Dynamic Spillover of Money Market Turmoil from FX Swap to Cross-Currency Swap Markets: *Evidence from the 2007–2008 Turmoil*

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The functioning of money markets has been severely impaired since the summer of 2007. What began as a deterioration in a limited segment of the U.S. subprime mortgage sector quickly spread to other markets (IMF [2008]). Uncertainty about losses increased the liquidity needs of financial institutions, as well as their reluctance to lend to each other in money markets, the U.S. dollar market, in particular. The spreads of interbank short-term interest rates over overnight index swaps (OIS) widened substantially in August 2007 and then persisted at high levels (Taylor and Williams [2008a, 2008b]).

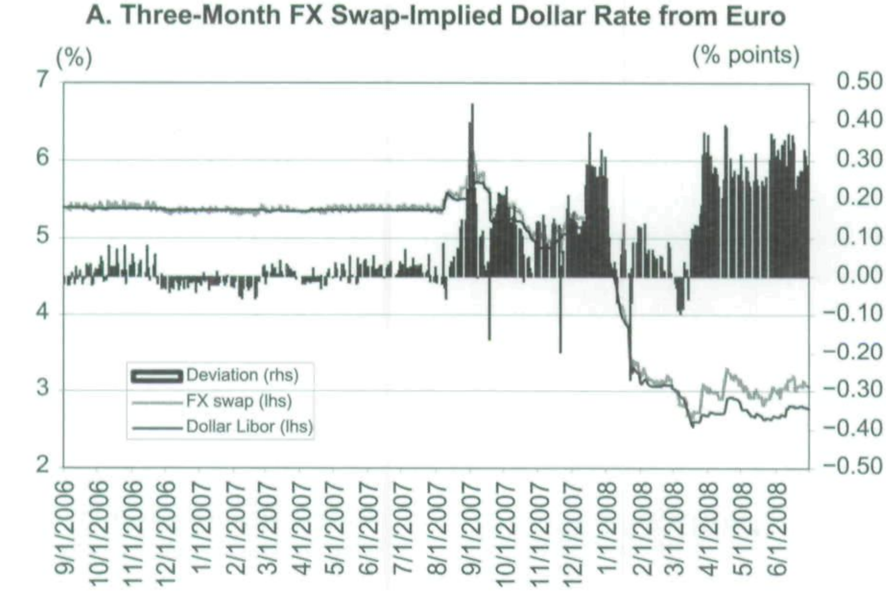
As documented in Baba, Packer, and Nagano [2008], the turmoil in money markets spilled over through the short-term foreign exchange (FX) swap market to the longer-term cross-currency swap markets. The three-month FX swap-implied dollar rate using euro as a funding currency moved together quite closely with dollar London Interbank Offered Rate (LIBOR) in the period preceding the turmoil in money markets (Exhibit 1, Panel A).[1] Since August 2007, however, the spread between the FX swap-implied dollar rate and dollar LIBOR widened considerably, reaching higher than 40 basis points in September 2007, which indicates a large deviation from short-term covered interest parity (CIP). Although the spread narrowed substantially immediately after 2008 began, it resurged from early March.

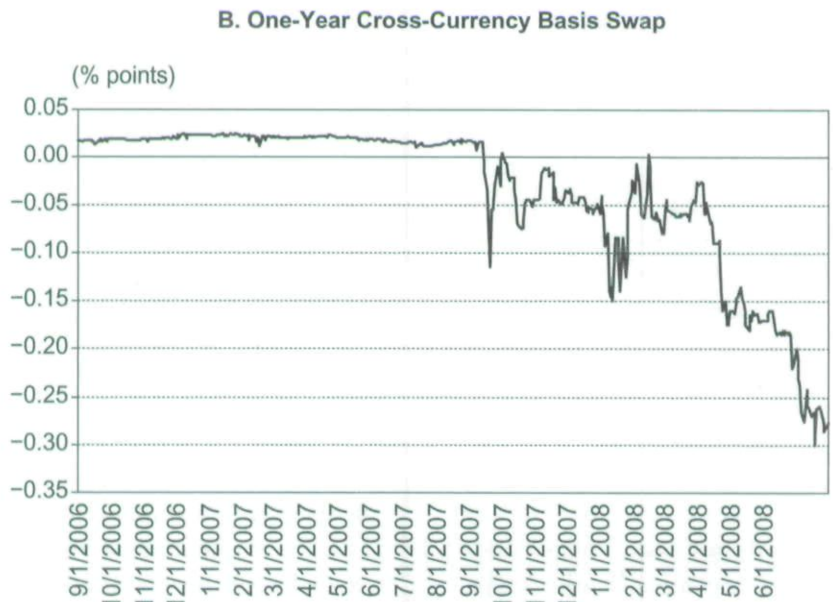
The price of the longer-term cross-currency basis swap between the euro and the dollar followed a very similar trend after the onset of the turmoil, deviating substantially from long-term CIP (Exhibit 1, Panel B).[2] The recent distortions in the cross-currency basis swap prices for the euro and dollar pair were particularly large by its own historical standards.

Baba, Packer, and Nagano [2008] argue that dollar-funding shortages of non-U.S. financial institutions were largely behind these developments. More specifically, soon after the turmoil began, European financial institutions attempted to secure dollar funding to support U.S. conduits for which they had committed backup liquidity facilities. At the same time, U.S. financial institutions appeared to become significantly more cautious about lending dollars to other institutions in the uncollateralized interbank markets. This is because of heightened counterparty risk, as well as their own need to hoard cash on hand. Facing unfavorable demand and supply conditions and the associated impairment of liquidity in the interbank markets, a large number of European institutions first moved to actively convert euros into dollars through FX swaps and then used longer-term cross-currency swaps, once they realized that the financial turmoil would last longer than initially thought. These developments were observed, despite coordinated efforts by central banks at an early stage to

EXHIBIT 1

FX Swap and Cross-Currency Basis Swap between Euro and U.S. Dollar





Notes: The FX swap-implied dollar rate from euro is calculated based on euro LIBOR. One-year cross-currency basis swap price is based on the Euribor and dollar LIBOR.

make dollar funding more readily available to non-U.S. financial institutions.[3]

In this article, I empirically investigate the above-mentioned dynamic spillover effects of the money market turmoil during the period of August 2007–June 2008 through the FX swap market to the cross-currency basis swap markets focusing on the euro and dollar pair. Specifically, let me first investigate the cointegrating relationship between these markets, paying particular attention to the comparison between two periods: before and during the turmoil. Let me then move on to the estimation of the error correction model, based on which

I investigate the dynamic spillover effects in terms of the Granger causality. I also analyze the time-varying volatilities of, and correlation between these two markets and test a volatility spillover, using the bivariate generalized autoregressive conditional heteroskedasticity (GARCH) model. Finally, I investigate the role of money market turmoil in the co-movement of both swap markets during the turmoil.

In the literature, a number of studies test short-term and long-term CIP conditions, and some identify the specific periods in which such parity conditions collapsed. However, to the best of my knowledge, no study analyzes the dynamic relationship between the collapse of the short-term CIP and that of the long-term CIP, and the role of the money market turmoil in the co-movement of both CIP deviations.

FX SWAP AND CROSS-CURRENCY BASIS SWAP MARKETS

Both FX swap and cross-currency basis swap are a contract in which one party simultaneously borrows one currency from, and lends another to the same party. They can be viewed as effectively collateralized transactions, but the collateral does not cover the entire counterparty risk. For example, if the counterparty were to default during the contract period, the party would need to reconstruct the position at the current market price, which entails replacement cost. Furthermore, Duffie and Huang [1996] show that FX and cross-currency swaps are subject to more exposure to counterparty risk than are interest rate swaps, due to the exchange of notional amounts.

FX Swap and Short-Term Covered Interest Parity

When non-U.S. financial institutions need short-term dollar funds, they can borrow directly in the dollar cash market or combine domestic currency borrowing with an FX swap.[4] For example, an institution funding itself in euros but desiring dollar funding could swap the proceeds for dollars, in effect selling euros for dollars at the FX spot rate, while contracting to exchange in the reverse direction at maturity at the FX forward rate. Exhibit 2, Panel A illustrates the fund flows involved in this euro/dollar swap. In this article, let me call the total cost of raising dollars using euros as a funding currency through the FX swap market "the FX swap-implied dollar rate from the euro." The equality of the FX swap-implied dollar rate and dollar deposit rate defines a condition of indifference as

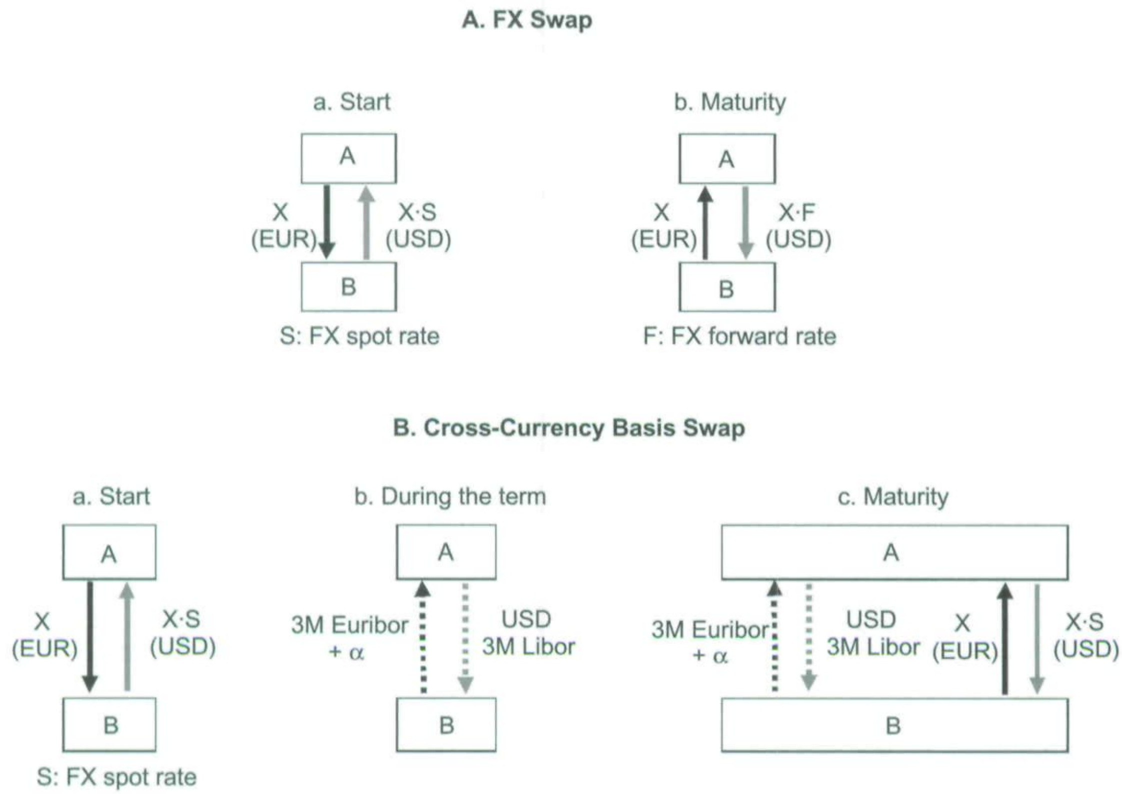
$$\frac{F_{t,t+s}}{S_t}(1+r_{t,t+s}^{EUR}) = 1 + r_{t,t+s}^{USD} \tag{1}$$

Here, the left-hand side of Equation (1) corresponds to the FX swap-implied dollar rate from the euro, where S_t is the FX spot rate between the euro and the dollar at time t, $F_{t,t+s}$ is the FX forward rate contracted at time t for exchange at time $t + s$, and $r_{t,t+s}^{EUR}$ is the uncollateralized euro deposit fixed interest rate from time t to time $t + s$. $F_{t,t+s}/S_t$ corresponds to the euro/dollar forward discount rate that is conventionally used as the FX swap price. $r_{t,t+s}^{USD}$ is the uncollateralized dollar deposit fixed interest rate (dollar LIBOR, in this article). Equation (1) is equivalent to the covered interest parity (CIP) condition in the international finance literature.

CIP states that interest rate differentials between currencies should be perfectly reflected in the FX forward discount rates, because otherwise an arbitrageur could transact in interest and exchange markets to make a risk-free profit. A number of studies assess the degree to which short-term CIP is supported by the data. Most of them show that deviations from the short-term CIP condition have diminished significantly at least among G10 currencies. However, Taylor [1989] finds that, despite increasing efficiency in FX markets, deviations from CIP tend to be evident during periods of uncertainty and turmoil, and persist for some time.[5,6]

For CIP to hold strictly depends on negligible transaction costs, as well as the lack of political risk, counterparty risk, liquidity risk, and measurement error. While transaction costs and political risk are largely negligible in today's G10 currency markets, counterparty risk may have increased significantly under the recent turmoil. To the extent that counterparty risk was concentrated on one end of the FX swap market, a deviation from CIP could have emerged. This is particularly the case, when uncollateralized dollar deposit markets malfunctioned under the turmoil, and so the only channel of dollar funding was the FX swap market. For example, if European financial institutions typically on the dollar borrowing side of the FX swap market were perceived as risky by U.S. financial institutions on the dollar lending side, then risk premia could have been added to FX swap prices.

EXHIBIT 2
FX Swap and Cross-Currency Basis Swap



Liquidity risk may have played a role, as well, particularly if market liquidity was impaired due to outsized or one-sided order flow, with effects compounded by perceptions of increased counterparty risk. In the case of dollar funding shortages of European financial institutions, their order flow for dollars in the FX swap market was reported to have surged during the recent financial turmoil. This was apparently due largely to constraints on borrowing in the uncollateralized dollar interbank market, where U.S. financial institutions appeared less willing to lend dollars to other institutions, because of perceptions of heightened counterparty risk as well as their own increased demand for dollar liquidity.

Finally, measurement error could have been heightened as well. During the recent turmoil, dollar LIBOR was reported to have underestimated the dollar funding costs that euro-zone financial institutions actually faced. The nonbinding nature of LIBOR may lead to biased quotes on the part of institutions wary of revealing information that might increase their borrowing costs in times of stress.

Cross-Currency Basis Swap and Long-Term Covered Interest Parity

The long-term cross-currency swap market was also significantly affected by the recent turmoil in the money markets. Market participants argue that FX swaps are still relatively costly at maturities equal to or longer than one year, even under normal conditions, because of low market liquidity. Thus, for such maturities, cross-currency swaps are more broadly used than FX swaps. There are numerous types of cross-currency swap contracts, among which the most widely used in recent years is the cross-currency basis swap.

A cross-currency basis swap is a contract in which one party borrows one currency from another party and simultaneously lends the same value, at current spot rates, of a second currency to the same party. The parties involved in cross-currency basis swaps tend to be financial institutions, either acting on their own or as agents for non-financial corporations.[7]

Exhibit 2, Panel B, illustrates the fund flows when euro and dollar obligations are swapped. In such a swap contract, parties effectively borrow from each other in different currencies, exchanging principals at both the start and maturity of the swap, as well as regular interest rate payments. Since the amount of future principal payment is fixed at the start of the contract, cross-currency basis swaps are largely free from FX risk in its traditional sense, but entail replacement cost, as are FX swaps. Though the structure is different from FX swaps, cross-currency swaps serve the same economic function as FX swaps.

The conventional quoting procedure for cross-currency basis swaps is as follows. A euro/dollar 10-year basis swap, for example, may be quoted as Euro Interbank Offered Rate (Euribor) plus α basis points versus dollar LIBOR flat. This means that the lender/borrower of dollar/euro funds is obligated to pay Euribor plus α basis points every three months in exchange for receiving dollar LIBOR flat. In this fashion, the prices for swaps α involving dollars turn negative when there is strong demand for dollars relative to euros.

Because the interest rates exchanged in cross-currency basis swaps are floating rates, for the comparison with the short-term CIP condition reflected in the FX swap prices, converting floating rates into fixed rates through interest rate swaps is needed. As shown in Popper [1993], among others, after this conversion and abstracting from the above-mentioned potential distortions stemming from the reasons similar to the case of the short-term CIP, the long-term CIP condition for the cross-currency swap market can be written as

$$1+r_{t,t+s}^{USD} = (1+r_{t,t+s}^{EUR}) + [(1+r_{t,t+s}^{USD}) - (1+r_{t,t+s}^{EUR} + \alpha)] \quad (2)$$

Equation (2) suggests that in theory, α should be zero when long-term CIP holds perfectly. Put differently, α measures the deviation from long-term CIP observed in the cross-currency basis swap market. Due to its greater liquidity than that of the FX swap market at maturities longer than one year, the cross-currency swap market is the main source of data for testing the long-term CIP condition. Using the data up to the early 1990s, Popper [1993], Fletcher and Taylor [1994, 1996], Fletcher and Sultan [1997], and Takezawa [1995] find that non-negligible deviations exist from the CIP condition at various times using cross-currency swap prices but that such deviations diminished over time.[8]

Based on Equations (1) and (2), the deviation of the FX swap-implied dollar rate from the dollar deposit rate (FX swap deviation) can be compared with the usual price quotation of α in the cross-currency basis swap market. In other words, in terms of the traditional international finance literature, this article intends to assess the dynamic spillover effects of the deviation from the short-term CIP to that from long-term CIP.

EMPIRICAL METHODOLOGIES TO MEASURE DYNAMIC SPILLOVER EFFECTS

First of all, let me use Johansen's [1991, 1995] cointegration test to investigate the long-term relationship between the FX swap deviation and the basis swap price based on the following vector error correction model (VECM):

$$\Delta R_t = \Pi R_{t-1} + \sum_{i-1}^{k-1} \Gamma_i \Delta R_{t-i} + \varepsilon_t \quad (3)$$

where

$$\Pi = \sum_{i-1}^{k} \mathrm{A}_i - \mathrm{I}$$

and

$$\Gamma_i = -\sum_{j=i+1}^{k} \mathrm{A}_j$$

Here, R_t denotes the vector consisting of the FX swap deviation and basis swap price. Granger's representation theorem states that if the coefficient matrix Π has reduced rank $r < 2$, then there exist $2 \times \mathrm{r}$ matrices α and β with rank r such that $\Pi = \alpha\beta'$, where $\beta' R_t$ is I(0).[9] Here, r is the number of cointegrating relations and each column of β is the cointegrating vector. Johansen's method is to estimate the Π matrix from an unrestricted VAR and to test whether the restrictions implied by the reduced rank of Π can be rejected. The number of cointegrating relations is determined by the trace statistic and the maximum eigenvalue statistic. Based on the estimated VECM, the Granger causality test is conducted to gauge the dynamic interaction between the two swap markets.

Next, I use the bivariate generalized autoregressive conditional heteroskedasticity (GARCH) model to compute conditional volatilities of, and correlation between, the FX swap deviation and the basis swap price, as well as to test a volatility spillover between the two swap markets. In the literature, a simple cross-market correlation is often used to posit such a spillover effect. As argued by Forbes and Rigobon [2002], however, during crises when markets are highly volatile, estimates of simple correlation coefficients using a rolling window tend to be biased upward, because conditional heteroskedasticity is not modeled explicitly. The use of bivariate GARCH models enables us to avoid this criticism. The basic structure of the bivariate GARCH model can be written as

$$\Delta R_t = \mu_t + \varepsilon_t \quad \varepsilon_t \left| \Omega_{t-1} \sim G(0, \mathrm{H}_t) \right. \tag{4}$$

where $\mu_t = \mathrm{E}(\Delta \mathrm{R}_t | \Omega_{t-1})$ is the conditional mean of the bivariate vector consisting of the first differenced FX swap deviation and the basis swap price ΔR_t at time t given the past information set Ω_{t-1}, ε_t is the corresponding shocks of the bivariate series, which are assumed to follow the bivariate Gaussian distribution G, and H_t is the conditional covariance matrix at time t. I use the same VECM as in Equation (3) to compute the conditional mean of the bivariate series. Thus, this article adopts the following two-step estimation strategy: 1) estimate the conditional mean equation using the VECM, and 2) apply the bivariate GARCH model to the residuals obtained from the VECM.[10]

There exist numerous parameterization methods for the conditional covariance matrix H_t in Equation (4). Among others, I employ the BEKK(1, 1) model[11] proposed by Engle and Kroner [1995]. This model can be written as

$$H_t = A_0 A_0' + A_1(\varepsilon_{t-1}\varepsilon_{t-1}')A_1' + B_1 H_{t-1} B_1' \tag{5}$$

where A_0 is a 2×2 lower triangular matrix and A_1 (ARCH coefficients) and B_2 (GARCH coefficients) are the corresponding unrestricted square matrices.

The BEKK model has a very flexible and rich structure capable of capturing the dynamics of volatilities and correlation, which enables us to test the volatility spillover between the two markets under study by looking at off-diagonal ARCH and GARCH coefficients. The BEKK model also has the advantage that the positive semi-definiteness of the time-varying covariance matrices is guaranteed. The time-varying conditional correlation can be given by $H_t^{(21)} \Big/ \sqrt{H_t^{(11)} H_t^{(22)}}$.

Data

Throughout the empirical analysis that follows, I use the following two separate periods: one of relative tranquility from September 1, 2006, through August 8, 2007, and one of turmoil from August 9, 2007, through June 30, 2008. I follow Taylor and Williams [2008a, 2008b] in the choice of the date when the turmoil of 2007–2008 started. On that date, BNP Paribas announced the freezing of redemptions for three of its investment funds, citing an inability to value them. After that, the risk premia embedded in short-term money market rates, as represented by the LIBOR-OIS spreads, widened substantially in most major currencies.

FX swap deviation. For the euro funding rate, I use euro LIBOR. For the euro/dollar forward discount rate, I use the NY composite FX spot and forward rates taken from Bloomberg, where the composite bid rate is equal to the highest bid rate of more than 30 contributing financial institutions and the composite ask rate is the lowest ask rate offered by these same institutions. The average of the composite bid and ask rates as of 5:00 pm New York time is used. Dollar LIBOR is subtracted from the FX swap-implied dollar rate to compute the FX swap deviation. The three-month maturity is used throughout the article, a maturity which has been the focus of much recent analysis of turmoil in money markets (e.g., see Taylor and Williams [2008a, 2008b]).

The LIBOR fixings are released on a daily basis by the British Bankers' Association (BBA). The LIBOR fixing is meant to capture the rates paid on unsecured interbank deposits at large globally active banks. The BBA surveys a panel of banks every business day, asking them to provide the rates at which they could borrow reasonable amounts just prior to 11:00 am London time. Note however that the rates quoted by the panel banks are non-binding, in that the banks are under no obligation to prove that they can actually trade at those rates. For each maturity, the BBA excludes the highest and lowest quartile of rates, and takes a simple average.

Cross-currency basis swap price. As for the cross-currency basis swap price, I use NY composite prices as of 5:00 pm New York time taken from Bloomberg, as is the case with the FX forward discount rates. The price data is based on Euribor against dollar LIBOR flat and thus it is converted into euro LIBOR base by adding the spread between Euribor and euro LIBOR.[12] I use one-year maturity, as it is the shortest maturity for this instrument and should thus be most influenced by developments in the short-term FX swap markets. In what follows, the cross-currency basis swap price α is multiplied by −1 to make the direction consistent with the FX swap deviation, so that a positive number reflects a higher demand for dollars than euros in both swap markets.

Summary statistics. Exhibit 3 shows summary statistics for the FX swap deviation and cross-currency basis swap price. Quite evident is a large increase in both the mean and standard deviation of both variables under the turmoil. The Augmented Dickey–Fuller tests shows that both variables are I(1), before and during the turmoil. Thus, let me proceed to the cointegration analysis below. The Ljung–Box Q statistics for the first 10 lags of autocorrelation indicates significant autocorrelation for both the level and squared level of each variable. This result indicates that careful modeling will be necessary for both the conditional mean and conditional volatility equations to remove the influence of autocorrelations on model estimates.

ESTIMATION RESULTS FOR DYNAMIC SPILLOVER EFFECTS

Exhibit 4 shows the estimation results of the Johansen cointegration test and the VECM before the turmoil, while Exhibit 5 gives the parallel set of estimation results during the turmoil. Exhibit 6 reports the estimation results for the corresponding bivariate GARCH model; Exhibits 7 and 8 show the conditional standard deviation and correlation, respectively, obtained from the bivariate GARCH model.

EXHIBIT 3
Summary Statistics

A. Before Turmoil (% points)

	FX swap deviation	Basis swap price
Mean	0.005	–0.019
Standard deviation	0.026	0.003
Max	0.086	–0.009
Min	−0.056	–0.026
ADF (level)	−2.630	–1.297
ADF (1st difference)	−23.292**	–26.286**
Q(10)	447.72**	1001.7**
$Q^2(10)$	84.56**	1024.6**

B. Under Turmoil (% points)

	FX swap deviation	Basis swap price
Mean	0.156	0.091
Standard deviation	0.125	0.077
Max	0.446	0.298
Min	–0.272	–0.015
ADF (level)	–2.582	–0.934
ADF (1st difference)	–18.608**	–16.745**
Q(10)	802.71**	1653.4**
$Q^2(10)$	680.15**	1650.3**

*Notes: The basis swap price is multiplied by −1 after converted into euro LIBOR base from Euribor base. The ADF is the Augmented Dickey–Fuller unit root test statistic, where the constant term is included and the lag length is chosen based on the modified Schwarz information criterion. The Q(10) and $Q^2(10)$ are Ljung–Box Q test statistics for the first 10 lags of the level and squared level, respectively. ** denotes the 1% significance level.*

EXHIBIT 4
Cointegration and VECM before Turmoil

A. Johansen Cointegration Test

Number of cointegrating vectors			
Trace statistic		Maximum eigenvalue statistic	
None	At most 1	None	At most 1
46.007**	6.840	39.167**	6.840

B. Cointegrating Vector

Estimated cointegrating vector	Restriction test on vector
(FX swap, Basis swap, Constant)	(1,–1, C)
(1,–5.380**, –0.107**)	14.643**
	(1,–1)
	11.020**

C. VECM

	D(FX swap)	D(Basis swap)
Error correction term	–0.377**	0.027**
	(0.077)	(0.008)
D(FX swap (–1))	–0.260**	–0.010
	(0.080)	(0.008)
D(FX swap (–2))	–0.132*	–0.011
	(0.068)	(0.007)
D(Basis swap (–1))	–1.622**	–0.512**
	(0.670)	(0.066)
D(Basis swap (–2))	–0.635	–0.199**
	(0.631)	(0.062)

	$Q(10)$	
FX swap	Basis swap	Bivariate
44.163**	13.001	73.652**
	$Q^2(10)$	
FX swap	Basis swap	Bivariate
37.079**	10.732	59.626*

D. Granger Causality Wald Test

FX swap to basis swap	Basis swap to FX swap
2.866	5.929

Notes: The Johansen cointegration test statistics are based on the specification including a constant term and the lag length is chosen based on the Schwarz information criterion. The restriction test on the cointegrating vector is conducted by the likelihood ratio test. The $Q(10)$ and $Q^2(10)$ are Ljung–Box Q test statistics for the first 10 lags of the residuals and squared residuals, respectively.

***and *denote the 1% and 5% significance levels, respectively.*

Cointegration and VECM Results

As reported in Panel A of Exhibit 4, both trace and maximum eigenvalue test results show that the FX swap deviation and the basis swap price are significantly in a cointegrating relationship. The estimated cointegrating vector between the FX swap deviation and the basis swap price is (1, –5.380, –0.107), where the last term is a constant, and the restrictions (1, –1, C) and (1, –1) are rejected at the 1% significance level, respectively, as shown in Exhibit 4, Panel B. This result suggests the existence of long-run underlying factors common to both swap markets, although the long-term relationship is far from one-on-one.

As reported in Panel C of Exhibit 4, the Q-statistics for the first 10 lags of the autocorrelation of the VECM

EXHIBIT 5

Cointegration and VECM under Turmoil

A. Johansen Cointegration Test

Number of cointegrating vectors			
Trace statistic		Maximum eigenvalue statistic	
None	At most 1	None	At most 1
25.857**	2.435	23.422**	2.435

B. Cointegrating Vector

Estimated cointegrating vector	Restriction test on vector
(FX swap, Basis swap, Constant)	(1,–1, C)
(1, –0.980**, –0.055*)	0.010
	(1,–1)
	2.050

C. VECM

	D(FX swap)	D(Basis swap)
Error correction term	–0.218**	0.014
	(0.056)	(0.014)
D(FX swap (–1))	–0.087	0.069**
	(0.076)	(0.018)
D(FX swap (–2))	0.029	0.044**
	(0.073)	(0.018)
D(Basis swap (–1))	0.073	–0.249**
	(0.290)	(0.070)
D(Basis swap (–2))	–0.133	–0.152
	(0.281)	(0.068)

	***Q*(10)**	
FX swap	Basis swap	Bivariate
4.920	9.207	52.782
	***Q*²(10)**	
FX swap	Basis swap	Bivariate
7.608	36.368**	62.738**

D. Granger Causality Wald Test

FX swap to basis swap	Basis swap to FX swap
15.416**	0.343

Notes: The Johansen cointegration test statistics are based on the specification including a constant term and the lag length is chosen based on the Schwarz information criterion. The restriction test on the cointegrating vector is conducted by the likelihood ratio test. The Q(10) and $Q^2(10)$ are Ljung–Box Q test statistics for the first 10 lags of the residuals and squared residuals, respectively.

*** and * denote the 1% and 5% significance levels, respectively.*

residuals show significant residual autocorrelation for the FX swap deviation and the bivariate combination (Portmanteau test). The same statistics also show significant autocorrelation for the squared residuals of the FX swap deviation and bivariate combination. Estimated error correction terms are significant for both the FX swap deviation and the basis swap price, indicating that once the two swap market prices deviate from their long-term cointegrating relationship, both markets adjust.

As shown in Exhibit 4, Panel D, the Granger causality test result based on the VECM shows no causality in either direction between the FX swap deviation and the basis swap price ahead of the turmoil.

The results look quite different during the period of turmoil, as reported in Exhibit 5. Both trace and maximum eigenvalue test results show that the two swap markets are in a significant cointegrating relationship during the turmoil (Exhibit 5, Panel A). In contrast to the results

EXHIBIT 6
Bivariate GARCH Model

	Before turmoil	Under turmoil
ARCH (F to F)	0.209	0.280**
	(0.107)	(0.072)
ARCH (F to B)	–0.007	0.029*
	(0.012)	(0.013)
ARCH (B to F)	0.661	–0.098
	(1.015)	(0.259)
ARCH (B to B)	0.346**	0.272**
	(0.102)	(0.068)
GARCH (F to F)	0.986**	0.841**
	(0.052)	(0.064)
GARCH (F to B)	0.008	–0.040*
	(0.006)	(0.011)
GARCH (B to F)	–1.026	0.283
	(0.757)	(0.154)
GARCH (B to B)	0.825**	0.986**
	(0.097)	(0.042)
		$Q^2(10)$
FX swap	17.919	2.160
Basis swap	3.721	12.950
Bivariate test	47.087	27.465

Notes: The $Q^2(10)$ is the Ljung–Box test statistic for the first 10 lags of the squared standardized residuals. (F to B) indicates the direction of volatility spillover from the FX swap to the basis swap, for example. Numbers in parentheses are standard errors.

*** and * denote the 1% and 5% significance levels, respectively.*

for the earlier period, the restrictions (1, –1, C) and (1, –1) are not rejected significantly under the turmoil, suggesting a significant long-term one-on-one correspondence between the FX swap deviation and basis swap price under the turmoil (Exhibit 5, Panel B).

Meanwhile, the Q-statistics for autocorrelation of the VECM residuals show no significant residual autocorrelation remaining for any of the series, implying that the VECM is properly specified during the turmoil (Exhibit 5, Panel C). However, the same statistics for the squared residuals show significant autocorrelation for the basis swap price and the bivariate combination, indicative of the need to remove potential ARCH effects from the VECM residuals. Only the estimated error correction term for the FX swap deviation is significant, suggesting that since the turmoil began, the basis swap price has been less likely to adjust than the FX swap deviation when the two swap markets deviate from their long-term cointegrating relationship.

Finally, in contrast to the period before the turmoil, significant Granger causality is found from the FX swap deviation to the basis swap price, though no causality is found in the opposite direction (Exhibit 5, Panel D). This suggests that the FX swap market is the main venue for spreading the turmoil in money markets to the long-term cross-currency swap market. This is consistent with market observations that some European financial institutions turned from short-term dollar funding through FX swaps to longer-term dollar funding through the cross-currency swap market, once they realized that the financial turmoil would last longer than initially thought.

Bivariate GARCH Model Results

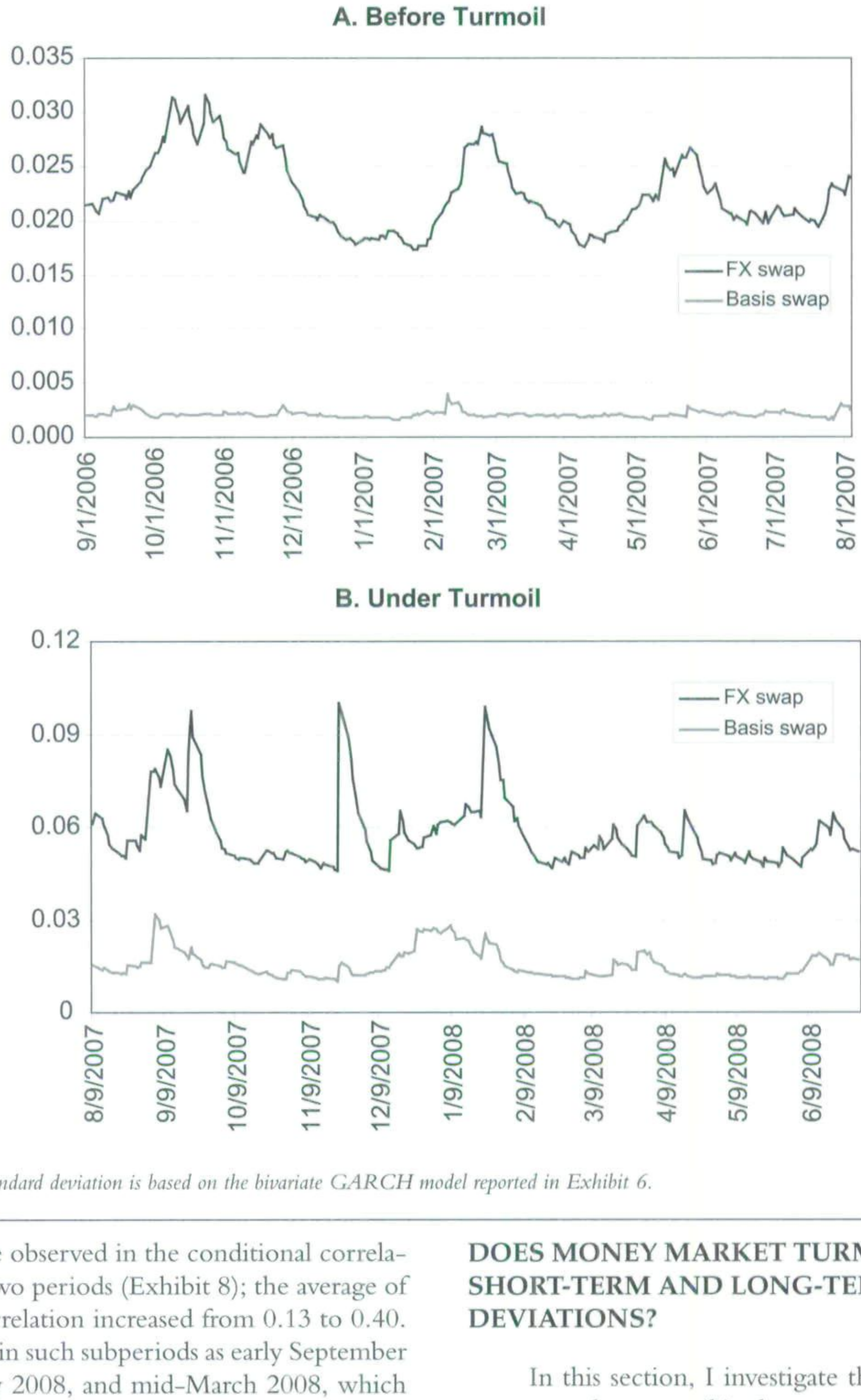
Exhibit 6 reports the estimation results for the corresponding bivariate GARCH model. The Q-statistics for squared standardized residuals show no significant autocorrelation for all variables in both periods. This result suggests that the GARCH model does an excellent job in fitting the time-varying volatilities; together with the VECM result described above, overall model specification is found to work particularly well during the period of turmoil.

Volatility tends to persistently cluster in the FX swap and basis swap markets in both periods, as indicated by the large and (mostly) significantly positive estimates of the diagonal ARCH and GARCH coefficients. As shown in Exhibit 7, the conditional standard deviation obtained from the bivariate GARCH model is much higher for both swap markets under the turmoil than the preceding period.

Volatility spillover across markets is found apparent only during the turmoil in the direction from the FX swap to the basis swap for both ARCH and GARCH effects, as shown by significant off-diagonal coefficients in the BEKK(1, 1) specifications. Many studies including French and Roll [1986] attribute the volatility of financial assets to new information flows. In this regard, this estimation result suggests that such information flows likely changed significantly after the onset of the recent turmoil, during which information was consistently transmitted from the short-term FX swap market to the longer-term cross-currency basis swap market.

Measures of conditional correlation are also consistent with a much higher dynamic linkage between these two swap markets under the turmoil. In particular, a large

E X H I B I T 7
Conditional Standard Deviation



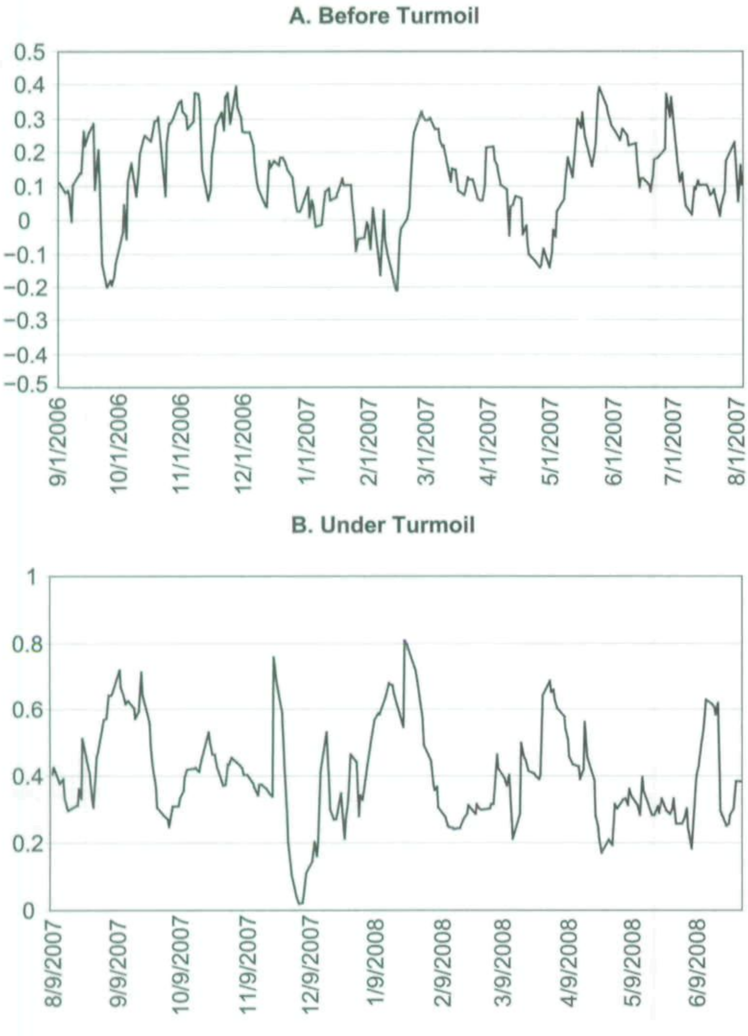
Note: The conditional standard deviation is based on the bivariate GARCH model reported in Exhibit 6.

upward shift can be observed in the conditional correlation between the two periods (Exhibit 8); the average of the conditional correlation increased from 0.13 to 0.40. Correlation spiked in such subperiods as early September 2007, early January 2008, and mid-March 2008, which coincided with periods when the FX swap deviation surged, as shown in Exhibit 1.

DOES MONEY MARKET TURMOIL CO-MOVE SHORT-TERM AND LONG-TERM CIP DEVIATIONS?

In this section, I investigate the role of the recent money market turmoil in the co-movement of the short-term and long-term CIP deviations. I use the following decomposition formula for the short-term CIP deviation

E X H I B I T 8
Conditional Correlation



Note: The conditional correlation is based on the bivariate GARCH model reported in Exhibit 6.

observed in the FX swap market proposed in Baba and Packer [2008]:

$$
\begin{aligned}
&F/S(1+Libor^{EUR})-(1+Libor^{USD}) \\
&\quad \approx [(\ln F-\ln S)-(OIS^{USD}-OIS^{EUR})] \\
&\quad + [(Libor^{EUR}-OIS^{EUR})-(Libor^{USD}-OIS^{USD})]
\end{aligned} \tag{6}
$$

where the left-hand side of Equation (6) is the short-term CIP deviation measured by euro and dollar LIBOR rates. The first term on the right-hand side of the equation is the interest rate differential between the euro and the dollar reflected in the FX forward discount rate measured as a difference from the overnight index swap (OIS) rate difference between the same currency pair.[13] The OIS rates can be regarded as a proxy for expected future overnight rates for the following two reasons. First, the counterparty risk associated with the OIS contracts is relatively small due to the lack of the exchange of principal. Second, the liquidity risk premia contained in OIS rates should be very small due to the lack of any initial cash flows. The second term corresponds to the difference in the LIBOR-OIS spreads between the euro and the dollar. Based on Equation (6), I use the following set of variables.

CDS Spread Difference between European and U.S. Financial Institutions

The first variable attempts to capture the difference in counterparty risk perceptions between European and U.S. financial institutions. The use of this variable is based on the observation that European (U.S.) financial institutions are largely on the dollar borrowing (lending) side of the FX swap market, and thus an asymmetric increase in counterparty risk for European institutions relative to U.S. ones could raise the deviations from CIP.

I use the difference in CDS spreads between two aggregate sectoral CDS spread indices capturing a broad array of financial institutions in each region. Specifically, I use the CDS spread for European financials with investment-grade ratings included in the iTraxx Europe series and the CDS spread for U.S. financials with the same ratings.

These CDS spread data are provided by JP Morgan Chase. The former is measured as of 5:00 pm London time, and the latter, as of 5:00 pm New York time.

LIBOR-OIS Spread Difference between Euro and Dollar

Under normal circumstances, OIS rates tend to move very closely to the corresponding currency LIBOR. After the onset of the financial turmoil in the summer of 2007, however, the LIBOR-OIS spreads widened substantially, particularly for the dollar and the euro.

Market observers suggested several possible drivers for these widened spreads. One is a deterioration in funding liquidity for banks (IMF [2008]).[14] This is closely related to greater concerns about banks' ability to liquidate positions in certain assets, or increased market liquidity risk. Another potential factor is a rise in counterparty risk for the LIBOR panel banks. In this study, I use the difference between euro and dollar LIBOR-OIS spreads. The OIS rates are as of 5:00 pm New York time and are from Bloomberg.

Broad-Based Deposit Rate-OIS Spread Difference between Dollar and Euro

In contrast to LIBOR, which reflects the funding costs of only its panel banks, FX swap-implied dollar rates and the cross-currency basis swap prices may well reflect the funding costs of a wider range of financial institutions. Thus, deviations from CIP may stem from the difference in composition of the financial institutions between the FX and basis swap markets and LIBOR.

To capture this effect, I use the three-month Eurodollar deposit rate released by the Federal Reserve, as well as Euribor (Euro Interbank Offered Rate). The Eurodollar rate is based on rates actually observed in the Eurodollar interbank deposit market as of around 9:30 am New York time, and it reflects a wider array of financial institutions than the LIBOR panel banks. As for the Euribor, which is fixed around 11:00 am CET, its contributing panel consists of more than 40 financial institutions, most of which are Eurozone banks. In the estimation, I use the difference between the spread of the Eurodollar over the dollar OIS rate and the spread of Euribor over the euro OIS rate.

Estimation Results

Estimation is done using as a dependent variable the first principal component derived from the FX swap deviation and the basis swap price. The first principal component can be regarded as a common factor for both CIP deviations. The ratio explained by the principal component of the total variability is 71% before the turmoil, and 87% under the turmoil.

Exhibit 9 reports the OLS results. Before the turmoil, only the LIBOR–OIS spread has a significantly expected (positive) effect on the principal component, while the CDS spread difference has a significantly wrong sign and the broad spread difference has an expected but insignificant coefficient. Under the turmoil, however, all the variables including the CDS spread difference have significant expected effects on the principal component. Further, the adjusted R-squared values increase substantially from 24% before the turmoil to 70% under the turmoil. This result suggests the following: Both short-term and long-term CIP deviations are driven not only by a larger demand for dollars and worsening liquidity conditions in dollars against euros, reflected in the broad spread difference and the LIBOR–OIS spread difference, but also by counterparty risk perception toward European financial institutions (relative to the U.S. counterparts) that are on the dollar borrowing side in the FX swap and cross-currency basis swap markets.

EXHIBIT 9
Money Market Turmoil and Co-Movement of FX Swap and Basis Swap Markets

Dependent variable: First principal component from FX swap deviation and basis swap price

	Before turmoil	Under turmoil
CDS spread difference	–3.814**	0.198*
	(0.440)	(0.098)
Broad spread difference	9.382	9.324**
	(5.810)	(0.512)
LIBOR-OIS spread difference	21.157**	13.647**
	(7.217)	(0.585)
Constant	–0.564**	–0.429**
	(0.189)	(0.146)
Adj R-squared	0.242	0.703

Note: Numbers in parentheses are standard errors.

*** and * denote the 1% and 5% significance levels, respectively.*

CONCLUDING REMARKS

This article has empirically investigated the dynamic spillover effects of the money market turmoil that began in August 2007 on the covered interest parity deviations observed in the short-term FX swap market and the long-term cross-currency basis swap market. As documented in Baba, Packer, and Nagano [2008], an important aspect of the turmoil was a shortage of dollar funding, particularly for European financial institutions. At the same time, financial institutions on the dollar-lending side, chiefly U.S. financial institutions, became cautious in lending dollar funds, largely because of increased concerns over counterparty risk. Facing these unfavorable money market conditions, European institutions turned to the FX swap market to convert euros into dollars. Then, after market participants realized that the current money market turmoil would last longer than initially thought, European financial institutions reportedly turned from short-term dollar funding through FX swaps to long-term funding through cross-currency basis swaps.

The empirical results in this article broadly support the above observations. First of all, under the turmoil, the deviations from the short-term CIP condition observed in the FX swap market and from the long-term CIP condition observed in the cross-currency basis swap market are significantly in a one-on-one cointegrating relationship, which is not found before the turmoil. Second, only during the turmoil, a significant Granger causality effect goes from the FX swap deviation to the cross-currency basis swap price, based on the VECM model incorporating the cointegrating relationship. Third, the bivariate GARCH model using the above VECM as a mean equation shows a significant volatility spillover in the direction from the FX swap deviation to the basis swap price. Fourth, there is a substantial shift-up in both time-varying conditional volatilities of and the correlation between these variables. And finally, the common factor derived from the two deviations using the principal component analysis is significantly associated with the variables that reflect the recent money market turmoil, such as the CDS spread difference between European and U.S. financial institutions, the broad-based deposit rate–OIS spread difference between dollar and euro, and the LIBOR–OIS spread difference between euro and dollar.

ENDNOTES

[1]An FX swap is a contract in which two parties borrow and lend different currencies by combining the FX spot and forward contracts in the reverse direction. The liquid maturity zone for the FX swap is less than one year. The FX swap-implied dollar rate is defined as a total cost, in terms of a dollar rate, from raising euros in the uncollateralized deposit market and converting them into dollars through the FX swap market.

[2]A cross-currency basis swap is a contract equal to or longer than one year in which two parties borrow and lend the same value of different currencies at the FX spot rate as of the contract date. In the case of exchange of euros and dollars, during the contract term, the lender/borrower of dollar/euro funds is obliged to pay Euro Interbank Offered Rate (Euribor) plus α basis points every three months in exchange for receiving dollar Libor flat, where α is the price of the cross-currency basis swap.

[3]For details of the coordinated efforts by the central bank community, see Borio and Nelson [2008].

[4]FX swaps have been used to fund foreign currencies both for financial institutions and their customers, including exporters and importers, as well as for institutional investors who wish to hedge their positions of foreign bonds against the FX risk. FX swaps are also frequently used as a tool for speculative trading, typically by combining two positions with different maturities.

[5]According to Taylor [1989], significant deviations were observed on such occasions as the flotation of sterling in 1972 and inception of the European Monetary System in 1979.

[6]Akram, Rime, and Sarno [2008] investigate deviations from the CIP condition using tick data that covers seven months in 2004 and find some economically significant deviations from the CIP condition, albeit short-lived.

[7]The main purpose of the use of cross-currency basis swaps for non-financial corporations is to fund their foreign direct investment in foreign currencies. Cross-currency basis swaps have been also used as a tool for converting currencies of liabilities, particularly by issuers of bonds denominated in foreign currencies. These swaps can allow issuers desiring liabilities of a certain currency to access the investor base available in another. Mirroring the tenor of the transactions they are meant to fund, most cross-currency basis swaps are long-term, generally ranging between 1 and 30 years in maturity.

[8]They actually use the prices of cross-currency swaps in which fixed interest rates are exchanged or a fixed non-dollar interest rate is exchanged for a floating dollar rate during the contract term. In contrast, cross-currency basis swaps exchange dollar and non-dollar floating rates. Since the early 1990s, however, the cross-currency basis swap has become the most liquid instrument of all kinds of cross-currency swaps.

[9]See Engel and Granger [1987] for details.

[10]This two-step approach is asymptotically equivalent to a joint estimation of the VECM and bivariate GARCH model, as shown in Tse [1999].

[11]BEKK is the acronym for Baba, Engle, Kraft, and Kroner [1990].

[12]Euribor is also adjusted into a 360-days basis from an original 365-days basis to maintain consistency with other data.

[13]The OIS is an interest rate swap in which the floating leg is linked to an index of daily overnight rates. The two parties agree to exchange at maturity the difference between interest accrued at the agreed fixed rate and interest accrued through the geometric average of the floating index rate.

[14]Dudley [2008] ascribes a surge in LIBOR–OIS spreads to the re-intermediation of assets onto bank balance sheets and a deleveraging process.

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