An arbitrage-based risk diagnostic of the cross-currency basis swap

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Abstract The cross-currency basis measures the yield differential between the single currency and cross-currency swap markets. The construction of discount curves for the purposes of pricing and risk-managing cross-currency cash flows necessarily incorporates this basis, resulting in a sensitivity to fluctuations in its value. The basis has proved prone to significant volatility twice in the last ten years. More recently, the credit crisis provoked a wave of fixed-income hedge fund de-leveraging which drove the basis to unprecedented levels. This paper derives a quasi-arbitrage pricing diagnostic with respect to the basis. This diagnostic is used to explain some of the empirical drivers of the US dollar–yen spread.

Keywords: *currency basis swap, collateralised loan, Libor, credit-worthiness, convexity*

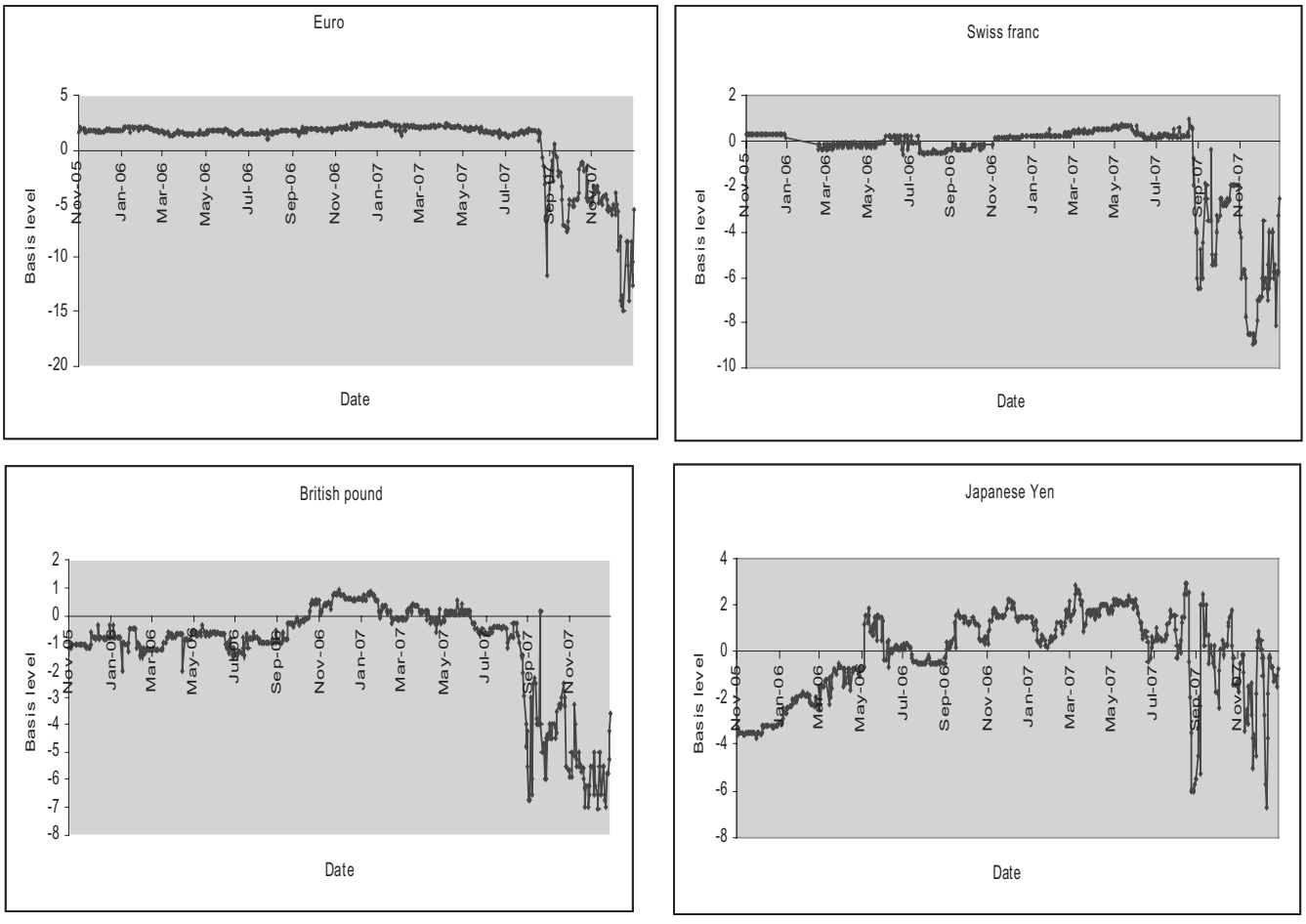
INTRODUCTION

One of the significant risk management consequences of the 2007–08 credit crunch has been the introduction of a volatile divergence between structurally-related market variables. Many such divergences (or 'basis risks') are relatively easily accounted for against the backdrop of current inter-bank credit risk containment; for example, the negative basis for cash/credit default swaps is a consequence of the premium value associated with banks' balance-sheet availability given conduit asset consolidation risk, while the widening of the Fed fund-Libor and treasury-swap yield have both resulted from perceived weakening in the creditworthiness of the Libor inter-bank market. However, the recently observed volatility in the cross-currency basis swap market is a less direct corollary of the credit crisis. This paper presents a framework for explaining the cross-currency basis in terms of its underlying risk dependencies. In so doing, it establishes a framework for quasi-arbitrage pricing and the hedging of exposures.

The cross-currency basis is a measure of the yield differential between the

single currency swap market and its associated cross-currency swap market. This is generally a feature of emerging economies, where capital controls are traditionally used to manage the cross-border volatility of both dollar and local currency capital flows, thereby influencing the value of the basis. However, the 2007–08 credit crunch continues to induce significant volatility also into the freely convertible euro and sterling currency forward markets of this, seemingly, otherwise benign basis risk (see Figure 1).

The existence of legislative controls on capital movement and currency convertibility frequently compromise the premises of cross-currency quasi-arbitrage pricing. However, the presence and persistence of a non-zero cross-currency basis spread in freely convertible, mature derivatives capital markets presents *prima facie* 'arbitrage' opportunities. Theoretically, these could be built through the engineering of a relative value pay–receive position in the respective swap and currency swap markets. This is explained in detail below. One can intuitively see that when the single currency fixed rate is



All spreads are quoted with respect to flat dollar Libor: a negative spread indicates the market's penchant for dollar funding as this is procured at the expense of receiving a funding cut on the non-dollar leg of the basis swap. Note the relatively low level of volatility preceding the 2007 credit crunch followed by systematic volatile negative widening of the basis as the CDO subprime crisis evolved into a wholesale money-market credit crisis.

Figure 1: History of movements in one-year cross-currency basis spreads relative to the US dollar

higher than its corresponding cross-currency swap rate (that is, matched tenor, matched funding, with identical day-count and roll-conventions) then receiving the fixed rate in the single currency market against simultaneously paying the (lower) fixed rate in the cross-currency swap market results in a relative yield pick-up with an interest-rate hedged position. In fact a highly-common, carry-oriented strategy deployed by interest rate traders is precisely to position against the widening of the cross-currency basis spread by paying the (negative) spread.

The basis swap market convention is to quote the spread relative to US dollar Libor flat. In the case presented in Table 1, the single currency swap market is quoted as 4.593 per cent versus 4.613 per cent, meaning a market-maker will pay 4.593 per cent fixed and receive 4.613 per cent fixed, in both cases against a six-month Euribor fixing. The cross-currency swap rate is quoted with reference to paying (receiving) a fixed Euro rate against receiving (paying) US dollar Libor. The cross-currency basis, ie the difference between the two markets, is effectively a floating-floating swap where counterparties exchange Euribor floating rates for US dollar Libor on a periodic basis with upfront and final maturity exchanges of euro–dollar notional principals. With the exception of US dollar–yen, the spread (difference) between the two swap markets has historically oscillated around zero with low volatility.

In reality, the aforementioned basis position is not risk-hedged and the volatility of the relative values of swap and currency swap markets is a reflection of the market price of economic premium associated with this residual risk. Systematic imbalances in the supply-and-demand dynamics of the two swap markets' liquidities contribute to and, at times, exacerbate, distortions in the relative value of the two swap markets. Notwithstanding this, it is ultimately the existence of this residual risk premium which prevents the unfettered forces of international arbitrage activity compressing a persistently wide cross-currency basis back to zero.

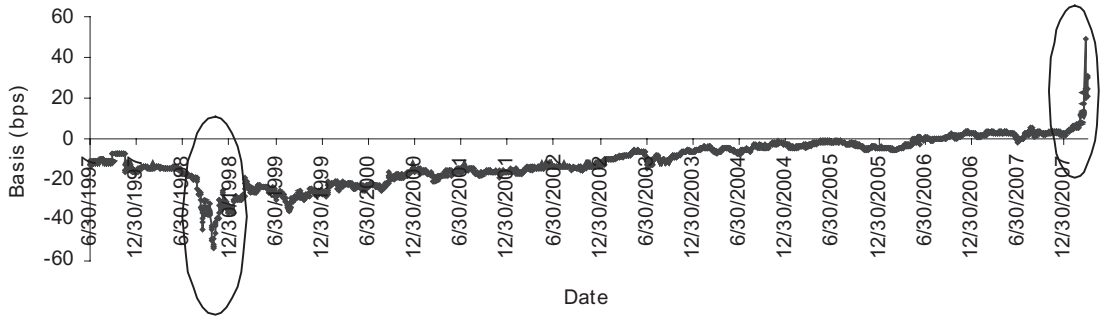
The following presents a cash-flow diagnostic of the residual risk premium in the cross-currency basis product.

CONSTRUCTION OF THE CROSS-CURRENCY BASIS 'ARBITRAGE'

Without loss of generality, the following discussion is restricted to a float-float basis swap, as such a swap can trivially be constructed by taking offsetting pay–receive positions in the fixed-rate swap and cross-currency swap markets. To distil the discussion to the perceived arbitrage anomalies of the basis swap market relative to the inter-bank loan market, the example is restricted to freely convertible capital markets with no legal or regulatory impediment on

Table 1: Market quotation convention (closing rates 4th January, 2008)

	Bid (pay)	Offer (receive)
One-year euro swap (30/360 vs six-month Euribor)	4.593%	4.613%
One-year cross-currency swap	4.528%	4.568%
Implied cross-currency basis	–6.4 bps	–4.5 bps



Note the two bouts of extreme volatility in October 1998 (Long Term Capital Management de-leverage event) and March 2008 (fixed-income hedge fund de-leverage).

Figure 2: Historical levels of the ten-year dollar–yen currency basis

the exchange of flows of the currency markets.

Counterparty A, observing that the dollar–yen cross-currency swap market is negative (recall the basis swap is quoted relative to US dollar Libor flat: a negative basis therefore indicates that it pays Japanese yen Libor less the market-quoted spread), executes a basis swap with Counterparty B by receiving US dollar Libor against paying Japanese yen Libor less the market-quoted spread.

Consider the cash flows of this transaction: on day one, Counterparty A delivers a US dollar notional principal to Counterparty B in return for which Counterparty B delivers an equivalent Japanese yen notional principal to Counterparty A. Subsequently, coupon flows are a function of these notional principal exchanges: Counterparty A has essentially lent US dollars to Counterparty B and thus receives US dollar Libor in interest receipts. Similarly, Counterparty B has lent Japanese yen to Counterparty A and receives Japanese yen Libor (less the currency basis spread). At the maturity of the swap, the notional principals are re-exchanged.

Now consider Counterparty A's motivational attempts to arbitrage the cross-currency basis swap market. Assume Counterparty A is a major international bank and that it funds at US dollar Libor flat. It thus borrows the US dollar notional principal required for the cross-currency swap's day one exchange from the inter-bank money market at US Libor and rolls the borrowing on exactly the same roll schedule as the cross-currency swap. At this stage Counterparty A has neutralised all US dollar cash flows from the cross-currency swap with the money-market funding operation: it borrows from the money market and lends this borrowing to Counterparty B through the currency swap. The interest receipts that Counterparty B pays Counterparty A precisely pay off Counterparty A's funding liabilities. This leaves the Japanese yen cash flows.

Counterparty A receives Japanese yen notional from the cross-currency swap. To meet the interest rate payment schedule required under the basis swap, it places the Japanese yen notional into the Japanese yen money market, which, by definition, secures Japanese yen Libor funding. Counterparty A is thus left receiving Japanese yen Libor on an ongoing basis from its rolling of the money-market placing and paying

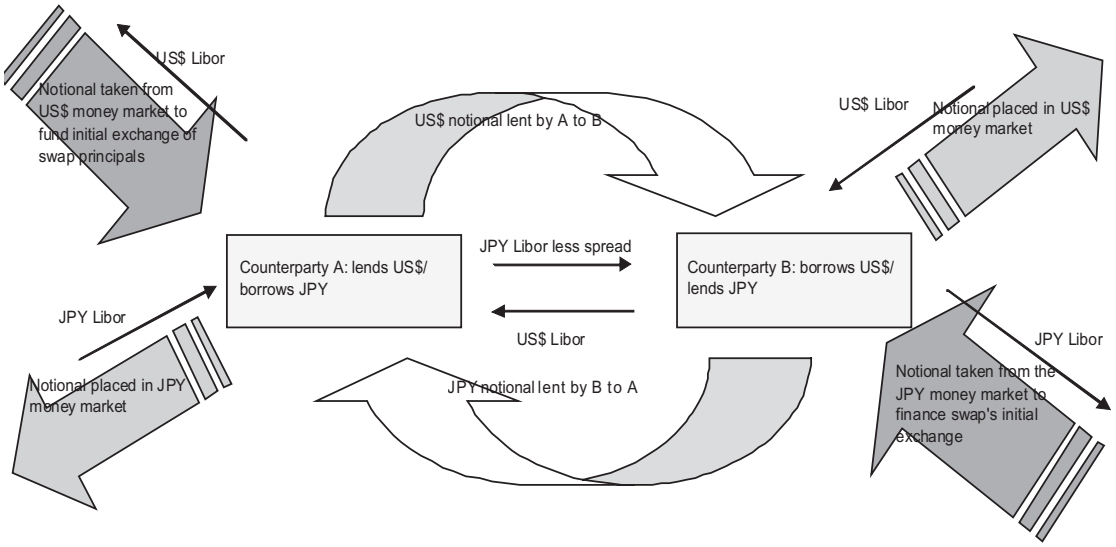
Japanese yen Libor less the cross-currency basis spread. At this stage, Counterparty A is left with a seeming arbitrage: it accrues the fixed cross-currency basis spread while being, in all other respects, cash-flow neutral. This is illustrated in Figure 3.

By symmetry, Counterparty B may execute the offsetting processes to Counterparty A: that is, borrowing in the Japanese yen money market to secure financing for the day one delivery of Japanese yen notional to Counterparty A, while placing the US dollar notional into the US dollar money market to secure US dollar Libor financing for the cross-currency swap's US dollar coupon cash flows.

Failure of the 'arbitrage'

In the above, Counterparty A is left accruing the (negative) cross-currency basis at Counterparty B's expense. Excluding Counterparty A's apparent 'free money' from the cross-currency basis swap spread, the structure is cash-flow neutral and therefore insensitive to interest-rate risks. This construct is thus an apparent violation of the fundamental principles of arbitrage central to derivatives pricing theory: carry is earned on a risk-free strategy.

In reality, while the above construct is insulated from the interest-rate market risks associated with the cash flows, it is not immune to a credit event in the money markets in which the currency basis swap's notional principals are placed. Herein lies the kernel of the residual risk: should Counterparty A experience a default by one or more of the constituents of the Libor consortium in which its Japanese yen notional is dispersed then it will face a financial loss equal to the lost principal (and, of second order, the lost accrual of interest of that piece of the lost principal) which it ultimately needs to pay back to Counterparty B at maturity of the currency basis swap. By symmetry, one



Counterparty A lends dollars to Counterparty B in the swap, funding these dollars at Libor from the dollar money market. Similarly, Counterparty B lends Japanese yen to Counterparty A. The Japanese yen received by Counterparty A is placed in the Japanese yen money market and earns Libor which is used to finance the swap's yen coupon. As Counterparty A pays Japanese yen Libor less the basis spread on the swap, it is left with an annuity equal to the currency basis spread for no interest-rate risk.

Figure 3: Schematic representation of the apparent 'arbitrage' between the cross-currency swap market and the respective money markets

should also note that Counterparty B faces the same form of unsecured credit risk on the notional principal it placed into the dollar market. The spread intrinsic to the basis swap thus represents the market premium of the relative default riskiness of these two money-market transactions.

In other words, the cross-currency basis swap may be viewed as a Japanese yen loan from Counterparty B to Counterparty A, collateralised by US dollar principal. Counterparty B is assuming less economic risk (as a consequence of this collateral) relative to the economic risk associated with an unsecured money market loan. By definition, the market price of an unsecured inter-bank loan is Libor (which comprises the risk-free cost of money plus the generic counterparty credit risk of default of the Libor money market). Counterparty B thus accrues less than Libor in the basis swap's collateralised form of a loan by virtue of its assuming less economic risk.

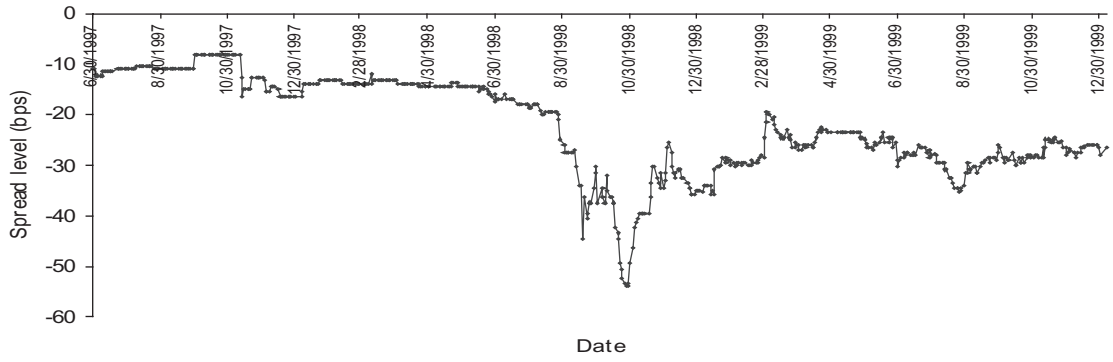
By reciprocity, Counterparty A similarly assumes less economic risk than that of an unsecured Libor loan for its (Japanese yen principal) collateralised US dollar loan to Counterparty B, although paradoxically it accrues yield. This is because it is a net bearer of economic risk relative to Counterparty B. Concurrently, the net beneficiary of the reciprocated collateral is Counterparty B, thus implying that Counterparty B is assuming less risk than Counterparty A. The basis swap spread paid by Counterparty B is thus a measure of the relative creditworthiness of the US dollar and Japanese yen money markets with respect to Japanese yen and US dollar notional collateral respectively.

With this analysis in mind, one can immediately infer the economic meaning of a negative basis spread: when the lender of dollars through the basis swap is a net beneficiary of the spread (that is, it pays less than Libor funding on the non-dollar borrowing received in exchange for the dollars) then, all else being equal, this implies the market is pricing a higher likelihood of default risk in the non-dollar Libor market relative to the dollar Libor market. The persistence of a negative Japanese yen currency basis through the latter half of the 1990s was, in part, a consequence of the perceived weakness of the Japanese yen money market, given Japan's non-performing loan problem. Figure 4 provides historical trends in the ten-year dollar–yen currency basis.

Refining the construction of the cross-currency basis 'arbitrage'

Having concluded that the cross-currency basis swap's spread reflects the relative creditworthiness of the two Libor markets associated with the swap, the specious 'arbitrage' construct established above may be enhanced as follows. First, recall that the risk assumed by Counterparty A in return for being paid the basis swap spread is that of credit default in the money market in which it places the basis swap's day one received notional principal. Counterparty A may circumvent any single-name exposure by syndicating out proportionate lending of this notional principal across the Japanese yen Libor consortium, thereby ensuring it (more or less) locks in the average inter-bank offer rate.

To hedge the residual credit default exposure to the bank consortium, it needs to buy a basket of credit default



The Japanese banks' non-performing loan problem following the collapse of the real-estate market undermined the creditworthiness of the Japanese yen money market relative to the US dollar money market, contributing to a persistently negative cross-currency basis from the latter half of the 1990s — the so-called 'Japanese premium'.

Figure 4: Historical trends in the ten-year dollar–yen currency basis, 1996–2000

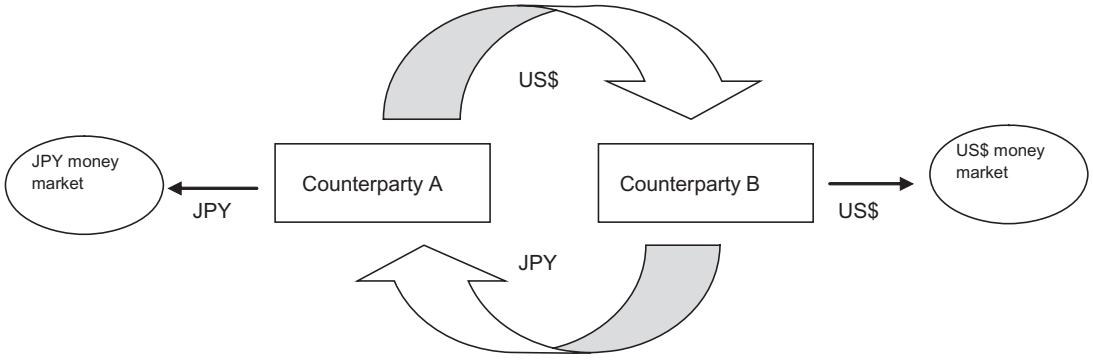
swaps on that consortium proportional to the syndication of its loan. Similarly, Counterparty B hedges its inter-bank Libor risk by purchasing a basket of default swaps on the US dollar Libor consortium. In both cases, the running cost of the credit default swap protection is passed through to each of the basis swap's counterparties, resulting in a net running annuity. A genuine arbitrage only exists to the extent that this net cost of credit basket default swap protection differs from the basis swap's fixed spread. The cross-currency basis spread can thus equivalently be considered as the spread differential between the cost of credit insurance of the two Libor money markets.

FURTHER CONSIDERATIONS: CORRELATION BETWEEN DEFAULT AND SWAP VALUE

The above analysis has shown how a cross-currency basis swap may be interpreted as a pair of bilateral collateralised loans: Counterparty A lends dollars and receives Japanese yen collateral while Counterparty B simultaneously lends Japanese yen and receives US dollar collateral. This shows how the basis swap spread may be considered as a measure of the relative cost of credit hedging in the swap's associated money markets.

As global money markets have consolidated and become increasingly international it is not uncommon now for the same financial institutions to contribute to the Libor inter-bank markets, leading to a broad convergence in creditworthiness across these markets. Notwithstanding this credit convergence, the currency basis swap markets have proved to be increasingly volatile through the credit crunch. At this stage of the discourse, no consideration has been given to the correlation between foreign exchange-rate movements (basis swap mark-to-market value) and counterparty/money-market default risk. The perceived correlation (and resultant convexity advantage) between foreign exchange rate movements and a money-market credit event explains the existence of a non-zero cross-currency basis, even when the creditworthiness of the respective money markets is equal.

In reference to Figure 5, suppose a default in the US money market transmits to Counterparty B being unable to repay the basis swap's US



The loan is financed by the placing of the basis swap's notional principals in the respective money markets. Convexity exists to the extent that a money-market default — which transmits to a swap counterparty default — is correlated with foreign exchange movement. For Counterparty A, a default in the US dollar money market leading to a default by Counterparty B is mitigated by the swap moving out-of-the-money for Counterparty A when this default correlates with strengthening of the Japanese yen. Similarly, B's convexity arises when a Japanese yen money-market event triggering a default by Counterparty A is coupled with strengthening of the US dollar. When the Japanese yen strengthens irrespective of which money market defaults then B is at a systematic disadvantage to A.

Figure 5: Schematic representation of the basis swap as a collateralised loan

dollar notional back to Counterparty A. If, at the same time, the Japanese yen strengthens, then from A's standpoint the basis swap's mark-to-market value is reduced. This correlated effect mitigates the loss to Counterparty A given a default by Counterparty B: this is termed 'positive default conditional convexity' to Counterparty A. Conversely, if the Japanese yen weakens on the credit event, then Counterparty A incurs an additional loss due to the appreciation of the basis swap value as B defaults: this is termed 'negative default conditional convexity'.

Given the symmetrical nature of the basis swap there are two complementary components to this convexity:

- Positive convexity for Counterparty A: US dollar Libor default Japanese yen collateral appreciates relative to the US dollar;
- Positive convexity for Counterparty B: Japanese yen Libor default US dollar collateral appreciates relative to the Japanese yen.

This has a net impact on the value of the cross-currency basis swap to the extent that the expected value of the two complementary convexities are non-symmetrical. For example, when there exists an expectation that the dollar–yen would decline less under the US dollar Libor default relative to the expected appreciation in dollar–yen, contingent on a Japanese yen Libor default, then this would negatively impact the cross-currency basis spread. This is a consequence of a net bearer of economic risk (in this case Counterparty A) requiring a premium to compensate for the expected loss arising from being at a convexity disadvantage (in this example, the lender of dollars/receiver of Japanese yen cash collateral owns less positive convexity than Counterparty B and is thus compensated by paying less funding on its Japanese yen collateral).

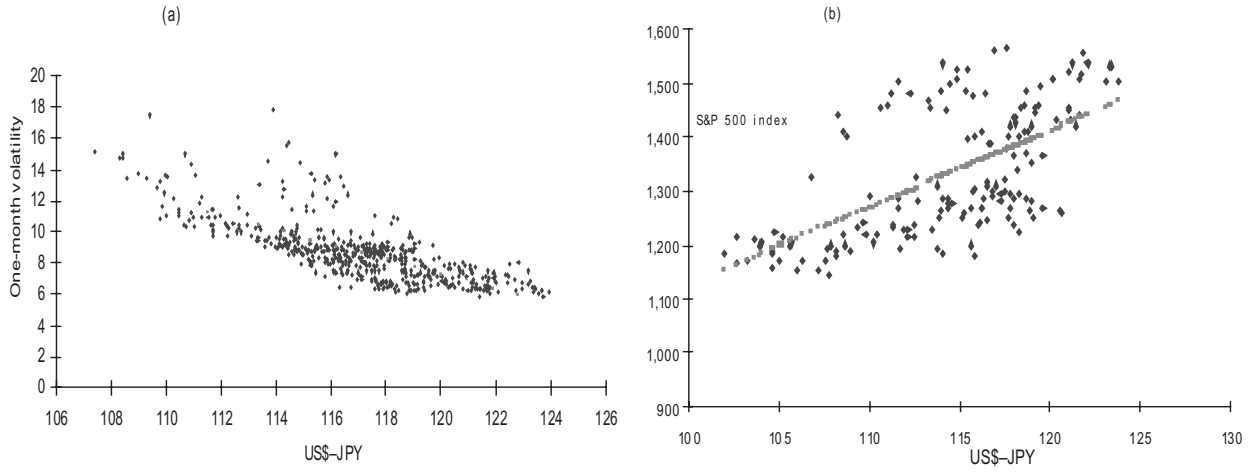
The persistence of ultra-low yields in the Japanese yen market has resulted in the yen becoming the global 'carry trade' funding currency for higher-yielding investments. As such, dollar–yen has become a barometer for risk aversion across capital markets: when macro volatility increases, dollar–yen has

tended to decline on expectations that the 'carry trade' will, in the face of increases in generic risk premium, be unwound (see Figure 6).

This perceived correlation between a weaker US dollar–yen and a systemic risk event (such as a default in the Libor money markets) impacts the dollar–yen currency basis by introducing an asymmetry in the value of the aforementioned convexities. In the limiting case, when the market prices Japanese yen appreciation irrespective of which Libor market defaults, then Counterparty B's convexity has negative value. Such a correlation positively influences the basis because it attributes a higher value to Counterparty A's convexity relative to Counterparty B's (Counterparty A is a beneficiary of this correlation and compensates Counterparty B through paying a less negative basis swap spread). This feature has contributed to the trend of less negative to, in fact, a positive US dollar–yen cross-currency basis in recent years (see Figure 7).

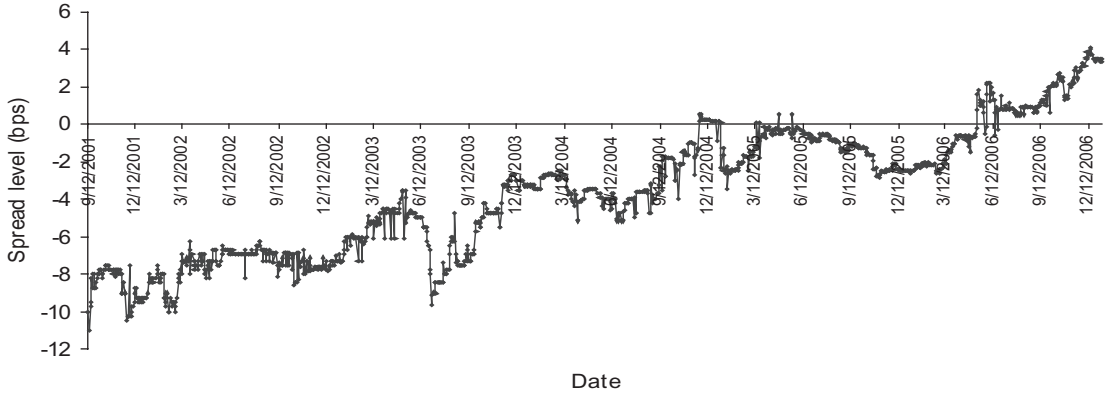
This convexity issue explains how a cross-currency basis spread may be priced at persistently non-zero levels although the respective creditworthiness of the associated money markets is balanced. Even when there is a perceived higher risk in the credit quality of the Japanese yen Libor market relative to the US dollar market, the positive correlation between Japanese yen appreciation and a systemic risk event may induce sufficient value into the convexity advantage in holding Japanese yen cash collateral over dollar collateral to result in a positive cross-currency basis.

In a situation where precisely the same participants contribute to the swap's two associated Libor markets, then a non-zero currency basis spread can be interpreted as the market pricing a systematic correlation in foreign exchange movement and the credit event. For example, where the US dollar and Japanese yen Libor markets comprise the same institutions, then a positive currency basis is a reflection of the market expectation that the Japanese



(a) The negative slope implies a bias to a stronger Japanese yen when future volatility expectations increase: correlation 75 per cent. (b) The positive slope indicates a correlation between declining equity prices and US dollar–yen correlation of 62 per cent.

Figure 6: Correlation between systemic risk event and US dollar–yen — (a) Historical regression of dollar–yen and one-month implied volatility (2005 to present); (b) S&P 500 index and dollar–yen (2004



Note the positive trend: as the Japanese non-performing loan problems were gradually addressed, the net creditworthiness of the Libor money markets narrowed, thus tightening the basis. More interestingly, observe the movement above parity in the basis spread since mid-2006. One factor contributing to this positive basis is the increased correlation between yen strength and a systemic risk event which increases the convexity value of Japanese yen collateral over dollar collateral contingent on a systemic event.

Figure 7: Historical trend of the five-year US dollar–yen cross-currency basis spread, 2001–2007

yen will appreciate relative to the dollar on a Libor credit event (the Libor credit events in each money market being one and the same, given that the participants are identical).

IMPLICATIONS FOR RISK MANAGEMENT

The above has shown that the cross-currency basis spread is a function of two risk components:

- the relative creditworthiness (or likelihood of default) of the basis swap's corresponding Libor money markets;
- the correlation between foreign exchange movements and the likelihood of a Libor/counterparty credit event.

In general, the basis will vary as the market's expectations of these two components change. When there is symmetry in the expectation of foreign exchange movements given a Libor credit event (the US dollar is expected to strengthen on a Japanese yen Libor credit event by an amount equal to the expected strengthening in Japanese yen on a US dollar Libor credit event) or when there is expected to be zero correlation between foreign exchange movements conditional on a Libor credit event, then the currency basis spread is exclusively dependent on the relative credit strengths of the two Libor markets.

When the credit quality of the two Libor markets is balanced then the cross-currency basis spread is solely determined by the expected conditional correlation of Libor default and foreign exchange movements. When the dollar is expected to weaken on a credit event in either Libor market then the net bearer of risk is the lender of non-dollars in the basis swap as its dollar collateral is expected to devalue on a credit event. In such a case, the cross-currency basis will be positive (assuming the two Libor markets are equal in creditworthiness).

In order to arbitrage a non-zero currency basis swap with the Libor money markets, the respective placings of the swap's notional principals need to be credit-hedged. In an arbitrage-free efficient market, the basis swap spread is therefore equal to the net cost of simultaneously buying and selling a pair

of baskets of credit default swaps on the basis swap's associated Libor market constituents. Differences in the net value of these baskets' default swaps relative to the cross-currency basis yield potential arbitrage opportunities. Conversely, an effective hedge for a currency basis exposure is to simultaneously buy and sell baskets of credit protection on the respective Libor money markets.