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Cross-currency transmission of money market tensions

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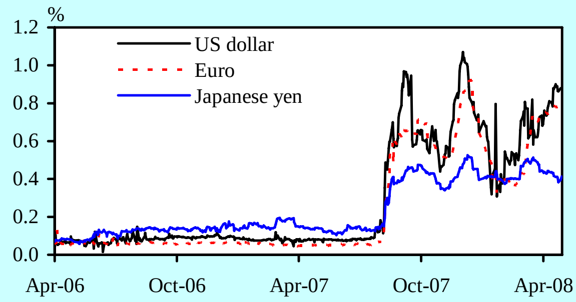
Funding conditions in global money markets have tightened since August 2007. In various currency-denominated money markets, term funding rates have come under upward pressure because of heightened concerns about counterparty credit and liquidity risks. Although the magnitude of upward pressure on interbank rates has differed across markets, the direction of its movements has followed a similar pattern. In this Review, using a vector autoregression model, we analyze the cross-currency transmission mechanism of term funding premia across the US dollar, euro, and Japanese yen markets. We find that the increased volatility in these markets results from not only changes in the variances of shocks impacting the market but also changes in the structure of the market. Under heightened uncertainty about US dollar funding, the interdependent relationship across these markets has strengthened via cross-market rebalancing activities of risk-averse financial institutions. In addition, market liquidity of the foreign exchange (FX) swap deteriorated after August 2007, which made it difficult for FX swap markets to mitigate the dislocation of US dollar liquidity. As a result, shocks for US dollar funding were not efficiently absorbed in global money markets, and the FX swap implied dollar rates from euro and yen were under persistent upward pressure. This strain in the FX swap markets was then fed back into the unsecured US dollar market, leading to further upward pressure on US dollar interbank rates.

Introduction

The tensions in term funding markets since August 2007 have been considerable. For example, the spreads between Libor and the comparable overnight index swap (OIS) rates rose sharply and have remained at high levels, reflecting the increase in credit risk and liquidity premium. Figure 1 shows the 3-month Libor-OIS spreads for three major currencies, the US dollar, euro and Japanese yen, and suggests two interesting facts.

First, during the turmoil in money markets, these three spreads were highly correlated with each other. For example, three spikes can be identified in September 2007, December 2007 and March 2008 for all currencies. Market contacts have suggested that the high correlation across currencies has been caused by cross-market rebalancing activities of financial institutions which have faced a shortage of US dollar funding. For example, these financial institutions have increased their borrowings in euro and yen, and actively converted them into US dollar through foreign exchange (FX) swaps, which has led to the tightening conditions in euro and yen markets.

Figure 1: Libor-OIS spreads



Sources: Bloomberg; Meitan Tradition.

Second, not only the mean but also the variance of each Libor-OIS spread increased. The standard deviation of the US dollar spread rose from 0.014% in the pre-turmoil period (April 2006 - July 2007) to

0.198% during the turmoil (August 2007 - April 2008), by roughly 14 times; that of the euro spread rose from 0.007% to 0.173%, by 24 times; that of the Japanese yen spread rose from 0.018% to 0.045%, by 2.5 times. In addition, the spreads have become persistent for all currencies. Although the degree of the increase in variances and persistence of the Libor-OIS spreads differs across currencies, the structure of the money markets appears to have changed since August 2007.

In the following, we briefly explain the information content of Libor-OIS spreads, and then investigate the backgrounds of the two facts given above. Using a vector autoregression (VAR) model, we show how the cross-currency transmission mechanism of term funding premia has changed since last summer, and explain how the tensions have propagated globally with interaction between money markets and FX swap markets.

Decomposition of Libor-OIS spreads: credit risk and liquidity premium

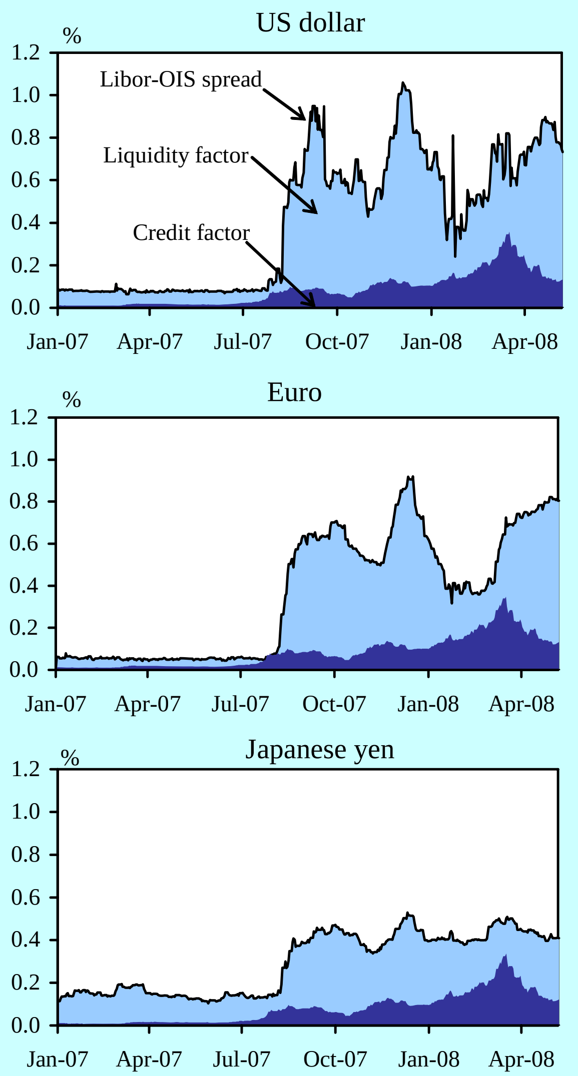
Libor is the most widely used benchmark for the short-term interbank interest rate. In principle, Libor reflects current and expected future overnight interest rates over the corresponding period of time and the premium associated with counterparty credit risk and liquidity risk.

The counterparty credit risk premium arises because Libor is the rate on unsecured lending to financial institutions, and the lender requires compensation for the risk of a default on this credit.

The liquidity premium arises out of banks' incentive to protect their liquidity positions under uncertainty. Liquidity can be seen as the ease with which a bank can access cash by obtaining credit from another bank. As uncertainty about market conditions increases or the strains in markets grow, banks find it harder to secure term funding. This is because some banks have an increased demand for funding but other banks become reluctant to provide cash since they seek to protect their own liquidity positions. Such developments push the Libor well above what could be considered reasonable compensation for default risk.

On the other hand, the OIS rate can be viewed as a mirror of pure expectation about future overnight interest rates since OIS transactions do not involve a cash flow and the premium for its liquidity and credit risk is quite limited.[1] Therefore, the Libor-OIS spread can be considered as a good indicator of credit risk and liquidity premium.

Figure 2: Decomposition of Libor-OIS spreads



Note: Authors' calculation.
Sources: Bloomberg; Meitan Tradition.

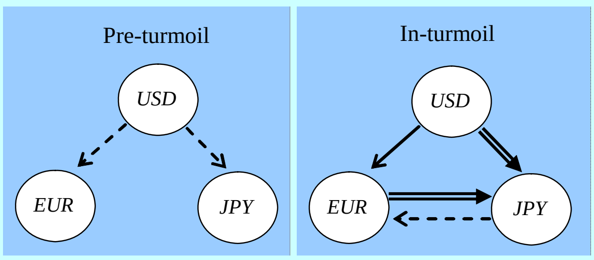
Figure 2 shows the decomposition of Libor-OIS spreads into credit risk premium and liquidity premium. The estimates of credit premium are based on prices of credit default swaps for banks in the Libor panel.[2] We assume that any difference between the observed Libor-OIS spread and the estimated credit premium reflects the liquidity premium.

The credit premium affects the Libor-OIS spreads for different currencies in a similar way because internationally active banks should pay the same credit premium in all currency markets and the Libor panels are very similar across currencies. This partially leads to the correlation between the spreads. Figure 2 shows, however, that the credit risk premium does not have much explanatory power for fluctuations in Libor-OIS spreads. Instead, the liquidity premium has larger explanatory power for all currency spreads, and seems to have played a crucial role in the cross-currency transmission of term funding premia.

US dollar liquidity shortages in interbank markets

The high correlation of the Libor-OIS spreads across currencies suggests that a funding shock occurring in a certain currency money market led to an increase in the liquidity premium and then spilled over to the other currency markets. In order to statistically verify this view and analyze the cross-currency transmission mechanism of term funding premium, we estimate the trivariate VAR model based on the 3-month Libor-OIS spreads (daily data) for the US dollar (*USD*), euro (*EUR*) and Japanese yen (*JPY*).[3] VAR is an econometric model used to capture the evolution and the interdependencies between multiple time series. We set the beginning of the sample period at April 2006 to exclude the Bank of Japan's quantitative easing period, and split the sample period into two sub-samples: April 2006 - July 2007 (pre-turmoil) and August 2007 - April 2008 (in-turmoil), in order to examine how the cross-currency transmission mechanism of term funding premia changed after the subprime woes.

Figure 3: Granger causality of Libor-OIS spreads



Note: The double, single and dotted arrows indicate that the null hypothesis of no causality can be rejected at the 1%, 5% and 10% significance level, respectively.

Figure 3 presents results of the Granger causality test. Granger causality is a statistical concept of causality that is based on prediction, i.e. a technique for determining whether one spread is useful in forecasting another. In the pre-turmoil period, there is no statistically significant causality between markets, and each currency market moved almost independently. This implies that the liquidity premium is currency-specific under normal market conditions and can be well-controlled by a central bank through its market operations. In the turmoil period, however, we find strong causalities in the Granger sense (1) from *USD* to *EUR* and *JPY* and (2) from *EUR* to *JPY*.

Figure 4: Variance decomposition of Libor-OIS spreads

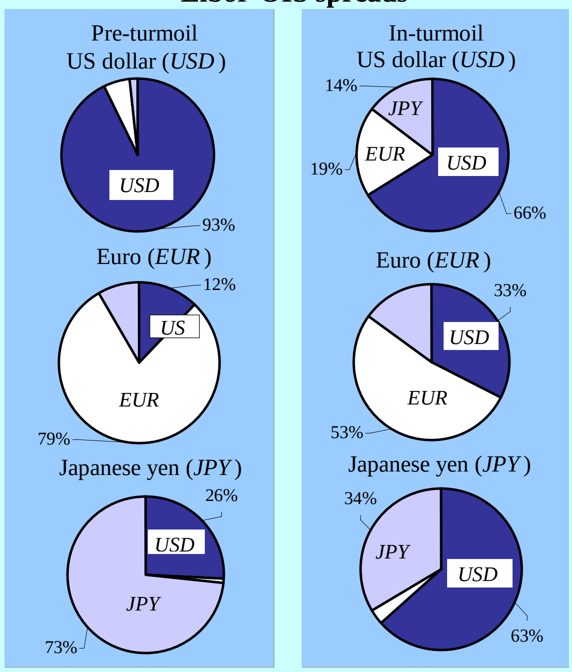


Figure 4 shows the results of the variance decomposition, which provides information about the relative importance of each shock in affecting the spreads in the VAR. The results are consistent with those of the Granger causality test: (1) While a large percentage of variances of *EUR* and *JPY* spreads is attributable to their own shocks in the pre-turmoil period, this proportion drops in the turmoil period, and *USD* shocks instead come to account for a larger percentage; (2) *EUR* shocks remain unimportant on the variance of *JPY* spread, implying that Granger causality from *EUR* to *JPY* in the turmoil period results from the indirect impact of *USD* shocks via *EUR* spread; (3) While more than

90% of the variance of *USD* spread is attributable to its own shocks in the pre-turmoil period, this proportion drops in the turmoil period, and *EUR* and *JPY* shocks come to account for a larger percentage.

What drove the causality among currencies during the turmoil? As noted earlier, internationally active banks pay the same credit premium in all currency markets, and the credit premium affects the Libor-OIS spreads for different currencies in a similar way. Therefore, the credit premium leads to a correlation but not one-way causality among currencies, and the fluctuations in liquidity premium instead result in Granger causality from one currency to another. The results of VAR are consistent with the general view that a large shock of US dollar funding, i.e. US dollar liquidity shortages in interbank markets, caused the upward pressure on term funding rates, and its effect spilled over into other currency markets.

Source of liquidity premium and its cross-currency transmission

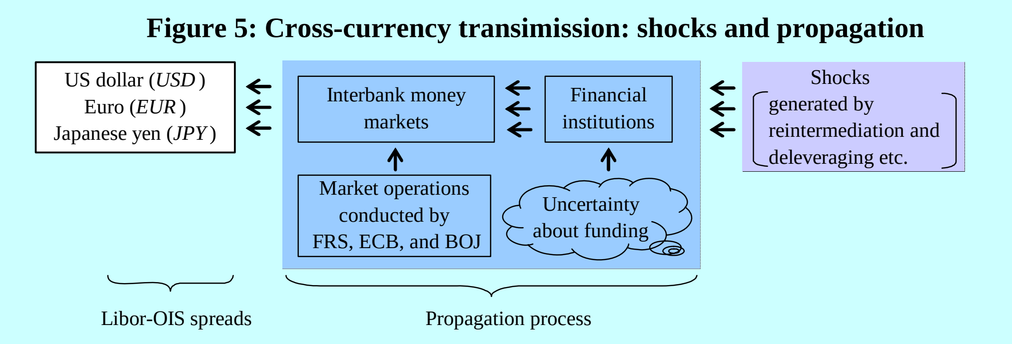
The shortage of US dollar liquidity in interbank markets mainly resulted from increased pressure on the balance sheets of banks. This balance sheet pressure is a consequence of the reintermediation process of financial flows back through the banking system. The collapse of large parts of the structured finance market left banks holding assets which they had expected to transfer off their balance sheets and facing obligations to off-balance-sheet vehicles whose normal commercial paper funding has dried up. For example, many banks including non-US banks had provided committed US dollar liquidity lines to specialist financial vehicles, conduits and corporates. Heightened uncertainty about if and when these lines might be drawn increased the banks' demand for US dollar term funds, and simultaneously made them reluctant to lend beyond short maturities.

In addition, the tensions in term funding markets were amplified by deleveraging. Many assets were viewed as having more credit risk, price risk, and liquidity risk than anticipated before. This perception of increased risk led to deleveraging, which pushed down asset prices for less liquid assets. The decline in asset prices generated losses for financial institutions and eroded their capital, making banks less willing to lend to others.

Facing a shortage of US dollar liquidity, many financial institutions, especially European banks, moved actively to convert other currencies into US dollars through FX swaps. In addition, internationally active banks target their liquidity positions and exposures at a global level, and therefore change their cash holdings and lending/borrowing position in a similar way across currencies: hoarding more liquidity and lending less cash to other banks. These changes in banks' behavior tighten demand/supply conditions in the global interbank markets and hence increase the pressure on term funding rates.

As noted in the Introduction, the prominent feature of Libor-OIS spreads during the turmoil is not only the increase in the mean but also the increase in the variance. With regard to the liquidity premium, the increase in the variance is caused by the rise in the magnitude of the funding shocks and/or the change in the propagation mechanism of funding shocks (Figure 5). The propagation of funding shocks to the liquidity premium crucially depends on the degree of uncertainty surrounding banks. For example, as uncertainty about if and when committed liquidity lines to borrowers might be drawn increases, financial institutions which face funding shocks become more cautious and try to hoard more liquidity and lend less cash to other banks for a longer period. This leads to a higher and more persistent liquidity premium.

In principle, central banks cannot control the magnitude of the daily funding shocks generated through the reintermediation and deleveraging process, because they are exogenous factors for central banks, at least in the short run. On the other hand, central banks may be able to affect the mechanism by which funding shocks propagate to the liquidity premium, by conducting market operations in order to reduce uncertainty about financial institutions' funding environment. In this sense, it is important to examine the significance of changes in the magnitude of the shocks themselves



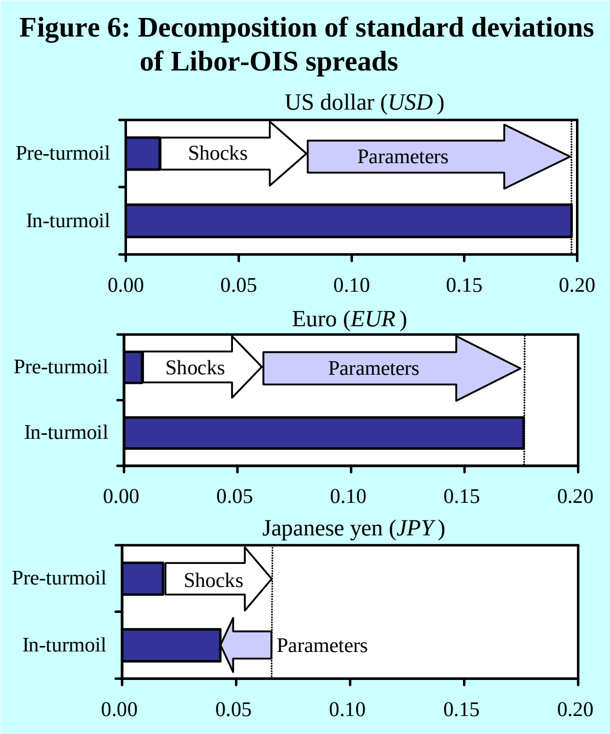
for explaining the increase in the variance of spreads, as well as the significance of changes in propagation and dynamic interaction between spreads, plausibly due to changes in uncertainty about financial institutions' funding environment.

Why did Libor-OIS spreads become volatile and persistent?

In order to quantify the relative contribution of changes in shocks versus changes in propagation mechanism, we used our VAR model to compute unconditional standard deviations of Libor-OIS spreads that go into the system under some assumption. The bar chart (deepest-colored) in Figure 6 shows the unconditional standard deviations which are computed from using each period's own shocks and parameters of the VAR model. These are fairly similar to the actual sample standard deviations.

Our counterfactual examines what happens to the unconditional standard deviations when we substitute the turmoil periods shocks into the model for the pre-turmoil period. [4] The white arrows labeled "shocks" in Figure 6 indicate the difference between our counterfactual and standard deviations computed using data from the pre-turmoil period. That is, it indicates to what degree standard deviations change when we change the magnitude of the shocks from the pre-turmoil period to the in-turmoil period by keeping the parameters unchanged in the VAR. The purple arrows labeled "parameters" indicate the difference between our counterfactual and standard deviations computed using data from the turmoil period. That is, it indicates to what degree standard deviations change when we change the parameters from the pre-turmoil period to the in-turmoil period by keeping the magnitude of the shocks unchanged in the VAR. Needless to say, changes in "parameters" reflect changes in the propagation mechanism which is affected by uncertainty surrounding financial institutions' funding environment and central banks' stance on market operations (Figure 5).

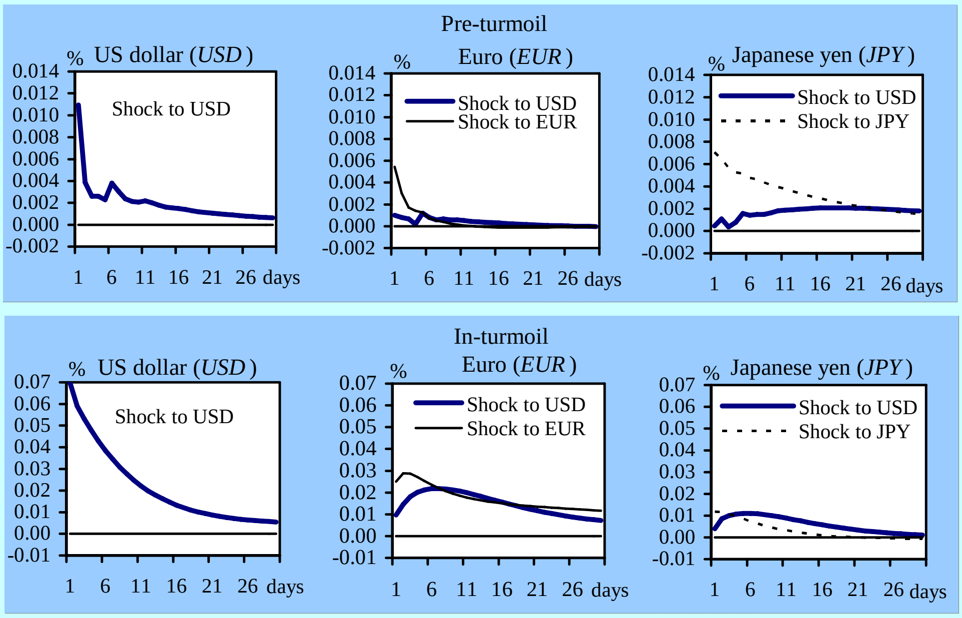
There are three important findings from Figure 6.



First, for all currency spreads, the increase in the magnitude of "shocks" is a significant factor for explaining the increase in standard deviations. The largest increase in "shocks" is observed in the *USD* spread, which is consistent with the causality tests and variance decompositions.

Second, for both *USD* and *EUR* spreads, the

Figure 7: Impulse responses of Libor-OIS spreads



change in "parameters" has much greater explanatory power for an increase in standard deviation than the change in "shocks." This implies that, during the turmoil, the impact of funding shocks on the liquidity premium is drastically amplified and disseminated across markets under heightened uncertainty surrounding banks' funding.

Third, in contrast to *USD* and *EUR* spreads, the contribution of changes in "parameters" for the *JPY* spread is negative. This implies that, in the Japanese money market, the impact of funding shocks on the liquidity premium is less during the turmoil than before.

With regard to the effect of changes in "parameters," we find consistent results from impulse response analysis of the VAR. Figure 7 displays the impulse response functions to funding shocks (i.e. an increase in spreads of one standard deviation) for each sample period. Impulse response functions trace the dynamic effects of a shock to one spread on to the other spreads in the VAR. The key result from the comparison across sample periods is that the responses of both *USD* and *EUR* spreads become very persistent during the turmoil, which implies the increase in the variance of spreads. On the other hand, the response of the *JPY* spread becomes less persistent, which implies the decrease in the variance of the spread.

The reason why the contribution of changes in propagation for the increase in the variance of *USD* and *EUR* spreads is so large and why the effect of funding shocks on these spreads becomes persistent is increased uncertainty surrounding financial institutions' funding due to their large exposure to subprime-related products. On the other hand, the negative contribution of changes in propagation for the increase in the variance of *JPY* spreads reflects relatively little uncertainty about funding in the Japanese yen market, which may be attributed to at least the following two factors: (1) Japanese banks' exposure to subprime-related products was relatively limited; and (2) the Bank of Japan sought to stabilize the overnight rate at around the target level by more actively supplying liquidity using a variety of operational tools as well as extending the average term of providing operations (see Box for further discussion).

Market liquidity of FX swaps

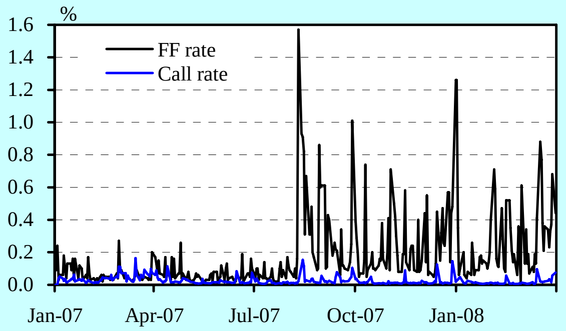
Now, we review how money markets and FX swap markets interact with each other and how the tension in each market propagates globally. European banks, as noted earlier, funded a significantly large amount of US dollars in FX swap markets to meet large, but uncertain, funding needs. To do this, they borrow in the euro unsecured cash market and convert euro into US dollar in the FX

Box: Intraday volatility of overnight interest rates and central banks' market operations

Intraday volatility of overnight rates reflects the magnitude of financial institutions' liquidity gap and the degree of fine-tuning of central banks' market operations. The larger the financial institutions' liquidity gap, the higher the intraday volatility of overnight interest rates. Meanwhile, the more inclined central banks are to fill liquidity gaps in the market, the lower the intraday volatility of interest rates.

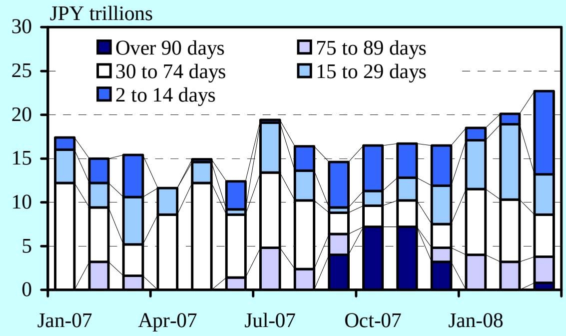
Since August 2007, intraday volatility of the federal funds rate has risen because of the increase in liquidity gap (Box Figure 1). European banks try to cover their dollar short positions during European trading time, but this is at a time when US banks are reluctant to lend, as they prefer to wait until later in the day when uncertainties related to their net positions are reduced. Due to this time-zone friction, European banks which have raised their demand for dollar liquidity have encountered difficulties in funding their short positions, leading to the rise in intraday liquidity gap in the federal funds market. On the other hand, intraday volatility of the call rates in Japan's overnight market has remained low. This is probably because there is relatively little uncertainty about Japanese banks' funding environment due to their limited exposure to subprime-related products. In addition, by actively providing liquidity using a variety of operational tools and by extending the average term of providing operations – e.g. the Bank of Japan started providing funds covering calendar and fiscal year-end, earlier than in previous years - (Box Figure 2), the Bank of Japan has stabilized the overnight rates at around the target level in order to prevent the intraday liquidity gap from widening.

Box Figure 1: Intraday standard deviations of overnight interest rates



Sources: Bloomberg; Bank of Japan.

Box Figure 2: The Bank of Japan's funds-supplying operations by maturity



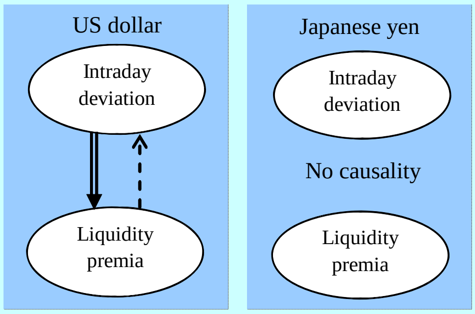
Note: Funds-supplying operations against pooled collateral.
Source: Bank of Japan.

Intraday volatility of overnight interest rates may affect the liquidity premium on term funding. If the intraday volatility of overnight rates gets high, banks become concerned about their daily funding and are inclined to raise more funds from term funding markets, which leads to an increase in liquidity premium. In contrast, if the intraday volatility of overnight rates remains low, banks feel secure about their daily funding and are less inclined to raise funds from term funding markets, which reduces the liquidity premium.

In order to analyze the interdependencies between intraday volatility of the overnight interest rates and liquidity premium on term funding, we estimate the bivariate VAR model for USD and JPY markets, comprising the liquidity premium on 3-month Libor-OIS spreads (shown in Figure 2) and intraday standard deviations of overnight interest rates (shown in Box Figure 1).[5]

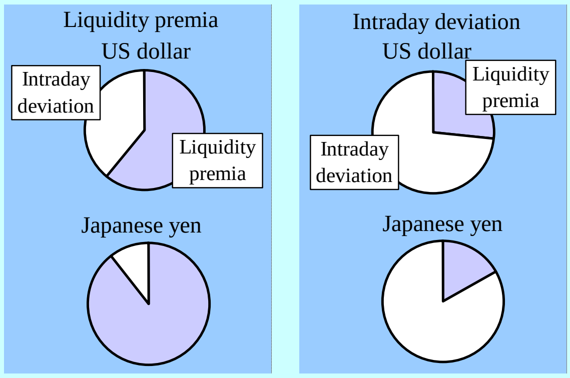
Box Figure 3 shows the results of the Granger causality tests. We find a clear causality in the Granger sense from the intraday volatility of the overnight interest rates to the liquidity premium on term funding for USD, but not for JPY. Variance decompositions suggest that 40% of the variance of the liquidity premium on USD term funding is attributable to the intraday volatility of the federal funds rates, while only 10% of the variance of the liquidity premium on JPY term funding is attributable to the intraday volatility of the call rates (Box Figure 4). These results imply that the difference in intraday volatility of overnight rates between the US federal funds market and Japanese call market results in the difference in liquidity premium of term funding between USD and JPY markets.

Box Figure 3: Granger causality



Note: The double and dotted arrows indicate that the null hypothesis of no causality can be rejected at the 1% and 10% significance level, respectively.

Box Figure 4: Variance decomposition



swap market. If their counterparties of FX swap transactions invest the received euros in the euro money market, then demand/supply conditions in the euro market do not change in total.[6]

The terms and instruments of the counterparties' investment, however, might be different from those of European banks' funding. For instance, while European banks are eager to borrow euros in the unsecured interbank term funding market, their counterparties of 3-month FX transactions may invest euros in the overnight repo market in order to avoid credit and liquidity risk. This kind of mismatch would influence demand/supply conditions for each term and instrument market at least in the short run, and would consequently raise pressure on the unsecured euro term funding market. The mechanism by which banks raise US dollars via the dollar/yen FX swap market is the same as that just noted for the euro/dollar FX swap market.

Here, we define the cost of raising US dollar funds in the FX swap markets as "FX swap implied dollar rates."[7] In the case when banks raise US dollars via the euro/dollar FX swap market, the FX swap implied dollar rate from euro can be defined as

$$1+EurUSD=F/S(1+EUR),$$

where S and F represent the FX spot and forward rates between the euro and dollar, and EUR is the unsecured euro funding rate (euro Libor). F/S corresponds to the euro/dollar forward discount rate that is used for the FX swap price quotation. In the same manner, we can define the FX swap implied dollar rate from yen as *JpyUSD*.

Figure 8: Instruments for US dollar funding

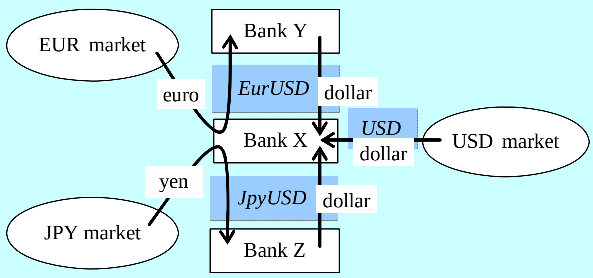
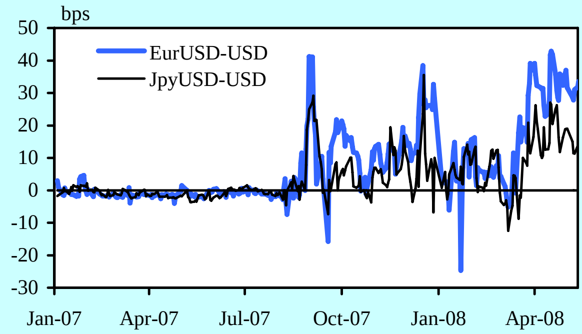


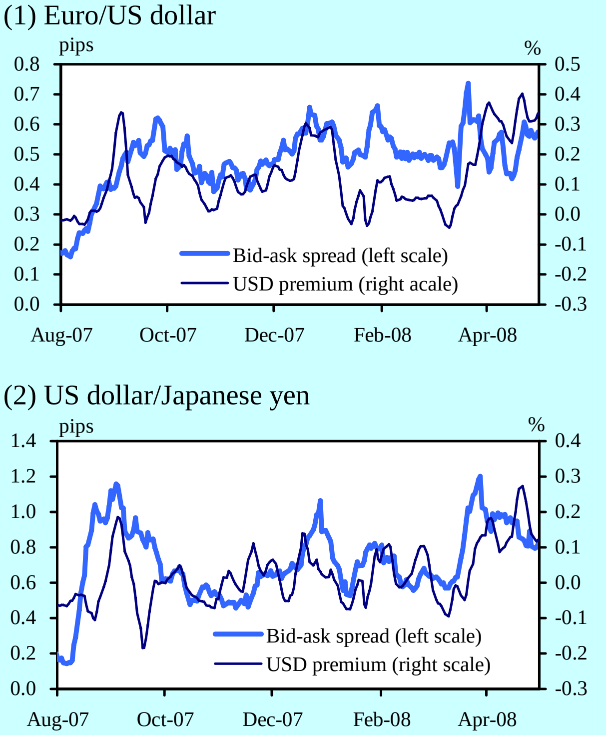
Figure 9: US dollar funding premia



Note: Authors' calculation.
Source: Meitan Tradition.

Financial institutions try to continuously conduct arbitrage transactions between the US dollar interbank market and FX swap markets (Figure 8). They compare the US dollar deposit rate (US dollar Libor: *USD*) with the FX swap implied dollar rates (*EurUSD*, *JpyUSD*). When the latter is higher than the former, borrowers shift their funding source from the FX swap market to the US dollar money market, while lenders shift their loans in the opposite direction. Hence, the FX swap implied dollar rates usually move along with the US dollar deposit rate. Indeed, as shown in Figure 9, the spreads between the FX swap implied dollar rates (*EurUSD*, *JpyUSD*) and US dollar Libor (*USD*) were quite narrow in the pre-turmoil period. However, these spreads widened considerably after August 2007, implying that the US dollar funding premium in the FX swap markets rose during the turmoil.

Figure 10: Bid-ask spreads of FX swap



Notes: 1. Daily Bid-ask spread is the average of hourly closing bid-ask spreads from Bloomberg.
2. 5-day moving averages.
Sources: Bloomberg; Meitan Tradition.

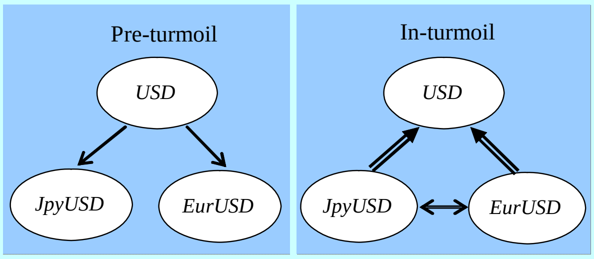
The US dollar funding premium in the FX swap market mainly results from the deterioration in market liquidity. The efforts of many non-US banks to convert euro or yen into US dollar reduced market liquidity of FX swaps, as it became difficult for them to find sellers of US dollars. Such a view is supported by the movement of the bid-ask spreads on the FX forward discount rates for the euro/dollar and dollar/yen pairs, which is a proxy for the market liquidity of FX swaps. When market liquidity is low and the bid-ask spread widens, large-volume transactions are likely to have a significant market impact on the FX implied dollar rate. As shown in Figure 10, the bid-ask spreads widened in FX swap markets for the euro/dollar and dollar/yen pairs in August 2007, and then the US dollar funding premium in the FX swap markets moved, on the whole, together with these bid-ask spreads.

FX swap implied dollar rates and US dollar Libor: Empirical analysis

Facing the decline in market liquidity of FX swaps, banks rebalanced their positions both in the FX swap markets and in the US dollar unsecured cash markets. In order to investigate the significance of this effect, we again estimate the VAR model which comprises three variables: *USD*, *EurUSD*, and *JpyUSD*. All three variables are defined as the spreads over the corresponding US dollar OIS rate.[8]

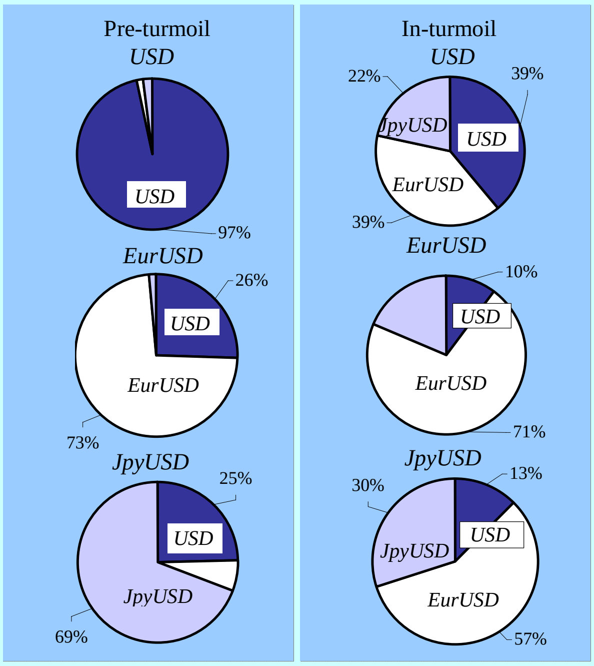
The Granger causality test suggests a structural change of causality after August 2007 (Figure 11). While causalities from *USD* to *EurUSD* and *JpyUSD* are observed during the pre-turmoil period (April 2006 - July 2007), reverse-causalities from *EurUSD* and *JpyUSD* to *USD* are observed during the turmoil period (August 2007 - April 2008).

Figure 11: Granger causality of dollar rates



Note: The double and single arrows indicate that the null hypothesis of no causality can be rejected at the 1% and 5% significance level, respectively.

Figure 12: Variance decomposition of dollar rates

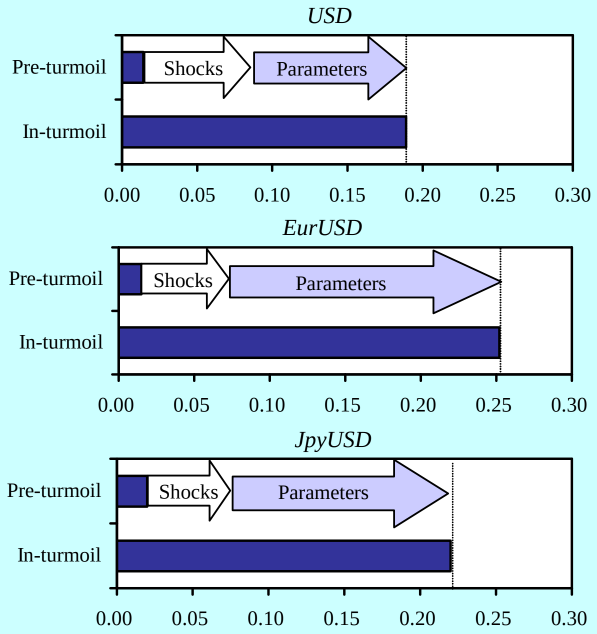


The results of variance decomposition are consistent with Granger causality (Figure 12): (1) While 97% of the variance of *USD* is attributable to its own shocks in the pre-turmoil period, this proportion drops to less than 40% in the turmoil period, and *EurUSD* and *JpyUSD* shocks instead come to have larger explanatory power for the variance of *USD*; (2) While *USD* shocks account for around 25% of the variance of *EurUSD* and *JpyUSD* in the pre-turmoil period, this proportion falls to around 10% in the turmoil period, and the sum of *EurUSD* and *JpyUSD* shocks instead comes to have larger explanatory power for their own variances.

These results imply that while demand/supply conditions in the US dollar interbank market significantly affected the FX swap implied dollar rate before August 2007, the strong demand for US dollar funding in the FX swap markets conversely led to upward pressure on term funding rates in the US dollar market from August 2007 onward. Reverse causalities mainly result from the deterioration of market liquidity of FX swaps. When the FX swap markets are fully liquid, they can absorb demand/supply shocks in the US dollar market by diversifying the effects of shocks to other currency-denominated money markets. When the FX swap markets are illiquid, however, it is difficult for banks to find sellers of US dollars, which exerts upward pressure on FX swap implied dollar rates. In this case, some borrowers try to increase the direct funding of the US dollars by paying additional premium in the unsecured US dollar market, while some lenders shift their loans from the US dollar market to the FX swap market. This then leads to upward pressures on US dollar interbank rates. In addition to such a rebalancing channel, the strain in FX swap markets may be fed back into the US dollar market through a signaling channel of Non-US banks' liquidity shortages.

In order to quantify the impact of the deteriorated market liquidity of FX swaps on dollar rates, we again used our VAR models to compute unconditional standard deviations of *USD*, *EurUSD* and *JpyUSD* (Figure 13). The increase in the unconditional standard deviation can be decomposed into contributions of changes in "shocks" and "parameters," the same as in Figure 6. The contribution of changes in "shocks" mainly represents funding shocks in each market, and the contribution of changes in "parameters" reflects changes in the propagation mechanism which is affected by uncertainty about financial institutions' funding environment including the state of market liquidity of FX swaps.

Figure 13: Decomposition of standard deviations of dollar rates



For all three dollar rates, the contribution of changes in "parameters" is larger than that of changes in "shocks." In addition, the standard deviations of *EurUSD* and *JpyUSD* are larger than that of *USD*, because the contribution of changes in "parameters" of *EurUSD* and *JpyUSD* is much larger than that of *USD*. This results from the influence of the deteriorated market liquidity of FX swaps, which exerted significant upward pressure on FX swap implied dollar rates in the turmoil period.

Conclusion

We reviewed the recent turmoil in global money markets triggered by the subprime woes. Our analysis suggested that the cross-currency transmission mechanism of term funding premia changed after August 2007, and the risk premium associated with term funding became highly correlated across currencies. In particular, heightened uncertainty about US dollar funding had a significant effect on the other currency markets. We also found that the deterioration in market liquidity of FX swaps played a crucial role in the cross-currency transmission of liquidity tensions.

To mitigate the liquidity tensions in money markets, central banks in the major economies initiated efforts from August 2007 to stabilize markets by providing substantial liquidity through flexible open-market operations beyond the traditional framework. Measures taken under the Federal Reserve's initiative included the establishment of a Term Auction Facility (TAF) and FX swap lines with the European Central Bank (ECB) and the Swiss National Bank (SNB). It is difficult to measure the direct effect of these liquidity policies, but the spread between the stop-out rate of TAF and the minimum bid rate has risen and fallen as term funding pressures have fluctuated, and the expansion of the size of the TAF program and the FX swaps program with the ECB and SNB has led to a fall in the stop-out rate.[9] This suggests that these policies have been helpful in improving market function, although further study is needed.

[1] OISs are interest rate swaps in which the floating leg is linked to a published index of daily overnight rates. The two parties agree to exchange, at maturity, the difference between interest accrued at the agreed fixed rate and interest accrued through the geometric average of the floating index rate.

[2] We derive the cumulative probability of default for a 5-year horizon, with the recovery rate of 40%, from 5-year CDS prices on the Libor panel banks, and convert it into that for a 3-month horizon under the assumption that the probability in each time interval of 3 months is unchanged during the next 5 years. For details of the estimation method, see Bank of England [2007] "An Indicative Decomposition of Libor Spreads" *Quarterly Bulletin*, December 2007.

[3] A lag length is selected using the Akaike information criterion. The VAR is identified by using Cholesky decomposition, with the order being the *USD*, *EUR*, and *JPY*.

[4] Ahmed *et al*. [2004] conducted a similar counterfactual exercise for the US macro economy to identify factors contributing to the Great Moderation. See Ahmed, Levin, and Wilson [2004] "Recent U.S. Macroeconomic Stability: Good Policies, Good Practices, or Good Luck?" *Review of Economics and Statistics*, No. 86.

[5] The sample period is from January 2007 to March 2008. The Cholesky ordering is intraday standard deviation, liquidity premium. We use weekly data to remove noisy spikes in intraday volatility of overnight rates related to reserve maintenances.

[6] See Jordan, *et al*. [2008] "Cross Currency Transmission of Credit and Liquidity Tensions in Money Markets," mimeo.

[7] See European Central Bank [2007] *Financial Stability Review*, December 2007, and Baba, Packer and Nagano [2008] "The spillover of money market turbulence to FX swap and cross-currency swap markets," *Bank for International Settlements Quarterly Review*, March 2008.

[8] The variables are daily data and the Choleski ordering is *USD*, *EurUSD*, *JpyUSD*.

[9] Dudley [2008], "May You Live in Interesting Times: The Sequel," Remarks at the Federal Reserve Bank of Chicago's 44th Annual Conference on Bank Structure and Competition.

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