Money Market Integration during the Global Financial Crisis: Evidence from the Interbank Markets in Tokyo and London*

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Abstract

In this paper, we explore how international money markets were integrated 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 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 risk premiums. The regression results suggest that counter-party credit risk was responsible for the different responses 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 integration during the 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 and time differences, 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 Japanese money market was integrated with the London money market 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 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 United States (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 particular, it is not clear how well the synchronization with LIBOR persists when economies are in financial crisis.

The following analysis investigates to what extent TIBOR was synchronized with LIBOR in 2007-2009. To calculate the synchronization, dollar-denominated TIBOR is matched with the dollar-denominated LIBOR. Yen-denominated TIBOR is also matched with the yen-denominated 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 global financial crisis. Regardless of the currency denomination, the Tokyo market is highly synchronized with the London market in tranquil periods. However, during the global financial crisis, the interbank offered rates show substantial deviations even denominated in the same currency. More interestingly, there are remarkable asymmetric responses in 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, suggesting that the London market carried a larger counter-party credit risk than did the Tokyo market. 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 local-currency-denominated markets had a “home bias” feature reflecting different risk premiums under the liquidity crisis. Our regression results show that credit risk was responsible for the different responses 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 integration 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. 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 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 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 the degree of integration 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 dollar-denominated and local-currency-denominated rates. Our regression results suggest the importance of distinguishing not only between credit risk and liquidity risk but also between liquidity risks denominated in different currencies.

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. Section 6 reports the results of our regressions. Section 7 concludes and refers to the implications.

2. The Interbank Offered Rates

In the following analysis, we use the daily offer rates for the 3-month TIBOR and the 3-month LIBOR. This section briefly describes the data of interbank offered rates used in the analyses. The daily data for the London analyses are downloaded from Datastream. The data for Tokyo are downloaded from the Nikkei Financial QUEST database.

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. For example, a multinational corporation with a very good credit rating may be able to borrow money for 1 year at LIBOR plus four or five points.

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).[1] 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

[1] 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.

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," this chapter refers to LIBOR denominated in the US dollar as “Eurodollar LIBOR” and LIBOR in the Japanese yen as “Euroyen LIBOR.”

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.

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). Although there is a partial overlap of reference banks between LIBOR and TIBOR, the reference banks in TIBOR are dominated by Japanese banks.[2] 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 (“Eurodollar

[2] 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.

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.

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

Before exploring the degree of integration 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. Integration 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, given similar risk characteristics and regulatory treatments, 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 exceeds 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.

That the annual average spread becomes close to 0.09 points in 2008 and exceeds 0.1 points in 2009 implies that TIBOR becomes significantly higher than LIBOR during the global financial crisis; and that risk premiums in the Eurodollar markets boost both LIBOR and TIBOR during the crisis, but the impacts are greater on TIBOR than on LIBOR. This result is 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.

Figure 1 depicts the time series of the 3-month Eurodollar LIBOR and TIBOR from January 2007 to December 2009. For comparison, the figure also depicts the 3-month overnight index swap (OIS) in the New York market as a proxy for the risk-free 3-month rate in the US dollar.[3] The figure shows that the three series move very closely before August 2007, but, after August 2007, both LIBOR and TIBOR deviate substantially upward from the OIS. The upward deviations reflect risk premiums in the two interbank markets under the global crisis - after the failure of Lehman Brothers in September 2008, the deviations become much larger. At the same time, TIBOR starts to show modest upward deviations from

[3] The OIS rate is closely connected to the average overnight interest rate expected to prevail over the next 3 months. An OIS is structured as follows: at maturity, the parties exchange the difference between the interest that would be accrued from repeatedly rolling over an investment in the overnight market and the interest that would be accrued at the agreed OIS fixed rate. The OIS market is liquid and the loss in the event of a counterparty default involves with only the accrued interest but not the principal as no money changes hands until the maturity date.

LIBOR, which persist in 2009 even as the deviations from the OIS become smaller.

3.2. Integration in the Japanese Yen

The last subsection investigated the relationship between the two daily offer rates for 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).[4] 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 and regulatory treatments, 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 becomes large during 1995--1999, especially in 1998, when the credit quality of Japanese banks deteriorated substantially. But the deviations are smaller than those in the Eurodollar markets. This suggests that the credit risk during the Japanese banking crisis is 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 US dollar vis-à-vis in the Japanese yen.

The Table shows that the annual average, when positive, is very small in nonfinancial crisis periods. But it becomes significantly different from zero during 2003–2005, when the Bank of Japan intensified its quantitative easing policy. The unconventional monetary policy

[4] 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.

distorted yen-denominated money markets but not dollar-denominated ones. The asymmetry made the TIBOR–LIBOR spreads significantly different from zero only 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 become 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 raise 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 2 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 17 August 2009. During the Japanese banking crisis, the TIBOR–LIBOR spreads start to take positive values in the summer of 1995 in both the Eurodollar and the Euroyen markets. The spreads become temporarily small from April 1996 to October 1997, then become very large after the collapse of major Japanese financial institutions in November 1997. The spreads remain large through March 1999. A key feature in this period is that the TIBOR–LIBOR spreads have very large positive values in both markets, although they are 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 start to take

opposite signs in the two markets. Before August 2007, the spreads are close to zero in both markets. But after August 2007, the spreads start to take positive values in the Eurodollar market and negative values in the Euroyen market. Before the summer of 2008, the absolute value of the deviations is slightly larger in the Euroyen than in the Eurodollar market. Then, after September 2008, it becomes larger in the Eurodollar than in the Euroyen market. The asymmetric impacts in the two markets are in marked contrast with what is observed during the Japanese banking crisis. The asymmetric deviations continue into the beginning of 2009. After January 2009, the TIBOR−LIBOR spreads start 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". Since we 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 deterioriated 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 thus 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 index for the United Kingdom and the United States. The data is based

on CMA Data Vision and is 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. Since the CDS index for Japan is volatile, the following analysis used its logged value in the regression.

Unlike credit risk, it is difficult to measure liquidity risk directly. But under 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) and the Bank of England (BOE) as well as its announcements. For each FX Swap, we include a dummy variable which takes one on the dates for the operations and zero otherwise. We also include a dummy variable which takes one on the dates when FRB announced the swaps lines and zero otherwise.

To measure another effects on the liquidity risk premium, we include dummies for the FRB's Term Auction Facility (TAF)[5] as well as the BOJ's "outright purchases of CP" and "special funds-supplying operations to facilitate corporate financing".[6] Each dummy variable takes one on the dates when each operation took place and zero otherwise. These facilities

[5] 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).

[6] "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.

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. In contrast, 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 OIS rates as well as deviations from the covered interest parity (CPI) condition as auxiliary variables. The inclusion of these auxiliary variables is to check the robustness of our estimation results. In contrast to interbank loans, OIS transactions contain little liquidity or credit risk premium. The OIS rates thus 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 deviation from the covered interest parity (CPI) condition of the yen-dollar exchange rates, we use the OIS rates in Tokyo and New York markets as well as spot and forward exchange rates. To the extent that OIS transactions contain little liquidity or credit risk premium, the deviations allow us to calculate the risks which are specific in the foreign exchange market.

6. Econometric Tests

In this section, we endeavor to test how various factors—including the risk measures and liquidity measures explored in previous sections —affect the TIBOR–LIBOR spread. Our tests are performed with simple OLS regressions, whose results are summarized in Tables 3 and 4. 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. The dependent variable in each regression is either the three-month Eurodollar TIBOR−LIBOR spread, shown in Table 3, or the three-month Euroyen TIBOR−LIBOR spread, shown in Table 4. 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 $Rf(h)_t$. Thus, equation (1) implies that the TIBOR−LIBOR spreads reflect the difference either in counter-party credit risk $Risk(h, k)_t$ or in liquidity risk $Liquidity(h, k)_t$ between the two markets. For each regression, we include their lagged values (two lags) of the TIBOR - LIBOR spreads as explanatory variables to correct serial correlations. Both of the tables show the estimation results with and without the auxiliary variables. Although some of the auxiliary variables are significant, the essential results are the same without the auxiliary variables.

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, 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, three dummies of the FX Swap Lines are significant for the Eurodollar TIBOR − LIBOR spread but not for the Euroyen TIBOR − LIBOR 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. The opposite signs between these FX swap facilities indicate that the BOJ's swap line was more effective in reducing 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 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.

In our regressions, no dummy variable to measure liquidity risk is significant for the Euroyen TIBOR − LIBOR 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 the 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 spread 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.

7. Concluding Remarks

Global financial integration may help the region promote the development of national and regional financial markets. This paper explores the degree of international money market integration 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. Their financial integration therefore helps to prevent global liquidity crises.

After matching the currency denomination, how TIBOR has been synchronized with LIBOR is investigated. Our noteworthy finding is the remarkably asymmetric responses in how the Tokyo market reflects both credit and liquidity risk premiums during the global financial crisis. We find that the asymmetric impacts in the dollar-denominated and local currency-denominated markets have 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 are 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. Coordinated central bank liquidity provisions were useful in reducing the risk premiums in the US dollar transactions. But their effectiveness was asymmetric across the markets.

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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

Dependent variable: Eurodollar TIBOR – LIBOR

	Coefficient	t-Statistic	Coefficient	t-Statistic
C	-0.00114	-0.03	-0.08305	-6.50
Dollar SPR(-1)	0.72158	21.34	0.78742	22.74
Yen SPR(-1)	0.06795	0.47	-0.15541	-1.05
Dollar SPR(-2)	-0.25436	-7.55	-0.17300	-5.07
Yen SPR(-2)	-0.02269	-0.16	0.05501	0.37
CDS(Japan)	0.01094	2.27	0.02231	6.91
CDS(UK)	-0.00019	-2.92	-0.00018	-2.58
CD(USA)	-0.00002	-0.81	-0.00001	-0.30
SWAP(BOJ)	-0.01905	-2.63	-0.02675	-3.54
SWAP(BOE)	0.01370	2.66	0.02497	4.78
FRBSWAP	0.22703	8.10	0.29443	10.45
TAF	0.00194	0.36	0.00025	0.04
BOJ(Corporate)	0.00083	0.14	-0.00053	-0.09
BOJ4(CP)	0.00397	0.61	0.00542	0.79
Deviation CIP	0.04234	8.84		
OISYEN	-0.03455	-1.71		
OISDOLLAR	-0.00157	-0.55		
Adj. R-squared	0.807		0.785	
D-W stat	2.048		2.138	

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.

Table 4. Determinants of Euroyen TIBOR - LIBOR Spreads

Dependent variable: Euroyen TIBOR – LIBOR

	Coefficient	t-Statistic	Coefficient	t-Statistic
C	-0.00238	-0.27	-0.01365	-4.17
Yen SPR(-1)	1.00345	26.04	1.04090	27.32
Dollar SPR(-1)	0.01724	1.91	0.00877	0.99
Yen SPR(-2)	-0.04749	-1.26	-0.06384	-1.68
Dollar SPR(-2)	-0.00834	-0.93	-0.01689	-1.93
CDS(Japan)	0.00258	2.01	0.00361	4.37
CDS(UK)	-0.00006	-3.52	-0.00005	-3.09
CD(USA)	0.00000	0.65	0.00000	-0.31
SWAP(BOJ)	-0.00257	-1.33	-0.00161	-0.83
SWAP(BOE)	0.00040	0.29	-0.00032	-0.24
FRBSWAP	0.00996	1.33	0.00066	0.09
TAF	-0.00143	-1.00	-0.00113	-0.79
BOJ(Corporate)	0.00072	0.46	0.00107	0.67
BOJ4(CP)	0.00035	0.20	0.00046	0.26
Deviation CIP	-0.00418	-3.28		
OISYEN	-0.01179	-2.19		
OISDOLLAR	-0.00046	-0.60		
Adj. R-squared	0.991		0.991	
D-W stat	1.992		2.014	

Note: Explanatory variables are the same as those in Table 3.

Figure 1. TIBOR, LIBOR, and OIS in the US Dollar

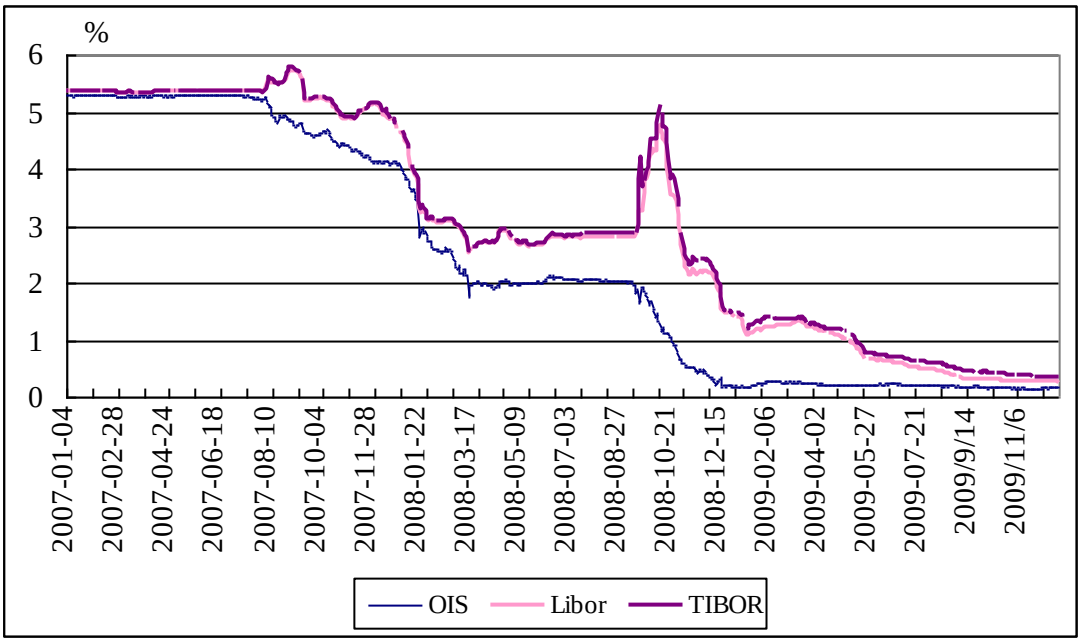
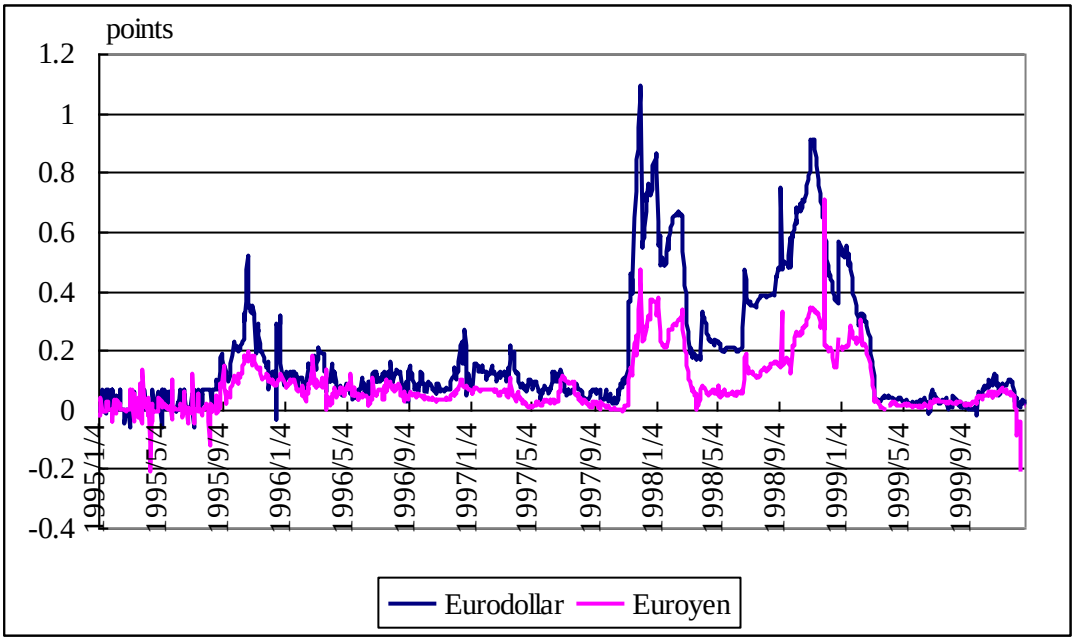


Figure 2. The TIBOR – LIBOR spreads in the Eurodollar and the Euroyen markets

(1) The Period of the Japanese Banking Crisis



(2) The Period of the Global Financial Crisis

