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Liquidity Crunch in Late 2008: High-Frequency Differentials between Forward-Implied Funding Costs and Money Market Rates

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Abstract

The US Federal Reserve and the European Central Bank have adopted a number of measures, including aggressive policy rate cuts, to ease the liquidity crunch in the financial markets following the collapse of Lehman Brothers. Using high frequency spot and forward foreign exchange and interest rate quotes that are potentially executable for the period surrounding the 2008 global financial turmoil, this study examines the variations of intraday funding liquidity across the global financial markets that span different time zones. Moreover, the paper also tests how and to what extent policy actions undertaken by central banks affect the dynamics of market liquidity conditions. Similar to Hui *et al.* (2009), the paper uses the differential between the US dollar interest rate implied by the covered interest rate parity condition and the corresponding US dollar interest rate as a proxy for the liquidity (or the lack of it) in the US dollar money market. The study focuses on the EUR/USD exchange rate and compares the most stressful crisis period with other relatively less stressful periods. The intraday funding liquidity condition during the most tumultuous period shows that the pressures in the demand for US dollars through foreign exchange and forward markets spilled over to the Asian markets. The paper also examines how policy announcements by the central banks affect the dynamics of market

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liquidity. The study employs autoregressive models to capture the potential effects of monetary policy announcements on both the mean and volatility of the liquidity proxy. The empirical results show that the coordinated cuts of policy rates failed to stimulate lending in the short-term US money market, whereas the uncapped currency swap lines offered by the Federal Reserve to other central banks succeeded in easing the liquidity condition in the market. The policy is more effective and persistent for the very short end of the money market.

Keywords: Financial Crisis, Intraday Liquidity, CIP Deviation, Monetary Policy
JEL Classification: G14, G15, E5

1. Introduction

Triggered by the bankruptcy of Lehman Brothers in September 2008, the US sub-prime crisis that emerged in mid-2007 had developed into a global financial tsunami which paralysed many financial markets in the US, Europe and other regions. One channel for the financial spillover was severe disruptions in international money markets, especially the US dollar denominated money markets. The deleveraging process where financial institutions tried to reduce their exposures, created an enormous demand for US dollar liquidity while potential lenders withdrew from the market as concerns over counterparty and liquidity risks heightened. As a result, many US banks were facing severe US dollar funding shortages. On the other hand, many European banks also faced a severe liquidity crunch because of their large US dollar gaps.

Since US banks were reluctant to lend to non-US banks and non-bank institutions in general, it was difficult for European banks to directly access the US money markets. In order to obtain the needed US dollar, many non-US banks and non-bank institutions synthesised de facto US dollar loans through the foreign exchange and forward markets.[1] First, they borrowed funds from the euro and other money markets, exchanged them for the US dollar in the spot market, and short US-dollar forwards for future repayment of the foreign currency loans. In normal times, covered interest parity (CIP) should hold and the all-in-cost of fund (or the synthetic USD loan rate) via FX swaps or forwards should be very close to the cost of borrowing dollar directly from the US money market. However, during the global financial crisis, the large demand for synthetic USD loans raised Euro and other money market rates as well as the spot exchange for the US dollar, while lowered dollar forwards. These effects substantially pushed the synthetic US dollar loan rates above the corresponding money market rates. In a rather prolonged period after the Lehman Brothers failure, significant deviations of the USD-EUR forward-implied rate from the CIP were observed.[2]

The spread between the forward-implied US-dollar rate and the corresponding dollar rate in the US money market is a proxy for the deficiency of liquidity in the US-dollar denominated money market. Hui *et al.* (2009) and Baba and Parker (2009) find that, after the Lehman Brothers' collapse, large and highly variable spreads were observed in the European markets. McGuire and von Peter (2009) remarked that European banking systems built up long US-dollar positions vis-à-vis non-banks institutions and funded them by interbank borrowing via FX swaps. This exposed them to funding risk and an acute funding liquidity crunch during the global financial crisis.

[1] Coffey *et al.* (2009) documented the difficulty facing the small firms and non-US banks in obtaining US dollar liquidity during the crisis period.

[2] Mancini Griffoli and Ranaldo (2010) attributed the persistent deviations to the inability of traders to raise capital to take arbitrage because of deleveraging imperatives, prudential hoarding and limited available capital.

In response to the tight liquidity condition of the money market, the US Federal Reserve (Fed) lowered the target federal funds rate three times in less than three months in 2008, from 2% before the collapse of Lehman Brothers at the beginning of September to a target range of 0%-0.25% at the end of December. The first cut on October 8, 2008 was a coordinated action with the European Central Bank (ECB) and four other central banks.[3] Furthermore, the ECB cut interest rates two more times to 2.5% at the end of December 2008. An exceptional action taken by the Fed was to uncap the temporary swap facilities with the ECB, Bank of England (BOE), Swiss National Bank (SNB) and Bank of Japan (BoJ) on October 13, 2008 in order to improve liquidity in short-term US dollar funding markets[4] overseas.

This study examines the spread between the forward-implied US dollar rate and its corresponding interest rate using intraday bid-ask quotes of spot exchange rates, forward exchange rates and money market rates in the period from September 1 to December 31, 2008. These data are captured in real time from ICAP's Electronic Banking System (EBS). The spread enables us to gauge the change in the funding liquidity conditions across different time zones before and after the bankruptcy of Lehman Brothers. The study also investigates how and to what extent the monetary policy actions of the Fed and the ECB taken during the period, including the aggressive lowering of the fed funds target rate and the ECB policy rate, might have improved the US dollar liquidity condition. Furthermore, we study whether the US dollar swap arrangements between the Fed and the three European central banks has alleviated the dollar shortage of European banks.[5]

This paper proceeds as follows. Section 2 provides a brief overview of the global financial crisis and the monetary interventions taken by the Fed and the ECB. Section 3 discusses the intraday data. Section 4 describes the intraday patterns and examines the statistical properties of the spreads across different time zones. Section 5 details the methodology and summarises the empirical results. The last section concludes.

2. A Brief Overview of the Global Financial Crisis and Monetary Interventions

Many economists consider that the global financial crisis first began when the value of mortgage backed securities plunged in the US in mid-2007 as housing prices plummeted at the end of a prolonged property boom. The property bubble was fuelled by excessive lending under loosened underwriting standards

[3] The Fed, ECB, Bank of England, Bank of Canada and Sweden's Riksbank each reduced their benchmark rates by 50 basis points. The People's bank of China cut its key rate by 0.27 percentage point.

[4] Sizes of the reciprocal currency arrangements (swap lines) between the Federal Reserve and the BoE, the ECB, and the SNB were increased to accommodate whatever quantity of US dollar funding was demanded. The Bank of Japan was considering the introduction of similar measures. Please see details at http://www.federalreserve.gov/newsevents/press/monetary/20081013a.htm.

[5] Using the CIP deviations between the US dollar and the HK dollar, Fung and Yu investigated the effectiveness of the policy actions taken by the Hong Kong authorities.

which created a large pool of sub-prime mortgages in the system. The liquidity crisis was a direct result of the huge losses accumulated in the US banking system.

In March 2008, one of the US investment banks, Bear Stearns got into trouble because of a rumour that it did not have sufficient capital and liquidity to settle its transactions. This resulted in massive financial market disturbances and a fire-sale of the investment bank to JP Morgan Chase. The collapse of Bear Stearns raised the concern for counterparty risk in the global financial markets.

On September 14, 2008 the global financial crisis reached its watershed when Lehman Brothers filed for bankruptcy protection after being denied support by the US government. The Lehman case was then the largest bankruptcy case in US history and the investment bank was the largest underwriter of mortgage obligations. However, another financial institution, the AIG, had a better fate as it was rescued by the Fed with a USD 85 billion credit facility to prevent it from going bankrupt. In the following two weeks, the two remaining investment banks, Goldman Sachs and Morgan Stanley, converted into 'bank holding companies' in order to gain access to market liquidity. Following the collapse of Lehman Brothers, the contagion effect of the crisis swiftly spread to almost all major financial markets.

When the crisis first emerged, neither policymakers nor financial market participants anticipated the scale of the crisis that the financial system was heading for. One of the primary tools that the Fed used during the crisis was to cut the fed funds target rate. The Fed actually raised the rate to 5.25% in June 2006 and only started the first interest rate cut to 4.75% in September 2007 (Figure 1). When the crisis evolved, the Fed continued to cut the fed funds target rate six more times to 2% in April 2008. In order to rescue the whole financial system and prevent the economy from sinking into a deep recession, the Fed cut the fed funds target rate twice, each by 50 basis points, in October 2008 and finally cut the rate to a target range between 0 and 0.25% in December of the year.

Given the unprecedented scale of the financial crisis, many European financial institutions were also seriously affected. The ECB cut its policy rate by 50 basis points to 3.75% on October 8, 2008, with two more cuts to reduce the rate to 2.5% before the end of the year. Table 1 below shows the dates of the policy rates cuts by the Fed and the ECB.

Right after the bankruptcy of Lehman Brothers in mid September 2008, the crisis intensified tremendously and the US dollar interbank market came to a virtual halt both onshore and offshore. On October 13, 2008, in order to provide broader access to the US dollar liquidity in short-term US dollar funding markets, the Fed announced that it would uncap temporarily the swap facilities to the ECB, BoE and SNB so that they could provide sufficient US-dollar funding to meet liquidity demand. It was expected that this action would ease the short-term liquidity condition to non-US banks and other institutions.

3. Data

A true deviation from CIP presents a pure arbitrage opportunity to a market trader given the concurrent executable prices of all related securities. However, the accuracy with which the deviation from CIP is measured depends critically on the quality of the exchange rates and interest rates data. Non-execution and non-synchronicity are the usual data problems that exist in the measured deviations from CIP illusory (Taylor, 1987). This study adopts intraday time-stamped executable quote data to avoid the above two problems.

Executable intraday quoted prices of the EUR/USD spot exchange rate, forward exchange rate and deposit rates of USD and EUR from September 1 through December 31, 2008 are obtained from ICAP Inc. These quotes, collected from ICAP's global electronic broking system, are the firm commitment of dealers. Each record contains a pair of bid and ask prices with time stamped to the nearest second. The selected tenors of the forward rates and deposit rates are 1 week, 1 month and 12 months.

The data are pre-filtered for human or system errors using the algorithm described in Dacorogna *et al.* (1993).[6, 7] Moreover all data over the weekend from Friday 21:00 Greenwich Mean Time (GMT) to Sunday 21:00 GMT are excluded.

Triplets of synchronous exchange rates, interest rates, and forward rates are constructed at the end of every one minute interval. CIP implied USD borrowing rates are estimated with the following equation:

$$i_{USD}^{CIP} = \frac{F_{EUR/USD}^{A}}{S_{EUR/USD}^{B}}(1+i_{EUR}^{A})-1 \qquad (1)$$

where F^A is the ask quote of EUR/USD forward rate, S^B is the bid quote of EUR/USD spot rate, and i_{Euro}^{A} is the lending rate of Euro in the European money market. For each one-minute interval, we use its last bid and ask quotes. We then calculate the deviation of the CIP implied USD borrowing rate from the ask quote of the corresponding USD deposit rate and denote the deviation as the spread.

Daily average and realised volatility of the spreads are obtained, respectively, from the average and the standard deviation of the minute-by-minute spreads. The intraday average and realised volatility of spreads are the main variables used in the econometric analysis of the paper. The use of them will help to increase the ability for us to detect the effects of monetary policy action or exceptional measure

6 For more detailed discussions on high-frequency financial data, see Dacorogna *et al.* (2001).

7 In total, 296089 observations are filtered out (7.35% of the total observations in the original dataset). Given the small proportion the deleted observations account for, they are not expected to impact the final results.

announcements which might be indiscernible in a lower frequency setting, such as daily closing quotes (Goodhart *et al.* 1993 and Almeida *et al.* 1998). Taking the daily frequency for example, the exchange rates may fluctuate widely and rapidly within a day in response to an announcement, but if little changes from the day's open or previous close, this will falsely convey low or no daily volatility of CIP deviations. The intraday average and volatility of spreads that constructed from high frequency data, on the other hand, incorporate intraday variations within the day and could reveal the reactions of financial markets to the monetary actions or exceptional measures taken by the Fed or the ECB.

4. Pattern and Statistical Property of the Estimated Spreads

Figure 2 depicts the average spread for each 15-minute interval within a day for 1-week, 1-month and 12-month tenors for three sub-sample periods (the opening hour of London and NY markets would move backward 1 hour when the day-light saving time ends). The first period is the pre-Lehman-default period from September 1 to 14, 2008, while the second period is the most chaotic period from September 15 to 19 during which Lehman Brothers collapsed. The last period is the so-called post-Lehman-default period from September 22 to December 31, 2008.

The first panel shows that the spread of the 1-week tenor in the Lehman-default period was more volatile and much higher than that in the pre-Lehman default period by about 270 basis points, reflecting extremely huge demand for US dollar liquidity that could not be satisfied by the US dollar money market as well the severe panic among the market participants. The spread in the post-Lehman-default period did not fall back to the level of the pre-Lehman-default period and maintained a gap in the range of 80 to 100 basis points.

As shown in the second panel of Figure 2, the intraday spread of the 1-month tenor in the Lehman-default period increased significantly above that in the pre-Lehman-default period by about 60 basis points, but not as much as that of 1-week tenor. The difference might be due to much larger liquidity funding demand in the shorter-term tenor. Like the spread of the 1-week tenor, the spread of the 1-month tenor in the post-Lehman-default period did not go back to the level prior to the Lehman default. The gap was about 50 basis points, again not as much as that of the 1-week tenor.

The last panel of Figure 2 shows the intraday average spreads of the 12-month tenor in the pre-, during- and post-Lehman-default periods. Unlike the spreads of the other two tenors, the difference between the spreads of the 12-month tenor before and during the default period became negative and the gap was about 17 basis points on average. This might reflect the fact that, unlike the short-term tenor borrowing, the FX forward market is not so functional for long-term US dollar funding. However, in the post-default period, the spread of the 12-month tenor returned to the level near zero as in the pre-default period, which is quite different from the other two tenors.

The noticeable higher spreads of both the 1-week and 1-month tenors in the Asian trading hours before the opening of the London market reflect the combination of the acute shortage of US dollar liquidity during the Lehman-default period and the preference of Asian financial institutions to keep precautionary balances of US dollars at hand. In the BIS CGFS No. 37 paper (2010), market intelligence indicates that the huge pressure on demand for US dollars prompted European banks to source US dollars in Asian markets even before the opening of European markets. Our high frequency data show empirical evidence of this.

Figure 3 depicts the average realised volatility of the spread for each 15-minute interval of the three tenors in the three periods. As expected, the intraday realised volatility of the 1-week tenor in the default period was larger than those of the other two maturities in the same period. The large spikes in the opening hours of the London market divulged that the funding markets, particularly the London market, were in a terrible chaos because of the liquidity risk and huge counterparty risk following the US government allowing one of its significantly important financial institutions to collapse.

While high-frequency data have their advantages, they also impose new challenges on researchers. On one hand, the additional price observations allow us to infer how prices, in level or volatility, react to information such as the collapse of Lehman Brothers. Furthermore, more observations enable us to estimate and forecast volatility more accurately, which benefits policymakers, derivatives traders and portfolio mangers. In particular, we cannot directly estimate intraday or daily realised volatility from using daily closing data. However, on the other hand, microstructure effects become more obvious and intraday patterns in trading behaviour have to be modelled. These will significantly increase the effort and complexity in computation. Therefore, in this study and to avoid unnecessarily complicated computation, we use the daily average spread and daily realised volatility to estimate the effects of the monetary and rescue actions taken by the authorities.

5. Empirical Method and Results

This study tests whether and to what extent the monetary policy or other exceptional interventions taken by the Fed and the ECB had eased the US-dollar shortage during the crisis. Prior to the global financial crisis, there were a large number of studies using intraday data to study financial market responses to monetary policies. Among the early works, Goodhart *et al.* (1993) and Almeida (1998) investigate the effects of macroeconomic news on foreign exchange markets. More recently, the studies of Andersson (2007) and Gurkaynak *et al.* (2005) investigate financial market responses, both the bond and stock markets, to the Fed and the ECB monetary policy actions. Most of these studies have to deal with the intraday seasonality pattern before they can test the effects of monetary policy. In our study, at this stage, in order to avoid the complicated computation, we use daily average and the daily realised volatility of the one-minute spreads.

Figure 4 depicts the series of the daily average spread and the daily realised volatility of the three tenors in the whole sample period, from September 1 to December 31, 2008. In the first panel, the daily average spreads of the 1-week tenor clearly show the extreme tense of the funding market with big spikes in the period from September 15 to October 14, 2008. The daily average spreads of the 1-month tenor have similar spikes but with smaller magnitudes. In the last panel, the daily realised volatility of the shorter tenor is much larger than that of the longer tenor.

In this study, we employ regression analysis with policy-action dummies to estimate the effects of the monetary policy actions and an exceptional measure taken by the Fed and the ECB. Table 2 reports the results of the unit root test of the daily average spread and daily realised volatility of the spreads in the sample period.

The ADF tests suggest that all the series are stationary except the daily average spread of the 12-month tenor. Given that policy actions may influence both the spread level and its realised volatility, we employ the following two autoregressive equations to gauge the effects:[8]

$$Spread_t = a + \sum_{i=1}^{n} Spread_{t-i} + PA_t + \varepsilon_t \quad (2)$$

$$Volatility_t = b + \sum_{j=1}^{m} Volatility_{t-j} + PA_t + \xi_t \quad (3)$$

where PA_t is the policy-action dummy, ε_t and ξ_t are the residuals.

Table 3 reports the parameter estimation results of the daily average spread and the effectiveness of the policy actions in the whole sample period. Since the series of the daily average spread of the 12-month tenor is non-stationary, we do not include the series in the OLS estimation.

The results show that the coefficient of the dummy of coordinated interest rate cuts by the Fed and the ECB, with other four central banks, on October 8, 2008 has a positive sign with statistical significance. In fact, the market on October 7, 2008 already speculated an interest rate cut upcoming soon as Bernanke signalled in his remarks on that day that the Fed was ready to lower the interest rate as the condition of the economy and financial market continued deteriorating. When the Fed actually announced a 50 basis points cut the next day, the market perceived this as a confirmation of the severity of the crisis and that the financial turmoil might well lengthen the period of weak economic performance and further increase the risks to financial markets. Moreover, we have found that the Lehman's collapse had a rather persistent effect on the spread as shown by the significant parameters of the following several days. The

[8] We include autoregressive terms of lag two in the regressions according to the AIC criteria.

last fed funds target rate cut on December 16, 2008 in the sample period has no impact on the US-dollar funding market, although it was the largest cut in magnitude, 75 basis points. Similarly, the two interest rate cuts by the ECB are statistically insignificant, suggesting that the policy actions failed to reduce the CIP deviations.

Although the monetary policy actions appear to have no desirable effects on reducing the CIP deviations during the sample period, the announcement of the uncapped currency swap lines between the Fed and the three European central banks, ECB, BoE and SNB, reduced (with statistical significance) the daily average of the spreads, suggesting that the policy action effectively relieved the US-dollar shortage of non-US banks and helped mitigate the dislocations of the short-term US dollar funding markets.

It is a small surprise that the heteroskedasticity tests in the above autoregressive models show no strong evidence of heteroskedasticity which is quite common among daily financial data. Thus, we do not have to use any GARCH model to adjust for the heteroskedasticity.

Table 4 depicts the parameter estimations of the three autoregressive equations of the daily realised volatility of three tenors. We use the same policy-action dummies to gauge the effectiveness of the actions taken by the Fed and the ECB.

The estimations show similar results with those of the daily average spreads. The coordinated interest rate cut on October 8 has an impact on the realised volatility of the spreads, i.e. CIP deviations. Furthermore, the uncapped currency swap line also has impacts on the 1-week and 1-month tenors, albeit of quite small magnitudes, on the announcement day and the following day.

In sum, our empirical results suggest that the traditional monetary policy actions, even the aggressive interest rate cuts taken by the Fed and the ECB during the sample period from September 1 to December 31, 2008, appeared to be ineffective to mitigate the shortage of US dollars in the global funding markets. On October 9, 2008, it was reported that the cost of borrowing in dollars in London soared to the highest level that year as the coordinated interest-rate reductions worldwide failed to revive lending among banks for any longer than a day. This reinforced the fact that in the pinnacle of the global financial crisis the US dollar money market was broken and the transmission mechanism from central banks was not working.

However, the exceptional action—uncapping the currency swap arrangements between the Fed and the three European central banks on October 13, 2008—effectively reduced the CIP deviations. With the swaps, the ECB, BoE and SNB could offer European banks unlimited US dollar funds at fixed interest rates against collateral. The flood of US dollars enhanced the efforts by the central banks to unfreeze money markets which seemed to respond to this action favourably since the action would provide liquidity to the most needed financial institutions directly. Fleming and Klagge (2010) confirm that the swap lines,

which ended in early 2010, enhanced the ability of the ECB, BoE and SNB to provide US dollar funding to financial institutions in their jurisdictions and mitigated funding pressures internationally.

6. Conclusion

This study uses high-frequency, executable bid and ask quotes of spot and forward foreign exchange and of interest rates for the period from September 1 to December 31, 2008 to gauge the dynamics of market liquidity condition and to investigate how and whether the monetary policy actions taken by the Fed and the ECB relieved the stress in the US-dollar money markets by observing the change in the CIP-implied spread during the period. Our results on intraday patterns of the CIP deviations suggest that, during the week of the collapse of Lehman Brothers, because of huge funding liquidity and counterparty risks, both on-shore and off-shore US-dollar money markets were paralysed, and non-US banks had to obtain US-dollar loans through FX spot and forward markets. In particular, European banks, because of their dependence on cross-border US funding, had to source US dollars globally and came to the markets in Asia. Our empirical results indicate that the traditional monetary actions, even the very aggressive interest rate cuts taken by the Fed and the ECB, failed to mitigate the US dollar liquidity shortage when the market was extremely counterparty-risk averse. However, the unlimited and guaranteed US-dollar loans directly from the central banks to financial institutions under their jurisdictions effectively reduced the CIP deviations and improved the liquidity condition of the money markets.

References

Almeida, A., C. Goodhart and R. Payne (1998), "The Effects of Macroeconomic News on High Frequency Exchange Rate Behaviour," *Journal of Financial and Quantitative Analysis*, 33(3): 383-408.

Andersson, M. (2007), "Using Intraday Data to Gauge Financial Market Response to FED and ECB Monetary Policy Decisions," European Central Bank Working Paper, 726/2007.

Baba, N. and F. Parker (2009), "From Turmoil to Crisis Dislocations in the FX Swap Market before and after the Failure of Lehman Brothers," Bank for International Settlements Working Paper No.285.

Bank for International Settlements (2010), "The Functioning and Resilience of Cross-border Funding Markets," Committee on the Global Financial System, CGFS Paper, No.37.

Coffey, N., W. Hrung, H-L. Nguyen and A. Sarkar (2009), "The Global Financial Crisis and Offshore Dollar Markets," Current Issues in Economics and Finance, 15(6), Federal Reserve Bank of New York.

Dacorogna, M. M., U. A. Mueller, R. J. Nagler, R. B. Olsen and O. V. Pictet (1993), "A Geographical Model for the Daily and Weekly Seasonal Volatility in the Foreign Exchange Market," *Journal of International Money and Finance*, 12: 413-38.

Dacorogna, M. M., R. Gencay, U. A. Mueller, R. B. Olsen and O. V. Pictet (2001), *An Introduction to High-Frequency Finance*, San Diego, Academic Press.

Fleming, M. and N. Klagge (2010), "The Federal Reserve's Foreign Exchange Swap Lines," Current Issues in Economics and Finance, 16(4), Federal Reserve Bank of New York.

Fung, L. and I-W. Yu (2009), "Dislocations in FX Swap and Money Markets in Hong Kong and Policy Actions during the Financial Crisis of 2008," Hong Kong Monetary Authority Working Paper, 17/2009.

Goodhart, C. A. E., S. G. Hall, S. G. B. Henry and B. Pesaran (1993), "News Effects in a High-Frequency Model of the Sterling-Dollar Exchange Rate," *Journal of Applied Econometrics*, 8: 1-13.

Gurkaynak, R., B. Sack and E. Swanson (2005), "Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements," *International Journal of Banking*.

Hui, C. H., H. Genberg and T. K. Chung (2009), "Funding Liquidity Risk and Deviations from Interest-Rate Parity during the Financial Crisis of 2007-2009," Hong Kong Monetary Authority Working Paper, 13/2009.

Mancini Griffoli, T. and A. Ranaldo (2010), "Limits to Arbitrage during the Crisis, Funding Liquidity Constraints and Covered Interest Parity," Swiss National Bank Working Paper, 2010-14.

McGuire, P. and G. V. Peter (2009), "The US Dollar Shortage in Global Banking," Bank for International Settlements Quarterly Review, March.

Taylor, M. (1987), "Covered Interest Parity: A High-Frequency, High-Quality Data," *Economica*, 54(216): 429-38.

Table 1. Policy Rates Changes between 1 September and 31 December 2008

Announcement date	European Central Bank (*Minimum bid rate on the main refinancing operations*)	US Federal Reserve (*Federal funds target rate*)
Beginning: Sept 1, 2008	4.25%	2%
Oct 8	3.75% (-50 bps)	1.5% (-50 bps)
Oct 29		1% (-50 bps)
Nov 6	3.25% (-50 bps)	
Dec 4	2.5% (-75 bps)	
Dec 16		0 – 0.25% (Target range)
End: Dec 31, 2008	2.5%	0-0.25%

Table 2. ADF Unit Root Test Results

	Daily average of spreads			Daily realised volatility of spreads		
	1 week	1 month	12 month	1 week	1 month	12 month
T-statistics	-5.91	-5.79	-2.02	-3.58	-4.31	-7.11
P-value	0.00	0.00	0.28	0.01	0.00	0.00

Table 3. Estimated Results on Daily Average of Spread for the Sample Period

Tenor	1 week	1 month
Constant	**0.80*** **	**0.17*** **
	(5.18)	(2.73)
Spread $_{t-2}$	**-0.20*** **	-0.16
	(-2.78)	(-1.51)
Spread $_{t-1}$	**0.60*** **	**0.88*** **
	(4.76)	(8.13)
Lehman $_{t-4}$	**-1.25***	**-1.81*** **
	(-1.89)	(-5.14)
Lehman $_{t-3}$	**3.25*** **	-0.53
	(6.05)	(-1.43)
Lehman $_{t-2}$	**2.64*** **	**1.55*** **
	(6.57)	(4.72)
Lehman $_{t-1}$	**1.05*** **	0.05
	(2.76)	(0.15)
Lehman $_{t}$	-0.10	0.13
	(-0.27)	(0.39)
FED Oct8 $_{t-2}$	**1.10****	0.27
	(2.54)	(0.79)
FED Oct8 $_{t-1}$	0.24	0.38
	(0.46)	(1.1)
FED Oct8 $_{t}$	**2.25*** **	**1.00*** **
	(5.35)	(2.99)
FED Oct8 $_{t+1}$	**1.45*** **	0.25
	(3.79)	(0.76)
FED Oct29 $_{t-2}$	**0.72***	-0.06
	(1.84)	(-0.19)
FED Oct29 $_{t-1}$	**0.63***	0.09
	(1.66)	(0.26)
FED Oct29 $_{t}$	0.32	-0.37
	(0.85)	(-1.12)
FED Dec16 $_{t}$	-0.60	-0.14
	(-1.56)	(-0.43)
ECB Nov6 $_{t}$	-0.24	0.15
	(-0.64)	(0.47)
ECB Dec4 $_{t}$	0.03	0.06
	(0.07)	((0.17)
SWAP Oct13 $_{t}$	**-1.05****	**-1.15*** **
	(-2.53)	(-3.33)
Adjusted R-square	0.83	0.66
Q-statistics (12)	4.81	15.79
Heteroskedasticity Test (F-statistics)	0.09	0.78

Note: *, ** and *** indicates significance at the 10%, 5% and 1% confidence level respectively, and t-statistics are included in parentheses.

Table 4. Estimated Results on Daily Realised Volatility

	1 week	1 month	12 month
Constant	**0.33*** **	**0.07*** **	**0.05*** **
	(11.98)	(3.07)	(4.37)
Volatility $_{t-2}$	**-0.09** **	-0.04	-0.02
	(-2)	(-0.43)	(-0.24)
Volatility $_{t-1}$	**0.29*** **	**0.59*** **	0.15
	(6.19)	(4.26)	(1.05)
Lehman $_{t-4}$	**2.31*** **	**-0.25** *	-0.03
	(18.39)	(-1.75)	(-0.42)
Lehman $_{t-3}$	0.04	**0.63*** **	**0.26*** **
	(0.29)	(5.6)	(4.76)
Lehman $_{t-2}$	**1.36*** **	**0.39*** **	**0.13** **
	(12.17)	(3.79)	(2.37)
Lehman $_{t-1}$	**0.72*** **	**0.33*** **	**0.10** *
	(6.77)	(3.56)	(1.9)
Lehman $_{t}$	0.03	0.02	-0.03
	(0.25)	(0.22)	(-0.57)
FED Oct8 $_{t-2}$	**0.46*** **	**0.32*** **	-0.01
	(4.21)	(3.3)	(-0.11)
FED Oct8 $_{t-1}$	**0.45*** **	-0.14	0.00
	(4.08)	(-1.41)	(0.01)
FED Oct8$_{t}$	**0.41*** **	**0.22** **	**0.19*** **
	(3.74)	(2.1)	(3.76)
FED Oct8 $_{t+1}$	**0.41*** **	**0.34*** **	-0.01
	(3.87)	(3.72)	(-0.1)
FED Oct29$_{t}$	-0.01	0.03	0.03
	(-0.07)	(0.35)	(0.54)
FED Oct29 $_{t+1}$	0.01	0.06	0.09*
	(0.12)	(0.61)	(1.66)
FED Dec16 $_{t-1}$	-0.03	-0.04	0.26***
	(-0.27)	(-0.48)	(4.87)
FED Dec16$_{t}$	-0.02	0.06	**0.09** *
	(-0.16)	(0.64)	(1.66)
ECB Nov6	0.06	-0.03	**0.21*** **
	(0.53)	(-0.28)	(4)
ECB Dec4	-0.04	-0.04	0.04
	(-0.35)	(-0.46)	(0.82)
SWAP Oct13 $_{t-1}$	**0.29*** **	**-0.16** *	0.00
	(2.69)	(-1.67)	(-0.03)
SWAP Oct13 $_{t}$	**0.21** *	0.10	0.03
	(1.88)	(0.97)	(0.56)
Adjusted R-square	0.91	0.72	0.48
Q-statistics (12)	3.69	7.01	10.18
Heteroskedasticity Test (F-statistics)	0.61	0.36	1.35

Note: *, ** and *** indicates significance at the 10%, 5% and 1% confidence level respectively, and t-statistics are included in parentheses.

Figure 1. Policy Rates of Federal Reserve and ECB

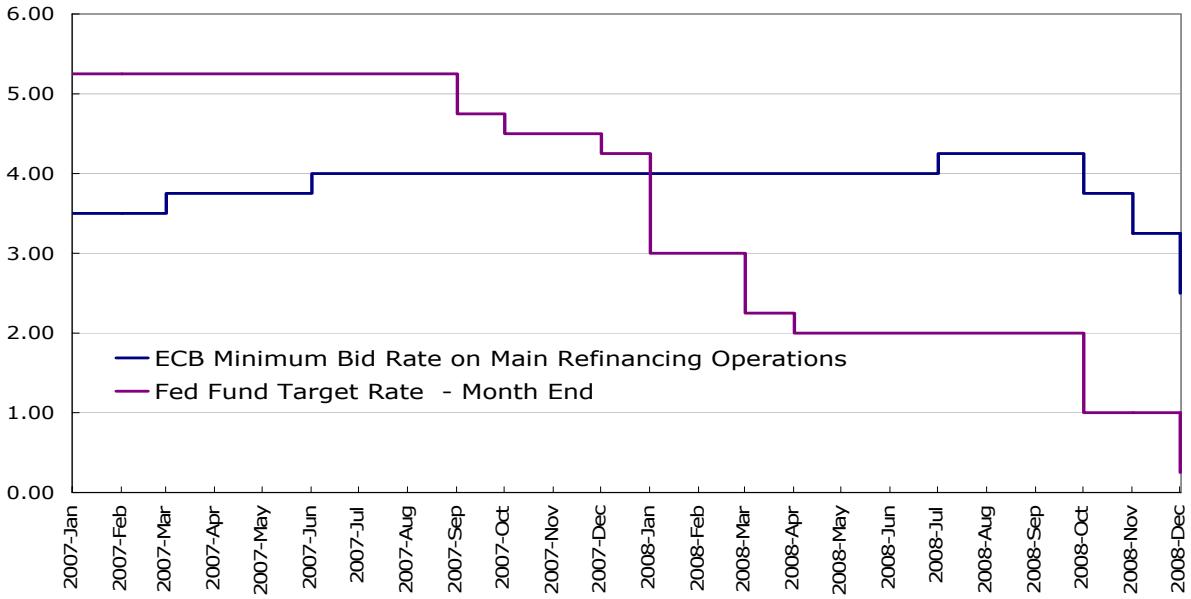
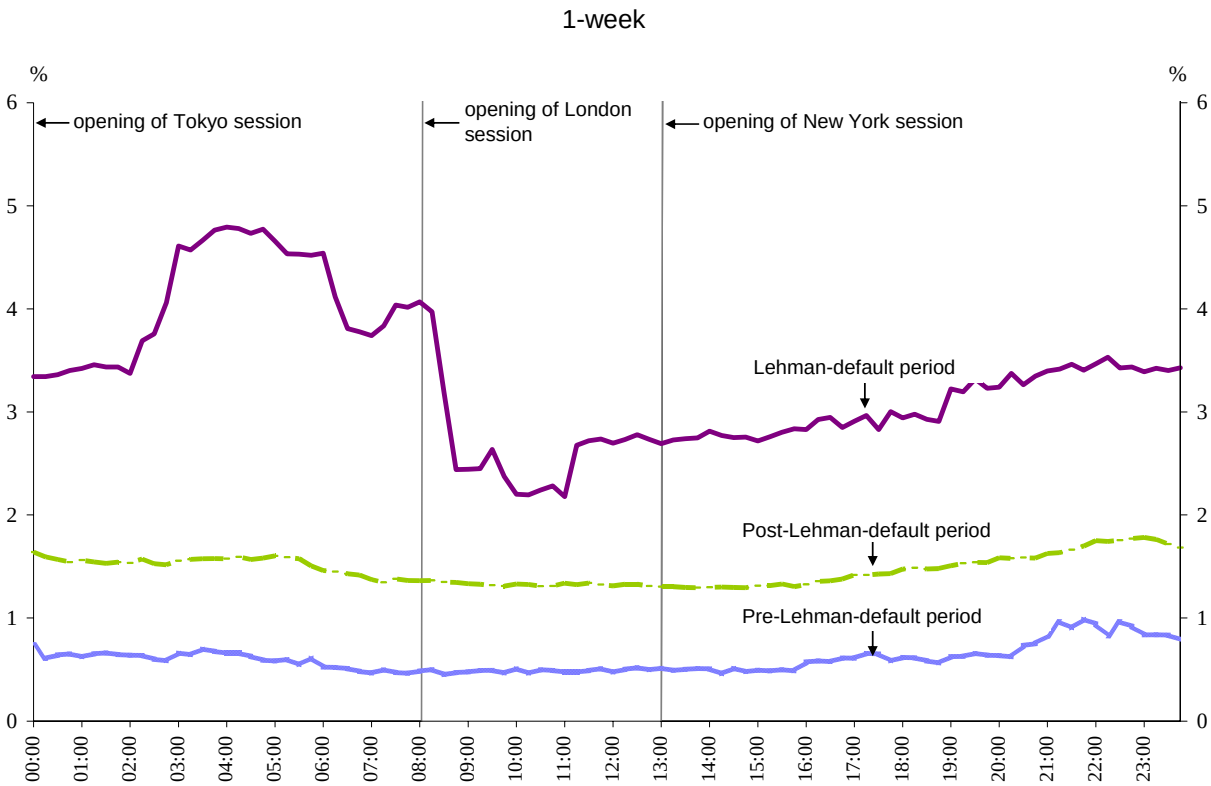
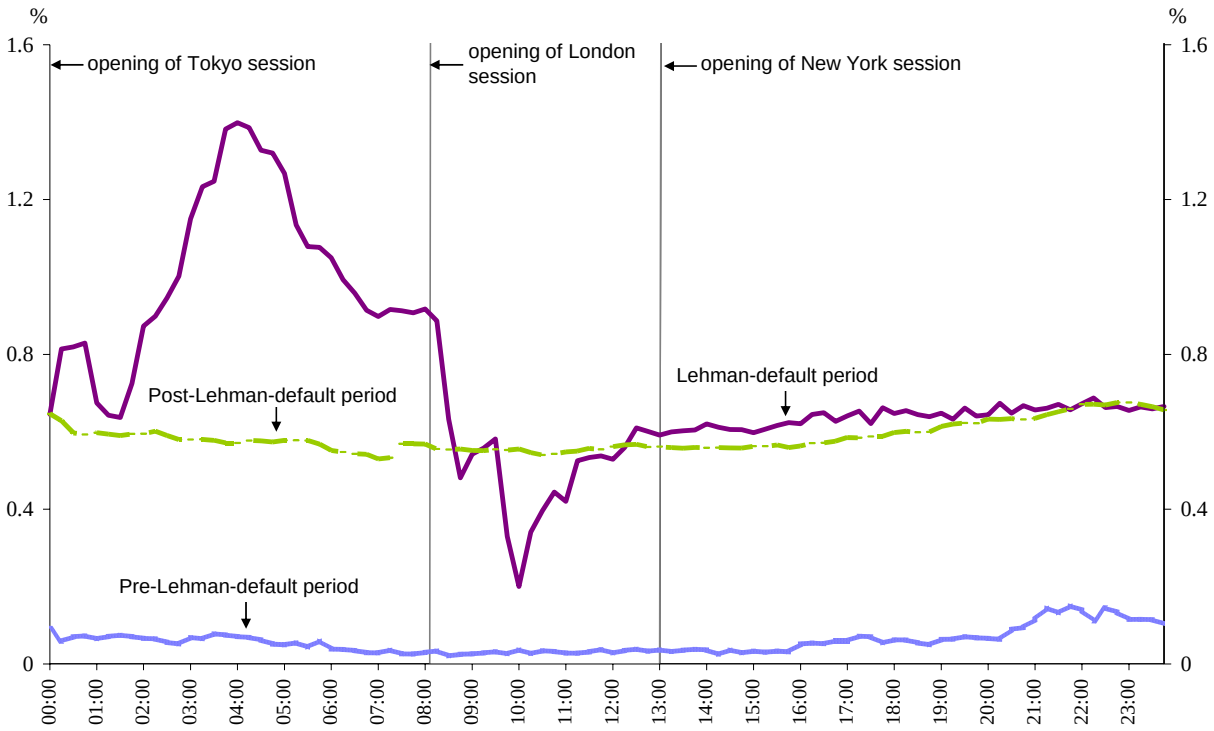


Figure 2. Average Spread of Each 15-Minute Interval



1-month



12-month

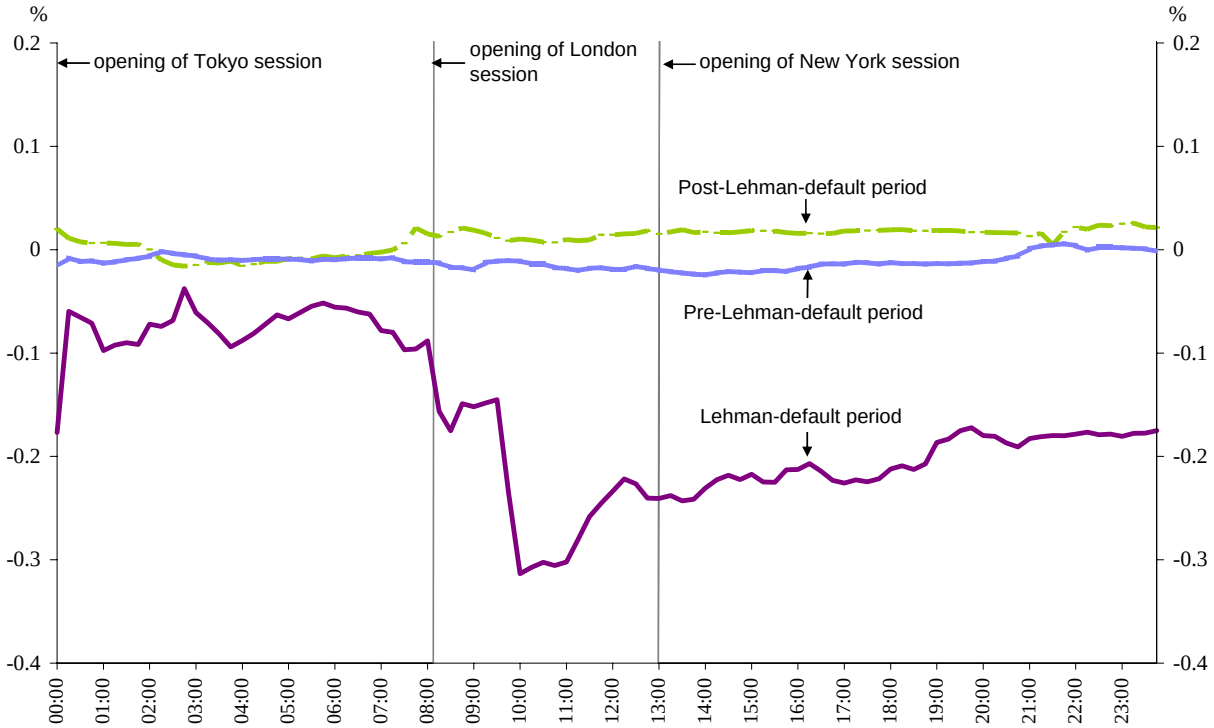
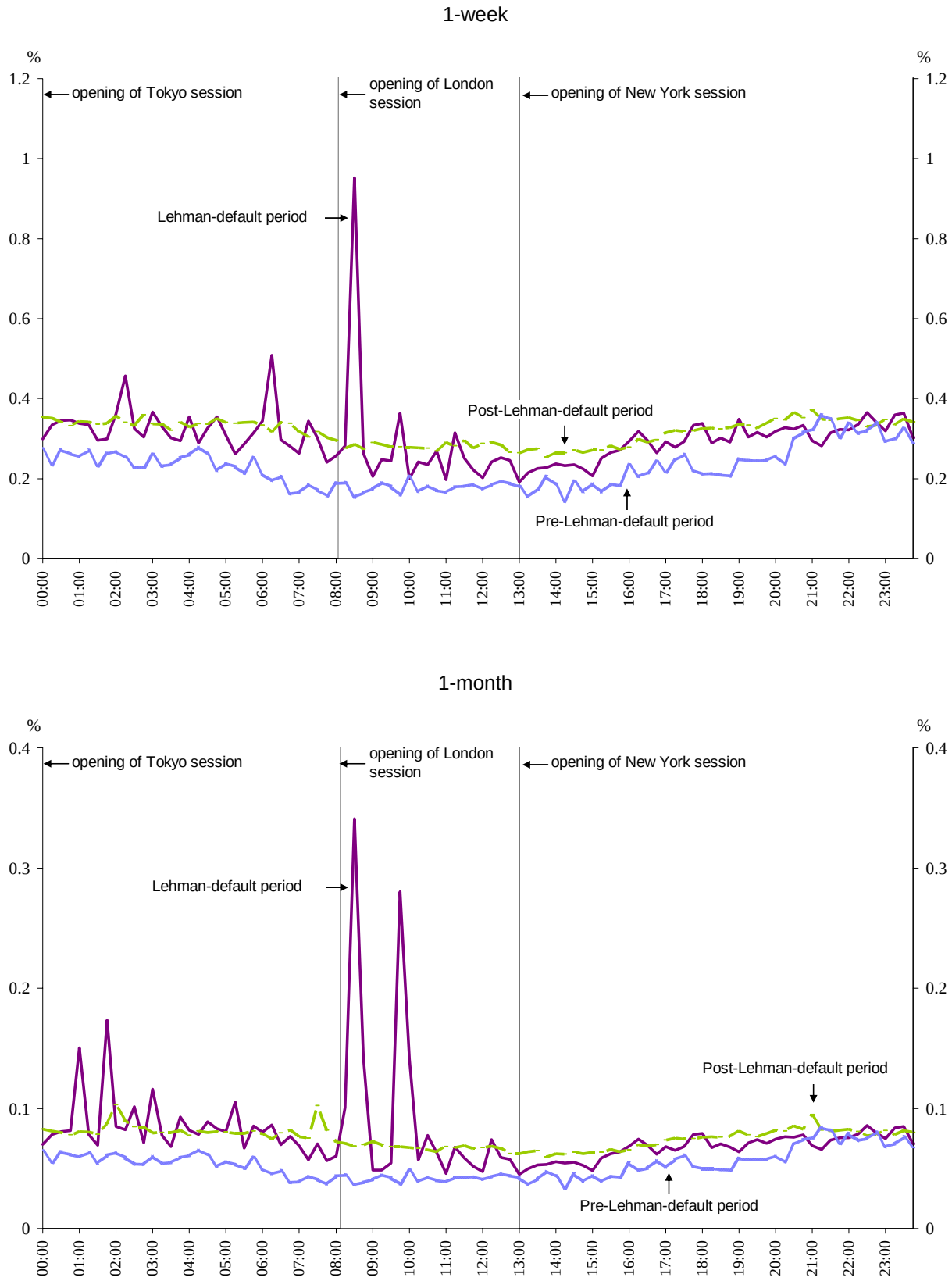


Figure 3. Average Standard Deviation of Spread for Each 15-Minute Interval



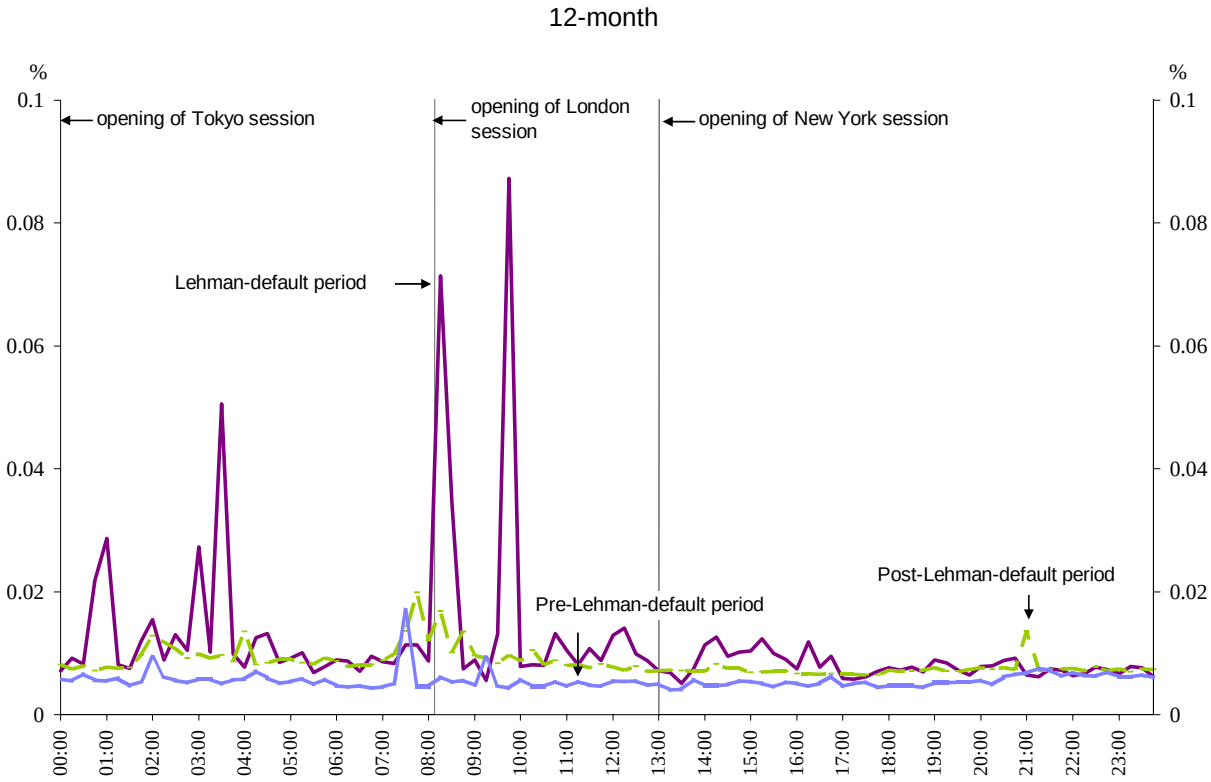
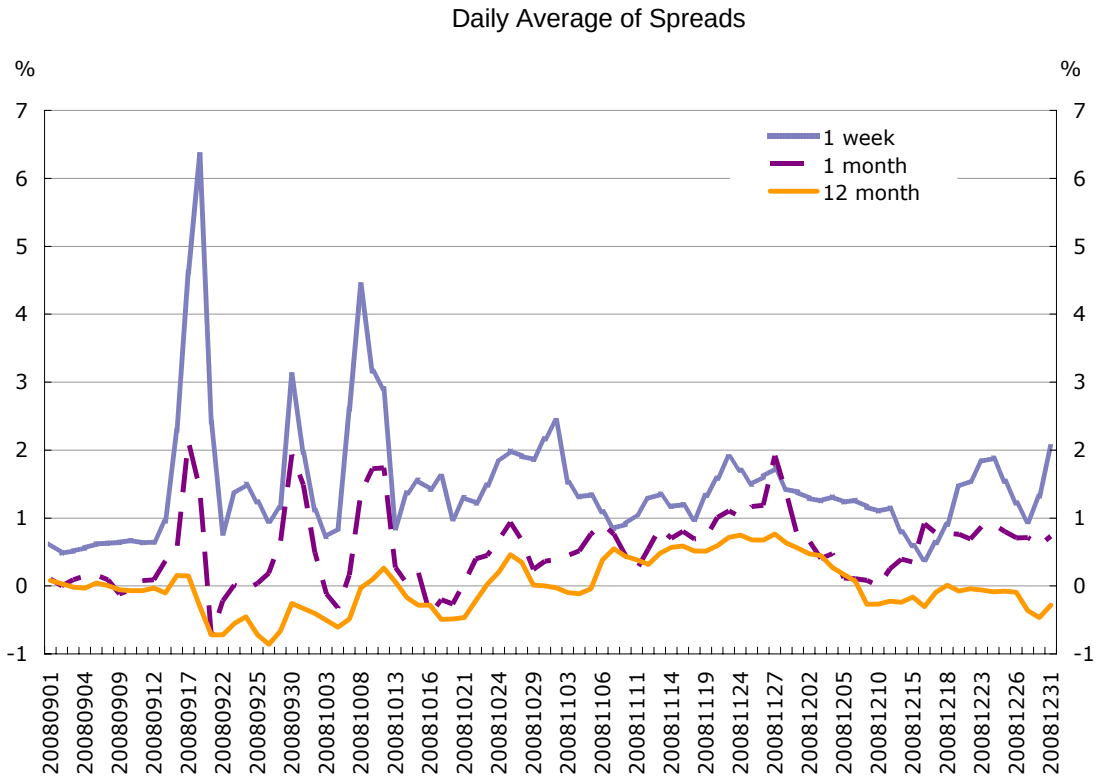
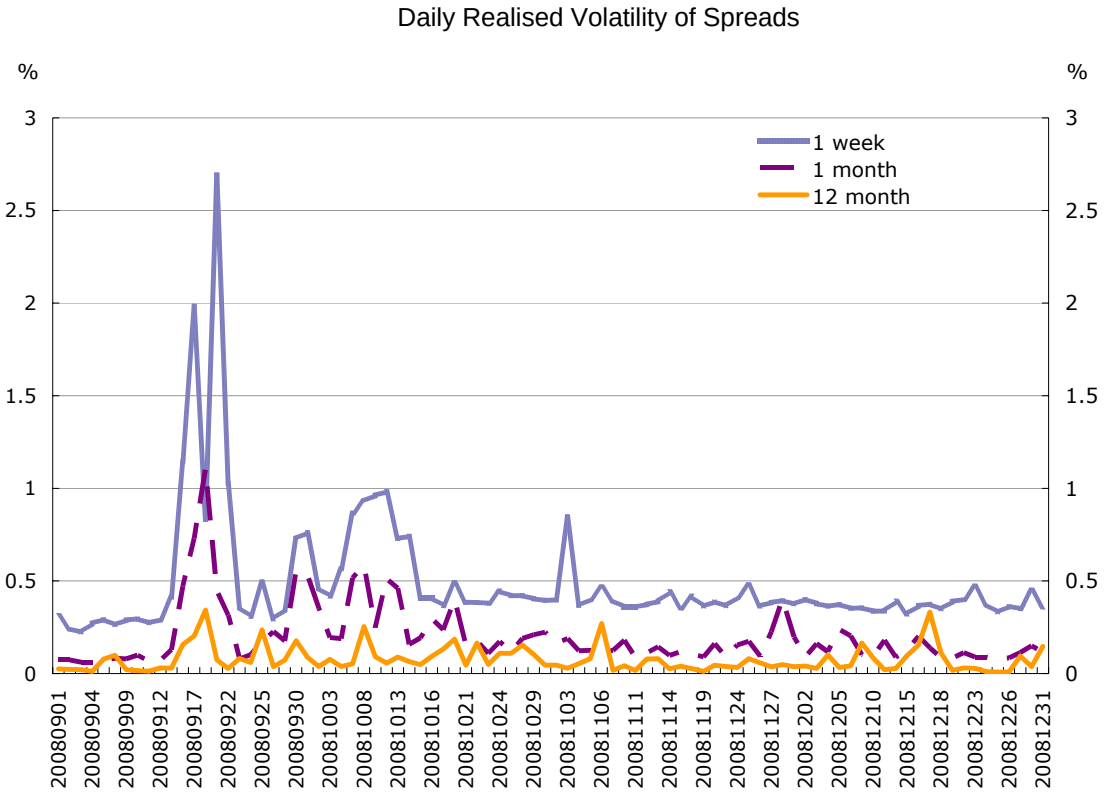

12-month
%
0.1
0.08
0.06
0.04
0.02
0
opening of Tokyo session
opening of London session
opening of New York session
Lehman-default period
Pre-Lehman-default period
Post-Lehman-default period
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00

Figure 4.


Daily Average of Spreads
%
7
6
5
4
3
2
1
0
-1
1 week
1 month
12 month
20080901
20080904
20080909
20080912
20080917
20080922
20080925
20080930
20081003
20081008
20081013
20081016
20081021
20081024
20081029
20081103
20081106
20081111
20081114
20081119
20081124
20081127
20081202
20081205
20081210
20081215
20081218
20081223
20081226
20081231


Daily Realised Volatility of Spreads
%
%
3
2.5
2
1.5
1
0.5
0
1 week
1 month
12 month
20080901
20080904
20080909
20080912
20080917
20080922
20080925
20080930
20081003
20081008
20081013
20081016
20081021
20081024
20081029
20081103
20081106
20081111
20081114
20081119
20081124
20081127
20081202
20081205
20081210
20081215
20081218
20081223
20081226
20081231