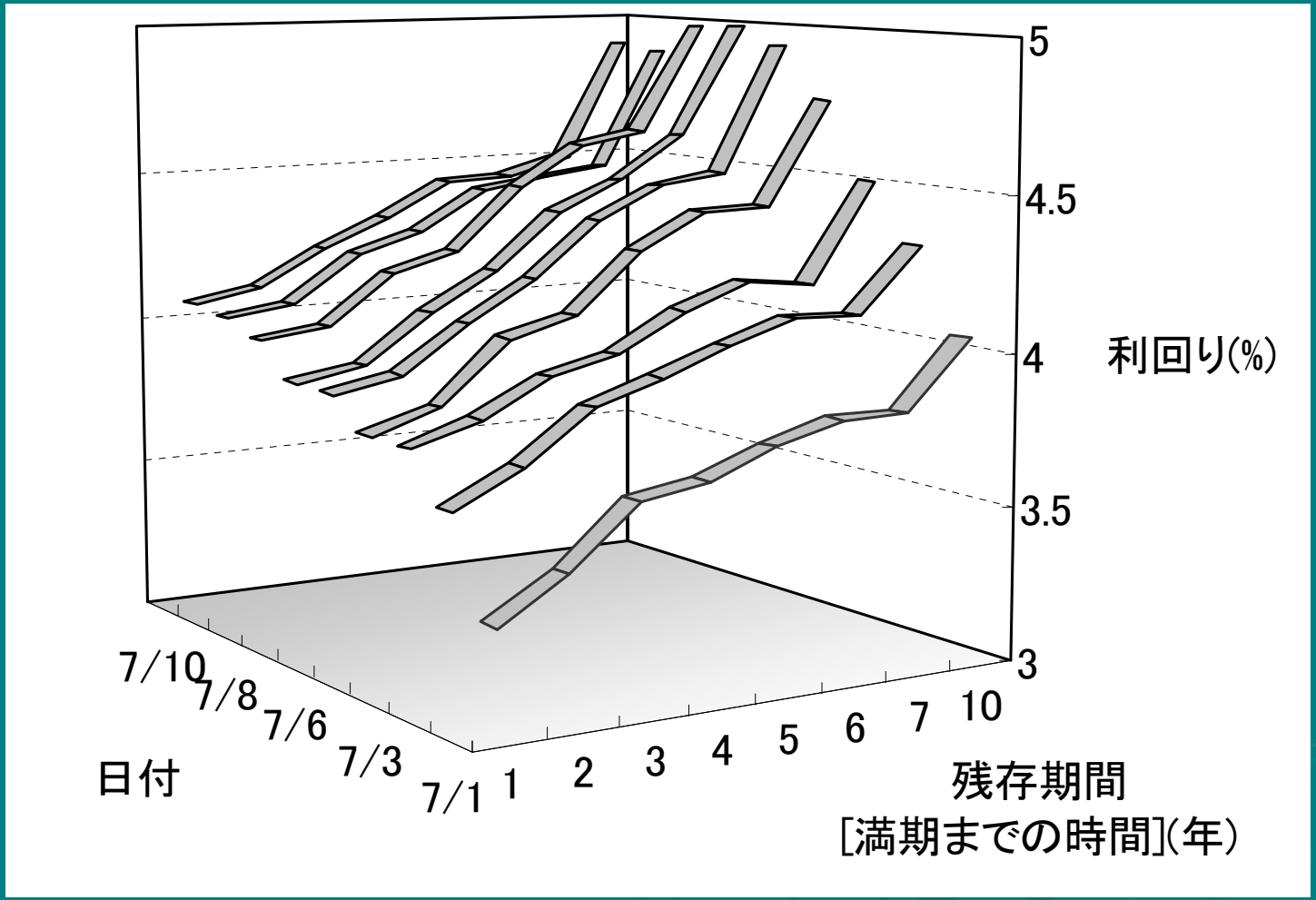
- **Relative comparison of bond yields**



What kind of model is appropriate for the comparison?

Spline-curve, Factor Analysis, Butterfly Spread

Yield Dynamics

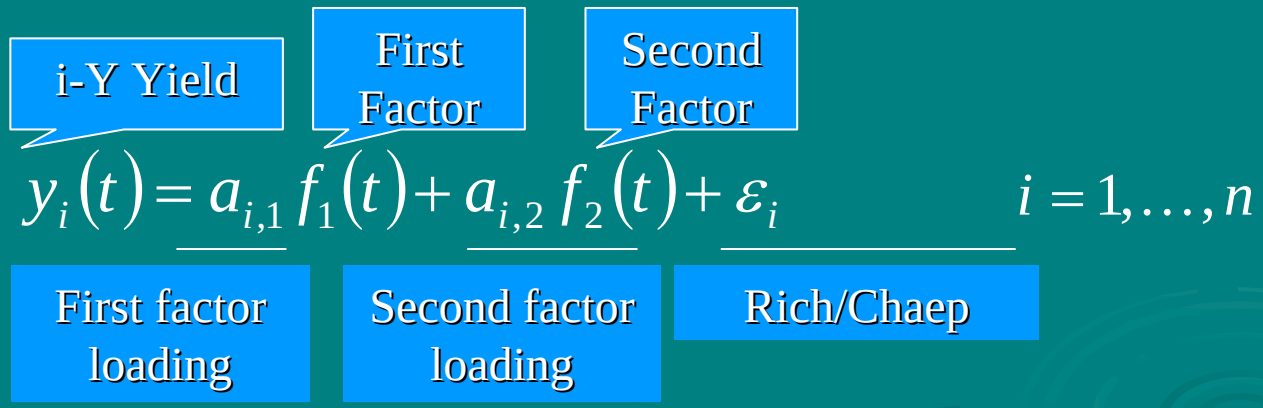


Time-series-wise relative comparison of bond yields

- Factor Analysis

The yield of each maturity bond is represented by the linear combination of factor loading (maturity specific) and the common factor (time series) .

The difference between the actual yield and the represented yield clarifies trading opportunity.



- Regression Based Butterfly Analysis (Industry)

Butterfly Spread Analysis

Y_S , Y_M , Y_L : Three different maturity bond yields from the short end

$$Y_M - Y_S = \alpha(Y_L - Y_S) + \beta + \varepsilon$$

$$Y_M - \{(1-\alpha)Y_S + \alpha Y_L + \beta\} = \varepsilon$$

⇐ Butterfly Spread

(4Yyield)　(3Yyield) (5Yyield)

Relative comparison of the yields based on the butterfly spreads

One evaluation model of the market efficiency

Important remarks on empirical analysis

- **What is the criteria of fairness in the butterfly analysis?**

※ **The butterfly spread is not corrected when it stays within Bid/Offer spread**

⇒ Introduce some thresholds

- **How to remove the effects of yield level and market volatility?**

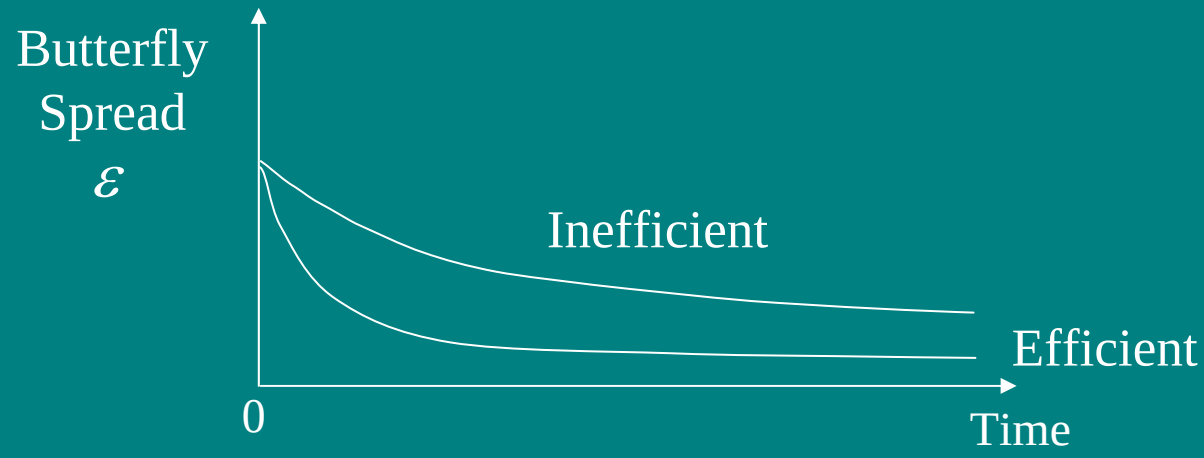
$$|\varepsilon| = \gamma Y_M + \delta\sigma + \xi$$ ⇒ Use ξ

※ When the coefficients are not statistically significant, we may use butterfly spread itself.

Count # of the business days that the butterfly spread exceed the threshold quarterly basis

Model2

○ Focus on the correction speed of the richness/cheapness



Once the butterfly spread exceeds the threshold, its dynamics follows:

$$d\varepsilon_t = -\kappa\varepsilon_t dt + \sigma_{SP} dW_t$$

κ : Mean-reversion parameter σ_{SP} : Volatility

※ **Half lives of the butterfly spread**: $\tau = \frac{1}{\kappa}\ln 2$

⇒ Another evaluation model of the market efficiency

Model3

- The model to capture the timing of the change in efficiency

Model1 : Quantify # of the butterfly spreads that exceed the threshold quarterly basis.

Model2 : Quantify the average half-lives of the butterfly spreads (Dates) quarterly basis.

$$Y_t \sim \begin{cases} POI(\lambda) & t = 1, \cdots, k \\ POI(\phi) & t = k+1, \cdots, n \end{cases}$$

λ : Intensity in Inefficient

ϕ : Intensity in Efficient

n : # of data, k : **the timing of the change**

Markov Chain Monte Carlo Method (MCMC)

MCMC

(λ, ϕ) Priors : $\lambda \sim Gamma(a_0, b_0), \phi \sim Gamma(c_0, d_0)$

k Prior : discrete uniform distribution on 1, 2, ⋯,n.

(λ, ϕ) Posteriors : $\lambda \sim Gamma(a_1, b_1), \phi \sim Gamma(c_1, d_1)$

Where, $a_1 = a_0 + \sum_{t=1}^{k} y_t, b_1 = b_0 + k, c_1 = c_0 + \sum_{t=k+1}^{n} y_t, d_1 = d_0 + (n-k)$

k Posteriors :

$$\pi(k|\lambda, \phi, y) = \frac{w_k}{\sum_t w_t}, \qquad w_k = \lambda^{a_1 - 1} \phi^{c_1 - 1} \exp\{-(\lambda - \phi)k\}$$

Method of the Empirical Analysis

Model1

STEP1-1:

In each quarter, derive ξ based on the daily data

STEP1-2:

In each quarter, count # of days that the butterfly spread ξ exceeds the threshold.

Model2

STEP2-1:

Derive ξ as in STEP1-1

STEP2-2:

Estimate the mean-reversion parameter of ξ

STEP2-3:

Compute the averages of the half-lives τ for all butterfly trade combination

Model3

Estimate the timing of the change in market efficiency

Data and the Setting

○ Data periods

Jan.4.1989～Mar.31.2005

(4Q1988～4Q2004)

○ JGB Yields

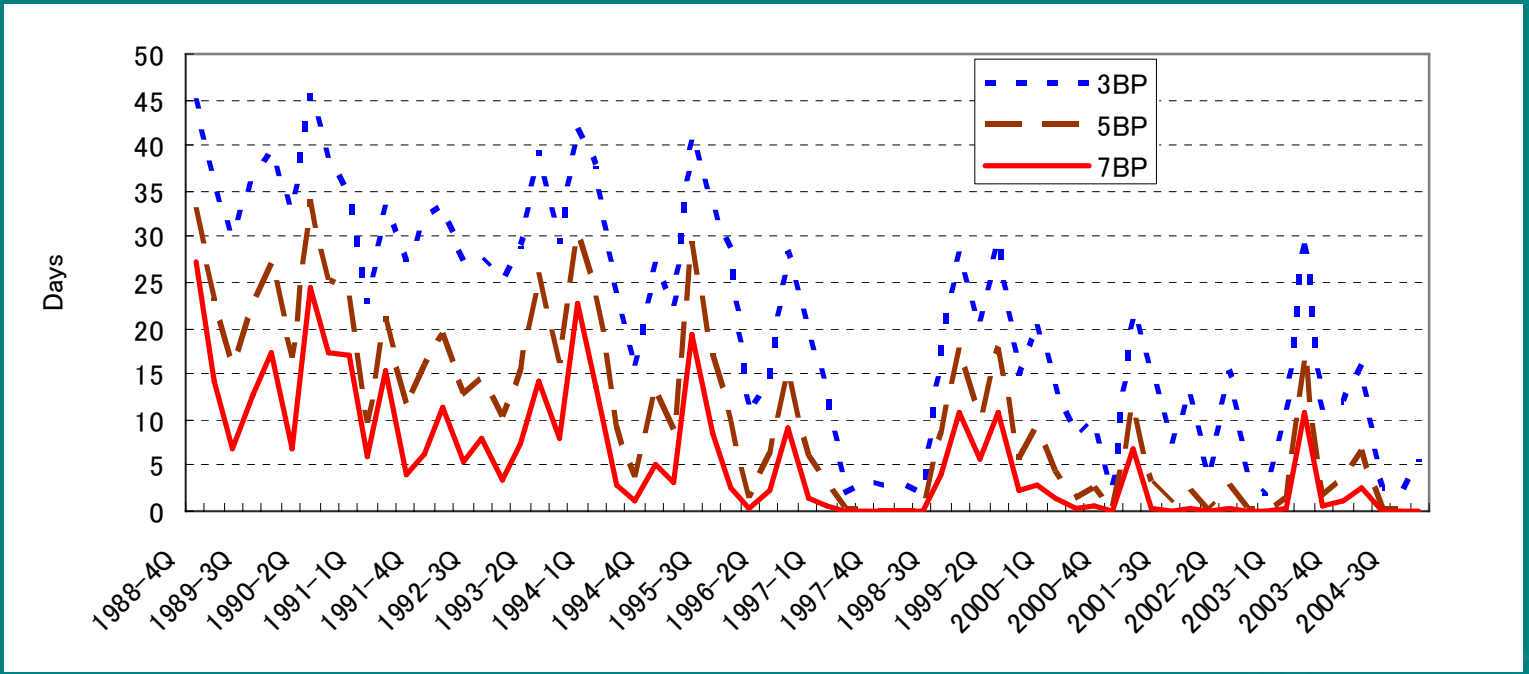
2Y・5Y・7Y・10Y・20Y JGB Yields

(10 kinds of butterfly spreads)

○ Threshold Values

3BP・5BP・7BP (Three kinds of settings)

Average # of days for which all kinds of butterfly spread ε exceeded each threshold value

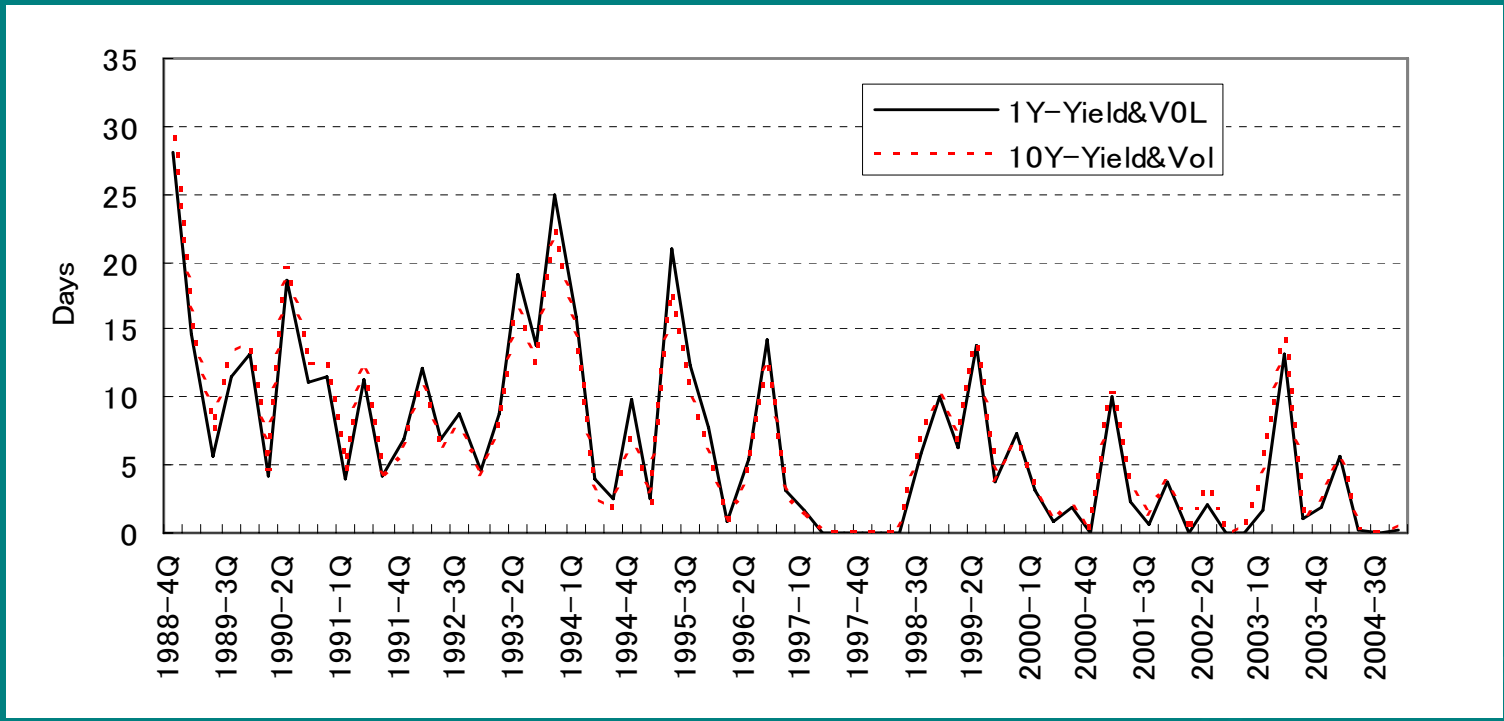


$\Rightarrow$ Decreased in late 1990s

The effects of yield level and volatility

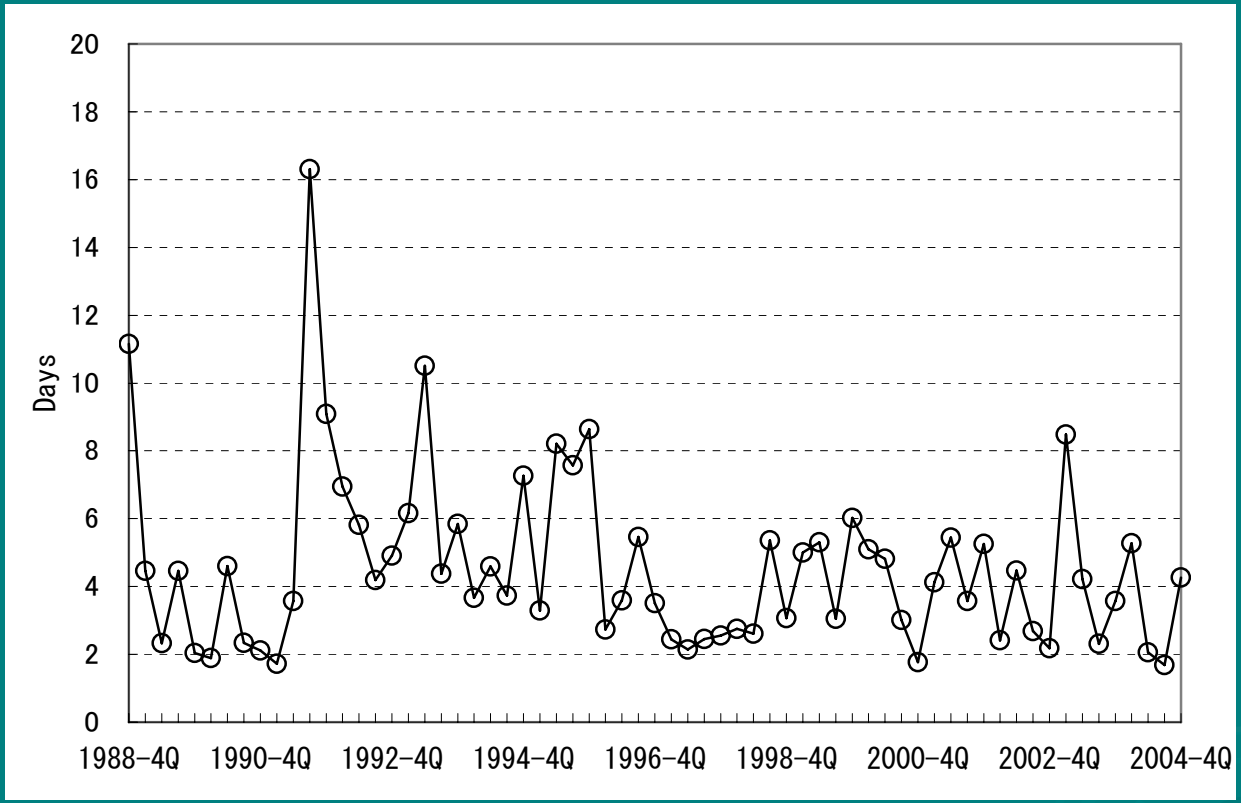
	1-Year Yield		Volatility			10-Year Yield		Volatility		
	γ	t-value	δ	t-value	R^2	γ	t-value	δ	t-value	R^2
"2-5-7"	0.29	19.3	0.024	15.4	0.18	0.46	23.8	0.021	13.8	0.21
"2-5-10"	0.46	21.0	0.025	11.1	0.16	0.64	22.4	0.023	10.2	0.17
"2-5-20"	0.52	19.4	0.028	10.1	0.14	0.63	17.5	0.028	10.0	0.12
"2-7-10"	0.40	20.5	0.023	11.4	0.16	0.56	22.0	0.021	10.5	0.17
"2-7-20"	0.52	18.1	0.022	7.5	0.11	0.58	15.0	0.023	7.8	0.09
"2-10-20"	0.40	18.9	0.022	10.2	0.13	0.48	16.9	0.023	10.1	0.12
"5-7-10"	0.29	20.3	0.015	10.6	0.15	0.43	23.3	0.013	9.3	0.17
"5-7-20"	0.32	18.7	0.016	9.3	0.13	0.45	19.7	0.015	8.5	0.14
"5-10-20"	0.33	21.4	0.023	14.1	0.18	0.47	22.9	0.021	13.2	0.20
"7-10-20"	0.26	19.1	0.017	12.2	0.15	0.41	22.9	0.015	10.8	0.18

Average # of days for which all kinds of butterfly spread ξ exceeded each threshold value



$\Rightarrow$ Decreased in late 1990s

Averages of the half-lives for all butterfly trade combinations



⇒ Decreased in late 1990s

Parameter estimation results for Model3 based on the Model1results ε : all the quarters

	Threshold Value	Mean	S.D.	95%Low	95%High
λ	3BP	31.2	0.34	30.6	31.9
	5BP	18.5	0.26	18.0	19.0
	7BP	10.8	0.21	10.4	11.2
ϕ	3BP	12.3	0.19	12.0	12.7
	5BP	4.5	0.11	4.3	4.8
	7BP	2.3	0.08	2.2	2.5
k	3BP	30.3	0.03	30.3	30.4
	5BP	29.2	0.03	29.1	29.2
	7BP	27.8	0.05	27.7	27.9

The timing of the change in market efficiency is around k=30 (Q1FY1996)

Parameter estimation results for Model3 based on the Model1results
ε: excluding Q21997-Q21998

	Threshold Value	Mean	S.D.	95%Low	95%High
λ	3BP	29.8	0.13	29.5	30.0
	5BP	17.4	0.10	17.2	17.6
	7BP	10.5	0.07	10.4	10.7
ϕ	3BP	13.2	0.09	13.0	13.4
	5BP	5.1	0.16	4.8	5.4
	7BP	2.5	0.03	2.4	2.6
k	3BP	34.4	0.11	34.2	34.6
	5BP	32.3	0.32	31.7	32.9
	7BP	29.6	0.12	29.4	29.9

The timing of the change in market efficiency is around k=30～35 (k=30:Q1FY1996)

Parameter estimation results for Model3 based on the Model1results ξ : all the quarters

	Control Yield	Mean	S.D.	95%Low	95%High
λ	1Year	10.1	0.19	9.7	10.4
	10Year	9.9	0.19	9.5	10.3
ϕ	1Year	3.2	0.10	3.0	3.4
	10Year	3.4	0.11	3.2	3.6
k	1Year	34.4	0.29	33.8	35.0
	10Year	32.7	0.29	32.1	33.2

The timing of the change in market efficiency is around k=32～35 (k=30:Q1FY1996)

Parameter estimation results for Model3 based on the Model1results

ξ : excluding Q21997-Q21998

	Control Yield	Mean	S.D.	95%Low	95%High
λ	1Year	9.9	0.06	9.8	10.0
	10Year	9.8	0.08	9.7	10.0
ϕ	1Year	3.7	0.04	3.6	3.7
	10Year	4.3	0.06	4.2	4.4
k	1Year	35.5	0.12	35.3	35.7
	10Year	31.5	0.20	31.1	31.8

The timing of the change in market efficiency is around k=31～36 (k=30:Q1FY1996)

Parameter estimation results for Model3 based on the Model2 results τ : all the quarters

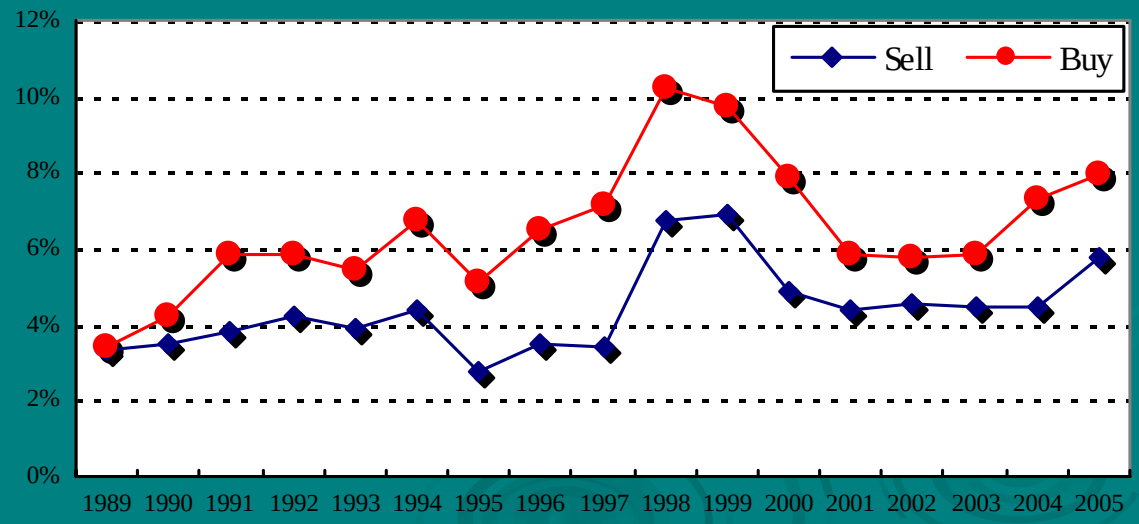
	Mean	S.D.	95%Low	95%High
λ	5.4	0.13	5.1	5.6
ϕ	3.8	0.11	3.6	4.0
k	33.1	0.10	32.9	6.7

The timing of the change in market efficiency is around k=33 (k=30:Q1FY1996)

Background of the change in JGB market efficiency

- Deregulations on repo/reverse market
- Regarding the issuance, from syndication to competitive bidding
- Overseas investors participate in the market
- Increasing variety of available JGB

Percentage of overseas investors in JGB market



Summary

○ We examined the change in the market efficiency.

We introduced three models.

Model1：Relative comparison of bond yields

Model2：Price correction speed of the bond

Model3: Timing of the change in efficiency

Around FY1996, the JGB market became efficient

- MoF and TSE accelerated JGB market reform. (Repo)
- The presence of overseas investors