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Discussion Paper No. 253

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February, 2010

TOHOKU ECONOMICS RESEARCH GROUP

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Japanese Interest Rate Swap Pricing*’**

by

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February, 2010

Keywords: swap spread, Japanese swap pricing, time-varying coefficient
JEL Classification Number: G12; G14; C10

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* The second and third authors’ research were respectively supported by Grant-in-Aid for Scientific Research (19530287) from Japan Society for the Promotion of Science) and Grant-in-Aid 20530271 from the Ministry of Education, Culture, Sport, Science and Technology of Japan.
** An earlier version of this paper was presented at the All China Economics (ACE) International Conference, Hong Kong in December, 2009. The authors are greatful for the participants. Many constructive comments from J. A. Batten are particularly helpful for improving the paper.
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Abstract:

This paper investigates the two questions on the pricing of interest rate swap in the Japanese market by applying a time varying coefficient regression model: (i) Do the risk factors which determine the spread in the US market also hold in the Japanese market? (ii) How does the degree of sensitivity of the swap spread to the risks vary over time (in particular, focusing on the impact of the "Asian financial crisis" and the "global financial crisis")?

Both default risk of counter party and liquidity risk price the swap spread in the Japanese interest rate swap market. But, influences to swap pricing of these two risks are somewhat different. Roughly speaking, liquidity risk plays more important role in shorter maturities and default risk is more important for longer maturities. The above two kind of risks play different roles during the financial crises of the "Asian financial crisis" in 1997 to1998 and the "global financial" crisis from 2007. The liquidity risk was a key factor in the former crisis, but not in the latter crisis for longer maturities. Default risk of LIBOR does not clearly display any determinants in the Japanese markets.

1. Introduction

The swap buyer makes a fixed interest payment in exchange for a variable cash flow based upon a floating London Interbank Offered Rate (LIBOR). The interest rate that determines the fixed payment is called the swap rate. The interest rate swap spread defined by the swap rate minus the par yield (i.e., a coupon rate when the price equals the face value) on a Treasury bond of the same maturity. In practice, the swap spread is the main pricing variable of an interest rate swap. For example, a market participant might accept a market maker's bid quote of, say, a swap spread of 40 basis points for a 5-year swap against 3-month LIBOR. If the current yield on a 5-year Treasury note is 5.00%, then, by accepting this quote, the participant has agreed to pay LIBOR and receive a fixed rate of 5.40% (Brown, Harlow, and Smith, 1994, p. 76, footnote 2). Such an actual institutional pricing of swap rate (adding some risks to the par yield on a Treasury bond of the same maturity) implies the pricing based on the par yield on a Treasury bond and also induces the co-integration (long-run equilibrium) in statistical sense between the swap rate and the par yield on a Treasury bond: see Morris, Neal, and Rolph (1998). On the other hand, the actual institutional pricing of swap rate is supported in a theoretical sense. Cooper and Mello (1991) modeled an interest rate swap as the equivalent of an exchange of risky floating-rate bonds for risky fixed-rate bonds. As easily induced by these, when both bonds are default-free like Treasure bonds and bills, the swap rate should be the same as the par yield on a Treasury bond. The standard interest rate swap rate adds the risk premium to the par yield on a Treasury bond, supporting the institutional pricing methods.

Based on the institutional and theoretical pricing, what kinds of risk premium are added to the interest rate swap? [1] Or what is determinant of the interest rate swap spread? Grinblatt (1995) attributes the swap spread to the liquidity difference between Treasure bonds and Eurodollar borrowings. Longstaff and Schwartz (1995), Duffie and Huang (1996) and Lekkos and Milas (2001), Blanco, Brennan and Marsh (2005), In, Brown and Fang (2003), and Afonso and Strauch (2007) model swap spreads as a risk premium to compensate swap counterparties for various risks. Their results were supported by the empirical tests. However, Lekkos and Milas (2001) have noted that the impact from changes in the term structure on swap spreads is not uniform across swap maturities. Hung and Chen (2007) find that liquidity premium is the only contributor to the 2-year swap spread variance in monetary tightening cycles, and the impact of default risk varies across both monetary cycles and swap maturities. They have analyzed whether the relative importance of these determinants and consequently the swap spreads generating process vary between the different monetary policy regimes in the USA.

However, the monetary policy and market conditions in Japan are very different from those of the USA. Hence, the following questions naturally arise: (i) Do the risk factors which determine the spread in the US market also hold in the Japanese market? (ii) How

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[1] A natural question arises as to how the swapping firms obtain benefit or surplus from swaps to compensate the swap counterparties: Lang et al (1998). Titman (1992) and Li and Mao (2003) investigate the investor's behaviors on the interest rate swap. These are in different research stream for interest rate swap from our research.

does the degree of sensitivity of the swap spread to the risks vary over the different market conditions? The growth of interest rate derivatives from 1990 to 2006 in the Japanese market stands conspicuous. Interest rate options increased greatly to 44 trillion USD, while interest rate swaps soared over one trillion to 230 trillion USD[2]. Although, Japanese yen interest rate swap now plays a pivotal role in the global market, we have only scarce research on the Japanese market so far. Therefore, this research will be important to shed a light on the swap pricing.

The purpose of this paper is to provide the Japanese swap pricing model and to investigate empirically whether the three risk factors of default risk of LIBOR, liquidity risk and default risk of counterparty determine the swap spread. Further, we measure how the swap spread pricing the risks varies over the sample periods from 1996 to 2009 (in particular, focusing on the impact of the "Asian financial crisis" and the "global financial crisis"). We apply the time varying coefficient regression model with an EGARCH error term.

The empirical study in this paper reveals the following facts. Both default risk of counter party and liquidity risk price the swap spread in the Japanese interest rate swap market. However, these two risks played different role during the two financial crises of the Asian crisis in 1997 to1998 and the global financial crisis originated by the “subprime loan problem” in 2007. The liquidity risk was a key factor in the Asian financial crisis, but not in the global financial crisis for relatively long term maturities. Default risk of LIBOR does not display any clear determinants in the Japanese markets.

The paper is organized as follows: Section 2 sketches the Japanese interest rate swap markets. Section 3 explains the Japanese swap pricing model and statistical methods. Section 4 describes data and preliminary analysis. Section 5 discusses the results of empirical study on the pricing model for the Japanese market and Section 6 concludes the paper.

2. Japanese Interest Rate Swap Markets

The market for interest rate derivatives, in general, and for swaps, in particular, has grown exponentially in the last decade. Recent estimates indicate that in the notional outstanding volume of transactions of privately negotiated (over-the-counter) derivatives at the end of December 2007, the total notional amount of interest rate swaps outstanding amounted to $310trillion from that of $29 trillion at the end of 1997[3].

Among the major players, Japanese yen interest rate swap plays a pivotal role in the global interest rate derivatives market. It amounts to an average of 17% of the total outstanding interest rate derivatives worldwide. Given the importance of the yen in international trade and finance, it is not surprising that yen interest rate swaps form a

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2 See Bank for International Settlements (2007, pp.7, Table1).

3 At that period, all counterparties (net) notional amounts outstanding are Euro 119, US dollar 96, Japanese yen, 49, and Pound sterling 23 (in millions of US dollars). And interest rate swap market shares by currency are Euro 40%, USD 34%, Yen 17% and Pound sterling 8%. Source: BIS(2009) OTC derivatives market activity in the second half of 2008

substantial proportion of this volume, next to those denominated in US dollars. The expansion in the Japanese yen interest rate swap speaks for the importance of understanding the yen swap pricing mechanism.

Interest rate swaps are sometimes quoted at a margin or spread above the government bond nearest in maturity to the final date of the swap. This is because the government bonds are often used as a partial hedge for mismatched swap portfolios or books. But in JPY swaps, we have the different quotation system. Interest rate swaps in Japan are not quoted by spread, but are quoted by absolute level. This is partly because of the historical background of JPY interest rate swaps.

In mid 1980's, interest rate swap in Japan has launched. Many Japanese banks started to run Swap desks, to hedge their swap position. In 1986, a US bank started market make of the interest rate swaps in the Japanese market. At that time, JGB was thought to be "kinky" market. Transactions are concentrated on "benchmark issue"(*shihyo meigara*), arbitrages were insufficient. For these reasons, the Japanese interest rate swap rates, not the JGB rate, plays as a reference rate for mid to long term transaction, quotation was not based spreads over JGB yields.

The situation began to change in late 1990's. The financial deregulation accelerates, and the Ministry of Finance came to issue JGB of many varieties in maturity. Trades dispersed, and the arbitrage became active and the role of the "benchmark issue" was over by the end of March 1999.

3. Swap Pricing Model and Statistical Methodology

3.1 An Interest Rate Swap Pricing Model

An interest rate swap is a contractual agreement for one party to pay a fixed rate interest every period in exchange for receiving a stream of cash flows based upon a floating rate interest every period (say, LIBOR), where both rates are measured in annual bases.

First, we consider n swap settlements between long-run government bond par yield and its short-run par yield on dates 1 to n. We assume there is no default risk for the government bonds. Let us define the variables. L_0 denotes a coupon rate on the long-run government bond (fixed rate), $SHORT_i$ is a rate of 1-year government bond at time i (floating rate), S_0 denote a swap rate at time 0 (fixed rate), r_i is a floating interest rate of default free pure discount bond of i-year maturity (i.e. $1/(1+r_i)^i$ is discount factor for time i). Then, no arbitrage condition leads to the equation

$$\sum_{i=1}^{n}\frac{1}{\left(1+r_i\right)^i}S_0=\sum_{i=1}^{n}\frac{1}{\left(1+r_i\right)^i}E_0\left(SHORT_{i-1}\right) \qquad (1)$$

where $E_0()$ is the expectation operator based on the information up to time 0. We suppose that the investors hedge the $SHORT_i$ by using the following forward rate:

$$E_0(SHORT_i) = \frac{(1+r_i)^i}{(1+r_{i-1})^{i-1}} - 1 . \quad (2)$$

Then, the swap rate S_0 is determined as:

$$S_0 = \frac{\sum_{i=1}^{n} 1/(1+r_{i-1})^{i-1}}{\sum_{i=1}^{n} 1/(1+r_i)^i} - 1 . \quad (3)$$

Equation (3) implies that

$$\sum_{i=1}^{n} \frac{1}{(1+r_i)^i} S_0 A_0 + \frac{1}{(1+r_n)^n} A_0 = A_0 \quad (4)$$

where A_0 is the face value of government bond. It means that the swap rate S_0 is equal to yield to maturity of the n-year government bond (L_0) , i.e. $S_0 = L_0$.

3.2 Pricing for Swap between the n-year Government Bond and LIBOR

Second, we consider the swap between the n-year government bond and LIBOR. We define the swap spread as SP = S - L: the difference between swap rate for private bonds exchange and the long-run government bond yield. The long-run government bond yield is a swap rate for short-run for government bonds on the same maturity. Lekkos and Milas (2001), Blanco, Brennan and Marsh (2005), Huang and Chen(2006), In, Brown and Fang (2003), Huang and Chen (2007)and Afonso and Strauch (2007) consider the following. Comparing (i) the risks between the short-run private and government bond yields, (ii) the risk between the short-run government bond yield and the long run government bond yield (i.e., the swap rate of government bonds), and (iii) the risk between the long run government bond yield and the swap rate of private bonds, the swap spread SP must be expressed by a function of some risk components, such as

$$SP = f(TR, LR, DR) , \quad (5)$$

where TR (default risk of LIBOR) , LR (liquidity risk) and DR (default risk of counter party against the government bonds). Assuming linearity for simplicity, we have

$$SP_t = TR_t + LR_t + DR_t \quad (6)$$

We use Eq.(6) as a base model of theoretical analysis. We have to construct the empirical model for Eq.(6). All of risk variables are proxies made by the other financial variables. Then, Eq.(6) can be rewritten as follows:

$$SP_t = c_0 + \beta_1 PTR_t + \beta_2 PLR_t + \beta_3 PDR_t \qquad (7)$$

where PTR, PLR, and PDR are proxies for TR, LR and DR respectively. This general model nests the previously proposed hypotheses; the LIBOR risk hypothesis ($\beta_1 > 0$), the Liquidity risk hypothesis ($\beta_2 > 0$), and Default risk hypothesis ($\beta_3 > 0$). These hypotheses were supported by many previous literatures (Longstaff and Schwartz (1995); Duffie and Huang (1996); Lekkos and Milas (2001); In, Brown and Fang (2003); Afonso and Strauch (2007); Huang and Chen (2007), Grinblatt (1995) and Huang and Chen (2007)). These risks make the swap price increase. On the other hand, Morris, Neal, and Rolph (1998) found the cointegration between the swap rate and the par yield of Treasure bonds, the LIBOR risk and Default risk.

In this paper, we take the 1st difference of Eq. (6) and employ two types of empirical models. The first is the ordinary constant coefficient model as

$$\Delta \mathrm{SP}_t = \mathrm{c}_0 + \mathrm{c}_1 \Delta \mathrm{SP}_{t-1} + \beta_1 \Delta \mathrm{PTR}_t + \beta_2 \Delta \mathrm{PLR}_t + \beta_3 \Delta \mathrm{PDR}_t + \varepsilon_t \qquad (8)$$

$$\varepsilon_t \mid \mathrm{I}_{t-1} \sim \mathrm{N}\left(0, \sigma_t^2\right)$$

where Δ denotes a lag operator and the coefficients β_i ($i = 1,\ 2,\ 3$) are constant over time. In the volatility of error term, we assume EGARCH model as

$$\ln \sigma_t^2 = \phi_0 + \phi_1 \ln \sigma_{t-1}^2 + \phi_2 \left(|\varepsilon_{t-1}| / \sigma_{t-1} + \phi_3\, \varepsilon_{t-1} / \sigma_{t-1} \right). \qquad (9)$$

However, the response of investors to the risk factors may possibly differ over time depending on the state of economy. For instance, the investors may be more sensitive to the default risk of counterparty during periods of weak economy than periods of strong economy. Then the coefficient β_3 is larger during the former periods than the latter. We investigate this hypothesis by using a time varying coefficient model:

$$\Delta \mathrm{SP}_t = \mathrm{c}_0 + \mathrm{c}_1 \Delta \mathrm{SP}_{t-1} + \beta_{1,t} \Delta \mathrm{PTR}_t + \beta_{2,t} \Delta \mathrm{PLR}_t + \beta_{3,t} \Delta \mathrm{PDR}_t + \varepsilon_t \,. \qquad (10)$$

The coefficients vary over time and follow the random walk process

$$\beta_{i,t} = \beta_{i,t-1} + \eta_t, \qquad \eta_t \sim N\left(0,\ \sigma_i^2\right), \qquad i = 1, 2, 3. \tag{11}$$

where the initial values of $\beta_{1,0}, \beta_{2,0}$ *and* $\beta_{3,0}$ are given fixed, and they are regarded as parameters to be estimated. The volatility of error term is also assumed to be followed by the EGARCH process in Eq. (9). The equations (9), (10) and (11) constitute a state space representation of a time series with an unobservable state variable[4]. We can simulate the process of $\left\{\beta_{i,t}\right\}_{t=1}^{T} \left(i = 1,2,3\right)$ by Kalman filter algorithm.

4. Data and Preliminary Analysis

We use daily data ranging from March 29, 1996 to September 15, 2009 which are collected from the Bloomberg and the Nikkei Financial Quest. The number of observation is 3187. As far as we are aware, this dataset constitutes the highest frequency as well as the longest sampling period for virtually all studies on swap spreads in Japan. We define the variables in the following:

S = Swap rate, L = Government-bond yield, S – L = Swap spread

The swap rates and the Government-bond yields of 2-, 3-, 5-, 7-, and 10-year maturity are used and the swap spreads are difference between the rates with same maturity.

PTR = the proxy of LIBOR risk

Following to Huang and Chen (2007), we use the conditional volatility of 6-month-LIBOR as LIBOR risk[5].

PLR = the proxy of Liquidity risk

Grinblatt (1995) uses the spread between LIBOR and Government-bond yield to measure a proxy for liquidity risk. In a similar way, we adopt the spread between the 1-year LIBOR and the 1-year Government bond yield. For instance, during periods of weak economy, the Government bond are considered more liquid than the LIBOR, and swaps thus command a larger liquidity premium.

PDR =the proxy of Default risk of counterparty

A number of proxies for the default risk have been mentioned in the literature. Sorensen and Bollier (1994) evaluates the price of swap counterparty default. According to their model, the price of default equals the volatility of the short rate. Given that swap default spreads are unobservable, many studies including Minton (1997) and Duffie and Singleton (1997) use the corporate quality spread (Baa-Aaa), while Huang and Chen (2007) used the

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4 This type of models was used for investigating the dynamic efficiency of the stock markets in the emerging economies by Rockinger and Urga (2000), and Rockinger and Urga (2001).

5 For calculating volatility, we used the rate of change in the 6-month-LIBOR process in percentage point exposition and applied the AR(1)-EGARCH model.

spread between the corporate bond and the government bond for the same maturity. In a similar line to their argument, we use "Nikkei public and corporate bond index (Nikkei kousyasai index)" as corporate bond[6]. This index has three kinds of maturity, "short (under 3- year)", "middle (over 3- year but under 7- year)", "long (over 7- year)". We define PDR2y = CB (short) - JGB2y, PDR3y = CB(middle) - JGB3y, PDR5y = CB(middle) - JGB5y, PDR7y = CB(middle) - JGB7y and PDR10y = CB(middle) - JGB10y.

We plot all the variables used by this paper in Figures 1(1) through 1(4). From Figure1(3), we can see that there is very low interest rate period from 2001 to 2006. This period is called the "zero-interest-rate period". The "Bank of Japan Monetary Policy Meetings: Announcement of Decisions" specifies the "zero-interest-rate period" and the "quantitative easing period". The quantitative easing policy was operated from 3/19/1999 to 3/9/2006. Based on this consideration, we split the whole sample period into the three sub-periods: the pre-zero-interest-rate period (29/3/1996 to 3/16/2001), the zero-interest-rate period (3/19/2001 to 3/9/2006), and the post-zero-interest-rate period (3/10/2006 to present time). This partition is generally consistent with the feature of movements of 1 year JGB yields in Figure 1(3).

From Figure1(4), we observe the following two facts for swap spreads: (i) Swap spreads are at the low levels during the "zero interest rate period", even those for longer maturity are negative at some times in this period, while they are at the higher levels during both the pre-zero interest rate period (i.e., the periods of financial turmoil in Japan) and the post- period. (ii) The spreads for 7-year and 10-year maturity steeply decline during the period of the "global financial crisis" originated by the subprime loan problem, while the spreads for shorter maturity are relatively stable.

Figure 1(5) indicates the proxy variables of risks. We find that (i) The LIBOR risk (volatility of 6-month LIBOR) are very small during the zero-interest-rate period. (ii) The liquidity risk drastically increases after the end of zero-interest-rate period. (iii) The default risks fluctuate more widely over time than the other two risk factors do, and a hump exists in the period of the "Asian financial crisis" and also in the "global financial crisis". The graphical observation on the swap spreads and the risk factors suggests that swap spreads might be related to these risk factors, supporting the Eq.(8).

Table 1 shows summary statistics for all the variables in level used in this paper. The sample averages of the swap rates and the JGB increase along with maturity. However, the average of the swap spreads decrease with maturity. The ADF tests for the level data indicate that all variables follow unit root process, except for SP2y (2-year Swap Spread) and PTR (volatility). This fact justifies for analyzing the 1st difference of the processes. Table 2 shows summary statistics for the1st difference of swap spreads and the proxy of risk. The Ljung-Box test for the first difference process of swap spreads is significant, indicating that the spreads are serially dependent. And the Ljung-Box test for the squared process of spreads is also significant, showing heteroscedastic volatility. These findings support applying the empirical model of (8) and (9).

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[6] The data of Nikkei kousyasai index from 8/6/2002 to 9/24/2002 are missing. The number of missing data is 33. We omitted these periods from our analysis.

[INSERT Figures 1(1) to 1(5)]

[INSERT Tables 1 and 2]

As a preliminary analysis, we examined the Granger causality from PTR (volatility), PLR (Liquidity), and PDR (default) to Swap spread, even though our main interest is contemporaneous relationships between the swap spread and the risk factors. We apply the VAR(p) model with the four variables in difference form

$$y_t = (\Delta \mathrm{SP}_t, \Delta \mathrm{PTR}_t, \Delta \mathrm{PLR}_t, \Delta \mathrm{PDR}_t)';$$

$$y_t = A_0 + A_1 y_{t-1} + \ldots + A_p y_{t-p} + u_t, \quad (12)$$

where the length of lags is determined by the SIC (Swartz information criterion). Table3 summarizes the results of the Granger causality tests. Roughly speaking, PLR (Liquidity) does Granger cause Swap spread, but PDR (default) does not cause. However, the testing results of PTR (volatility) are not conclusive. These findings are basically consistent with the results of Huang and Chen (2007).

[INSERT Table 3]

5. Empirical Results

(i) Non time-varying coefficient model

Tables 4(1) to (4) report the estimated results in Eq. (8) and (9) for each of 2- through 10- year maturity. The model is estimated by using the full samples and each of three sub-samples. We can see from the full sample s case of Table 4(1) that (i) the coefficients for PDR are significant for all maturities. (ii) The coefficients for PLR are significant for shorter maturities (2-year and 3-year) and insignificant for longer maturities (5-year, 7-year and 10-year). (iii) The coefficients for PTR are not significant for any maturities. These three facts are common to all three sub-sample periods with a few exceptions. Hence, we can safely conclude that (i) Liquidity risk plays relatively important role in swap pricing for the shorter maturities. (ii) As maturities become longer, the default risk plays relatively important role, while influence of liquidity risk become smaller. These estimated result can be intuitively acceptable, and also partially support the recent empirical studies from the US markets which find some risk factors as determinants on swap interest rates in the papers (Lekkos and Milas:2001; In, Brown and Fang:2003; Afonso and Strauch:2007; Huang and Chen:2007).

Looking closely at the values of estimated coefficients, we can see that they vary from period to period. This suggests that the coefficients of risk factors may vary over time.

[INSERT Table 4]

(ii) Time-varying coefficient model

In this subsection, we investigate how the sensitivity of the investors in the Japanese interest rate swap market to the risk factors changes over the time from 1996 through 2009. Table.5 shows the estimated results for the time varying model of Eq. (9), (10) and (11). The coefficients of $\beta_{1,0}, \beta_{2,0}$ *and* $\beta_{3,0}$ are the estimates of initial values of $\beta_{1,t}, \beta_{2,t}$ *and* $\beta_{3,t}$ respectively, and $\sigma(\beta_i)$. are the estimates of σ_i . In the time varying coefficient model, the estimates of $\beta_{1,t}, \beta_{2,t}$ *and* $\beta_{3,t}$ move along with time.

[INSERT Table 5]

Figure 2 illustrates the estimated series of time varying coefficients for PLR and PDR[7]. The coefficients of $\beta_{2,t}$ and $\beta_{3,t}$ represent the magnitude of response to the risk factors of PLR and PDR respectively.

[INSERT Figure 2]

First, we look at the coefficients of $\beta_{3,t}$ for the default risk of the counterparty (PDR). For relatively longer maturity series, the values of $\beta_{3,t}$ are high at the beginning stage of time, and have a declining trend toward 2007. This result is consistent with our constant coefficient analysis and can be interpreted as follows. The Japanese financial institutions had been suffered from the accumulated bad loans during the 1990s and the "Asian financial crisis". Therefore, the participants in the Japanese interest swap market were highly sensitive to the default risk of the counterparty in these periods especially for longer maturities. Then, the problem of bad loans was changed for the better in 2000s. The investors were becoming less sensitive to the default risk. But, the "global financial crisis" hit the countries over the world in 2007, and the Japanese swap spread seems to have become sensitive to the default risk again. This tendency is not clear for 2 year maturities, but as the maturity become longer, the down slope tendency is becoming apparent. However, the series of $\beta_{3,t}$ for 10-year maturity looks flat in the period of the "global

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7 We omitted graphs for the coefficients of PTR ($\beta_{1,t}$) because the coefficient stays fixed constant at the level of initial value for each year of maturity. This is clearly seen from the fact $\sigma(\beta_1) = 0$ in Table 5.

financial crisis". This may be concerned with steep drop of swap spread in the same period although we cannot identify the reason behind this observation. These empirical results are coincident with our constant coefficient analysis.

Second, we move to the coefficients of $\beta_{2,t}$ for the liquidity risk (PLR). We can observe from Figure 2 that (i) for all maturities, $\beta_{2,t}$ does not have any obvious time trends, but fluctuates wildly in comparison with $\beta_{3,t}$. (ii) For all maturities, $\beta_{2,t}$ has a big hump around 1997, which may be a reflection of rising risk caused by the "Asian financial crisis". The liquidity risk played a dominant role in this period. (iii) For 2-year and 3-year maturities, $\beta_{2,t}$ definitely increased in the period of the global financial crisis after 2007, while for longer maturities it did not increase in this period. The short term interest rate swap market in Japan was quite a sensitive to the liquidity risk caused by the global financial crisis. These results are coincident with our analysis by using the constant coefficient model.

Finally, we compare the values of $\beta_{2,t}$ and those of $\beta_{3,t}$. The Japanese economy has experienced the two financial crises of the "Asian financial crisis" in 1997 to1998 and the "global financial crisis" originated by the subprime loan problem in 2007. By careful visual examination of Figure 2, we find that (i) the graph of $\beta_{2,t}$ is basically above that of $\beta_{3,t}$ for 2-year and 3-year maturities, the two graphs are roughly even for 5-year maturity, and the order of magnitudes of the two graphs is reversed for the 7-year and 10-year maturities. (ii) During the "Asian financial crisis", $\beta_{2,t}$ is almost always above $\beta_{3,t}$ for all maturities although the difference is getting small along with length to maturity. The liquidity risk dominated the default risk in this period. (iii) During the "global financial crisis", $\beta_{3,t}$ dominates $\beta_{2,t}$ for 5- year, 7-year and 10-year maturities, but $\beta_{2,t}$ dominates $\beta_{3,t}$ for 2-year maturity.

The default risk and the liquidity risk played different role in the two financial crises for determining the swap spread in the Japanese interest rate swap market. For shorter maturities, in particular, 2- year, the liquidity risk is a key factor both in the period of the "Asian financial crisis" and the "global financial crisis". However, for 5-year and 7-year maturities, the liquidity risk played dominant role in the former crisis, while the default risk played more important role in the latter crisis.

6. Concluding Remarks

In this paper we investigated the two questions: (i) Do the risk factors which determine the spread in the US market also play the same role in the Japanese market? (ii) How does the degree of sensitivity of the swap spread to the risks vary over the sample periods from 1996 to 2007 (in particular, focusing on the impact of the recent "global financial crisis").

We examined the three risk factors of default risk of LIBOR, default risk of counter party and liquidity risk. The findings of our study are as follows. First, both default risk of counter party and liquidity risk price the swap spread in the Japanese interest rate swap market. But, influences to swap pricing of these two risks are somewhat different. Roughly speaking, liquidity risk plays dominant role in the shorter maturities while default risk is more important for the longer maturities. In particular, the two risks played different role during the two financial crises of the "Asian financial crisis" in 1997 to1998 and the "global financial" crisis from 2007. The liquidity risk was a key factor in the Asian financial crisis, but not in the global financial crisis for longer maturities. Second, default risk of LIBOR does not clearly display a determinant in the Japanese markets. The estimated results support the previous empirical work from the US markets.

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Table.1 Summary Statistics for Level of the Variables

Swap rate(St)	SR2y	SR3y	SR5y	SR7y	SR10y
Mean	0.591	0.765	1.120	1.439	1.798
Std Dev.	0.392	0.453	0.543	0.586	0.585
Skew	0.566	0.713	0.820	0.854	0.807
Kurt	2.655	3.413	3.959	4.058	3.993
ρ(1)	0.998	0.998	0.997	0.997	0.997
ADF	−2.199	−2.379	−2.465	−2.592	−2.585

JGB rate(Lt)	JGB2y	JGB3y	JGB5y	JGB7y	JGB10y
Mean	0.283	0.431	0.604	0.982	1.310
Std Dev.	0.262	0.337	0.380	0.487	0.544
Skew	0.533	0.638	0.670	0.970	1.161
Kurt	1.989	2.659	3.058	4.256	4.714
ρ(1)	0.997	0.997	0.996	0.995	0.995
ADF−test	−2.371	−2.664	−2.741	−3.074	−3.043

Swap Spread(SPt=St−Lt)	SP2y	SP3y	SP5y	SP7y	SP10y
Mean	0.161	0.161	0.137	0.129	0.111
Std Dev.	0.088	0.101	0.080	0.102	0.135
Skew	0.814	0.808	0.053	0.317	−0.122
Kurt	2.848	3.292	2.705	2.862	2.258
ρ(1)	0.985	0.988	0.985	0.989	0.990
ADF−test	−3.720**	−3.197	−3.285	−2.820	−3.018

Proxy of Risk	PDR2y	PDR3y	PDR5y	PDR7y	PDR10y
Mean	0.743	0.870	0.491	0.669	0.291
Std Dev.	0.484	0.378	0.321	0.199	0.206
Skew	0.466	0.420	0.613	0.928	1.590
Kurt	2.279	1.955	2.699	3.570	5.748
ρ(1)	0.999	0.996	0.997	0.992	0.994
ADF−test	−1.098	−1.787	−1.372	−1.952	−1.651

Proxy of Risk	PTR	PLR
Mean	1.366	0.194
Std Dev.	3.281	0.173
Skew	6.099	1.570
Kurt	54.025	4.384
ρ(1)	0.949	0.995
ADF−test	−10.651*	−2.204

Note : ρ(1) denotes 1st order auto−correlation. ADF−test denotes t−value of ADF test. The 10% , 5% and 1% critical values are -3.961, -3.411 and -3.127 respectively. "**" and "*" denote statistically significant at 1% and 5% level respectively.

Table.2 Summary Statistics for the 1st Difference

Swap Spread(SPt=St−Lt)	SP2y	SP3y	SP5y	SP7y	SP10y
Mean	0.000	0.000	0.000	0.000	0.000
Std Dev.	0.021	0.022	0.022	0.024	0.025
Skew	−0.615	−0.632	−0.453	−0.146	−1.005
Kurt	14.820	17.213	14.737	11.538	35.820
ρ(1)	−0.203	−0.213	−0.253	−0.267	−0.221
Q(12)	274.941	241.437	298.191	306.722	228.856
ρ(1)−2	0.280	0.351	0.327	0.273	0.285
Q(12)−2	997.218	1176.063	999.632	1069.909	413.349

Proxy of Risk	PDR2y	PDR3y	PDR5y	PDR7y	PDR10y
Mean	0.000	0.000	0.000	0.000	0.000
Std Dev.	0.031	0.037	0.042	0.050	0.047
Skew	-4.898	-0.221	0.058	0.046	0.031
Kurt	111.196	7.477	6.765	4.195	4.668
ρ(1)	-0.225	-0.348	-0.406	-0.431	-0.421
Q(12)	178.477	418.194	554.524	606.745	596.166
ρ(1)−2	0.023	0.253	0.340	0.352	0.354
Q(12)−2	2.076	393.131	624.921	1074.844	1058.706

Proxy of Risk	PTR	PLR
Mean	−0.002	0.000
Std Dev.	0.869	0.021
Skew	12.871	0.066
Kurt	269.650	11.071
ρ(1)	0.214	−0.217
Q(12)	289.951	207.942
ρ(1)−2	0.133	0.303
Q(12)−2	95.423	931.929

Note : ρ(1) denotes 1st order auto-correlations of 1st difference process and ρ(1)−2 denotes those of squared process. Q(12)−1 denotes the Ljung-Box Statistics of 1st difference process and Q(12)−2 denotes those of squared process. The 5% critical values are all 21.03.

Table.3 Testing Results of Granger Causality from the Risk Factors to the Swap Spread

Years to maturity	2Y	3Y	5Y	7Y	10Y
Lag-length (p)	2	3	3	3	5
Risk factors					
PTR	6.741*	0.434	2.646	3.375*	0.861
	(0.010)	(0.510)	(0.071)	(0.034)	(0.354)
PLR	6.829**	8.314**	1.934	3.789*	8.878**
	(0.009)	(0.004)	(0.145)	(0.023)	(0.003)
PDR	1.362	0.726	5.971**	0.067	0.351
	(0.243)	(0.394)	(0.003)	(0.935)	(0.554)

Note : The entries are values of test statistics which is asymptotically distributed as chi-square with p degrees of freedom. The null is that the Granger causality does not exist. P-values are in parenthesis. "**" and "*" denote statistically significant at 1% and 5% level respectively.

Table.4 Estimation Results of EGARCH Model

(1) Full Sample period (3/29/1996 - 15/9/2009 : Obs. = 3187)

Years to maturity	Const	SL(t−1)	PTR	PLR	PDR	EGARCH			
	c_0	c_1	β_1	β_2	β_3	ϕ_1	ϕ_2	ϕ_3	ϕ_4
2	0.000	−0.127	0.000	0.288**	0.043*	−0.122	0.997	0.127	0.043
	(0.000)	(0.019)	(0.001)	(0.022)	(0.018)	(0.017)	(0.002)	(0.018)	(0.022)
3	0.000	−0.118	0.000	0.139**	0.054**	−0.214	0.993	0.207	0.057
	(0.000)	(0.021)	(0.000)	(0.015)	(0.006)	(0.026)	(0.002)	(0.024)	(0.025)
5	0.000	−0.179	−0.001	0.018	0.055**	−0.244	0.991	0.228	0.054
	(0.000)	(0.022)	(0.001)	(0.014)	(0.006)	(0.048)	(0.005)	(0.027)	(0.033)
7	0.000	−0.191	0.000	0.034*	0.061**	−0.222	0.994	0.239	0.039
	(0.000)	(0.026)	(0.001)	(0.017)	(0.004)	(0.038)	(0.003)	(0.029)	(0.036)
10	0.000	−0.139	0.000	−0.002	0.053**	−0.217	0.991	0.200	0.025
	(0.000)	(0.026)	(0.000)	(0.017)	(0.006)	(0.050)	(0.004)	(0.032)	(0.033)

(2) Pre zero interest rate period (3/29/1996 - 16/3/2001: Obs. = 1191)

Years to maturity	Const	SL(t−1)	PTR	PLR	PDR	EGARCH			
	c_0	c_1	β_1	β_2	β_3	ϕ_1	ϕ_2	ϕ_3	ϕ_4
2	0.001	−0.174	−0.001	0.269**	0.230**	−0.338	0.978	0.228	0.121
	(0.001)	(0.027)	(0.001)	(0.027)	(0.028)	(0.085)	(0.009)	(0.040)	(0.048)
3	0.001	−0.238	0.000	0.143**	0.130**	−0.474	0.969	0.320	0.097
	(0.001)	(0.032)	(0.001)	(0.021)	(0.019)	(0.106)	(0.012)	(0.046)	(0.047)
5	0.000	−0.241	−0.001	0.030	0.143**	−0.473	0.970	0.344	0.042
	(0.001)	(0.037)	(0.001)	(0.019)	(0.021)	(0.088)	(0.010)	(0.041)	(0.063)
7	0.000	−0.262	0.000	0.077*	0.145**	−0.331	0.976	0.222	0.027
	(0.001)	(0.035)	(0.001)	(0.030)	(0.018)	(0.104)	(0.012)	(0.046)	(0.081)
10	0.000	−0.212	0.000	0.051	0.144**	−0.429	0.964	0.249	0.041
	(0.001)	(0.041)	(0.001)	(0.027)	(0.024)	(0.117)	(0.014)	(0.054)	(0.083)

(3) Zero interest rate period (19/3/2001 - 9/3/2006: Obs. = 1154)

Year	Const	SL(t−1)	PTR	PLR	PDR	EGARCH			
	c_0	c_1	β_1	β_2	β_3	ϕ_1	ϕ_2	ϕ_3	ϕ_4
2	0.000	−0.101	0.012	0.158**	0.037	−0.156	0.992	0.096	0.034
	(0.000)	(0.034)	(0.009)	(0.050)	(0.024)	(0.067)	(0.006)	(0.030)	(0.025)
3	0.000	−0.046	0.018	0.153*	0.050**	−0.215	0.989	0.147	0.025
	(0.000)	(0.037)	(0.011)	(0.068)	(0.009)	(0.070)	(0.005)	(0.041)	(0.039)
5	0.000	−0.100	0.021	−0.022	0.057**	−1.795	0.850	0.445	0.103
	(0.000)	(0.033)	(0.011)	(0.054)	(0.010)	(0.492)	(0.050)	(0.070)	(0.054)
7	0.000	−0.184	0.013	−0.037	0.053**	−0.612	0.965	0.373	0.017
	(0.000)	(0.050)	(0.019)	(0.070)	(0.005)	(0.146)	(0.013)	(0.058)	(0.066)
10	0.000	−0.168	0.034**	0.102	0.061**	−0.845	0.928	0.260	0.020
	(0.000)	(0.037)	(0.011)	(0.102)	(0.010)	(0.358)	(0.036)	(0.063)	(0.053)

(4) Post zero interest rate period (10/3/2006 - 15/9/2009 : Obs. = 842)

Year	Const	SL(t−1)	PTR	PLR	PDR	EGARCH			
	c_0	c_1	β_1	β_2	β_3	ϕ_1	ϕ_2	ϕ_3	ϕ_4
2	0.000	−0.025	0.001	0.205**	0.008	−0.124	0.994	0.097	0.012
	(0.000)	(0.037)	(0.001)	(0.031)	(0.014)	(0.059)	(0.006)	(0.027)	(0.032)
3	0.001	0.008	0.000	0.091**	0.027*	−0.135	0.994	0.104	0.061
	(0.000)	(0.045)	(0.001)	(0.025)	(0.012)	(0.064)	(0.005)	(0.036)	(0.050)
5	0.000	−0.011	−0.001	−0.001	0.025**	−0.277	0.985	0.183	0.064
	(0.000)	(0.038)	(0.001)	(0.021)	(0.007)	(0.080)	(0.006)	(0.057)	(0.055)
7	0.000	−0.041	−0.001*	0.005	0.058**	−0.378	0.977	0.232	0.091
	(0.000)	(0.040)	(0.001)	(0.018)	(0.007)	(0.090)	(0.007)	(0.056)	(0.040)
10	0.000	0.047	0.000	−0.051*	0.017	−0.442	0.972	0.269	−0.038
	(0.000)	(0.048)	(0.001)	(0.026)	(0.009)	(0.128)	(0.011)	(0.061)	(0.052)

Note : "**" and "*" on the columns of SP(t-1), PLR and PDR denote statistically significant at 1% and 5% level respectively. Standard errors are in parenthesis.

Table.5 Estimation Results of Time Varying Parameter Model

Year	Const	SL(t−1)	PTR		PLR		PDR		EGARCH			
	c	c_1	$\beta_{1,0}$	$\sigma(\beta_1)$	$\beta_{2,0}$	$\sigma(\beta_2)$	$\beta_{3,0}$	$\sigma(\beta_3)$	ϕ_1	ϕ_2	ϕ_3	ϕ_4
2	0.000	−0.061	−0.001	0.000	−0.050	0.036	0.066	0.040	−0.021	0.998	0.110	0.305
	(0.000)	(0.018)	(0.000)	(0.000)	(0.517)	(0.011)	(0.282)	(0.019)	(0.029)	(0.003)	(0.015)	(0.163)
3	0.000	−0.077	0.000	0.000	0.048	0.032	0.165	0.009	−0.056	0.993	0.198	0.236
	(0.000)	(0.021)	(0.000)	(0.000)	(0.157)	(0.003)	(0.018)	(0.001)	(0.016)	(0.002)	(0.022)	(0.053)
5	0.000	−0.109	−0.002	0.000	0.282	0.015	0.263	0.009	−0.143	0.982	0.308	0.121
	(0.000)	(0.136)	(0.002)	(0.001)	(0.173)	(0.045)	(0.092)	(0.001)	(0.004)	(0.001)	(0.085)	(0.206)
7	0.000	−0.112	0.000	0.000	0.330	0.049	0.254	0.004	−0.033	0.995	0.228	0.094
	(0.000)	(0.007)	(0.000)	(0.000)	(0.170)	(0.008)	(0.034)	(0.001)	(0.015)	(0.002)	(0.017)	(0.041)
10	0.000	−0.092	0.000	0.000	0.126	0.055	0.542	0.007	−0.147	0.981	0.275	0.097
	(0.000)	(0.000)	(0.000)	(0.000)	(0.180)	(0.001)	(0.056)	(0.000)	(0.004)	(0.000)	(0.016)	(0.038)

Note：The coefficients of $\beta_{i,0}$ denote initial values of $\beta_{i,t}$. (i = 1, 2, 3), and $\sigma(\beta_i)$. denote the estimates of σ_i in equation (11).Standard errors are in parenthesis.

Figure.1 (1) Swap Rate(S_t)

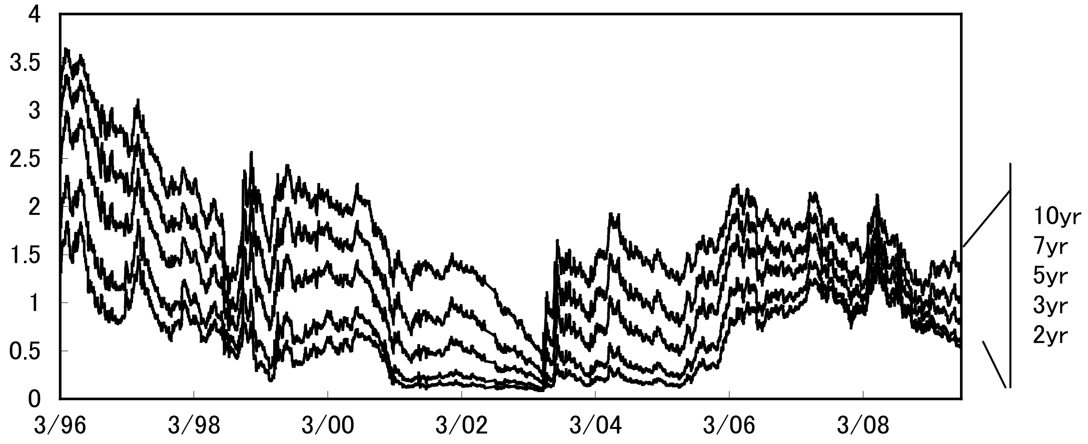


Figure.1 (2) JGB(Japanese Government Bond) rate (L_t)

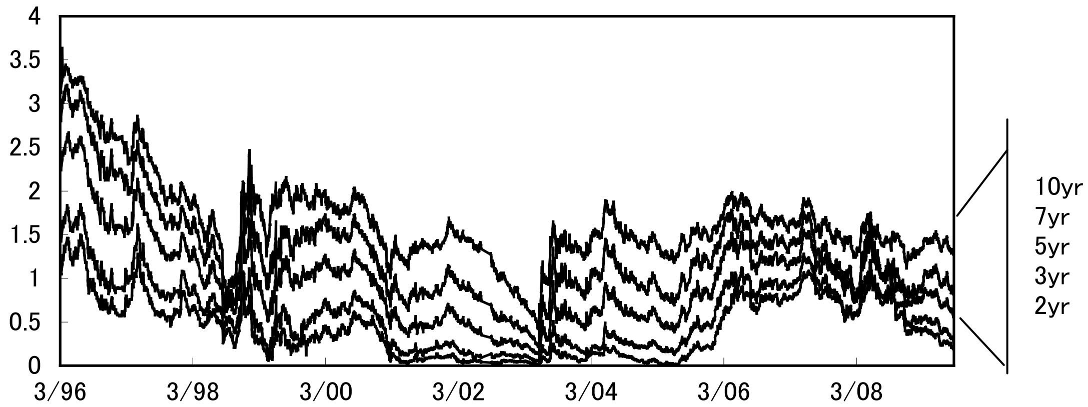


Figure.1 (3) 1year JGB(Japanese Government Bond) rate

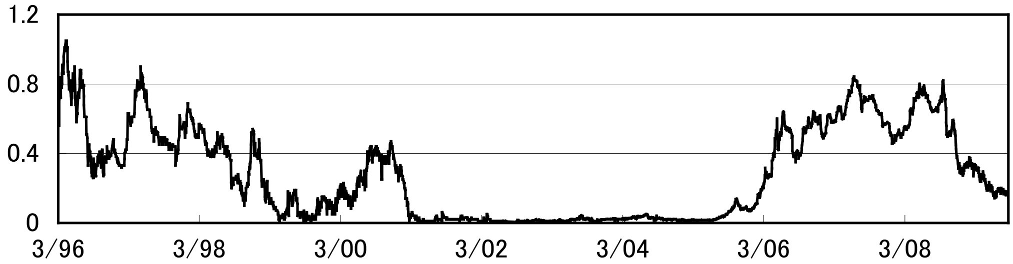


Figure.1 (4) Swap Spread ($SP_t = S_t - L_t$)

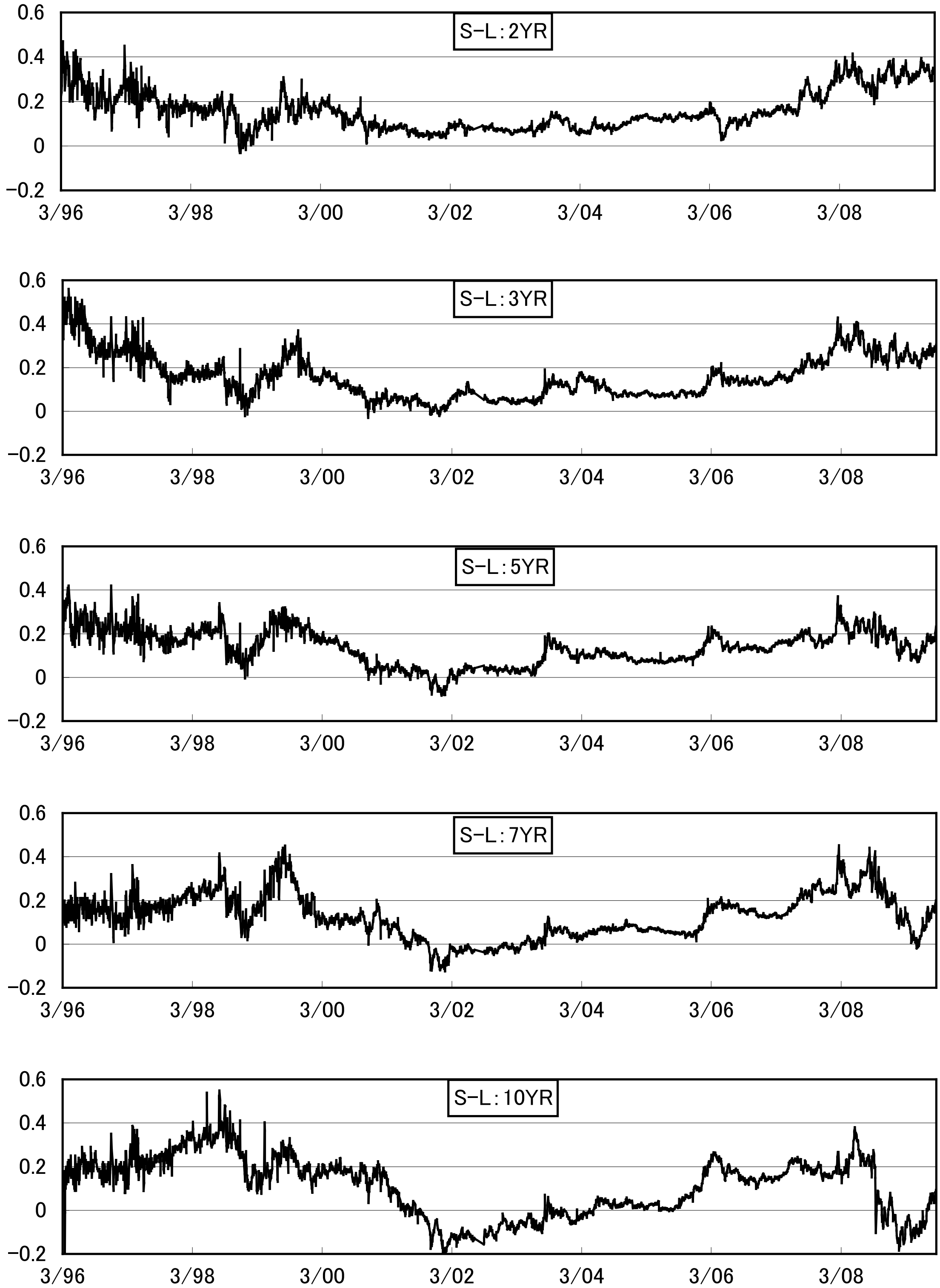
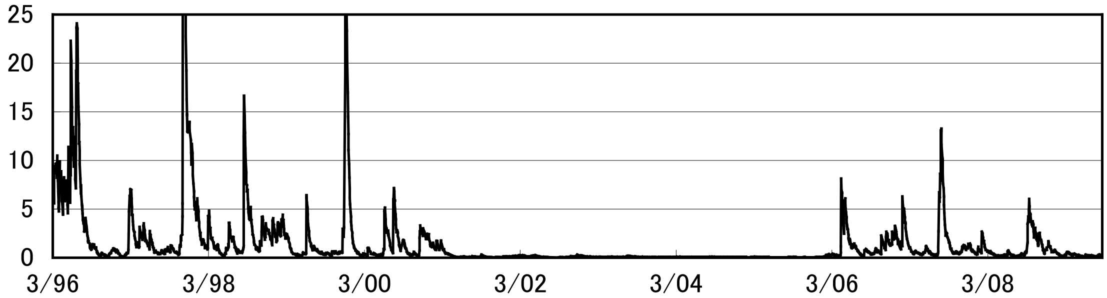
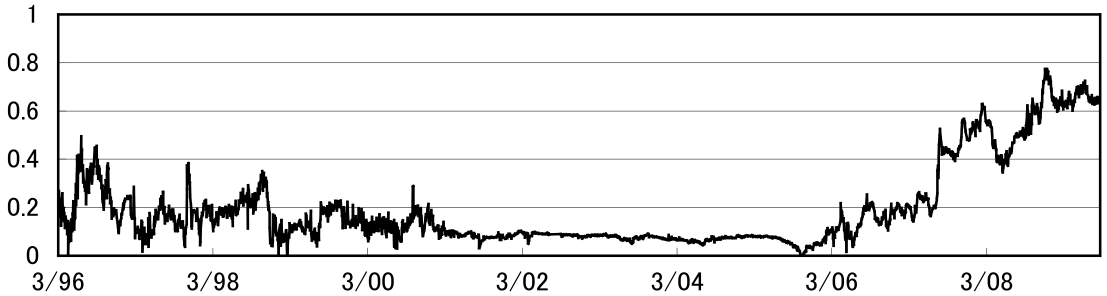


Figure.1 (4) Proxy of Risk

(a) PTR : LIBOR Risk (= Volatility of LIBOR6M)



(b) PLR : Liquidity Risk(= LIBOR1Y - JGB1Y)



(c) PDR : Default Risk (CB - JGB)

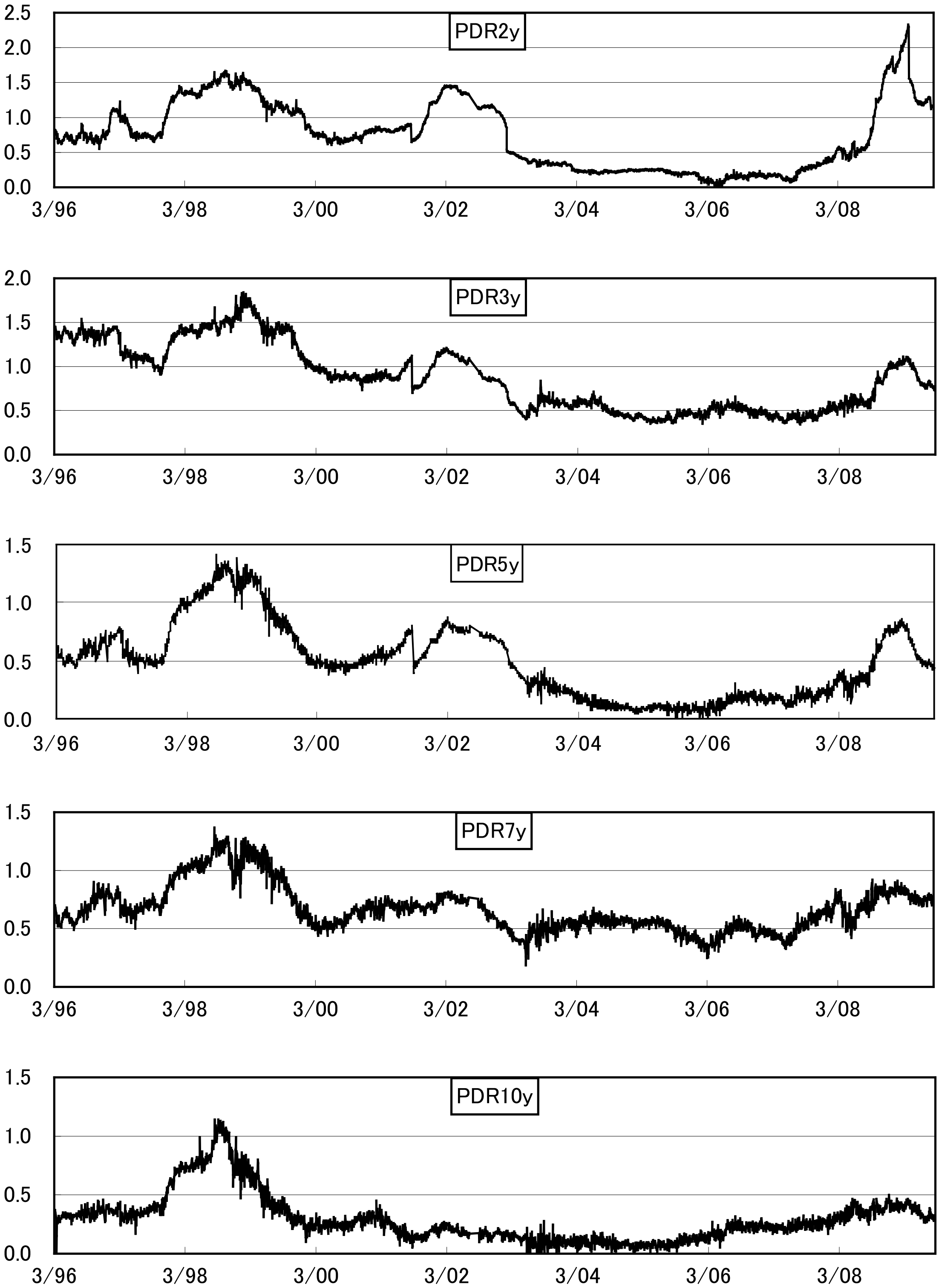
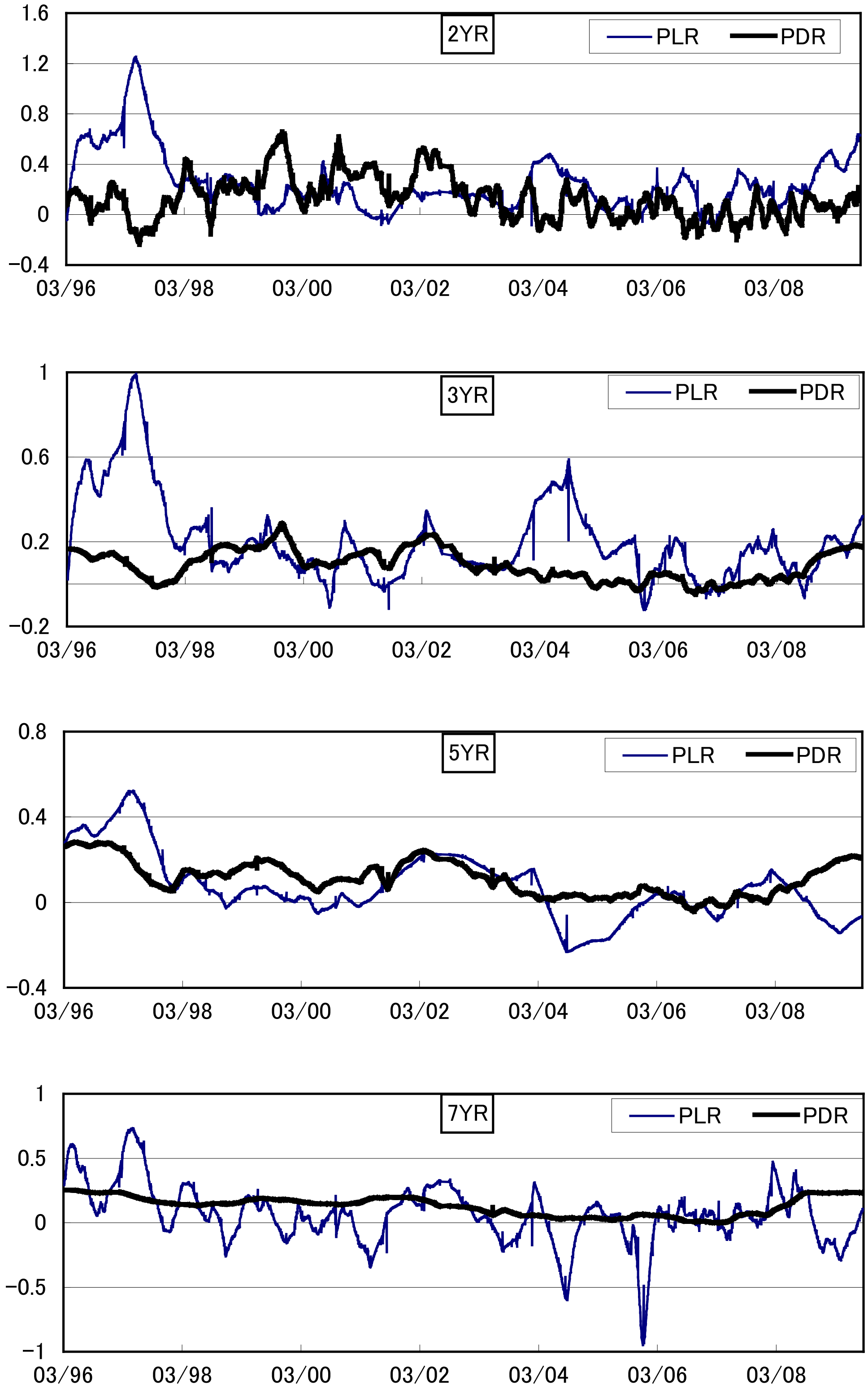
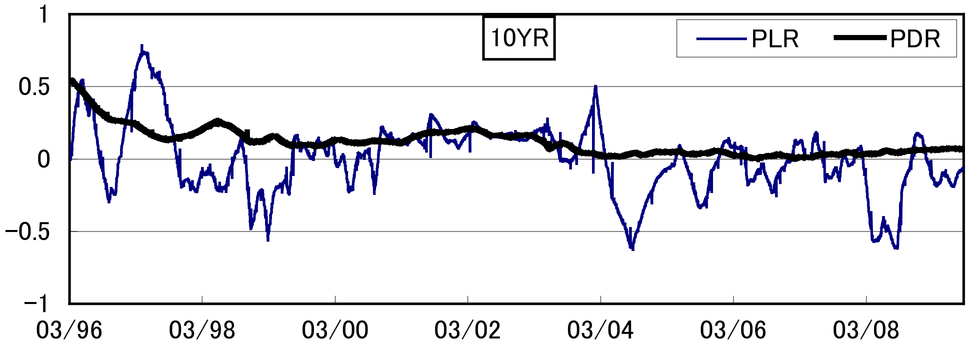


Figure.2 Estimates of Time Varying Parameters





10YR
PLR
PDR
1
0.5
0
−0.5
−1
03/96
03/98
03/00
03/02
03/04
03/06
03/08