Monetary Policy Effects on Liquidity Crunch in Late 2008: High-Frequency Differentials between Swap-Implied Funding Costs and Money Market Rates

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Abstract

The US Federal Reserve and 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 quote and interest rate data in the period from 1 September to 31 December 2008, this study investigates how these policy actions affect the dynamics of market liquidity condition. Following Hui et al. (2009), the paper uses the differential between the US dollar rate implied by the covered interest parity condition and the corresponding US dollar interest rate as a proxy for (the lack of) the liquidity in the US dollar money market. The study focuses on EUR/USD and compares the most stressful crisis period with other relatively less stressful periods. The paper then examines how policy action announcements by the central banks affect the dynamics of intraday money market liquidity. The study employs autoregressive models to capture the potential effects of monetary policy action announcements on both the mean and volatility of the liquidity proxy. The results show that the coordinated cuts of policy rates failed to stimulate lending in the short-term US money market, whereas the unlimited currency swap line offered by the Federal Reserve with other central banks succeeded in reducing the illiquidity and the effectiveness persisted longer for short-term funding.

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I. Introduction

After the collapse of Lehman Brothers in September 2008, the original sub-prime crisis emerged in the US in mid-2007 developed into a global financial tsunami, seriously paralysing financial markets in the US. The dislocation of financial market further spread to those of 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. However, 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. In addition, many European banks, because of their mismatch of US dollar assets and liabilities, were also facing this severe liquidity crunch.

Since US banks were reluctant to lend to non-US banks and non-bank institutions in general, it is difficult for European banks to directly assess the US money markets. In order to obtain the needed US dollar, many non-US banks and non-bank institutions synthesized de facto US dollar loans through the foreign exchange (FX) swap and forward market. First, they borrowed funds from the euro and other money markets, exchanged them for 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 swap or forward 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 US dollar, while lowered dollar forward. 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 USD-EUR FX-swap-implied rate from the CIP were observed.

The spread between the FX-swap-implied US dollar rate and the corresponding dollar rate in the US money market serves as a proxy for the deficiency of liquidity in the US dollar denominated money market. Hui et al. (2009) find that, after the Lehman Brothers' collapse, large positive spreads were observed in the European economies and their variations could be explained by both counterparty and funding liquidity risks. McGuire and von Peter (2009) remarked that European banking systems built up long US dollar position vis-à-vis non-banks and funded them by interbank borrowing and via FX swaps, exposing them to funding risk, and got into acute funding liquidity crunch during the global financial crisis.

In response to the tense liquidity condition of the money market, the US Federal Reserve (Fed) lowered the target federal funds rate three times in less than three months from 2% after the bankruptcy of Lehman Brothers in September 2008 to a target range of 0%-0.25% in December 2008. The first cut on 8 October was a coordinated action with the European Central Bank (ECB) and four other central banks[1]. Furthermore, the ECB cut interest rates two more times subsequently to 2.5% at December 2008. An exceptional action taken by the Fed was to enlarge the temporary swap facilities with the ECB, Bank of England (BOE), Swiss National Bank (SNB) and Bank of Japan (BoJ) on 13 October 2008 in order to improve liquidity in short-term US dollar funding markets[2].

This study examines the spread between the FX-swap-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 1 September to 31 December 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 before and after the Lehman Brothers' failure. The study also investigates how and to what extent the monetary policy actions of the Fed and ECB taken during the period, including the aggressive lowering of fed fund target rate and ECB policy rate, might have improved the US dollar liquidity condition. Furthermore, we study the effect of the exceptional measure, the US dollar swap arrangements between the Fed and the three European central banks, which we expect would have an effect, to a certain degree, on reducing the US dollar shortage of European banks.[3]

This paper proceeds as follows. Section II describes a brief overview of the global financial crisis and the monetary interventions taken by the US Fed and ECB. Section III discusses the intraday data and Section IV depicts the patterns and statistical properties of the spreads. Section V reports the empirical method and results of the effects of the monetary policy actions. The last section concludes.

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

[1] 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 0.27 percentage point.

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

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

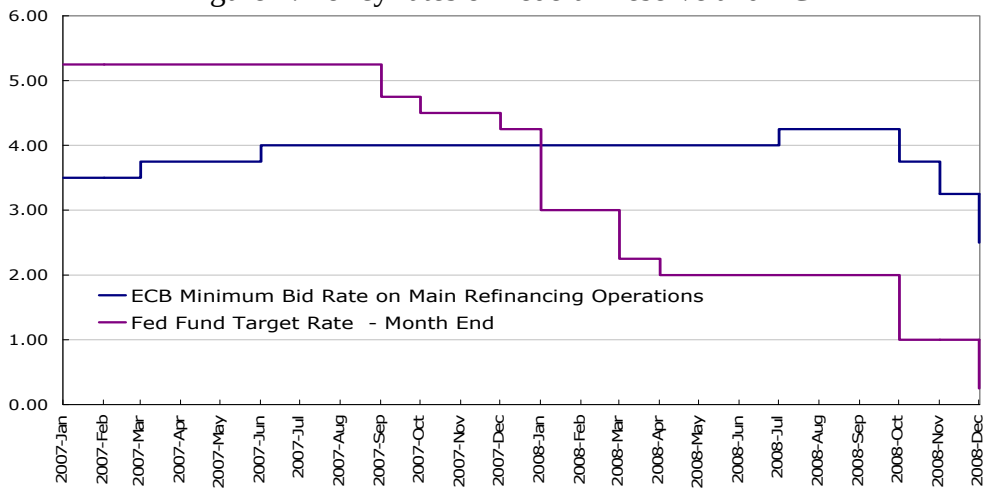
Most economists considered that the global financial crisis first originated when the value of securitised mortgage plunged in the US in mid-2007. The cause of the plunge was the falling housing prices in the US after a prolonged housing boom. The property bubble was fuelled by excessive lending under loosened underwriting standards 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 went into trouble because of the 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 highlighted the importance of counterparty risk in the global financial markets.

The global financial crisis reached its pinnacle when the fall of Lehman Brothers marked the largest bankruptcy case in the US history. Lehman Brothers was the largest underwriter of mortgage obligations and suffered tremendous losses as the US housing market deteriorated. On 14 September 2008, it came to light that Lehman Brothers would file for bankruptcy after being denied support by the US government. However, another financial institution, the AIG, had a better fate as it was helped by the Fed which created a USD 85 billion credit facility to save it from bankruptcy. In the following two weeks, the two remaining investment banks, Goldman Sachs and Morgan Stanley, converted into 'bank holding companies' in order to access to market liquidity. Following the collapse of Lehman Brothers, the contagion effect of the crisis swiftly spread to financial markets of almost all advanced and emerging market economies.

When the crisis first emerged, neither policymakers nor financial market participants anticipated the scale of the crisis that the financial system was heading for.

Figure 1: Policy rates of Federal Reserve and ECB



One of the primary tools that the Fed used during the crisis was to cut the federal 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 federal funds target rate six more times until the rate was at 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 federal funds target rate twice, each by 50 basis points, in October 2008 and finally cut the rate down to a range of 0 to 0.25% in December of the year.

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

Table 1: Policy rates changes between 1 September 2008 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: 1 Sep 08	4.25%	2%
8 Oct	3.75% (-50 bps)	1.5% (-50 bps)
29 Oct		1% (-50 bps)
6 Nov	3.25% (-50 bps)	
4 Dec	2.5% (-75 bps)	
16 Dec		0 – 0.25% (Target range)
End: 31 Dec 08	2.5%	0-0.25%

Right after the bankruptcy of Lehman Brothers in mid September 2008, the crisis intensified tremendously and the US dollar interbank lending came to a virtual halt in both onshore and offshore. On 13 October 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 enlarge temporarily the swap facilities to the ECB, BoE and SNB so that they could provide US-dollar funding in quantities sufficient to meet demand. This action might help to relax the insufficient liquidity to non-US banks and other institutions in short-term funding markets.

III. Data

The essence of a true deviation from CIP is that it presents a pure arbitrage opportunity to a market trader given the concurrent executable prices of all related securities. Therefore, the accuracy with which the deviation from CIP can be measured highly relies on the degree to which the exchange rates and interest rates

data are synchronous. In the empirical estimations using non-synchronous data, the reported deviations from CIP would almost reflect data imperfection rather than market inefficiency (Taylor, 1987). In light of this, we use high-frequency tick-by-tick data, the most synchronous data available, in this study and expect it would to a large extent improve the precision of the CIP deviations we estimate.

The data we utilize comprise the intraday quoted prices of the USD-EUR spot exchange rate, forward exchange rate and deposit rates of US dollar and Euro from 1 September through 31 December 2008. The dataset is provided by the ICAP inc., who collects tick-by-tick global electronic broking quotes. Each quote contains a bid and ask price that are potentially executable with time stamped to the nearest second. The tenors of the forward rates and deposit rates we use are one week, one month and twelve months.

Before proceeding, we filter the data for human or system errors using the filter algorithm described in Dacorogna et al. (1993).[4] Also, all data over the weekend from Friday 21:00 Greenwich Mean Time (GMT) to Sunday 21:00 GMT are excluded.

Based on the filtered data, the CIP implied USD borrowing rates are constructed at the frequency of every one minute by applying Equation 1:

$$i_{USD}^{CIP} = \frac{F^{A}}{S^{B}}(1 + i_{Euro}^{A}) - 1 \qquad (1)$$

where F^A is the ask quote of USD-EUR forward rate, S^B is the bid quote of USD-EUR spot rate, and i_{Euro}^{A} is the lending rate of Euro at 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 corresponding USD deposit rate and denote the deviation as the spread.

Lastly, we derive the intraday average and realised volatility of the spreads by calculating the average and the standard deviation of the one minute spreads during each one-day interval. The intraday average and realised volatility of spreads are the main variables we use in the econometric investigations in 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 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

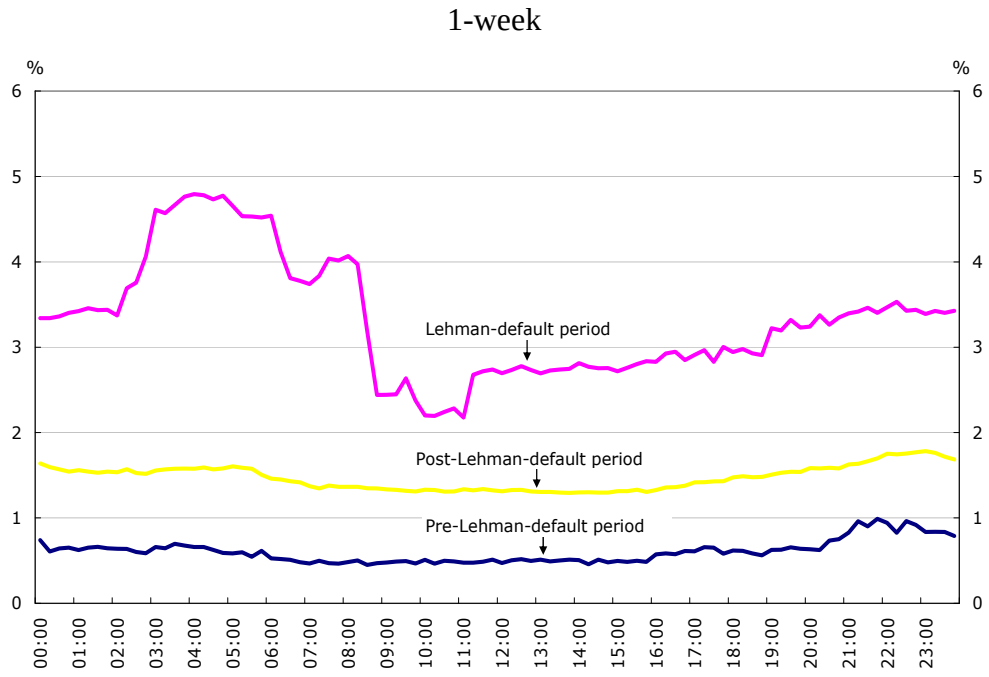
[4] For more detailed discussions on high-frequency financial data, see Dacorogna et al. (2001).

largely and rapidly within a day in response to an announcement, but nevertheless end close to the rates at the beginning of the day, thus falsely conveys low or none 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 therefore enable us to analyze finer details of the reactions of financial markets to the monetary actions or exceptional measures taken by the Fed or ECB.

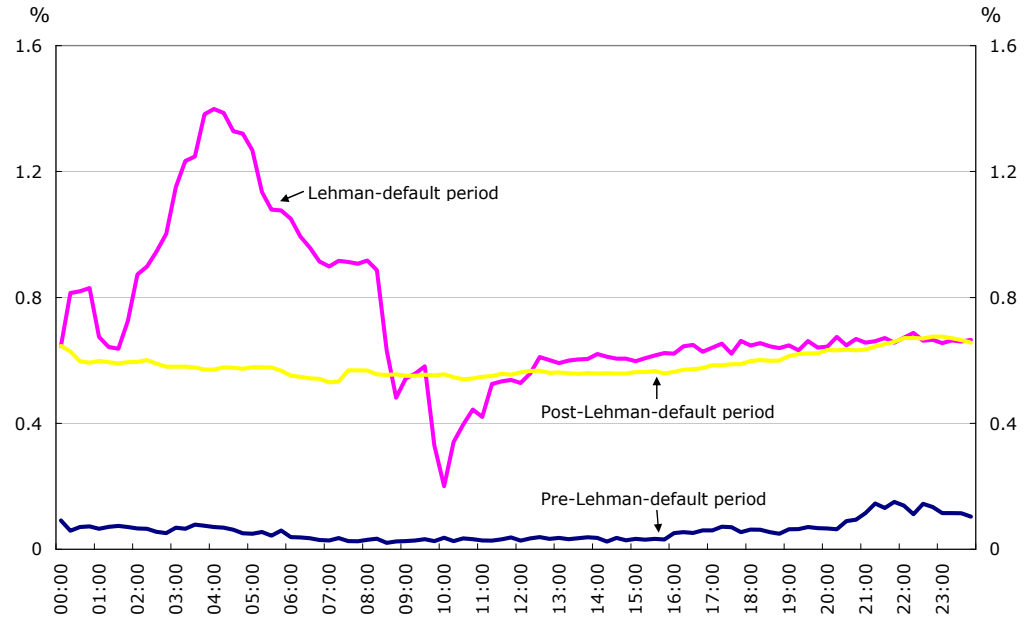
IV. Pattern and Statistical Property of the Estimated Spreads

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 first period is the pre-Lehman-default period from 1 to 14 September 2008, while the second period is the most chaotic period from 15 to 19 September during which Lehman Brothers collapsed. The last period is the so-called post-Lehman-default period from 22 September to 31 December 2008. The first panel shows that the spread of 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 as how severely panic were 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 of a range of 80 to 100 basis points.

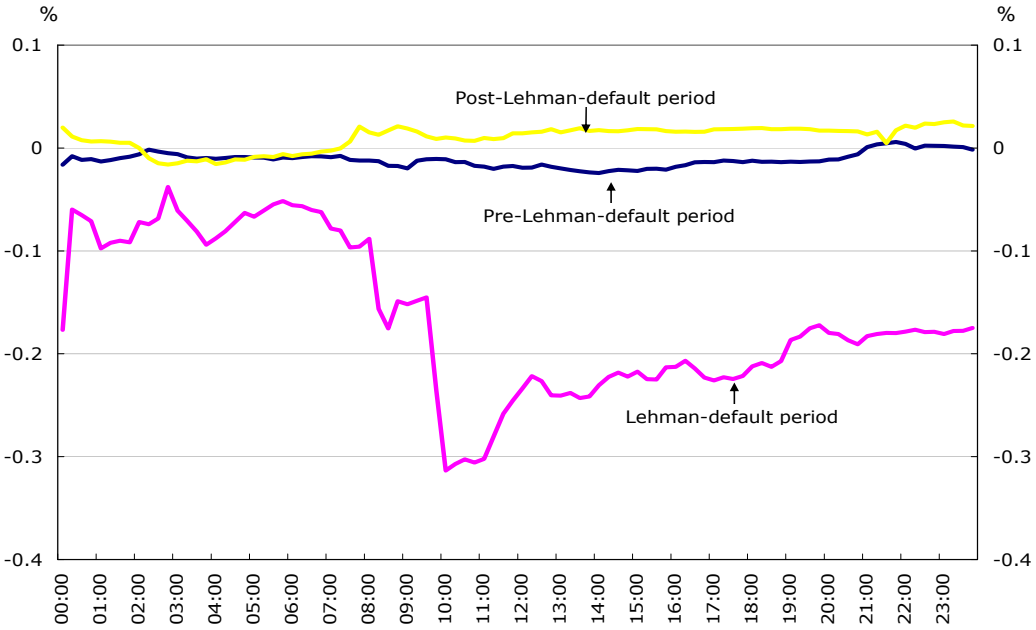
Figure 2: Average spread of each 15-minute interval



1-month



12-month



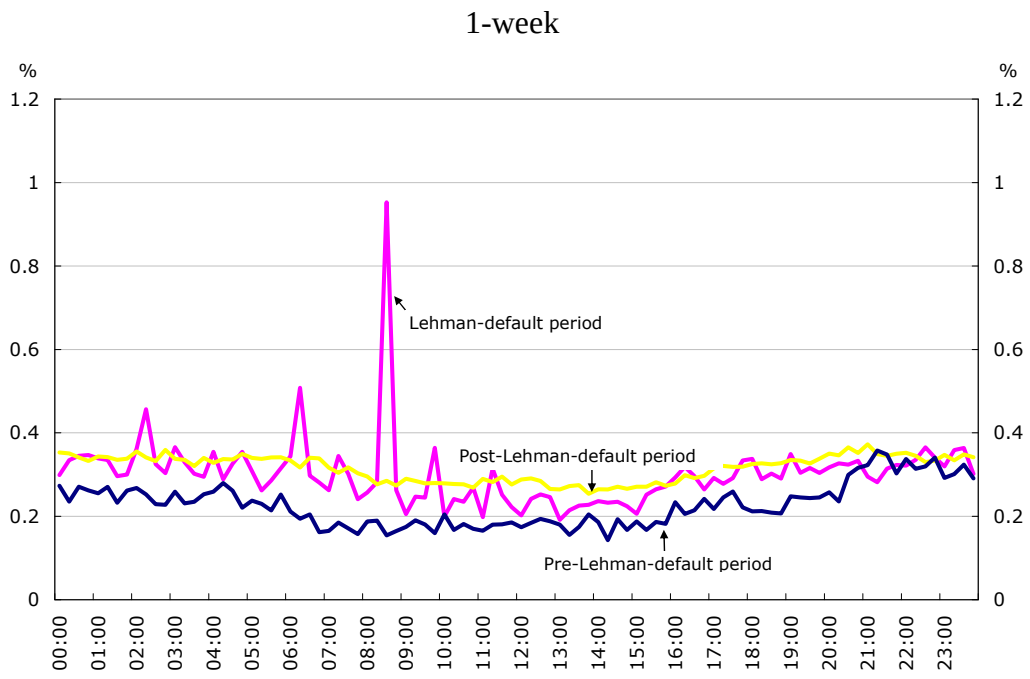
As shown in the second panel of Figure 2, the intraday spread of 1-month tenor in the Lehman-default period raised significantly above that in the pre-Lehman-default period by about 60 basis points, but not as much as that of 1-week tenor. The difference might be due to much larger liquidity funding demand in the shorter-term tenor. Like the spread of 1-week tenor, the spread of 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 1-week tenor. Lastly, the noticeable higher spreads in the hours before the opening

of London market reflect the combination of the panic during the Lehman-default period and thin euro-dollar trading in Asian markets. The spreads of 1-week tenor have a similar pattern in the same period.

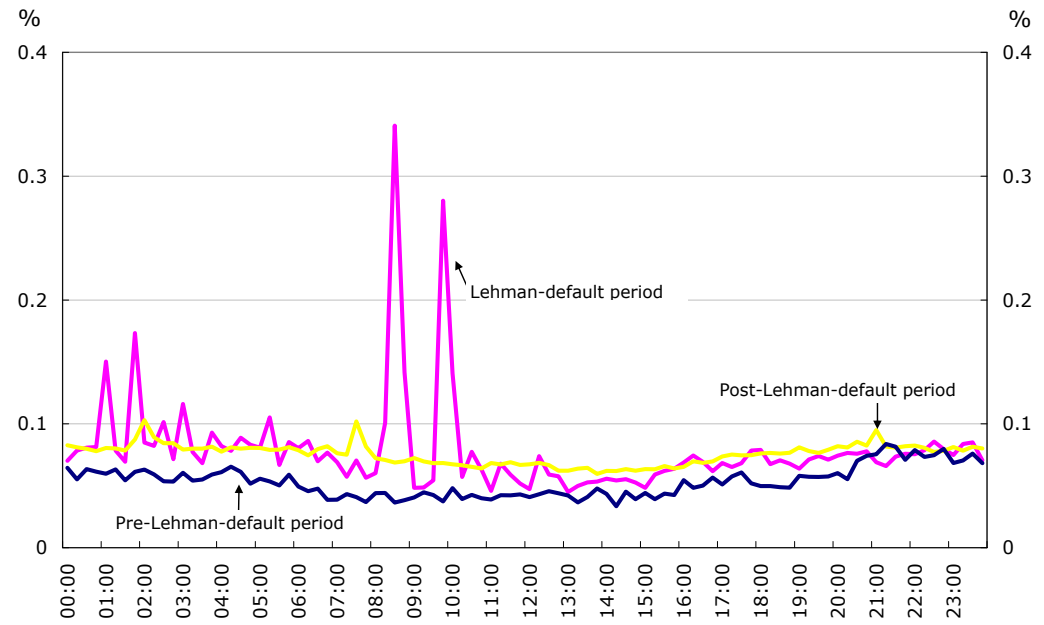
The last panel of Figure 2 shows that the intraday average spreads of 12-month tenor in the pre-, during- and post-Lehman-default periods. Unlike the spreads of the other two tenors, the difference between the spreads of 12-month tenor before and during the default period became negative and the gap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

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 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 let one of its significantly important financial institutions collapse. The patterns of the intraday spread and volatility of different tenors in different periods are very informative.

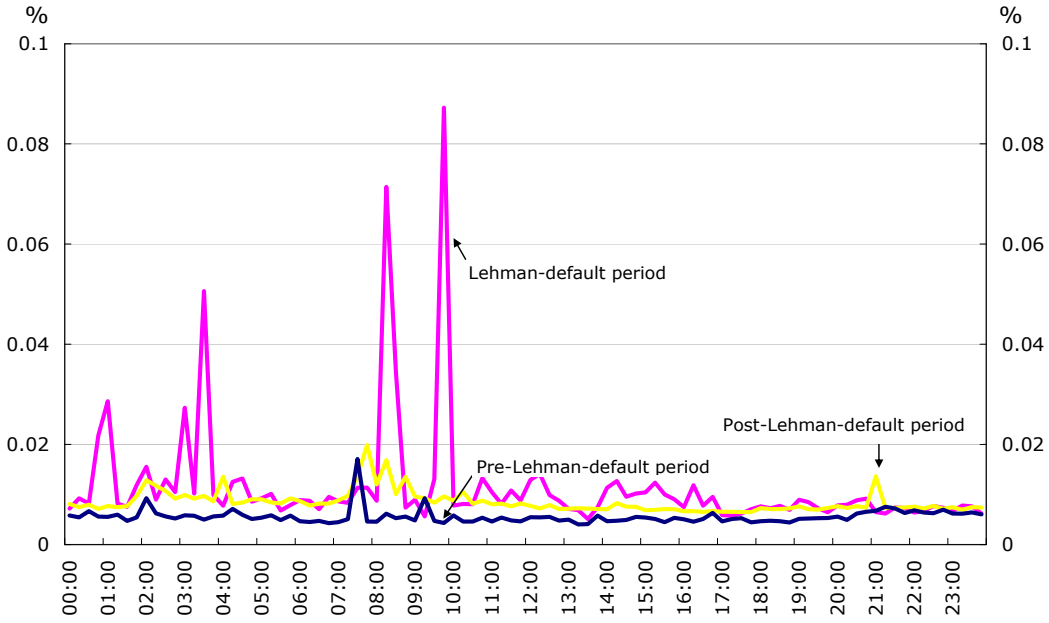
Figure 3: Average standard deviation of spread for each 15-minute interval



1-month



12-month



While high-frequency data have their advantages, they also impose new challenges to 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 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.

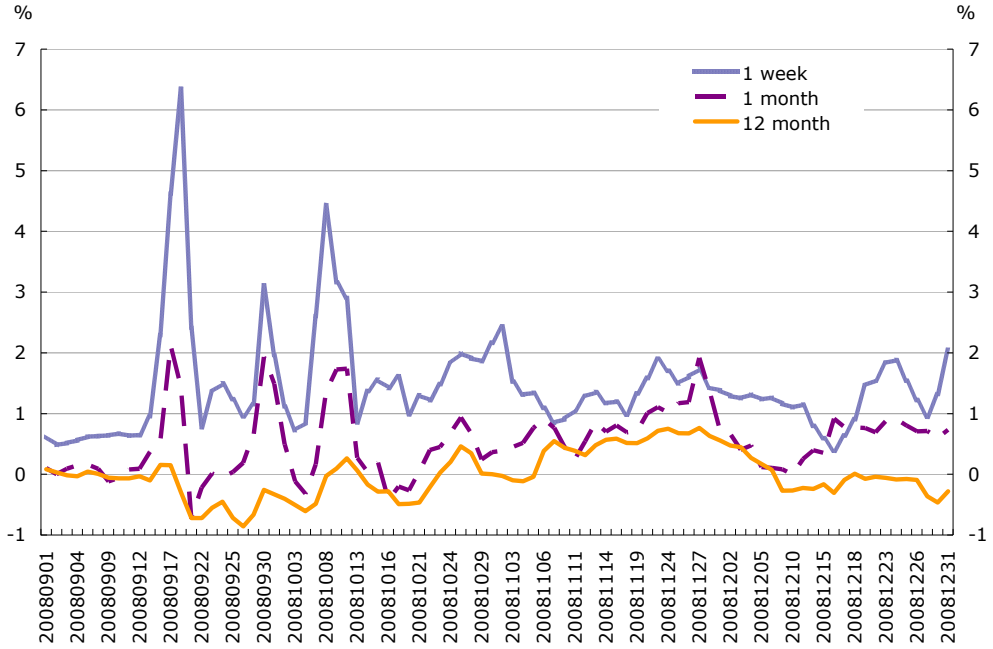
V. Empirical Method and Results

As mentioned above, the objective of this study is to test how the monetary policy or other exceptional actions taken by the Fed and ECB to address the global financial crisis have effects on the US-dollar shortage during the peak of the crisis. Prior to the global financial crisis, there have been 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 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 studies, at this stage, in order to avoid the complicated computation, we use daily average and the daily realised volatility of the one-minute spreads.

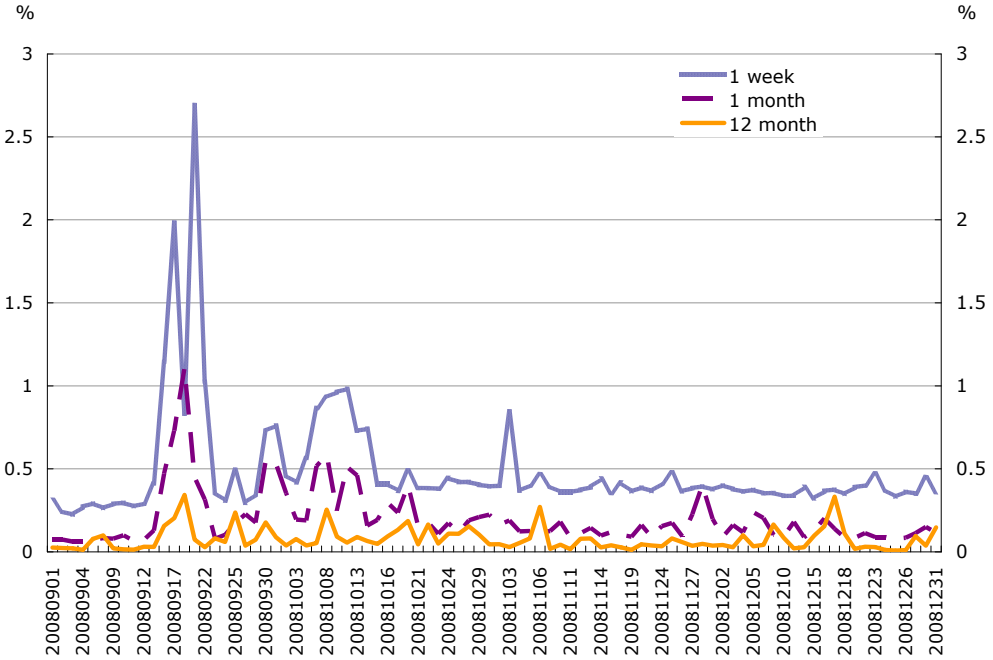
Figure 4 depicts the series of the daily average spread and the daily realised volatility of the three tenors in the whole sample period, from 1 September to 31 December 2008. In the first panel, the daily average spreads of 1-week tenor clearly show the extreme tense of the funding market with big spikes in the period from 15 September to 14 October 2008. The daily average spreads of 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.

Figure 4

Daily average of spreads



Daily realised volatility of spreads



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 ECB. Table 2 below reports the results of the unit root test of the daily average spread and daily realised volatility of the spreads in the sample period.

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

The ADF tests suggest that all the series are stationary except the daily average spread of 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[5]:

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

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

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 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 ECB, with other four central banks, on 8 October 2008 has a positive sign with statistical significance. In fact, the market on 7 October 2008 already speculated an interest rate cut upcoming soon as Bernanke signalled in his remark that day that the Fed was ready to lower interest rate as the condition of the economy and financial market continued deteriorating. When the Fed actually announced a 50 basis points cut on 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 has a rather persistent effect on the spread as shown by the significant parameters of the following several days. The last federal fund rate cut on 16 December 2008 in the sample period has no impact on the US-dollar funding market, although it was the largest cut

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

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.

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 10%, 5% and 1% confidence level respectively, and t-statistics are included in parentheses.

Although the monetary policy actions appear to have no desirable effects on reducing the CIP deviations during the sample period, the announcement of the unlimited currency swap line 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 mitigated 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 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 dummy 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 8 October has an impact on the realised volatility of the spreads, i.e. CIP deviations. Furthermore, the unlimited currency swap line also has impacts on 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 ECB during the sample period from 1 September to 31 December 2008, appeared to be ineffective to mitigate the shortage of US dollars in the global funding markets. On 9 October 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.

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 10%, 5% and 1% confidence level respectively, and t-statistics are included in parentheses.

However, the exceptional action—uncapping the currency swap arrangements between the Fed and the three European central banks on 13 October 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 this action favourably since the action would provide liquidity to the most needed financial institutions directly.

VI. Conclusion

This study uses high-frequency data of executable bid and ask quotes of spot and forward foreign exchange and of interest rates in the period from 1 September to 31 December 2008 to gauge the dynamics of market liquidity condition and to investigate how and whether the monetary policy actions taken by the Fed and ECB relieve the stress in the US-dollar money markets by observing the change in the CIP arbitrage spread during the period. Our results on intraday patterns of the CIP deviations suggest that, during the week in which Lehman Brothers collapsed, because of huge funding liquidity and counterparty risks, both on-shore and off-shore US-dollar money markets were paralysed; and particularly non-US banks had to obtain US-dollar loans through FX swap markets. Our empirical results indicate that the traditional monetary actions, even the very aggressive interest rate cuts taken by the Fed and ECB, failed to mitigate the US dollar liquidity shortage when the market was extremely counterparty-risk aversive. Only when the Fed uncapped its currency swaps with other four central banks, the unlimited and guaranteed US-dollar loans directly from the central banks to financial institutions effectively reduced the CIP deviations and improved the liquidity condition the money markets.

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