Dislocations in the FX swap and money markets in Hong Kong SAR during the global credit crisis of 2007–08

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I. Introduction

The subprime crisis emerged in the United States in mid-2007 and spilled over to other economies. From mid-2007 to mid-2008, the spillovers were relatively modest, but the situation began to change in mid-2008. Following the bankruptcy of Lehman Brothers in mid-September 2008, developments took a dramatic turn. One channel for those spillovers was severe disruptions in international money markets. Uncertainty about losses incurred by banks increased banks' liquidity needs as well as their reluctance to lend to each other in money markets. Reflecting these, and possibly other, factors, interbank short-term interest rates surged substantially after the failure of Lehman Brothers and persisted at high levels, prompting central banks around the world to adopt unprecedented policy measures to supply funds to banks. The Hong Kong dollar (HKD) money market was also hit hard by the liquidity squeeze.[2] The turbulence in the global interbank markets also spilled over to the foreign exchange (FX) swap markets, including in Hong Kong SAR. In response to the stress in the local financial markets, the Hong Kong Monetary Authority (HKMA) and the Hong Kong SAR Government announced a series of measures to help contain the global stresses from spilling over to the domestic banking system.

In this paper, we examine the anomalies and distress experienced in the local financial markets and attempt to provide answers to the following questions:

1. To what extent was the distress that originated from US dollar (USD) money markets transmitted to the HKD money market?
2. How effective were the policy actions undertaken by the HKMA and the Hong Kong SAR Government in mitigating the stress within the interbank market in Hong Kong SAR?
3. To what extent did the policy actions help to improve the efficiency of the money and FX swap markets in Hong Kong SAR?

II. Transmission of term funding shock and volatility linkage

In this study, we look at the Hibor-OIS spread as the indicator of interbank stress. This interbank stress indicator is derived by subtracting the HKD overnight index swap (OIS) rate of corresponding maturity from the Hong Kong interbank offered rate (Hibor) of the same

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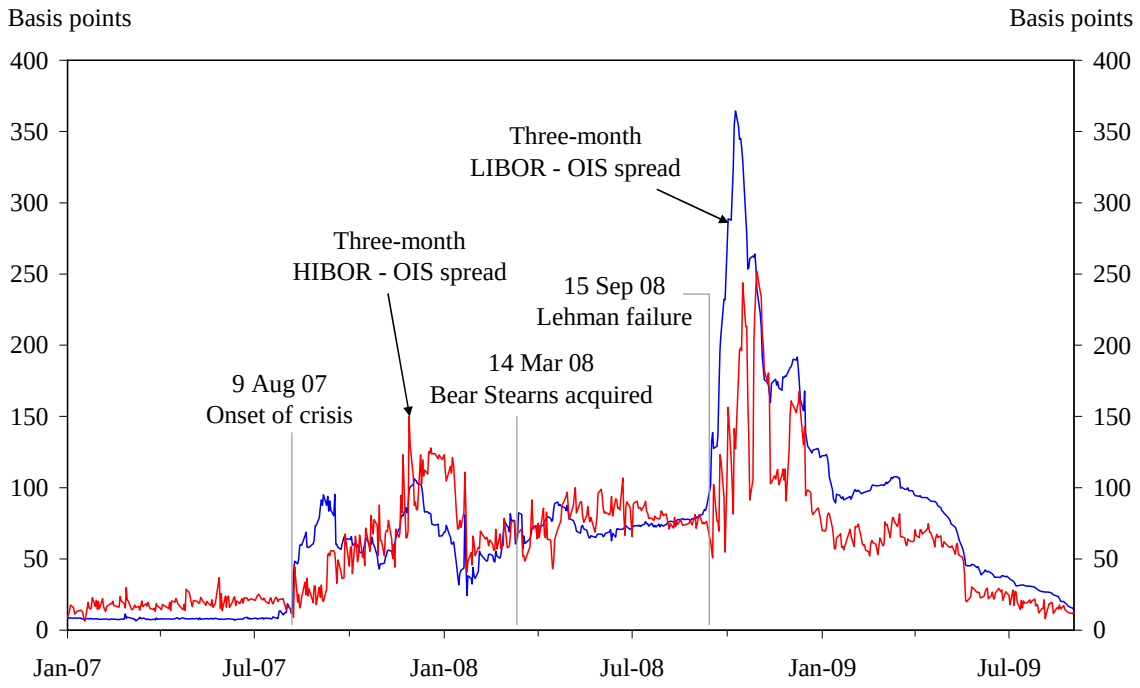
[2] Note that in this paper the words "money market" and "interbank market" are interchangeable.

maturity,[3] and is relevant to central banks in their assessment of interbank market distress and applicable policy actions.[4]

Chart 1 shows the three-month Hibor less the three-month OIS rate (the Hibor-OIS spread) against that of the USD (the Libor-OIS spread) from January 2007 to September 2009. It can be seen that, before the onset of the crisis on 9 August 2007, the Hibor-OIS spread averaged around 18.5 basis points (bp), compared to 8.4 bp of its USD counterpart.[5] As the financial crisis unfolded, the HKD money market responded to the developments in international financial markets with a sharp increase in the Hibor-OIS spread. With an increasing number of international banks reporting substantial asset writedowns due to subprime-related investments and the collapse of Lehman Brothers in September 2008, both HKD and USD interbank stress series rose sharply from late September to mid-October 2008. Global efforts to support financial stability and confidence in the banking system finally eased the stress in the money markets in November–December 2008.

Chart 1

Three-month Hibor-OIS and Libor-OIS spreads



Source: Bloomberg.

[3] In principle, the interbank rate of a given tenor reflects the current and expected future overnight interest rate and premia associated with liquidity and credit risks. The OIS rate, meanwhile, is closely related to the average overnight interest rate expected to prevail over the term of the swap. The spread between the interbank rate and the OIS rate can be used as an indicator to gauge the level of stress in the interbank market. A widened interbank rate-OIS spread reflects the increase in liquidity and/or counterparty default risks.

[4] Throughout the paper, the interbank stress indicator for the money markets under study will be referred to as the interbank stress of the respective money market.

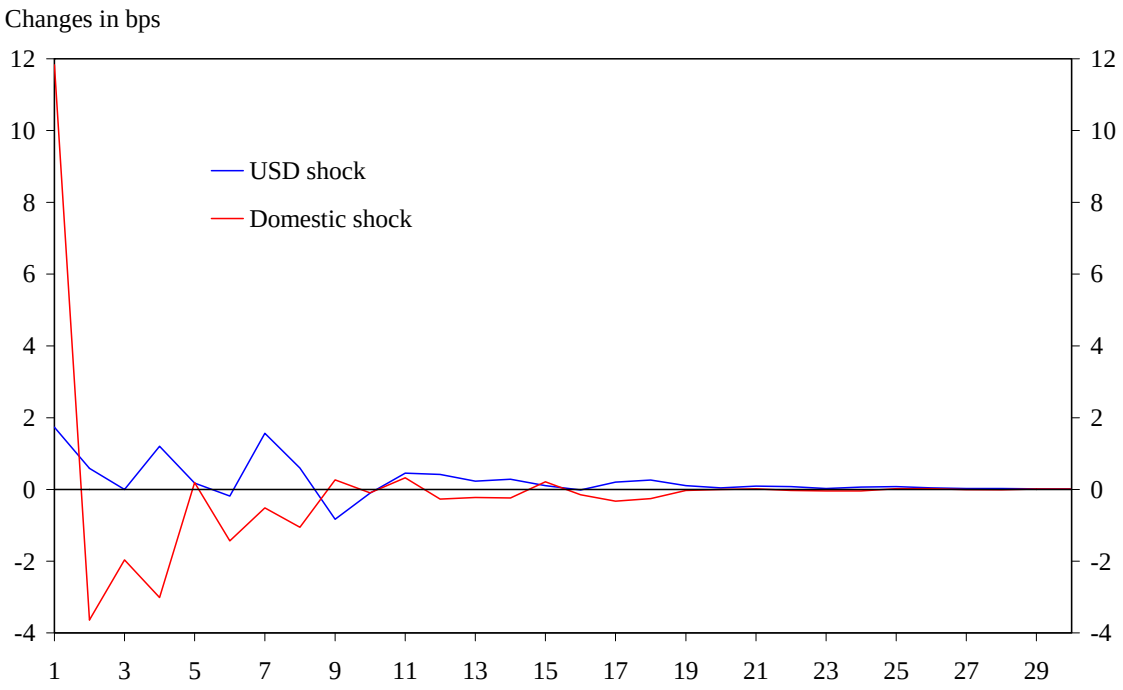
[5] We follow Taylor and Williams (2008) and choose 9 August 2007 as the onset of the turmoil when BNP Paribas froze redemptions for three of its investment funds.

One possible transmission mechanism of the USD shock to the HKD money market during the crisis may have been the increased use of the HKD money market to secure USD funding. As noted in Imakubo et al (2008), financial institutions were facing a shortage of USD funding when the USD Libor surged to an unprecedented level. US banks, which encountered increased financing difficulties and had to preserve funds on hand, were reluctant to lend their USD to peers. To secure USD funds, non-US financial institutions increased their borrowings in currencies other than USD and actively converted them into USD through FX swaps. Such a strategy could have led to the tightening of conditions in the HKD money market.[6]

The dynamic interrelationship between the USD and HKD interbank stress series is examined through the impulse response function of a bivariate vector error correction model (VECM).[7] Chart 2 shows the responses to changes in HKD interbank stress to a one-standard-deviation innovation in the changes in the USD series as well as in its own series for a period up to 30 days.[8]

Chart 2

Responses to changes in HKD interbank stress to one-standard-deviation of USD and domestic shocks



Source: HKMA estimates.

[6] Genberg et al (2009) analyse the link between the turbulence in money markets and the FX swap markets.

[7] For details, see Fung and Yu (2009a).

[8] An innovation refers to a shock to the random disturbance term on a series in the VECM system. Through the dynamic structure of the VECM system, a shock to one of the series is also transmitted to the other series in the system.

Chart 2 shows that the responses to the USD shock are gradual and persistent. The impact from the USD shock dies out to zero after 15 days. In relation to the impact of domestic shocks on its own money market, while overwhelming on the first day, the impact rapidly dies out to zero after nine days.

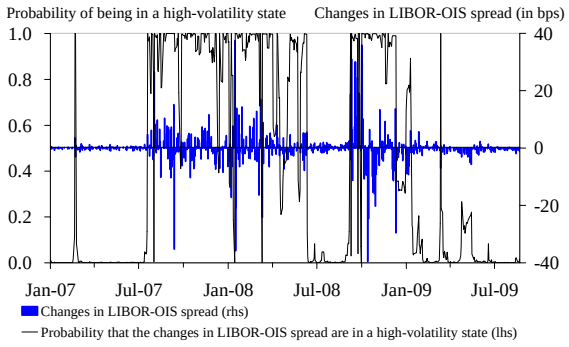
The results from the impulse response function show that the changes in HKD term funding stress are subject to pronounced and persistent influences from the USD shock. Hence, it appears that changes in interbank stress in the USD money market fed through to the HKD interbank market. This result is not surprising, as Hong Kong SAR is a small and open economy with a Linked Exchange Rate System (LERS), linking the Hong Kong dollar to the US dollar, and an international financial centre with some of the major international financial institutions participating in the local interbank market. In fact, as the funding stress first unfolded in the USD money market, exerting heavy pressure on many major international financial institutions, their ability to obtain term funding in the local interbank market could also have been affected.[9]

The above finding provides an assessment of the transmission of money market tensions from USD to HKD. If the variations in these interbank stress series are highly synchronised, the linkages may have implications for financial stability. To further examine whether these interbank stresses are synchronised, we model the possible switch in variance regimes by using a univariate regime-switching ARCH (SWARCH) model with two volatility regimes to identify periods of unusually high volatility. The graphs in Chart 3 feature the smoothed probabilities of the high-volatility state in each money market's interbank stress along with the changes in interbank rate-OIS spreads.[10]

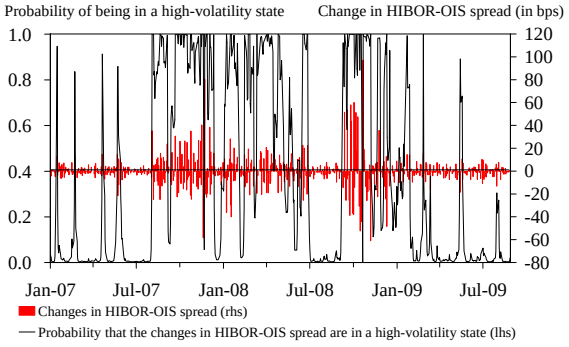
Chart 3

Smoothed probabilities of being in a high-volatility state and changes in interbank stress

The United States



Hong Kong SAR



Source: HKMA estimates.

[9] This may be due to the reappraisal of counterparty risks and the need to preserve liquidity by local banks.

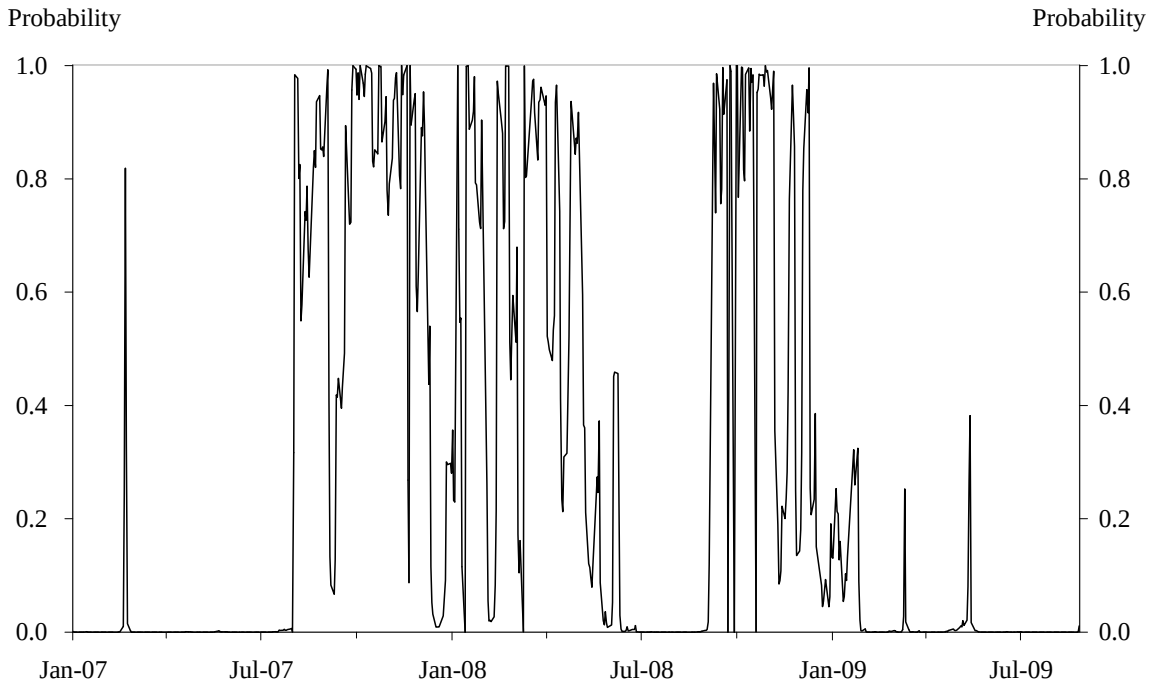
[10] The smoothed probability provides information about the likelihood that the changes in spread are in a particular volatility state at time *t* based on the full sample of observations.

By comparing the pattern of the smoothed probabilities across the USD and HKD money markets, it is possible to examine whether the high-volatility state occurred concurrently during the financial turmoil from the second half of 2007. As shown in Chart 3, the daily changes in interbank stress in the two money markets experience high volatility simultaneously on several occasions, such as in August 2007 and mid-September 2008, suggesting that a volatility linkage or co-movement exists between the money markets. The interbank stress in the two money markets had shifted to a low-volatility state by the end of January 2009.

The univariate SWARCH model is extended to a bivariate one in order to examine the issue of volatility linkages, especially in the high-volatility state. Chart 4 graphs the smoothed probabilities when the interbank stresses of the USD and HKD money markets are both in a high-volatility state. If we focus on the situation in September 2008, the money market pairs responded significantly to the collapse of Lehman Brothers and shifted to a high-volatility state for over a month. Therefore, a very significant adverse shock (ie a substantial increase in the variations of interbank stress) in the USD money market might have a destabilising impact on the HKD money market.

Chart 4

Smoothed probabilities of both markets in a high-volatility state



Source: HKMA estimates.

Results from the bivariate SWARCH estimation show that the expected duration for the USD and HKD money markets to jointly be in a high-volatility state is 5.5 days. That means, on average, that the two money markets are expected to stay in the high-volatility state for 5.5 days before they shift into other states of volatility. Hence, the expected duration provides useful information on the extent of the volatility linkage between money markets during a crisis period.

Overall, the above analysis shows that the transmission of USD money market stress to the HKD money market is rapid and persistent. The impact of a USD shock on the changes in

HKD interbank stress can last for 15 days before the impact dies out. There is also an indication of volatility co-movement between the interbank stress of these two money markets and the expected duration of their joint high-volatility state is 5.5 days. In the next section, we conduct an event study and examine the effectiveness of policy actions taken by the HKMA and the Hong Kong SAR Government in mitigating the stress in the HKD interbank market.

III. Effectiveness of policy actions on HKD interbank market stress and the dislocations in the FX swap market[11]

1. Dislocations in the FX swap market

In Section II, we examined how distress originating in USD money markets was transmitted to the HKD interbank market. When uncollateralised USD money markets malfunctioned and the interbank interest rates shot up during the turmoil, many non-US financial institutions relied heavily on FX swap markets to raise US dollars using local currencies. Heightened concerns over liquidity and counterparty risks rationed them out of the USD money markets, and they all bid for USD in the FX swap market, creating a one-sided market. This one-sided market induced an FX swap-market premium, ie a deviation from the covered interest parity (CIP) condition, as many non-US financial institutions found themselves facing similar USD funding shortages. This unusual pricing behaviour reflected dislocations in the FX swap markets and a similar situation was also observed in Hong Kong SAR.

The CIP condition is almost always observed. However, there are times and situations in which the condition breaks down.[12] One possibility is that, in times of financial turmoil, the risks as perceived by market participants might change, rendering the assumptions of the CIP condition inapplicable. Indeed, Baba and Packer (2008) and Genberg et al (2009) find that, in the recent global financial crisis, the turbulence in money markets spilled over to FX swap markets amid a reappraisal of counterparty risks.

During the financial crisis, the turbulence in the global interbank markets spilled over to the local financial markets in which deviations from the CIP condition were observed in terms of the difference between the FX swap-implied USD rate and the USD Libor as shown in the following equation:

$$CIP\ deviation = \underbrace{\frac{F_{t,t+x}}{S_t}\left(1 + r_{t,x}^{HKD}\right)}_{FX\ \ swap-implied\ \ USD\ \ rate} - \underbrace{\left(1 + r_{t,x}^{USD}\right)}_{USD\ \ interbank\ \ rate} \tag{1}$$

where S_t is the HKD per USD spot rate at time *t*. $F_{t,\,t+x}$ is the HKD per USD forward rate contracted at time *t* for exchange at time *t* + *x*. $r_{t,\,x}^{HKD}$ and $r_{t,\,x}^{USD}$ are the corresponding uncollateralised HKD and USD interest rates at time *t* with a tenor of *x*, proxied by the HKD interbank rate (Hibor) and the USD interbank rate (Libor) respectively with the same tenor.

In Chart 5, the red line measures how much the FX swap-implied three-month USD funding rate deviates from the corresponding USD Libor – the risk premium demanded by dollar

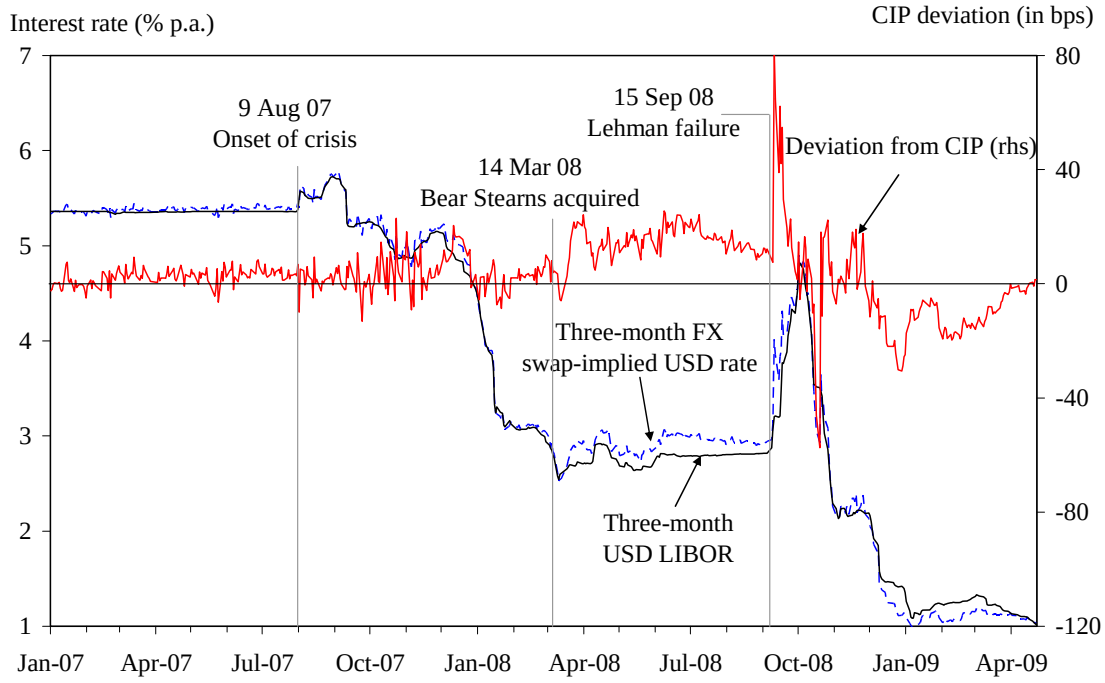
[11] For a detailed discussion, see Fung and Yu (2009b).

[12] See Taylor (1989) for such occasions during the flotation of sterling in 1972 and the inception of the European Monetary System in 1979.

lenders in the swap market or the departure from CIP in the local financial markets. As can be seen, before the summer of 2007, it oscillated around 0 basis points (bp), but subsequently started to follow an upward trend. Around the beginning of September 2008, it fluctuated wildly.

Chart 5

FX swap-implied USD rate, USD Libor and CIP deviation



Sources: Bloomberg and HKMA estimates.

In addition to the dislocations in the local FX swap market reflected by the CIP deviations, the HKD interbank market, as referred to above, was also under stress during the crisis. Again, we use the three-month Hibor-OIS spread as a measure of stress in the local interbank market. Chart 1 shows that the three-month Hibor-OIS spread increased when the crisis emerged in August 2007 and surged to more than 200 bp after the failure of Lehman Brothers in mid-September 2008.

2. Key policy actions and analysis framework

In response to the stress in the HKD interbank market following the collapse of Lehman Brothers in mid-September 2008, the HKMA and the Hong Kong SAR Government announced a series of measures to help contain the liquidity and solvency risks in the domestic banking system. Table 1 outlines these policy initiatives from September 2008 to March 2009.[13]

[13] See HKMA (2008) for more details on the measures that were implemented in response to the crisis.

Table 1

Policy measures announced by the HKMA and the Hong Kong SAR Government from September 2008 to March 2009

Announcement date	Measure
2008	
(1) 30 September	Five temporary liquidity measures
(2) 8 October	Modification of the Base Rate formula
(3) 14 October	Two precautionary measures to support confidence in the Hong Kong SAR banking system
(4) 20 October	Additional supply of three-month Exchange Fund Bills
(5) 6 November	Two refinements to the temporary liquidity measures
(6) 24 November	Additional supply of three-month Exchange Fund Bills
2009	
(7) 26 March	HKMA to continue the provision of liquidity assistance to banks

Source: HKMA (2008) and HKMA press releases.

3. Model specification

To capture the effects of policy actions or announcements as detailed in Table 1, a policy-action dummy variable is constructed where it is equal to one on days with policy actions or announcements and zero on other days. Given that the policy actions may influence both the level and volatility of the CIP deviation and three-month Hibor-OIS spread, we model the effect of policy actions or announcements under a standard exponential GARCH (EGARCH) model proposed by Nelson (1991). The EGARCH model has been widely used in analysing the effects of policy events on financial markets, as the model captures the asymmetric effect in the volatility of financial time series.

The dislocations in the HKD-USD FX swap market, measured by the changes in the CIP deviations, are assumed to be associated with the relative risk of the banking systems of Hong Kong SAR and the United States, along with the policy-action dummy.[14] A similar framework is applied to analyse the relationship between the interbank stress measured by the Hibor-OIS spread and the effectiveness of the policy actions.[15]

4. Effectiveness of the policy actions

Results from the EGARCH estimation show that the policy actions had no material impact on the three-month Hibor-OIS spread (the indicator of interbank market stress), indicating that they did not ease the distress in the longer end of the HKD interbank market following the collapse of Lehman Brothers.[16] This finding is, however, consistent with the recent study by the IMF (2009) which shows that the liquidity support measures initiated by the central banks

[14] The relative risk of the banking system can be considered as the funding liquidity risk (see Hui et al (2009)).

[15] Details of the model specification are set out in Annex I.

[16] Shortly after the measures were implemented, the overnight Hibor gradually eased.

in Japan, Sweden, Switzerland, the United Kingdom, the United States and the European Central Bank had an insignificant impact on the Libor-OIS spreads after the Lehman Brothers failure. The IMF study suggests that the finding does not necessarily mean that the policy actions to provide liquidity to the banking system were ineffective, but that those actions may have been anticipated by market participants. Therefore, their effects on the Libor-OIS spreads are not noticeable in the empirical tests. The same market reactions might also have happened in Hong Kong SAR, making the effects of the HKMA and Government policy actions on the Hibor-OIS spread not visible in our empirical analysis.

In relation to the dislocations in the FX swap market, it is found that the policy actions have a negative impact (with statistical significance) on the CIP deviations, suggesting that the policy actions effectively reduced the CIP deviations during the crisis. This implies that arbitrage opportunities diminished as the financial markets returned to normal, to a certain extent. In other words, following the failure of Lehman Brothers, the policy actions taken by the HKMA and the Government helped to mitigate the dislocations and therefore improved the efficiency in the money and FX swap markets to facilitate arbitrage transactions. In particular, the five temporary measures provided additional longer-term funding to banks against a wider range of collateral at a potentially lower interest cost. Banks were reassured about the availability of funds and more willing to lend in the interbank market. Furthermore, policy actions aimed at containing the solvency risk in the banking system relaxed the counterparty risk constraint on the markets and thus removed the financial dislocations.[17]

IV. Conclusions

This paper investigates the transmission of term funding stress from USD to HKD and examines the effectiveness of the policy actions taken by the HKMA and the Hong Kong SAR Government to mitigate the anomalies and stress in the FX swap and interbank markets in Hong Kong SAR during the financial crisis of 2008.

On the question of transmission of term funding stress, the results show a strong interdependence between the variations in USD and HKD interbank stress. Following a shock in the USD money market, the HKD interbank stress increased immediately and the impact died out in around 15 days. This suggests that for a market which is as open as Hong Kong SAR and with such a high degree of participation of foreign institutions, the US influence can be very profound. Similarly, the analyses find evidence of co-movements in interbank stress volatility in USD and HKD during the crisis. The expected duration when the two money markets are both in a high-volatility state can be as long as 5.5 days. The short-lived impact of a shock in the USD money market on the HKD money market can be attributed to the coordinated efforts by central banks and policymakers worldwide to contain the credit crisis.

On the effectiveness of the policy actions in mitigating the dislocations in the FX swap market and the stress in the HKD interbank market, the results suggest that the policy actions had no visible impact on the Hibor-OIS spread, indicating that they did not ease the distress in the HKD interbank market. However, this may be due to the fact that the policy actions might have been anticipated by market participants and, therefore, their effects might not have been visible in the HKD interbank market. On the other hand, the policy actions undertaken effectively reduced the dislocations in the FX swap market after the failure of Lehman Brothers. The reduction in the CIP deviations showed that the policy actions improved the efficiency of the money and FX swap markets where liquidity resumed to eliminate arbitrage opportunities.

[17] The EGARCH estimation results are reported in Annex II.

Appendix I:
EGARCH model specifications

The dislocations in the FX swap market between USD and HKD, measured by the changes in the CIP deviation (in basis points (bp)), are assumed to be associated with the relative risk of the banking systems of Hong Kong SAR and the United States, along with the policy-action dummy. The policy-action dummy is also put into the conditional variance equation to study whether it has any effects on the degree of volatility.

The conditional mean equation of the EGARCH model is written as:

$$\Delta CIP_t = a + \sum_{i=1}^{n} b_i \Delta CIP_{t-i} + c\Delta RRB_t + d\,PA_t + \varepsilon_{CIP,t},\ \varepsilon_{CIP,t} \sim N(0, \sigma^2_{CIP,t}), \quad \text{(A1)}$$

where Δ is the first difference operator. CIP_t is the CIP deviation (in bp) at time *t* for the respective crisis period. RRB_t is the variable for the relative risk of the banking systems of Hong Kong SAR and the United States at time *t*, which is measured by the difference (in bp) between the Hibor-OIS spread and the USD Libor-OIS spread during the global credit crisis of 2008. PA_t is the dummy variable for policy action announcements at time *t*. Lags of the dependent variable are included in equation (A1) to control for the serial correlation, if necessary. If the relative risk of the banking systems is a determinant of the premium or discount as reflected in the swap-implied USD rate, the estimated coefficient *c* in equation (A1) should be positive and statistically significant. If policy actions are helpful in reducing the CIP deviations, the estimated coefficient *d* should be negative (and it should also be statistically significant if the policy actions have a material impact on the CIP deviations).

In the EGARCH (p, q, r) model, the conditional variance equation is given as:

$$\ln(\sigma^2_{CIP,t}) = \varpi + \sum_{j=1}^{q} \beta_j \ln(\sigma^2_{CIP,t-j}) + \sum_{i=1}^{p} \alpha_i \left| \frac{\varepsilon_{CIP,t-i}}{\sigma_{CIP,t-i}} \right| + \sum_{k=1}^{r} \gamma_k \frac{\varepsilon_{CIP,t-k}}{\sigma_{CIP,t-k}} + \vartheta PA_t \quad \text{(A2)}$$

The coefficient ϑ measures the potential impact of the policy actions on the degree of volatility. If the policy actions have the desirable effect of reducing the volatility of the CIP deviation, the estimated coefficient ϑ is expected to have a negative sign. The coefficient β measures the persistent effect in the dynamics of the conditional variance σ^2, while the coefficient γ_k captures the asymmetric effect of news.

A similar framework is applied to the empirical analysis of the relationship between the interbank market stress and the effectiveness of policy actions. Fung and Yu (2009a) find that, during the credit crisis of 2008, the distress in the USD interbank market had a material impact on the HKD interbank market. Thus, in the conditional mean equation of the EGARCH model, the interbank stress indicator for HKD is assumed to have a linear relationship with the stress measure of the USD interbank market. The conditional mean equation is specified as:

$$\Delta IS^{HK}_t = a + \sum_{i=1}^{n} b_i \Delta IS^{HK}_{t-i} + cIS^{HK}_{t-1} + d\Delta IS^{US}_{t-1} + ePA_t + \varepsilon_{IS,t},\ \varepsilon_{IS,t} \sim N(0, \sigma^2_{IS,t}), \quad \text{(A3)}$$

where Δ is the first difference operator. IS^{HK}_t and IS^{US}_t are the interbank stress indicators for HKD and USD (in bp) respectively at time *t*, which are the Hibor-OIS spread and the USD Libor-OIS spread. The lagged term of the HKD interbank stress indicator (IS^{HK}_{t-1}) is included as a control variable in case the changes in the spread depend on its level. PA_t is the dummy variable for policy action announcements at time *t*. Lags of the dependent variable

are included in equation (A3) to control for the serial correlation, if necessary. If the policy actions ease the distress in the HKD interbank market, then it is expected that the estimated coefficient *e* should be negative (and should also be statistically different from zero if the policy actions have a material impact on the interbank stress indicator).

Similarly, the conditional variance equation in the EGARCH model is given as:

$$\ln(\sigma^2_{IS,t}) = \varpi + \sum_{j=1}^{q} \beta_j \ln(\sigma^2_{IS,t-j}) + \sum_{i=1}^{p} \alpha_i \left| \frac{\varepsilon_{IS,t-i}}{\sigma_{IS,t-i}} \right| + \sum_{k=1}^{r} \gamma_k \frac{\varepsilon_{IS,t-k}}{\sigma_{IS,t-k}} + \vartheta PA_t \qquad \text{(A4)}$$

The coefficient ϑ measures the potential impact of policy actions on the degree of volatility. Again, if policy actions have any effect in reducing the volatility of the Hibor-OIS spread, then the estimated coefficient ϑ is expected to have a negative sign.

Appendix II:
EGARCH model estimation results

Table A1

Estimation results of the CIP deviation, Hibor-OIS spread and the effectiveness of policy actions for the global credit crisis of 2008

Sample period: 16 Sep 2008 to 31 Mar 2009

Dependent variable: changes in CIP deviation (ΔCIP)		**Dependent variable: changes in Hibor-OIS spread (ΔIS)**	
Estimated coefficient in the conditional mean equation			
$\Delta CIP_t = a + \sum_{i=1}^{n} b_i \Delta CIP_{t-i} + c\Delta RRB_t + d\,PA_t + \varepsilon_{CIP,t}$		$\Delta IS_t^{HK} = a + \sum_{i=1}^{n} b_i \Delta IS_{t-i}^{HK} + cIS_{t-1}^{HK} + d\Delta IS_{t-1}^{US} + ePA_t + \varepsilon_{IS,t}$	
a	0.20	a	5.14
	(0.84)		(1.94)
b_1	–0.08	b_1	–
	(–1.15)		
c	0.21*	c	–0.08*
	(5.21)		(–2.04)
PA_t (**d**)	**–1.10****	d	0.32*
	(–1.86)		(2.11)
		PA_t (e)	**3.67**
			(0.33)
Estimated coefficient in the conditional variance equation			
$\ln(\sigma^2_{CIP,t}) = \varpi + \sum_{j=1}^{q} \beta_j \ln(\sigma^2_{CIP,t-j}) + \sum_{i=1}^{p} \alpha_i \left\lvert \frac{\varepsilon_{CIP,t-i}}{\sigma_{CIP,t-i}} \right\rvert + \sum_{k=1}^{r} \gamma_k \frac{\varepsilon_{CIP,t-k}}{\sigma_{CIP,t-k}} + \vartheta PA_t$		$\ln(\sigma^2_{IS,t}) = \varpi + \sum_{j=1}^{q} \beta_j \ln(\sigma^2_{IS,t-j}) + \sum_{i=1}^{p} \alpha_i \left\lvert \frac{\varepsilon_{IS,t-i}}{\sigma_{IS,t-i}} \right\rvert + \sum_{k=1}^{r} \gamma_k \frac{\varepsilon_{IS,t-k}}{\sigma_{IS,t-k}} + \vartheta PA_t$	
ϖ	0.14	ϖ	–0.11
	(0.84)		(–1.10)
β_1	0.98*	β_1	0.99*
	(165.13)		(68.46)
α_1	–0.17	α_1	0.19*
	(–0.86)		(2.07)
γ_1	–0.02	γ_1	–0.02
	(–0.34)		(–0.05)
PA_t (ϑ)	**0.27**	PA_t (ϑ)	**0.33**
	(1.01)		**(0.36)**

Notes: Figures in parentheses are z-statistics based on Bollerslev-Wooldrige robust standard errors. * indicates significance at the 5% confidence level. ** indicates significance at the 10% confidence level.

Source: HKMA estimates.

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