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Market-specific and Currency-specific Risk during the Global Financial Crisis: Evidence from the Interbank Markets in Tokyo and London

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Market-specific and Currency-specific Risk during the Global Financial Crisis: Evidence from the Interbank Markets in Tokyo and London[*]

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Abstract

This paper explores how international money markets reflected credit and liquidity risks during the global financial crisis. After matching the currency denomination, we investigate how the Tokyo Interbank Offered Rate (TIBOR) was synchronized with the London Interbank Offered Rate (LIBOR) denominated in the US dollar and the Japanese yen. Regardless of the currency denomination, TIBOR was highly synchronized with LIBOR in tranquil periods. However, the interbank rates showed substantial deviations in turbulent periods. We find remarkable asymmetric responses in reflecting market-specific and currency-specific risks during the crisis. The regression results suggest that counter-party credit risk increased the difference across the markets, while liquidity risk caused the difference across the currency denominations. They also support the view that a shortage of US dollar as liquidity distorted the international money markets during the crisis. We find that coordinated central bank liquidity provisions were useful in reducing liquidity risk in the US dollar transactions. But their effectiveness was asymmetric across the markets.

JEL codes: G15, G12, F36

Key words: credit risk, liquidity risk, interbank market, global financial crisis

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1. Introduction

In a well-integrated market, assets with the same risk characteristics would yield identical expected returns. Controlling regulatory treatments, the yield spreads among fixed-income assets denominated in the same currency should be equalized in normal times. However, reflecting risk characteristics, the spreads may show substantial differences in crisis periods. In this paper, we explore how the Tokyo and London money markets reflected credit and liquidity risks during the global financial crisis in 2007-2009. After matching the currency denomination, we investigate how the Tokyo Interbank Offered Rate (TIBOR) was synchronized with the London Interbank Offered Rate (LIBOR) denominated in the United States (US) dollar and the Japanese yen.

LIBOR, the world's most widely used benchmark for short-term interest rates, is calculated for 10 currencies including the US dollar and the Japanese yen. To the extent that the Japanese market segment is highly integrated with the world, TIBOR would show synchronization with LIBOR. However, as risk characteristics vary substantially, TIBOR may not be synchronized with LIBOR in crisis periods. In particular, it is not clear how well the synchronization with LIBOR persists when economies are under serious financial crisis.

The following analysis investigates to what extent TIBOR was synchronized with LIBOR in 2007-2009. To calculate the synchronization, dollar-denominated TIBOR (that is, Eurodollar TIBOR) is matched with dollar-denominated LIBOR (that is, Eurodollar LIBOR). Yen-denominated TIBOR (that is, Euroyen TIBOR) is also matched with yen-denominated LIBOR (that is, Euroyen LIBOR). The matches allow a comparison of their returns without exchange rate risk. The sample period of the analysis is noteworthy because it includes the periods before and after the global financial crisis. Regardless of the currency denomination, the Tokyo market was highly synchronized with the London market before the crisis broke out. However, during the global financial crisis, the interbank offered rates showed substantial deviations even denominated in the same currency. More interestingly, they show remarkable asymmetric responses reflecting regional risk premiums.

During the global financial crisis, the credit quality of European and US banks deteriorated substantially, but that of Japanese banks did not. We find that risk premiums raised LIBOR more than TIBOR when denominated in the Japanese yen but increased TIBOR more than LIBOR in dollar-denominated markets. The asymmetric impacts in the dollar-denominated and yen-denominated markets had a "home bias" feature reflecting different risk premiums under the liquidity crisis. Our regression results show that credit risk increased the difference across the markets, while liquidity risk caused the difference across the currency denominations. They also support the view that a shortage of US dollar as liquidity distorted the international money markets during the global financial crisis.

Several studies have explored the degree of integration in world money markets in normal times and in crisis periods. Exploring the London and New York interbank markets, Bartolini, Prati, and Hilton (2007) showed that the two markets were highly integrated in the period 2002--2004. McAndews (2008), on the other hand, found that LIBOR was significantly higher than the US rates at times of market distress beginning in August 2007. Baba and Packer (2009a,b) investigated dislocations in the foreign exchange swap market between the US dollar and three major European currencies under the global financial crisis and found that deviations from covered interest parity were negatively associated with the creditworthiness of European and US financial institutions.[1] In contrast, Michaud and Upper (2008) showed that the cross-sectional dispersion of the premiums was largely independent of banks' credit risk and was mainly driven by factors related to the funding liquidity under the global crisis. Castiglionesi, Feriozzi, and Lorenzoni (2009) proposed that integration helps to reallocate liquidity when different countries are hit by uncorrelated shocks but leads to larger spikes in interest rates on the interbank market when an aggregate liquidity shock hits.

As for the integration between the London and Tokyo interbank markets, numerous studies investigated a source of upward deviations of TIBOR from LIBOR in the late 1990s (see, among

[1] See also Genberg, Hui, Wong and Chung (2009) and Grioli and Ranaldo (2010) for their recent contribution to the same topc.

others, Hanajiri [1999], Batten and Covrig [2004], Covrig, Low, and Melvin [2004], Ito and Harada [2004], Peek and Rosengren [2001]). Galpin, Resnick, and Shoesmith (2009), using daily LIBOR, SIBOR (Singapore Interbank Offered Rate), and TIBOR, found a strong positive relationship between pairs of risk premiums. Analyzing the effects of the global financial crisis, Taylor and Williams (2009) showed how risk premiums of US-dollar-denominated LIBOR were correlated with those of yen-denominated TIBOR. But there are very few studies that explored the degree of integration between the Tokyo and London money markets during the global financial crisis.

The following analysis confirms part of the findings in previous studies. However, unlike previous studies, this analysis investigates how the global financial crisis affected risk premiums in Tokyo money market in 2007-2009. In the late 1990s, the Japanese banking crisis seriously damaged Japanese financial sectors. Regardless of the currency denomination, TIBOR therefore showed substantial upward deviations from LIBOR, reflecting increased regional risk premiums. However, we find that the global financial crisis had asymmetric impacts on risk premiums of the Tokyo interbank rates between the US-dollar-denominated and yen-denominated rates. This suggests the importance of distinguishing not only between credit risk and liquidity risk but also between liquidity risks denominated in different currencies. As in literature, we find that coordinated central bank liquidity provisions were useful in reducing liquidity risk in the US dollar transactions.[2] However, their effectiveness was asymmetric across the markets.

The rest of the paper is organized as follows. Section 2 briefly describes the interbank offered rates used in this paper. Section 3 investigates the degree that TIBOR has been integrated with LIBIOR throughout the 1990s and the 2000s. After exploring a simple model of our analysis in Section 4, Section 5 explains how to measure counter-party credit risk and liquidity risk. After explaining a basic framework of our econometric tests in Section 6, Sections 7 and 8 report the results of our regressions. Section 9 extends our analysis by using the interbank rates that have shorter and

[2] For example, Goldberg, Grittini, Miu, and Rose (2009) showed the contribution of foreign exchange swap lines among central banks to reducing dollar funding pressures and limiting stresses in money markets.

longer terms-to-maturity. Section 10 concludes and refers to the implications.

2. The Interbank Offered Rates

In the following analysis, we use the daily offer rates for TIBOR and LIBOR. This section briefly describes the data of these interbank offered rates used in the analyses.

London. LIBOR is a daily reference rate based on the interest rates at which banks borrow unsecured funds from other banks in the London wholesale money market (or interbank market). As the world's most widely used benchmark for short-term interest rates, LIBOR is the rate at which the world's most preferred borrowers are able to borrow money. It is also the rate upon which rates for less preferred borrowers are based.

LIBOR is calculated by Thomson Reuters and published by the British Bankers' Association after 11:00 a.m. each day (Greenwich mean time). It is a trimmed average of interbank deposit rates offered by designated contributor banks, for maturities ranging from overnight to 1 year. Each currency panel comprises 8, 12, or 16 contributor banks, and the reported interest is the mean of the middle values (the interquartile mean).[3] The rates are a benchmark rather than a tradable rate; the actual rate at which banks lend to one another varies throughout the day.

LIBOR is calculated for 10 currencies: the Australian dollar, Canadian dollar, Danish krone, euro, Japanese yen, New Zealand dollar, Pound sterling, Swedish krona, Swiss franc, and US dollar. The following analysis uses LIBOR denominated either in the US dollar or the Japanese yen. Because the US dollar traded on the offshore market is referred to as the "Eurodollar" and the Japanese Yen traded on the offshore market is referred to as the "Euroyen," we refer to LIBOR denominated in the US dollar as "Eurodollar LIBOR" and LIBOR in the Japanese yen as "Euroyen LIBOR." The daily

[3] In 2009, reference banks for the US dollar were Bank of America, Bank of Tokyo-Mitsubishi UFJ Ltd, Barclays Bank, Citibank NA, Credit Suisse, Deutsche Bank AG, HSBC, JP Morgan Chase, Lloyds Banking Group, Mizuho Corporate Bank, Norinchukin Bank, Rabobank, Royal Bank of Canada, Royal Bank of Scotland Group, Société Générale, UBS AG, and WestLB AG. Those in the Japanese yen are almost the same. But they include Mizuho Bank and Sumitomo Mitsui instead of Credit Suisse and Royal Bank of Canada.

data for the London analyses are downloaded from Datastream.

Tokyo. The Japan offshore market is a relatively unregulated market that was established in December 1986 to further liberalize and internationalize Japanese financial markets. The Tokyo market is Asia's largest money center. TIBOR is a daily reference rate based on the interest rates at which banks offer to lend unsecured funds to other banks in the Japan offshore market. The daily TIBOR data are available denominated in the Japanese yen and in the US dollar. Although there is a partial overlap of reference banks between LIBOR and TIBOR, the reference banks in TIBOR are dominated by Japanese banks.

The Japanese Bankers Association (JBA) has been publishing daily TIBOR denominated in the Japanese yen ("Japanese yen TIBOR") since November 1995 and "Euroyen TIBOR" since March 1998. The Japanese yen TIBOR reflects prevailing rates on the unsecured call market, while the Euroyen TIBOR reflects prevailing rates on the Japan offshore market. JBA calculates Euroyen TIBOR as a prevailing market rate based on quotes for 13 maturities (1 week, 1-12 months) provided by reference banks as of 11:00 a.m. each business day (Tokyo time).[4] The JBA excludes the top two and the two bottom reference rates for each maturity and takes the average of the remaining rates. These averages are published as the TIBOR rates (13 rates each for the Japanese yen and Euroyen) through information providers that have contracts with JBA. The JBA does not publish a TIBOR rate denominated in the US dollar which we refer to "Eurodollar TIBOR". But Bloomberg and Nikkei Quick News Inc. collect the Eurodollar TIBOR data. Bloomberg states that their Eurodollar TIBOR data are taken at the Tokyo close. The data for Tokyo are downloaded from the Nikkei Financial QUEST database.

[4] Reference banks in 2009 were Bank of Tokyo-Mitsubishi UFJ, Bank of Yokohama, Chuo Mitsui Trust and Banking Co., Deutsche Bank AG, JPMorgan Chase Bank, Mitsubishi UFJ Trust and Banking Corporation, Mizuho Bank, Mizuho Corporate Bank, Mizuho Trust and Banking Co., National Association, Norinchukin Bank, Resona Bank, Shinkin Central Bank, Shinsei Bank, Shoko Chukin Bank, Sumitomo Mitsui Banking Corporation, Sumitomo Trust and Banking Co., and UBS AG.

3. LIBOR and TIBOR in the 1990s and the 2000s

Before exploring risk premiums during the global financial crisis, this section investigates the nature of the relationship between the daily offer rates for the 3-month TIBOR and the 3-month LIBOR throughout the 1990s and the 2000s. The sample period is from 28 February 1991 to 30 December 2009. The period includes not only tranquil periods but also two turbulent periods, that is, the Japanese banking crisis and the global crisis periods.

3.1. Risk Premiums in the US Dollar

This subsection explores the nature of the relationship between the daily offer rates for the 3-month Eurodollar rates in the London and Tokyo markets: the US dollar-denominated TIBOR (Eurodollar TIBOR) and LIBOR (Eurodollar LIBOR). In the data set used, the different trading times could be a source of deviation between the two series. But, to the extent that the effects of the time difference are negligible, the arbitrage condition suggests that the two series will show similar dynamics because both are denominated in the same currency.

Table 1 summarizes annual average and annual standard deviations of Eurodollar spreads (that is, US-dollar-denominated TIBOR minus LIBOR) in each calendar year from 1991 to 2009. The annual average was positive throughout the sample period, but was below 0.1 points except for a few years and fell below 0.03 points from 2000 to 2007. The correlation between LIBOR and TIBOR from 2000 to 2007 exceeded 0.99, suggesting that, despite the time difference between London and Tokyo, LIBOR and TIBOR are normally highly integrated.

However, TIBOR became significantly higher than LIBOR during the period of the Japanese banking crisis. The annual average spread exceeded 0.1 points from 1996 to 1999. In particular, it exceeded 0.44 points in 1998, when the Japanese banking crisis became critical. The difference between LIBOR and TIBOR, which is often referred to as the "Japan premium" in the literature, can be interpreted as representing the credit risk of Japanese banks at that time.

In Table 1, the annual average spread became close to 0.09 points in 2008 and exceeded 0.1

points in 2009. This implies that TIBOR became significantly higher than LIBOR during the global financial crisis. Risk premiums in the Eurodollar markets boosted both LIBOR and TIBOR during the crisis, but the impacts were greater on TIBOR than on LIBOR. In terms of credit risk, the impacts are paradoxical because the credit quality of European and US banks had been downgraded substantially while that of Japanese banks had not been downgraded under the global financial crisis. The result suggests that liquidity risk, rather than credit risk, might have been important in US dollar transactions under the crisis.

3.2. Risk Premiums in the Japanese Yen

The last subsection investigated the relationship between the two daily offer rates for the 3-month Eurodollar LIBOR and TIBOR. This subsection explores the same relationship by using the daily offer rates for the 3-month yen-denominated rate in London (Euroyen LIBOR) and Tokyo (Euroyen TIBOR).[5] Except for the denomination currency, these rates are traded in the same manner as those used in the last subsection. To the extent that the choice of currency denomination does not change the risk characteristics, one can expect that the two series to show similar dynamics as those observed in the last section.

Table 2 summarizes annual average and standard deviation of the yen-denominated spreads (Euroyen TIBOR minus Euroyen LIBOR). As in the Eurodollar markets, the annual average became large during 1995--1999, especially in 1998, when the credit quality of Japanese banks deteriorated substantially. But the deviation was smaller than that in the Eurodollar markets. This suggests that the credit risk during the Japanese banking crisis was reflected less in the Euroyen TIBOR than in the Eurodollar TIBOR. In general, Japanese banks can access various alternative sources for their yen-denominated borrowings but may not do so for their dollar-denominated borrowings. During the crisis, this caused asymmetric increases in the observed risk premiums of Japanese banks in the

[5] Two alternative rates are available for yen-denominated TIBOR. In the following analysis, we use Euroyen TIBOR on the Japan offshore market. But the essential results are the same even if we use Japanese Yen TIBOR on the unsecured call market.

US dollar vis-à-vis in the Japanese yen.

The Table shows that the annual average, when positive, was very small in nonfinancial crisis periods. It showed modest deviation from zero during 2003–2005, when the Bank of Japan intensified its quantitative easing policy. The unconventional monetary policy distorted yen-denominated money markets but not dollar-denominated ones. The TIBOR–LIBOR spreads still remained small even in yen-denominated transactions in the first half of the 2000s.

A more noteworthy result in the Table is that the annual average Euroyen TIBOR–LIBOR spreads became negative in 2007 and 2008. This implies that, unlike in the Eurodollar markets, risk premiums raised LIBOR more than TIBOR in the Euroyen markets during the global financial crisis. Given that the credit quality of European and US banks declined substantially during the crisis but not that of Japanese banks, this is a natural consequence. However, as shown in Figure 1, the risk premiums raised TIBOR more than LIBOR in the Eurodollar markets at the same time. This indicates that during the global financial crisis, the choice of the denomination currency dramatically changed how risk premiums were reflected in each interbank market. The result suggests the importance of distinguishing not only between credit risk and liquidity risk but also between liquidity risks denominated in different currencies.

Figure 1 depicts the TIBOR–LIBOR spreads in both the Eurodollar and the Euroyen markets in the two crisis periods: that of the Japanese banking crisis (4 January 1995 to 30 December 1999) and that of the global financial crisis (1 January 2007 to 30 December 2009). During the Japanese banking crisis, the TIBOR–LIBOR spreads started to take positive values in the summer of 1995 in both the Eurodollar and the Euroyen markets. The spreads became temporarily small from April 1996 to October 1997, then became very large after the collapse of major Japanese financial institutions in November 1997. The spreads remained large through March 1999. A key feature in this period is that the TIBOR–LIBOR spreads had very large positive values in both markets, although they were larger in the Eurodollar rate than in the Euroyen rate. There is a strong co-movement of the spreads between the Eurodollar and Euroyen rates.

In contrast, during the global financial crisis, the TIBOR–LIBOR spreads started to take opposite signs in the two markets. Before August 2007, the spreads were close to zero in both markets. But after August 2007, the spreads started to take positive values in the Eurodollar market and negative values in the Euroyen market. Before the summer of 2008, the absolute values of the deviations were slightly larger in the Euroyen than in the Eurodollar market. Then, after September 2008, they became larger in the Eurodollar than in the Euroyen market. The asymmetric impacts in the two markets are in marked contrast with what was observed during the Japanese banking crisis. The asymmetric deviations continue into the beginning of 2009. After January 2009, the TIBOR–LIBOR spreads started to take positive values in both markets.

4. A Model

Ever since the turmoil began under the global financial crisis, several alternative explanations have been offered for the dramatic upward deviations of the money market rates from the corresponding risk free rates. The most commonly mentioned explanations might be summarized into "counterparty credit risk" and "liquidity risk". But since our main interest is to compare interbank rates in different money markets and in different currency denominations, the following analysis assumes that these risks consist of both currency-specific and market-specific factors. We denote the interbank money market rate denominated in currency h in market k in period t by $i(h, k)_t$ and decompose it as follows

$$(1) \qquad i(h, k)_t = Rf(h)_t + Risk(h, k)_t + Liquidity(h, k)_t,$$

where h = US dollar or Japanese yen and k = Tokyo or London.

In the right hand side of (1), $Rf(h)_t$ is risk-free rate denominated in currency h in period t. With the same terms to maturity, the risk-free rate captures the effect of expected future interest rate changes on $i(h, k)_t$. Expectations of future interest rate decline due to policy easing, for example,

will cause the term interbank rate to decline through decreasing the risk-free rate with the same term-to-maturity. Since the risk-free rate is not market-specific, $Rf(h)_t$ is independent of any specific factor in market *k*.

$Risk(h, k)_t$ is a counterparty credit risk in currency *h* in market *k* in period *t*. "Counterparty credit risk" means that banks became more reluctant to lend to other banks because of the perception that the risk of default on the loan had increased and/or the market price of taking on such risk had risen. During the global financial crisis, the credit quality of European and US banks deteriorated substantially, but that of Japanese banks did not. This suggests that the London market carried a larger counter-party credit risk than did the Tokyo market. It is likely that $Risk(h, k)_t$ is sensitive to the specific factor in market *k*.

$Liquidity(h, k)_t$ is a liquidity risk in currency *h* in market *k* in period *t*. "Liquidity risk" means that traders at one bank are reluctant to expose the traders' bank's funds during a period of time where those funds might be needed to cover the bank's own shortfalls. In the financial turmoil, the trader may not be given as much "balance sheet" to invest, which is perceived as a shortage of liquidity to the trader. In this situation, term loan markets come under stress, and term interest rates may be disconnected from overnight interest rates. Because of the role of the US dollar as the international currency, the traders were especially sensitive to a liquidity shortage of the US dollar in international transactions. It is likely that $Liquidity(h, k)_t$ is more conspicuous in the international transactions denominated in the US dollar.

5. "Counterparty Credit Risk" and "Liquidity Risk"

To measure counterparty credit risk in Tokyo, London, and New York, the following analysis uses the credit default swap (CDS) prices of the banks in each country. We use the daily time series of the 5 year financial service sector CDS index for Japan and the 5 year banks sector CDS indexes for the United Kingdom and the United States. The data is based on CMA Data Vision which was downloaded from Datastream. It is likely that the CDS index for each country reflects credit risk of

the banks in the country. We can therefore expect that the TIBOR - LIBOR spread is correlated positively with the CDS index for Japan and negatively with the CDS index for the UK. In our data set, the CDS index for Japan, which covers not only banking sector but also the other financial sector, is more volatile than the indexes has several large upward spikes. The following analysis thus used its logged value for the index for Japan.

Unlike credit risk, it is difficult to measure liquidity risk directly. But during the global financial crisis, the central banks made several attempts to improve liquidity premiums in money markets. To the extent that the central bank has the ability to reduce the liquidity risk premium effectively, measuring the effects of these attempts is a crucial first step toward understanding the nature of the liquidity risk premium. In the following analysis, we estimate the effects of the Federal Reserve Bank (FRB)'s Foreign Exchange (FX) Swap Lines with the Bank of Japan (BOJ), the Bank of England (BOE), and European Central Bank (ECB). For the FX Swap Lines with each central bank, we include a dummy variable which takes one on the dates for the operations and zero otherwise. For the FX Swap Lines with BOJ, we also include a dummy which equals to the amount allocated on the dates for the operations and zero otherwise. In addition, to capture the announcement effects of the FX Swap Lines, we include a dummy variable which takes one on the dates when FRB announced the swaps lines and zero otherwise.

To measure the effects of the other central banks' attempts to reduce liquidity risk premium, we include dummies for the FRB's Term Auction Facility (TAF)[6] as well as the BOJ's "outright purchases of CP" and "special funds-supplying operations to facilitate corporate financing".[7] The

[6] Under the Term Auction Facility (TAF), the FRB auctions term funds to depository institutions in the United States. All depository institutions that are eligible to borrow under the primary credit program is eligible to participate in TAF auctions. All advances must be fully collateralized. Each TAF auction is for a fixed amount, with the rate determined by the auction process (subject to a minimum bid rate).

[7] "Outright purchases of CP" is funds-supplying operations to purchase CP and ABCP that are deemed eligible as collateral by the BOJ and are a-1 rated, with a residual maturity of up to three months. The operations are conducted by a conventional auction with the minimum yields determined by the BOJ. "Special funds-supplying operations to facilitate corporate financing" is funds-supplying operations by which the BOJ extends loans to its counterparties for an unlimited amount against the value of corporate debt submitted to the BOJ as collateral by them at an interest rate equivalent to the target for the uncollateralized overnight call rate.

dummy variable for the BOJ's "outright purchases of CP" which equals to the amount allocated on the dates for the operations and zero otherwise. Each of the other dummy variable takes one on the dates when each operation took place and zero otherwise. These facilities and the FX swaps could have different effects on the LIBOR and the TIBOR. The swaps credit of the US dollar was available only to depositories outside the U.S. in the countries in which the central bank participated in the swaps program, while the TAF credit of the US dollar was only directly available to depository institutions in the U.S. The BOJ's "outright purchases of CP" and "special funds-supplying operations to facilitate corporate financing" increase availability of the Japanese yen only for financial institutions located in Japan. Comparing the effects of these facilities, we can see the difference of the liquidity premiums across the markets and across the currency denominations.

In addition to the above variables, we include both yen-denominated and dollar-denominated three-month overnight index swap (OIS) rate in the New York market, deviation from the covered interest parity (CIP) condition, and the Chicago Board Options Exchange Volatility Index (VIX) as auxiliary variables.[8] The inclusion of these auxiliary variables is to check the robustness of our estimation results. Since OIS transactions contain little liquidity or credit risk premium, the OIS rates almost equal the average of the overnight interest rates expected until maturity. Including the OIS rates may measure the effects of the expected future policy rates in Japan and in the United States. To calculate the deviation from the CIP condition of the yen-dollar exchange rates, we use the three-month OIS rates in Tokyo and New York markets as well as spot and three-month forward exchange rates. The deviations allow us to calculate the risks which are specific in the foreign exchange market. A large number of previous studies suggest substantial deviations from the CIP during the global financial crisis. Including the deviation from the CIP may measure the effects discussed in these studies. The VIX which was introduced by Whaley (1993) is a popular measure of the implied volatility of S&P 500 index options. A high value corresponds to a more volatile

[8] The data of the yen-denominated OIS was from the TOKYO TANSHI CO. LTD. The other data series were downloaded from Datastream.

market and therefore more costly options. Often referred to as the fear index, it represents one measure of the market's expectation of volatility over the next 30 day period.

6. Econometric Tests

In the following sections, we endeavor to test how various factors—including the risk measures and liquidity measures —affect the TIBOR–LIBOR spread. The dependent variable in the regression is either the three-month Eurodollar TIBOR–LIBOR spread or the three-month Euroyen TIBOR–LIBOR spread. For each dependent variable, we estimate the following equations:

(2) Eurodollar $\text{spread}_t = \text{constant} + \sum_h \sum_k Risk(h, k)_t + \sum_h \sum_k Liquidity(h, k)_t$,

(3) Euroyen $\text{spread}_t = \text{constant} + \sum_h \sum_k Risk(h, k)_t + \sum_h \sum_k Liquidity(h, k)_t$,

where h = US dollar or Japanese yen and k = Tokyo, London, Europe, or New York. For each equation, we also include the lagged values of the spreads, the lagged values of the first time difference of the spreads, and the auxiliary variables as explanatory variables.

Equations (2) and (3) imply that each TIBOR–LIBOR spread is determined by several counter-party credit risks and liquidity risks in the two markets. To the extent that the effect of the time difference is negligible, taking the difference between the interbank rates denominated in the same currency enables us to cleanse expectations effects that are reflected in the risk-free rate $Rf(h)_t$. In each regression we use daily data during the sample period from January 4, 2007 through December 30, 2009, a span of time that includes both the market turmoil period and a comparable period of time before and after the turmoil.

For equations (2) and (3), we perform our tests with OLS regressions and two extended GARCH models, that is, EGARCH and GJR-GARCH models. The OLS regression is primitive in that it cannot capture notable asset price features such as dynamic volatility changes. However, it provides a robust result that is less sensitive to a change of model specification. In contrast, the

EGARCH (exponential general autoregressive conditional heteroskedastic) model proposed by Nelson (1991) allows the sign and the magnitude of the variance of the error term to have separate effects on the volatility. The GJR-GARCH model proposed by Glosten, Jagannathan and Runkle (1993) allows threshold values of the variance of the error term. The two GARCH models are useful when asset pricing prices have different volatilities depending upside and downside risks or when only large shocks attract investors' attention.

Let u_t denote the error term of the estimated equation and assume that $u_t = z_t \sqrt{h_t}$. Then, the variance equations of EGARCH(2,2) and GJR-GARCH(2, 2) are respectively represented as

(4) $$ln(h_t) = c + f_{11}\cdot|z_{t-1}| + f_{12}\cdot|z_{t-2}| + f_{21}\cdot z_{t-1} + f_{22}\cdot z_{t-2} + f_{31}\cdot ln(h_{t-1}) + f_{32}\cdot ln(h_{t-2}),$$

(5) $$h_t = c + g_{11}\cdot u_{t-1}^2 + g_{12}\cdot u_{t-2}^2 + g_{21}\cdot u_{t-1}^2\cdot I_{t-1} + g_{22}\cdot u_{t-2}^2\cdot I_{t-2} + g_{31}\cdot h_{t-1} + g_{32}\cdot h_{t-2},$$

where $I_t = 1$ when $u_{t-1} < 0$ and 0 otherwise. To the extent that either f_{11} or f_{12} in EGARCH and either g_{21} or g_{22} in GJR-GARCH are significantly different from zero, each GARCH model suggests that the variance equations have asymmetric dynamic process. However, the estimation results of the models are sensitive to a change of model specification. Therefore, we estimate GARCH(m, n) for $0 \le m \le 2$ and $0 \le n \le 2$ and report the result of GARCH(m, n) that had the highest log likelihood.

7. Estimated Results by OLS Regressions

This section first reports the results of our tests with OLS regressions. The results are summarized in Table 3 for the Eurodollar TIBOR–LIBOR spread and Table 4 for the Euroyen TIBOR–LIBOR spread. Both of the tables show the estimation results with and without the auxiliary variables. In all cases, Breusch-Godfrey Serial Correlation LM Test rejects serial correlations in the residuals. Among the estimated coefficients, some of the auxiliary variables are significant. In particular, deviation from the CIP conditions is significantly positive for the

Eurodollar spread and significantly negative for the Euroyen spread. However, regardless of the inclusion of the auxiliary variables, the effects of credit and liquidity risks are essentially the same.

In all cases, both the CDS index for Japan and the CDS index for the UK enter with the correct sign and are highly significant. Although the CDS index for the USA is insignificant, this implies that credit risk of Japanese banks increases TIBOR and that of UK banks increases LIBOR. Regardless of the denomination currency, the market-specific counterparty credit risks are the important determinants of the TIBOR – LIBOR spread. During the global financial crisis, the credit quality of European banks declined substantially, but that of Japanese banks did not. This suggests that LIBOR carried a larger counter-party credit risk than did TIBOR in both yen and dollar transactions.

In contrast, most dummies of the FX Swap Lines are significant for the Eurodollar spread but not for the Euroyen spread. The FX swap facilities are designed to improve liquidity conditions in global money markets by providing foreign central banks with the capacity to deliver U.S. dollar funding to institutions in their jurisdictions. Using funds accessed through the swaps, the BOJ provided dollar liquidity to institutions in Japan and so did the BOE to institutions in the UK.

For the Eurodollar spread, the dummy for the BOJ's swap line is significantly negative especially when the amount allocated is used, while the dummy for the BOE's swap line is significantly positive. The opposite signs between these FX swap facilities indicate that the BOJ's swap line was more effective in reducing US dollar liquidity risk in the Tokyo market and so was the BOE's in the London market. The significantly positive sign of the dummy for the FRB's FX swap announcements, on the other hand, suggests that the FX swap facilities, on average, might have be more successful in reducing liquidity risk in London than in Tokyo. With the auxiliary variables, the ECB's swap line and the TAF credit have the same sign as the BOE's but are statistically insignificant.

For the Euroyen spread, the BOJ's swap line is significantly negative when the amount allocated is used for the dummy. The BOJ's swap line might have been effective in reducing yen liquidity risk in the Tokyo market. But the other dummy variables to measure liquidity risk are not

significant for the Euroyen spread. This is not only true for dummies of the FX Swap Lines and the TAF which provide dollar liquidity but also for dummies of BOJ's "outright purchases of CP" and "special funds-supplying operations to facilitate corporate financing" which provide yen liquidity. Regardless of the market location, yen-specific liquidity risk might not have been the important determinants of the TIBOR – LIBOR spreads during the global financial crisis.

Because of the role of the US dollar as the international currency, the traders are especially sensitive to a liquidity shortage of the US dollar under the critical environments. The shortage might have been more serious in Tokyo market than in London market because the latter is thicker than the former in terms of trading volume of the US dollar. This may explain why TIBOR was higher than LIBOR denominated in the US dollar during the global financial crisis.

8. Estimated Results by EGARCH, and GJR-GARCH

In this section, we examine how various factors affect the TIBOR–LIBOR spread by EGARCH and GJR-GARCH models. The results with the auxiliary variables are summarized in Table 5 for the Eurodollar TIBOR–LIBOR spread and Table 6 for the Euroyen TIBOR–LIBOR spread. The GARCH models did not converge when we include all of the explanatory variables. We thus report the results excluding both Japanese bank's stock excess returns and the ECB's swap line dummy and including only one of the two BOJ's swap line dummies, that is, the dummy for which the amount allocated is used. EGARCH(1,1) and GJR-GARCH(1,0) had the highest log likelihood for the Eurodollar spread and so did EGARCH(1,2) and GJR-GARCH(1,2) for the Euroyen spread. The Eurodollar TIBOR–LIBOR spread showed no asymmetry in EGARCH. However, in the other cases, the selected models suggest that the GARCH processes have not only significant persistence but also significant asymmetry.

In the GARCH models, several auxiliary variables show signs and significance levels that are different from those in the OLS regressions. For example, in Table 5, deviation from the CIP conditions, which was significantly positive in OLS, is still positive in GJR-GARCH but becomes

significantly negative in EGARCH. Dollar-denominated three-month OIS rate and VIX, both of which were not significant in the OLS regressions, become significantly positive in EGARCH and significantly negative in GJR-GARCH.

However, in our GARCH models, the effects of credit risk on the TIBOR–LIBOR spread are essentially the same as what we observed in the OLS regressions. In particular, the CDS index for Japan is significantly positive and the CDS index for the UK is significantly negative in all cases. Regardless of the denomination currency, credit risk of Japanese banks increases TIBOR and that of UK banks increases LIBOR. Unlike in the OLS regressions, the CDS index for the USA becomes significant for the Eurodollar spread. But its sign differs between EGARCH and GJR-GARCH, suggesting that its effects are not robust for the model specification.

In our GARCH models, the effects of liquidity risk on the TIBOR–LIBOR spreads are also very similar to what we observed in the OLS regressions. For the Eurodollar spread, the BOJ's swap line is significantly negative and the BOE's swap line is significantly positive in both EGARCH and GJR-GARCH. This indicates that in reducing dollar liquidity risk, the BOJ's swap line was effective in the Tokyo market and so was the BOE's in the London market. For the Eurodollar spread, both the FRB's swap announcement and the FRB's TAF are also significantly positive in both EGARCH and GJR-GARCH. This is in contrast with the results of our OLS regressions where the FRB's TAF was not significant. Our GRACH models suggest that not only the FRB's FX swap facilities but also the FRB's TAF might have be more successful in reducing US dollar liquidity risk in London than in Tokyo.

For the Euroyen spread, the FRB's FX swap announcement is significantly positive in both EGARCH and GJR-GARCH. This is in contrast with what we observed in the OLS regressions. However, the other dummy variables to measure liquidity risk are not significant except in almost all cases. Even the BOJ's swap line, which was significantly negative in our OLS regressions, is no longer significant in the GARCH models. This implies that the effect of BOJ's swap lines in the OLS regressions is not robust. Our GARCH models more strongly support the view that

yen-specific liquidity risk might not have been the important determinants of the Euroyen TIBOR – LIBOR spread during the global financial crisis.

9. Results under Shorter or Longer Terms to Maturity

Until the last section, we have investigated the degree of synchronization between TIBOR and LIBOR by using the three-month interbank rates. The use of the three-month rates is desirable in that three-month is most widely transacted term to maturity in the money markets. However, the terms-to-maturity transacted in the international interbank markets vary from 1 week to 12 months. It thus deserves to see to what extent our main results hold when we use the rates that have shorter or longer terms to maturity. This section explores this by using the one-month and the twelve-month interbank offered rates.

For the one-month and the twelve-month rates, Figures 2 depicts the TIBOR–LIBOR spreads in the Eurodollar and the Euroyen markets from 1 January 2007 to 30 December 2009. As we found for the three-month interbank rates, the TIBOR–LIBOR spreads in the two markets show opposite signs during the global financial crisis. Regardless of the term to maturity, the spreads took positive values in the Eurodollar market and negative values in the Euroyen market after the crisis broke out.

However, the amplitude of the spreads is very different depending on how long the term to maturity is. The absolute values of the Eurodollar TIBOR–LIBOR spreads became larger as the term-to-maturity is shorter. The spreads frequently became greater than 0.2 points and sometimes exceeded 0.4 for the one-month rate, while they rarely exceeded 0.1 points for the twelve-month rate. In contrast, the absolute values of Euroyen TIBOR–LIBOR spreads became larger as the term-to-maturity is longer. The spreads fell below -0.1 points after August in 2007 and became lower than -0.3 points in October 2008 for the twelve-month rate, while they usually lied between 0 and -0.1 points and rarely fell below -0.2 for the one-month rate. In addition, the spreads remained negative even in 2009 for the twelve-month rate, while they turned to be positive in 2009. The

difference probably suggests that US dollar liquidity risk is higher when transacting in shorter time horizon and that credit risk is larger when transacting in longer time horizon.

Using these spreads as dependent variables, we estimate our basic equations (2) and (3) by OLS regressions. The results are summarized in Table 7 for the Eurodollar TIBOR–LIBOR spreads and Table 8 for the Euroyen TIBOR–LIBOR spreads. They are the results excluding Japanese bank's stock excess returns and including only one of the two BOJ's swap line dummies, that is, the dummy for which the amount allocated is used. Compared with the results in section 7, some of them are slightly sensitive to the model specification. This may happen because transactions of one-month and twelve-month rates are not as thick as those of three-month rates. The tables report the estimation results without the auxiliary variables. But we include an auxiliary variable when the estimated coefficients are unstable for a small change of specification or when we cannot reject serial correlations.[9]

In both tables, the effects of credit risk on the TIBOR–LIBOR spreads are essentially the same as what we observed for the three-month rates. In particular, the CDS index for Japan is positive and the CDS index for the UK is negative in all cases, although the UK CDS index was insignificant for the twelve-month Eurodollar spreads. Regardless of the denomination currency, credit risk of Japanese banks increases TIBOR and that of UK banks increases LIBOR.

In both tables, the effects of liquidity risk on the spreads are also similar to what we observed for the three-month rates. For the Eurodollar spreads, the BOJ's swap line is significantly negative and the BOE's swap line is significantly positive for both the one-month and the twelve-month rates. This indicates that in reducing US dollar liquidity risk, the BOJ's swap line was effective in the Tokyo market and so was the BOE's in the London market. It also suggests that not only the FRB's FX swap facilities but also the ECB's swap line might have be more successful in

[9] For example, since one-month Eurodollar spread had an upward spike on September 19, 2008, we include a dummy for it to remove the effect of the outlier.

reducing US dollar liquidity risk in London than in Tokyo. For the Euroyen spreads, the results are the same as what we obtained by OLS regressions for the three-month rates. The BOJ's swap line is significantly negative. But the other dummy variables to measure liquidity risk are not significant for the Euroyen spreads. Regardless of the market location, yen-specific liquidity risk might not have been the important determinants of the TIBOR – LIBOR spreads during the global financial crisis.

10. Concluding Remarks

Financial crisis increases risk premiums in national and regional financial markets. This paper explored how international money markets reflected such risk premiums during the global financial crisis. Unlike medium- or long-term financial markets such as bond markets and stock markets, money markets play an important role in providing liquidity. Therefore, not only credit risk but also liquidity risk were important in the money markets during the global financial crisis.

After matching the currency denomination, how TIBOR has been synchronized with LIBOR was investigated. Our noteworthy finding is the remarkably asymmetric responses in how the Tokyo market reflected both credit and liquidity risk premiums during the global financial crisis. We find that the asymmetric impacts in the dollar-denominated and yen-denominated markets had a "home bias," reflecting different liquidity premiums during the financial crisis.

The regression results suggested that credit risk explains the difference across the markets, while liquidity risk explains the difference across the currency denominations. They also indicated the importance of US dollar liquidity provisions during the global financial crisis. During the global financial crisis, risk premiums in the US dollar transactions were driven not only by counter-party risk but also by factors related to funding liquidity. In particular, pressure in the interbank market made it critical for non-US banks to retain access to other sources of dollar funding. This suggests the importance of distinguishing not only between credit risk and liquidity risk but also between liquidity risks denominated in different currencies.

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Table 1. The Spreads between the LIBOR and the TIBOR in the US dollar

	1991	1992	1993	1994	1995	1996	1997
average	0.050	0.069	0.036	0.017	0.084	0.100	0.164
S.D.	0.036	0.041	0.050	0.033	0.110	0.041	0.219

	1998	1999	2000	2001	2002	2003	2004
average	0.442	0.098	0.007	0.011	0.028	0.029	0.008
S.D.	0.201	0.139	0.011	0.029	0.024	0.011	0.009

	2005	2006	2007	2008	2009
average	0.004	0.009	0.012	0.090	0.112
S.D.	0.008	0.006	0.024	0.117	0.029

Table 2. The Spreads between the LIBOR and the TIBOR in the Japanese Yen

	1991	1992	1993	1994	1995	1996	1997
average	0.009	0.002	0.004	0.007	0.039	0.059	0.060
S.D.	0.038	0.031	0.024	0.020	0.063	0.025	0.076

	1998	1999	2000	2001	2002	2003	2004
average	0.168	0.057	0.008	0.011	0.014	0.029	0.034
S.D.	0.104	0.078	0.012	0.016	0.009	0.011	0.008

	2005	2006	2007	2008	2009
average	0.032	0.008	−0.062	−0.097	0.069
S.D.	0.012	0.020	0.057	0.171	0.045

Table 3. Determinants of Eurodollar TIBOR - LIBOR Spreads: OLS Regressions

	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	−0.0091	−0.288	−0.0054	−0.169	−0.0851	−6.569
Dollar SPR(−1)	0.4799	14.838	0.4614	14.419	0.6306	22.030
Yen SPR(−1)	0.0579	1.590	0.0643	1.759	−0.1109	−4.524
dDollarSPR(−1)	0.2458	7.292	0.2581	7.662	0.1622	4.774
dYenSPR(−1)	0.0562	0.397	0.0187	0.132	−0.0158	−0.108
CDS(Japan)	0.0102	2.101	0.0101	2.075	0.0228	6.910
CDS(UK)	−0.0002	−2.634	−0.0002	−2.660	−0.0002	−2.777
CD(USA)	0.0000	−0.843	0.0000	−0.911	0.0000	−0.286
SWAPD(BOJ)	−0.0016	−0.178	−0.0185	−2.590	−0.0066	−0.712
SWAPA(BOJ)	−0.0016	−3.137			−0.0017	−3.202
SWAPD(BOE)	0.0119	2.255	0.0129	2.424	0.0249	4.696
SWAPD(ECB)	0.0108	1.026	0.0016	0.156	−0.0010	−0.097
FRBSWAP	0.2294	8.269	0.2273	8.146	0.2960	10.617
TAFUSA	0.0022	0.416	0.0019	0.366	0.0007	0.134
BOJ(Corporate)	0.0024	0.411	0.0009	0.160	0.0005	0.077
BOJ(CP)	0.0013	0.260	0.0007	0.138	0.0013	0.238
VIX	0.0002	0.940	0.0002	1.006		
CIP	0.0408	8.102	0.0409	8.085		
OISYEN	−0.0247	−1.156	−0.0269	−1.250		
OISDOLLAR	−0.0011	−0.410	−0.0015	−0.538		
Adj. R-squared	0.805		0.803		0.784	
LM Test	35.897		32.913		59.156	

Notes

1) Dollar SPR = Eurodollar TIBOR – LIBOR, Yen SPR = Euroyen TIBOR – LIBOR,
2) CDS(Japan), CDS(UK), and CDS(US) = 5 year CDS index for Japan, the United Kingdom, and the United States respectively.
3) SWAP(BOJ) and SWAP(BOE) = dummy that takes one when dollar liquidity was provided by BOJ and BOE respectively. FRBSWAP = dummy that takes one when FRB announced the swaps lines.
4) TAF = dummy that takes one the dates of TAF operation, BOJ(CP) and BOJ(Corporate) = dummy that takes one on the dates of BOJ's "outright purchases of CP" and "special funds-supplying operations to facilitate corporate financing" respectively.
5) LM test shows F-values based on Breusch-Godfrey Serial Correlation LM Test.

Table 4. Determinants of Euroyen TIBOR - LIBOR Spreads: OLS Regressions

	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	-0.0011	-0.133	-0.0003	-0.040	-0.0139	-4.187
Yen SPR(-1)	0.9426	97.317	0.9440	97.257	0.9749	154.711
Dollar SPR(-1)	0.0158	1.836	0.0119	1.404	-0.0037	-0.497
dYenSPR(-1)	0.0531	1.411	0.0452	1.202	0.0684	1.811
dDollarSPR(-1)	0.0041	0.462	0.0067	0.753	0.0141	1.612
CDS(Japan)	0.0031	2.413	0.0031	2.393	0.0037	4.327
CDS(UK)	-0.0001	-4.098	-0.0001	-4.116	-0.0001	-3.223
CD(USA)	0.0000	0.885	0.0000	0.824	0.0000	-0.268
SWAPD(BOJ)	0.0016	0.671	-0.0020	-1.033	0.0026	1.083
SWAPA(BOJ)	-0.0003	-2.475			-0.0003	-2.530
SWAPD(BOE)	0.0006	0.442	0.0008	0.583	-0.0007	-0.544
SWAPD(ECB)	-0.0033	-1.178	-0.0052	-1.939	-0.0004	-0.148
FRBSWAP	0.0111	1.499	0.0106	1.436	0.0013	0.184
TAFUSA	-0.0014	-1.007	-0.0014	-1.040	-0.0011	-0.786
BOJ(Corporate)	0.0007	0.453	0.0004	0.255	0.0012	0.769
BOJ(CP)	-0.0001	-0.038	-0.0002	-0.133	0.0002	0.141
VIX	-0.0001	-1.390	-0.0001	-1.328		
CIP	-0.0040	-2.998	-0.0040	-2.961		
OISYEN	-0.0162	-2.843	-0.0166	-2.913		
OISDOLLAR	-0.0005	-0.665	-0.0006	-0.767		
Adj. R-squared	0.991		0.991		0.991	
LM Test	4.992		5.477		2.369	

Notes

1) The dentitions of the explanatory variables are the same as those in Table 3.

2) LM test shows F-values based on Breusch-Godfrey Serial Correlation LM Test.

Table 5. Determinants of Eurodollar TIBOR - LIBOR Spreads: GARCH models

	EGARCH		GJR-GARCH	
	Coefficient	Z-Statistic	Coefficient	Z-Statistic
Constant	0.0173	0.958	-0.0263	-8.045
Dollar SPR(-1)	0.5578	55.646	0.9148	241.341
Yen SPR(-1)	0.0916	8.329	0.0200	5.778
dDollarSPR(-1)	-0.3827	-47.701	0.0205	2.468
dYenSPR(-1)	0.2047	4.866	0.0059	0.384
CDS(Japan)	0.0084	2.574	0.0046	9.416
CDS(UK)	-0.0004	-12.961	-0.0001	-11.454
CD(USA)	0.0001	4.112	0.0000	-4.270
SWAPA(BOJ)	-0.0008	-8.178	-0.0019	-14.610
SWAPD(BOE)	0.0051	2.123	0.0036	8.069
FRBSWAP	0.6205	139.527	0.4962	6.037
TAFUSA	0.0050	2.607	0.0040	5.116
BOJ(Corporate)	-0.0040	-1.539	0.0003	0.432
BOJ(CP)	0.0078	1.244	-0.0027	-2.268
VIX	0.0004	4.369	0.0003	15.893
CIP	-0.0138	-10.243	0.0129	19.187
OISYEN	0.0042	0.538	-0.0024	-0.940
OISDOLLAR	-0.0086	-6.374	0.0018	10.248
C	-8.3590	-72.864	0.0000	12.145
f(21)	1.1459	52.320		
f(31)	-0.1255	-6.916		
g(11)			4.1610	11.796
g(31)			-1.3852	-2.494
Adj. R-squared	0.549		0.731	

Notes

1) Except for the variance equation, the dentitions of the explanatory variables are the same as those in Table 3.

2) The parameters in the variance equations are those of the equations: $ln(h_t) = c + f_{21} \cdot z_{t-1} + f_{31} \cdot ln(h_{t-1})$ and $h_t = c + g_{11} \cdot u_{t-1}^2 + g_{21} \cdot u_{t-1}^2 \cdot I_{t-1}$.

Table 6. Determinants of Euroyen TIBOR - LIBOR Spreads: GARCH models

	EGARCH		GJR-GARCH	
	Coefficient	Z-Statistic	Coefficient	Z-Statistic
Constant	-0.0035	-1.399	0.0037	1.310
Yen SPR(-1)	0.9783	238.561	0.9472	238.637
Dollar SPR(-1)	0.0096	2.543	0.0176	3.854
dYenSPR(-1)	0.2244	4.489	0.1122	2.071
dDollarSPR(-1)	0.0099	2.806	0.0100	2.296
CDS(Japan)	0.0014	3.436	0.0020	5.142
CDS(UK)	0.0000	-3.838	0.0000	-6.677
CD(USA)	0.0000	-0.148	0.0000	1.261
SWAPA(BOJ)	0.0000	-0.432	0.0001	1.095
SWAPD(BOE)	0.0003	0.447	-0.0004	-0.620
FRBSWAP	0.0152	7.230	0.0186	4.885
TAFUSA	0.0002	0.381	-0.0003	-0.408
BOJ(Corporate)	0.0005	1.082	0.0004	0.653
BOJ(CP)	0.0000	-0.008	0.0000	-0.050
VIX	0.0000	0.865	-0.0001	-5.235
CIP	-0.0037	-4.857	-0.0035	-5.034
OISYEN	-0.0003	-0.184	-0.0234	-13.720
OISDOLLAR	-0.0005	-1.750	0.0006	2.167
constant	-0.6281	-8.882	0.0000	4.229
f(11)	0.6325	28.159		
f(21)	-0.0361	-1.872		
f(31)	0.3725	14.981		
f(32)	0.6083	23.502		
g(11)			0.5957	9.755
g(21)			0.2676	2.813
g(31)			0.3682	5.147
g(32)			0.1472	2.668
Adj. R-squared	0.991		0.991	

Notes

1) Except for the variance equation, the dentitions of the explanatory variables are the same as those in Table 3.

2) The parameters in the variance equations are those of the equations: $ln(h_t) = c + f_{11}\cdot|z_{t-1}| + f_{21}\cdot z_{t-1} + f_{31}\cdot ln(h_{t-1}) + f_{32}\cdot ln(h_{t-2})$ and $h_t = c + g_{11}\cdot u_{t-1}^2 + g_{21}\cdot u_{t-1}^2\cdot I_{t-1} + g_{31}\cdot h_{t-1} + g_{32}\cdot h_{t-2}$.

Table 7. Determinants of Eurodollar Spreads under Different Terms to Maturity

	one month rates		twelve month rates	
	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	-0.1044	-8.992	-0.0269	-2.2006
Dollar SPR(-1)	0.4978	20.169	0.5396	14.1185
Yen SPR(-1)	-0.2080	-8.353	0.0637	1.4356
dDollarSPR(-1)	-0.0066	-0.201	-0.1221	-3.3039
dYenSPR(-1)	0.1322	1.280	0.1113	0.7460
3M Yen S(-1)			-0.1179	-3.1847
CDS(Japan)	0.0261	8.817	0.0081	2.3765
CDS(UK)	-0.0002	-1.939	0.0000	-0.3019
CD(USA)	0.0001	3.330	0.0000	-0.5633
SWAPA(BOJ)	-0.0020	-4.007	-0.0010	-2.8080
SWAPD(BOE)	0.0122	2.018	0.0128	3.2413
SWAPD(ECB)	0.0198	1.657	0.0272	3.3038
FRBSWAP	0.4882	14.583	0.0796	3.5036
TAFUSA	-0.0013	-0.198	0.0055	1.2488
BOJ(Corporate)	0.0033	0.452	0.0052	1.0523
BOJ(CP)	-0.0024	-0.384	0.0012	0.2730
Dummy	0.8776	15.586		
Adj. R-squared	0.819		0.409	
LM Test	12.871		9.889	

Notes

1) 3M Yen S = three-month Euroyen TIBOR – LIBOR, and Dummy = dummy that takes one on September 19, 2008 and zero otherwise.
2) The dentitions of the other explanatory variables are the same as those in Table 3.
3) LM test shows F-values based on Breusch-Godfrey Serial Correlation LM Test.

Table 8. Determinants of Euroyen Spreads under Different Terms to Maturity

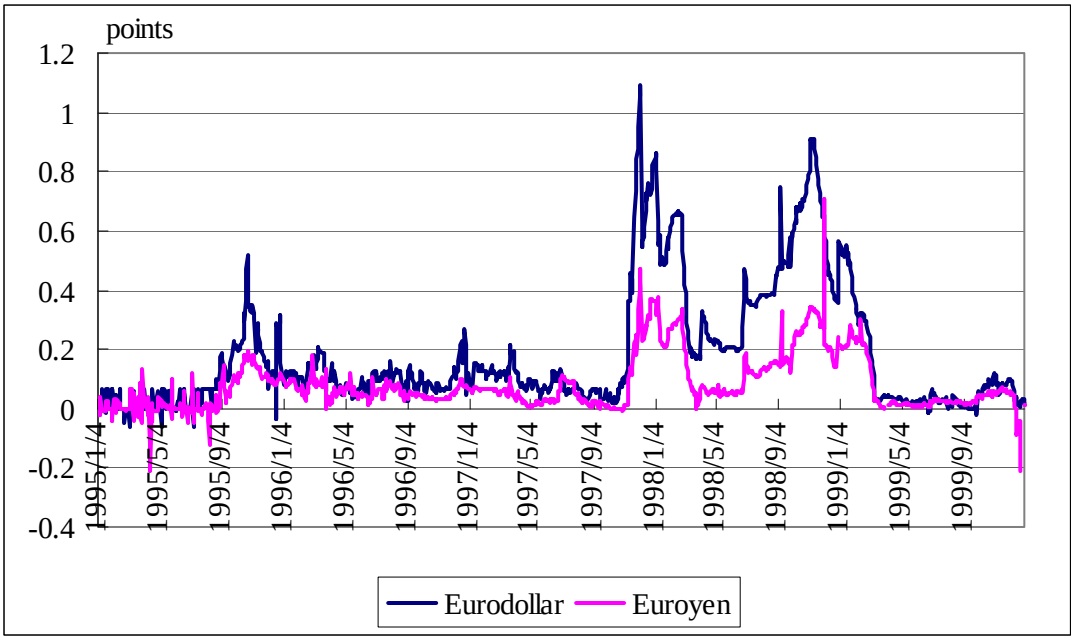
	one month rates		twelve month rates	
	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	-0.0263	-5.643	-0.0059	-3.4435
Yen SPR(-1)	0.9015	65.579	0.9844	164.6062
Dollar SPR(-1)	-0.0210	-1.061	0.0055	0.6714
dYenSPR(-1)	0.0678	1.814	0.0397	2.2593
dDollarSPR(-1)	0.0049	0.465	0.0015	0.3377
3M Dollar S(-1)	0.0270	1.788		
CDS(Japan)	0.0062	5.216	0.0015	3.2670
CDS(UK)	-0.0001	-2.871	0.0000	-2.9975
CD(USA)	0.0000	2.758	0.0000	-0.1530
SWAPA(BOJ)	-0.0005	-2.730	-0.0002	-2.6988
SWAPD(BOE)	0.0004	0.176	-0.0001	-0.0542
SWAPD(ECB)	-0.0072	-1.617	0.0011	0.5597
FRBSWAP	-0.0086	-0.675	-0.0022	-0.3868
TAFUSA	-0.0041	-1.733	-0.0003	-0.2338
BOJ(Corporate)	0.0009	0.359	0.0006	0.5164
BOJ(CP)	-0.0005	-0.210	0.0009	0.8671
CIP	-0.0130	-5.539		
Adj. R-squared	0.968		0.987	
LM Test	1.336		18.304	

Notes

1) 3M Dollar S = three-month Eurodollar TIBOR – LIBOR.
2) The dentitions of the other explanatory variables are the same as those in Table 3.
3) LM test shows F-values based on Breusch-Godfrey Serial Correlation LM Test.

Figure 1. The TIBOR − LIBOR spreads in the Eurodollar and the Euroyen

(1) The Period of the Japanese Banking Crisis



(2) The Period of the Global Financial Crisis

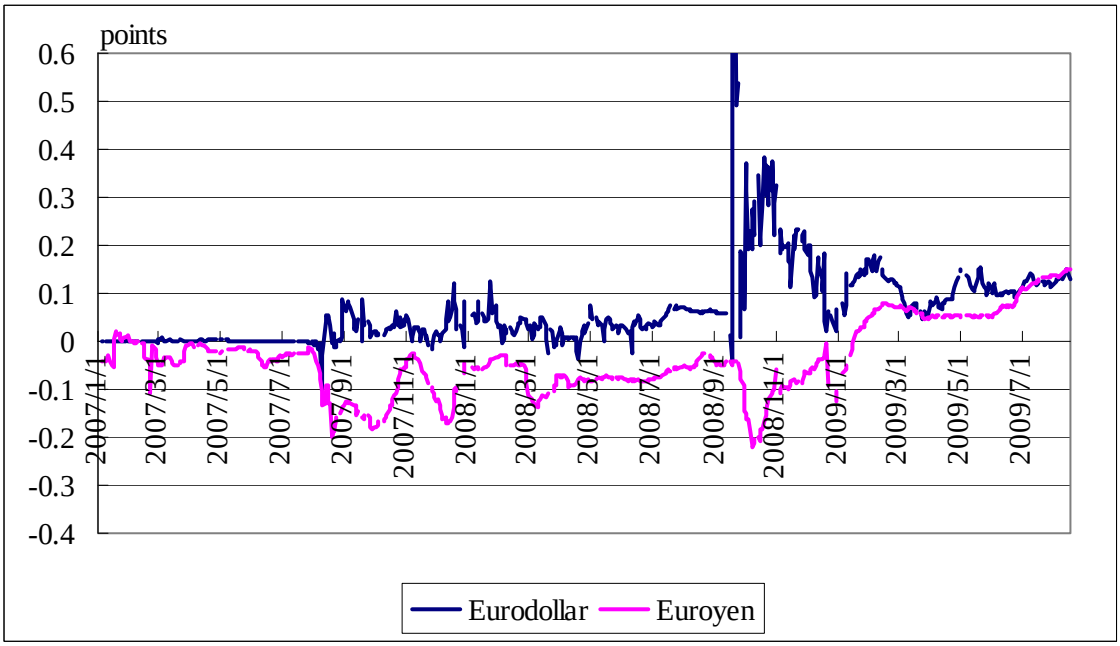
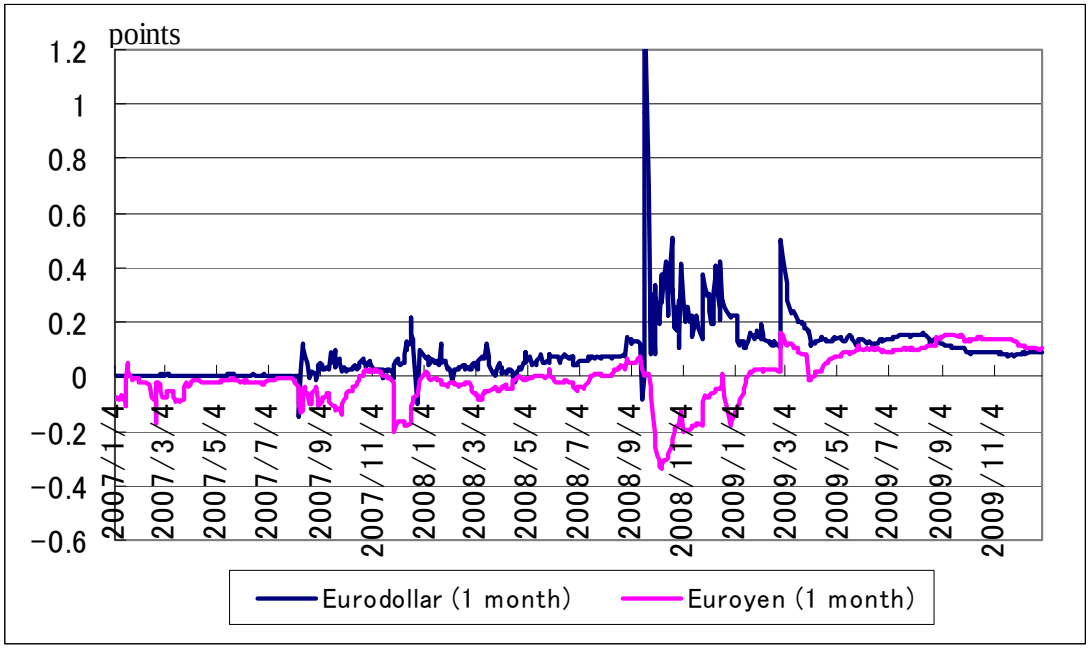


Figure 2. The Spreads under Shorter or Longer Terms-to-Maturity

(1) The TIBOR – LIBOR spreads for the One-month Rates



(2) The TIBOR – LIBOR spreads for the Twelve-month Rates