Deviations from Covered Interest Parity During the Credit Crisis

Spencer Jones[1]

The Leonard N. Stern School of Business
Glucksman Institute for Research in Securities Markets
Faculty Advisor: Richard Levich
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I. INTRODUCTION

Covered Interest Parity is ubiquitous as an equilibrium condition in the foreign exchange market and one of the fundamental examples of market efficiency in international capital markets. Historical testing of the relationship frequently supports the notion, with consideration given to transactions costs, that arbitrage opportunities across G10 currencies are rarely encountered and exist only for very brief periods. The credit crisis beginning in 2007 has caused significant disruption to money markets, and has resulted in significant volatility within foreign exchange markets. Recent research papers have suggested that turbulence within the money markets is prone to spill over into the foreign exchange markets, resulting in anomalies within the foreign exchange swap market. This paper revisits the classic analysis of Covered Interest Parity across four G10 currency pairs for various forward maturities, to document and better understand how deviations from parity have evolved and reacted to events throughout the ongoing currency crisis.

II. COVERED INTEREST PARITY THEORY AND ARBITRAGE

Covered Interest Parity (CIP) is the theory that positive returns cannot be earned by borrowing the home or base currency to invest the commensurate amount in a foreign currency on a covered basis. Most commonly this parity condition is expressed as;

$$(1+r_b) = (1+r_t)\frac{F}{S} \tag{1}$$

where r_b is the interest rate in the base currency and r_t a foreign currency interest rate, S is the spot nominal exchange rate, and F is the forward exchange rate for a maturity (t) equal to that of

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the borrowing / investment.[2] In general, S could represent a forward rate for a future date (t_0) with the two interest rates spanning the period t_0 through t.

To measure CIP deviations more precisely, we must also take into account transaction costs, in their most obvious form being captured by the bid-ask spread on quotes.

$$(1+r_b^A) \approx (1+\widehat{r}_b) = (1+r_t^B)\frac{F^B}{S^A} \tag{2}$$

Here the superscript A denotes the ask price on the rate, and superscript B the bid price. $\widehat{r}_b$ is the synthetic USD borrowing rate, constructed from the three elements on the right equation for Covered Interest Parity to hold perfectly. In normal markets, r_b^A and $\widehat{r}_b$ will be approximately equal, within a narrow range given by transaction costs.

For clarity of the calculations undertaken, day count conventions on interest rates[3] need to be observed.

$$(1+(r_b^A \times \frac{days_b}{daycount_b}) \approx (1+(\widehat{r}_b \times \frac{days_b}{daycount_b}) = (1+(r_t^B \times \frac{days_t}{daycount_t}) \times \frac{F^B}{S^A} \tag{3}$$

To accurately measure any deviations from covered interest parity and any "basis" created from arbitrage opportunities, quoted forward, spot and non-US currency interest rate were used to create an implied USD interest rate that would result in no deviation.

Where:

$$\widehat{r}_b = ((1+(r_t^B \times \frac{days_t}{daycount_t}) \times \frac{F^B}{S^A}) - 1) \times (\frac{daycount_b}{days_b}) \tag{4}$$

$$basis = r_b^A - \widehat{r}_b \tag{5}$$

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[2] It should be noted at this point that in analyzing USD relationships, market convention dictates that USD is not always the base currency in the pairs used. GBP and EUR are the base currency in their relationship with USD, with the quote being in dollars per single British Pound or Euro. For JPY and CAD, USD is the base currency. The formulas shown are for illustration, and adapted in the study.

[3] US and Canadian convention is Actual/360; UK and Japanese convention is Actual/365; Euro convention is 30/360

In simple terms, any difference between the observed US interest rate and the rate implied through the forward calculation would result in extra-ordinary returns, or an arbitrage opportunity. If the basis is negative, the arbitrage should be made by borrowing in the base currency and investing in the foreign currency. If positive, borrowing in the foreign currency and investing in the base currency yields the return.

The methodology employed in this paper tests for $\widehat{r}_b$ in two methods; based on non-USD LIBOR rates (in maturities of 3, 6 and 12 months) and a second implied by IMM interest rate futures contracts.

III. DATA DESCRIPTION

Data for the analysis were provided by Bloomberg. Though previous studies have highlighted the significance of contemporaneous data (Taylor, 1989), it is often difficult to locate data on interest rates, spot foreign exchange rates and forward points at many time horizons that are time synchronous. We used Bloomberg Composite Data for all key variables, making allowances for possible time discrepancies among the various series.[4]

Forward exchange rates for maturities 3, 6, and 12 months were quoted in points, as per market convention. These are quoted in "pips" to be added / subtracted from the spot rate. These are adjusted to 1/10000 for all currencies except for JPY, where the adjustment is 1/100.

Bloomberg began recording forward points in the interbank market to coincide with Chicago Mercantile Exchange International Money Market (IMM) dates in November 2003, creating a complete data set for all variables required from January 2004 onward. The decision to explore arbitrage opportunities using IMM interest rate futures, in addition to traditional

[4] Allowances for the timing discrepancy between the New York composite (4.30pm EST) and the 11.00 GMT LIBOR setting are made in the measurement of CIP holding prior to the crisis. The consistency of the data through the time period is considered more valuable and illustrative, as per Baba, Packer, and Nagano (2008).

money market interest rates, was encouraged by evidence of significant stress in the U.S. domestic money markets (Taylor & Williams, 2009) during the crisis period. It has been generally noted that throughout the crisis period with upward pressure and increased spreads in the cash market that Eurodollar futures have experienced less volatility and been a more reliable indication of market interest rates. Liquidity has remained strong in Eurodollar futures through the shorter dated contracts required in this analysis, whereas the validity of 12-month LIBOR quotes in the later time period is subject to question.

IV. PRELIMINARY DATA ANALYSIS

Before analyzing the CIP results, it will be valuable to inspect the general behavior of spot and foreign rates over the sample period. Earlier studies have observed that departures from CIP increase during turbulent periods in the foreign exchange market (Frenkel & Levich, 1977; Taylor 1989). In those studies, the authors focused their attention on periods where the foreign exchange régime was under transformation. While the primary stress facing CIP in the present case was derived from the money markets, a review of the volatility of the 90-day forward relative to the spot rate may be instructive.

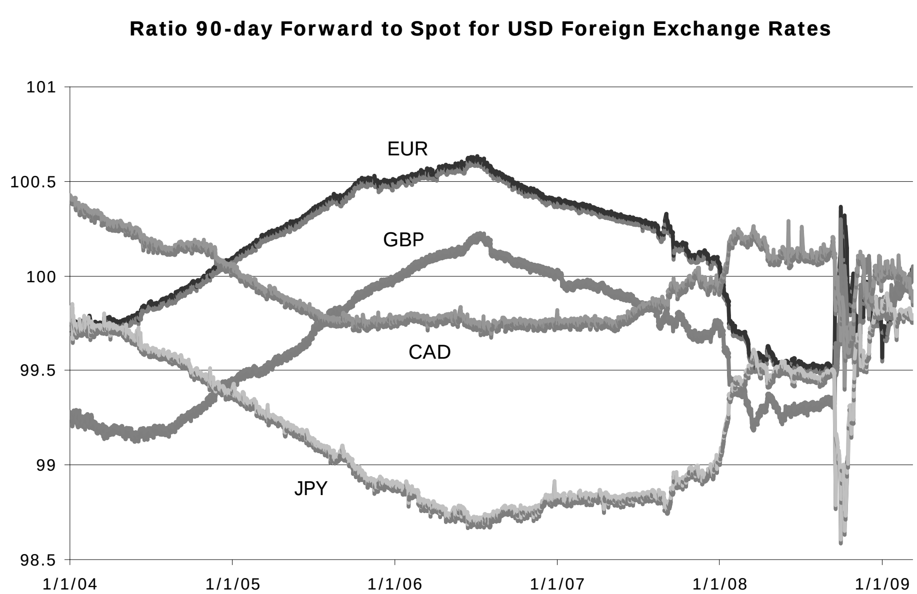

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Chart 1 (above) shows that the 90-day forward premium was significantly less volatile in the years prior to the first signs of the credit crisis in the summer 2007. Given that all of the currencies in the study have operated under a floating exchange rate regime since 1973, the relative absence of intervention and well functioning markets explains the gentle trends observed prior to the crisis. However, it is clear that the time series contains a major event beginning in September 2008, subsequent to which the forward premiums become highly volatile. This coincides with the collapse of Lehman Brothers and AIG. The data clearly exhibit periods that can be considered Tranquil (2004-August 2008) and Turbulent (September 2008 – date).

IV. COUNTERPARTY RISK AND DEVIATIONS FROM CIP

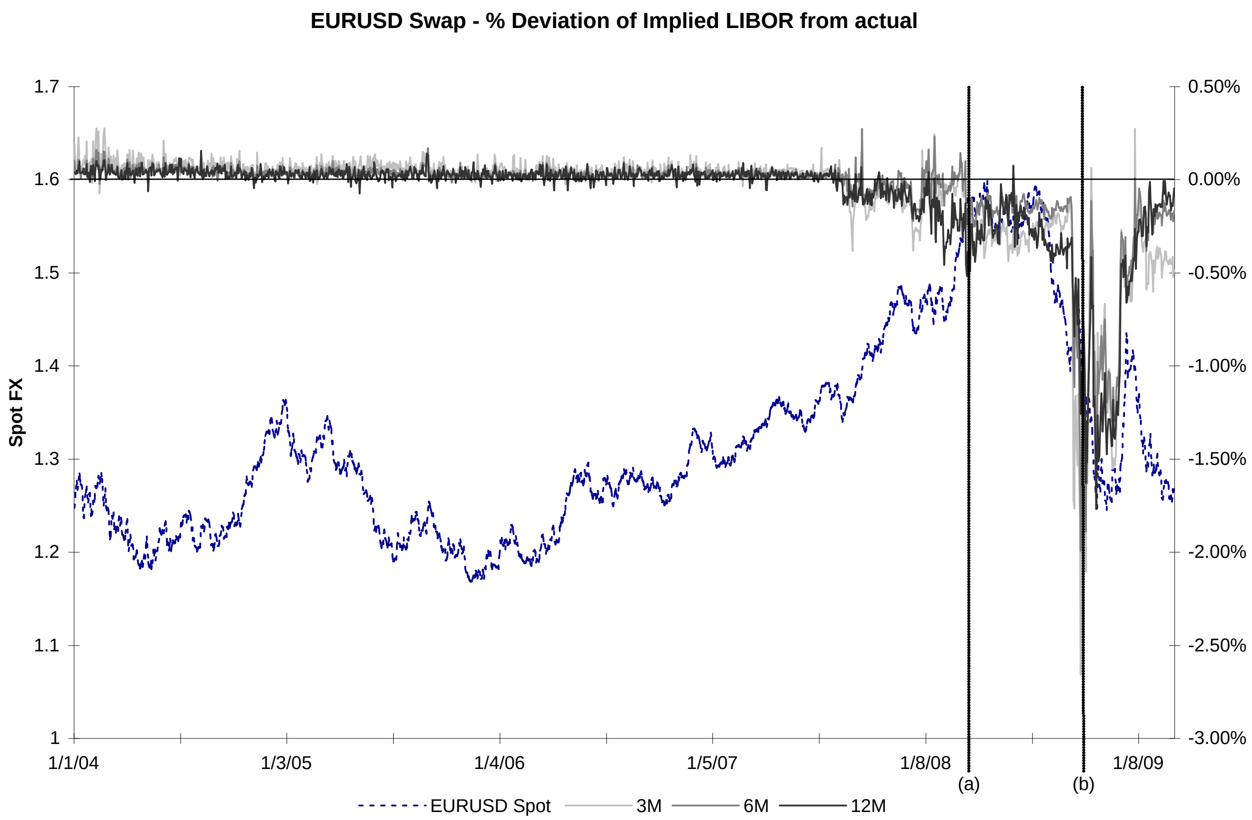
Recent studies on CIP have analyzed fairly short data samples on periods ending in 2007 (Baba, Packer, Nagano, 2008) or tested the CIP relationship using only LIBOR interest rates (Genberg, Hui, Wong, Chung, 2009). Both studies conclude that the deviations from CIP are primarily the result of counterparty risk in money market transactions, creating a perceived opportunity for extended periods of CIP arbitrage opportunities.

To examine these findings more closely, we test Covered Interest Parity using two different interest rate pairs:. Using spot rates, CIP was tested using market LIBOR rates and also using forward starting transactions using interest rate futures on Eurodollars and equivalent. Given that interest rate futures are settled through a highly capitalized clearing house, it follows that there should be a reduced level of counterparty risk in this approach at the expense of increased transaction costs. A test using an interpolated rate derived from short term cash and

LIBOR rates and longer futures was also performed, with results consistent with the above tests and very similar to the LIBOR results. More detail on this method can be found in Appendix A.

Five major currency pairs were tested using these approaches. Those currencies include the three most actively traded currency pairs (EURUSD, GBPUSD, and USDJPY), the North American G10 pair USDCAD, and also the cross between EURGBP. Testing CIP on a highly liquid, non-dollar based G10 pairing allows us to observe if deviations are more likely currency or counterparty derived. First, we will review the 2004-2009 relationship for the most liquid currency pair, EURUSD, shown in Chart 2 (below).

Relationships in all currency pairs displayed strong evidence in support of CIP over the period from 2004 until around August 2007, as can be seen in Chart 2. Deviations are consistently within the ±6bp range that can be attributed to brokerage fees (Clinton, 1988).

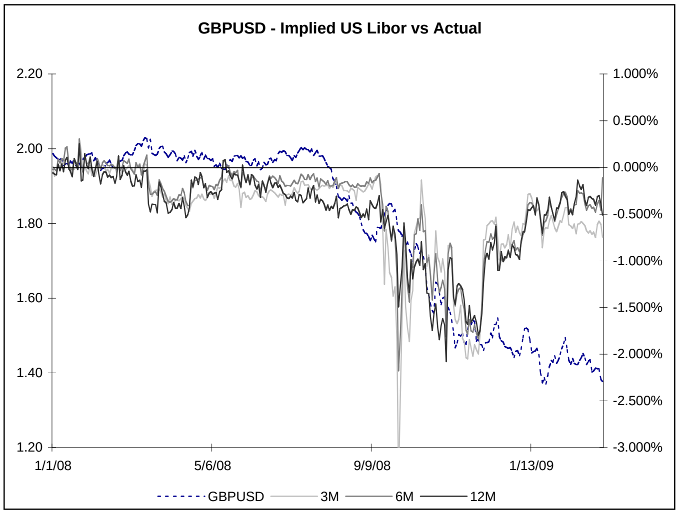


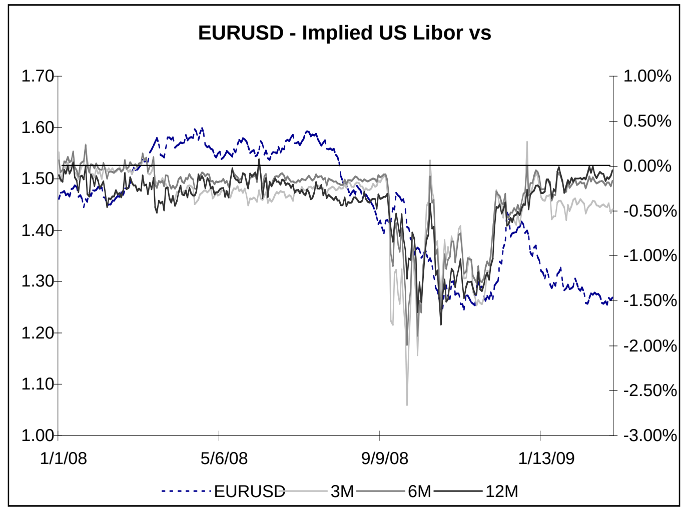
Where deviations are larger, it is possible that this is a result from the fact that the data are not fully time synchronized.

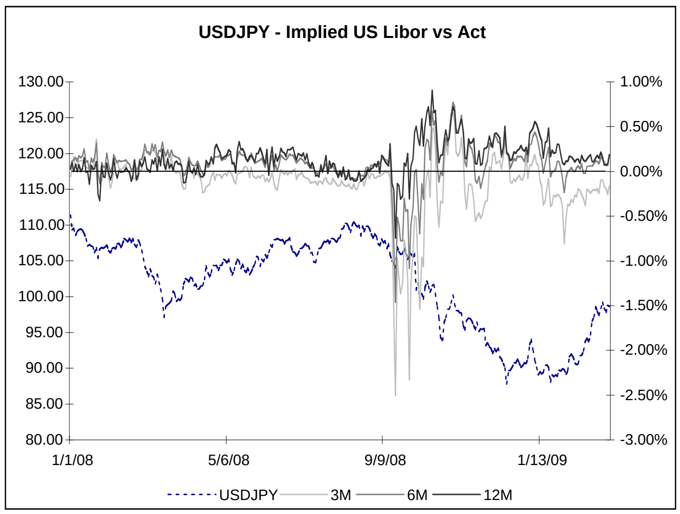
Both larger and more volatile deviations from CIP, begin at about the same point as the credit markets disruptions first began to occur. The collapse of British bank Northern Rock in September, followed by the crash in world equity markets from their peaks later in the year relates closely with divergences from CIP in all currencies examined (Charts for other currency pairs analyzed are found in Appendix B). The next spike, (a), is observed is 17 March 2008, the first day of trading after the announcement that Bear, Stearns & Co was to be acquired by JP Morgan, and the largest spike in the deviation is in late September 2008, (b), during the collapse of Lehman Brothers and AIG. The deviation at its peak shows that the foreign exchange forward implied USD Libor rates, $\hat{r}_b$, are 126-226bp higher than those observed in the market.

To understand the scale of the distortion observed, let us consider the position of an arbitrageur on 30 September. Assuming that USD funds were available, the arbitrager would attempt to borrow $1m dollars at 12-month USD LIBOR and enter into a foreign exchange swap to EUR to invest the funds for an identical term in Euro Libor. On completion of the swap and repayment of the loan, the arbitrageur will be left with approximately $12,600 (126bp) profit. Conversely, the calculation performed to create the synthetic USD rate shows that the market for obtaining USD funds from EUR implies a cost of funds in USD 126bp higher than the cost quoted in the market.

As the more interesting elements of the deviations from Covered Interest Parity are observable from March 2008 onward, the relationships for the three major liquid currency pairs (EURUSD, GBPUSD, USDJPY) will be analyzed with Charts 3-5 shown below.



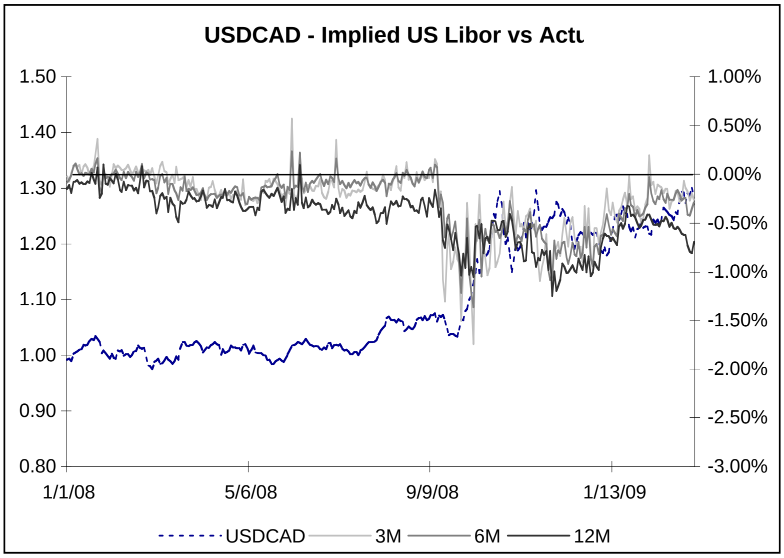




The direction of the covered arbitrage incentive was not identical across all currencies. Charts 3-5 show these deviations for the three currency groups, taking January 2008 as the starting point for the data, before significant distortions to rates occurred. It is clear from the charts above that the currency pairs most impacted by the credit crisis are the EURUSD and GBPUSD, with almost identical behavior against the Dollar. The charts show similar behavior, with the GBPUSD exhibiting slightly larger deviations from parity levels. For both currency pairs, there has been a financial incentive to exchange USD balances using a foreign exchange swap for EUR or GBP, or alternatively a penalty charged for obtaining dollars. In the case of

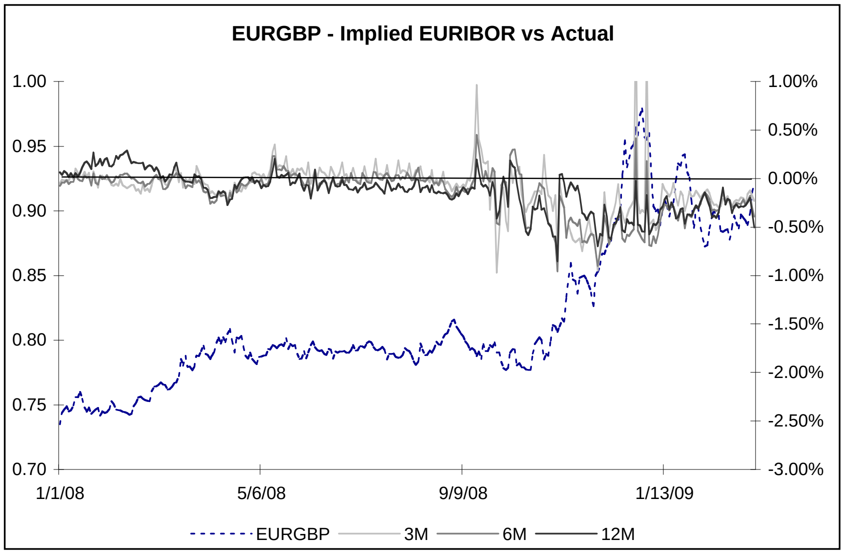
JPY, after an initial swing in the same direction as the other currencies, a reverse transaction has become the profitable covered arbitrage, moving money from JPY to USD under an FX swap.

This suggests that the direction and magnitude of the deviation from CIP is related to the relative health of the nation's banking sector, with Japanese banks being largely isolated from losses to date. As the Canadian banking sector has been solid in comparison to its North American neighbor, it could show similar behavior.



For the USDCAD there are two interesting observations; first, that the deviation, or yield, from the arbitrage is significantly less. Secondly , it shows a much faster movement back toward parity than any of the other pairs. In all cases the shorter term LIBOR rates exhibited higher volatility, and consequently greater potential arbitrage gains. The relationship does show that the synthetic USD rate through the forward was higher than the quoted rate, with no similarity to the USDJPY movements. This could be a result of the market being less liquid in the USDCAD, or alternatively the absence of the carry trade to create significant cash flows.

Given the recent evidence from Genberg, et al. (2009), the addition of the EURGBP currency pair adds valuable light to the analysis, primarily to assess whether deviations from CIP are a USD phenomenon or they are present elsewhere as well. As Chart 7 displays, while there is opportunity for arbitrage in the EURGBP currency pair, the profits resulting from the transaction would be significantly smaller than in any of the USD based transactions.



This evidence casts significant doubt upon one conjecture in Baba, et al. (2008) that the FX swap market is suffering from a result of increased counterparty risk. While it is certain that counterparty risk has increased over the time period, this should not necessarily contaminate the FX market as extremely as observed. A decrease in active counterparties or approved counterparties in the market would be unlikely to result in the level of distortions observed. Given the international nature of the main banks contributing to the daily LIBOR survey, increased counterparty risk ought to result in a very similar scale of deviation in the EURGBP market. To give fair consideration to Baba, et al. (2008), their analysis was reported in March 2008, in advance of the huge shifts we are able to observe here.

Baba, et al.'s (2008) alternative interpretation, that the CIP deviations are a result of high volumes of international currencies moving in to USD to meet liabilities, is much more plausible. The recent note from Genberg, et al. (2009) reaches a similar conclusion. As banks struggled to fund their USD commitments, they engaged in moving non-USD reserves through the spot exchange market to USD with a subsequent depreciation in foreign currency against the dollar. With the majority of financial institutions facing the same difficulty, it is easy to envision that many market participants were attempting to make the same transaction, depressing foreign currency prices further and creating the arbitrage opportunity.

V. THE MINIMUM RISK COVERED ARBITRAGE

While the level of CIP deviations illustrated above seem large enough to induce arbitrage, questions could still be raised as to whether the data are contemporaneous enough for a clean arbitrage transaction to take place[5]. Volatility in intra-day interest rates and futures rates has been high, such that the time gap (10.5 hours) between the 11am LIBOR fixing and the 4:30 pm New York exchange rate data used in our calculations could permit a swing in interest rates of 10bp or more.

By observing arbitrage opportunities using interest rate futures, we are able to eliminate any risk that the timing of trades would be responsible for the disparities. Bloomberg provides historic screen quotes for forward points to IMM dates, taken from a composite of market participants at a similar time to the IMM futures data they provide. Using this data, it is possible to create a synthetic test for parity, using a forward starting FX swap. The revised formula (3), (4) and (5) used for this test is shown in Appendix C.

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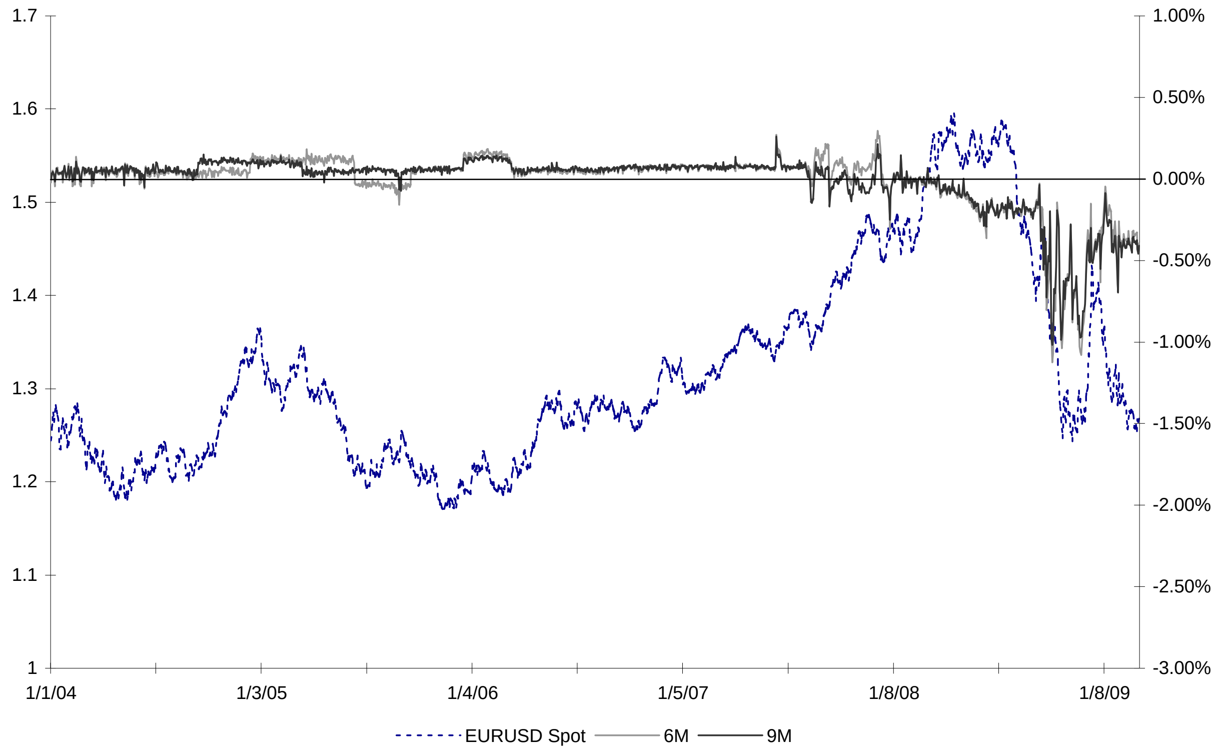
[5] Akram, Rime, Sarno (2008) observes tick level data on three major currencies at tick-level frequency, and does observe arbitrage opportunities that exist long enough for exploitation, though the data set is from 2004

EURUSD IMM Futures Implied Libor deviation vs Contracted



Because the IMM interest rate future cash settles for the difference between the execution date LIBOR of the relevant contract and the settlement date value, the arbitrageur can assure that they enter into the LIBOR transaction at a point timed to match the FX contracts already in place. Using this approach, we can observe in Chart 8 (above) that covered arbitrage remains a potentially viable transaction. The EURUSD currency pair is used here to demonstrate, with other currency pairs in Appendix D.

As observed in the case of LIBOR evidence earlier, there is support for CIP throughout the time period up to summer 2008. It is necessary to allow for larger deviations in the IMM structure than for LIBOR due to the increased number of transactions entered into for the trade. For a simple six-month or nine-month FX swap there are four transactions, whereas for the IMM approach there are ten or fourteen (two FX forward transactions, four/six futures contracts and then a further four/six LIBOR transactions).[6] Irrespective, it is clear that there is a major shift from the historical steady state seen up until the summer of 2008, with the familiar shock to the relationship in September 2008.

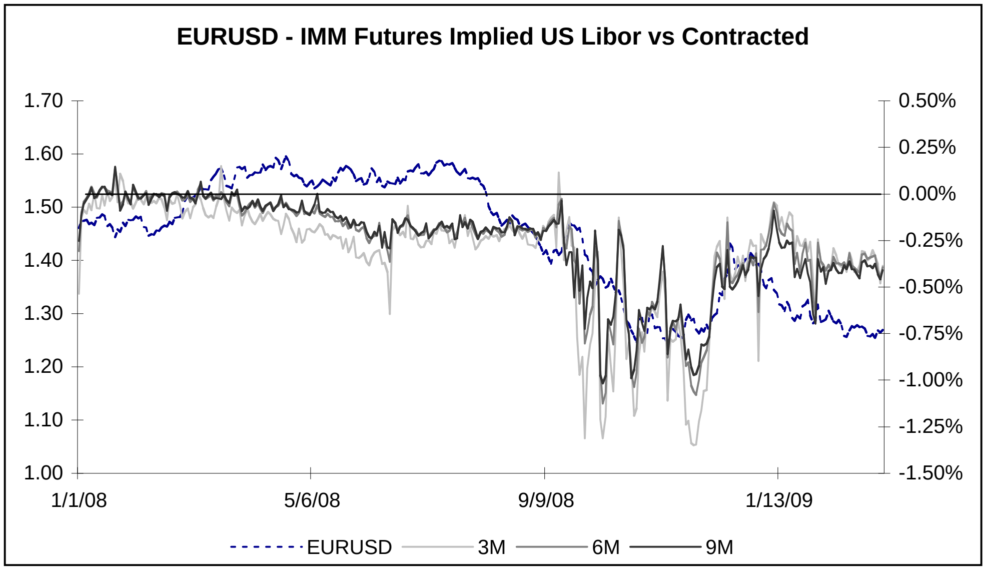


Chart 9 (above) shows that the development of opportunities for covered IMM arbitrage is a recent development, occurring after Baba et al.'s BIS paper written in March 2008. There are apparent arbitrage opportunities available from as early as mid-June 2008, and still larger apparent opportunities from September 2008 onwards. These opportunities are also observed in the GBPUSD data, and to a lesser extent in the USDJPY data, which can be reviewed in Appendix D.

[6] See Koh and Levich (1989) for an alternative description of arbitrage between two future dates.

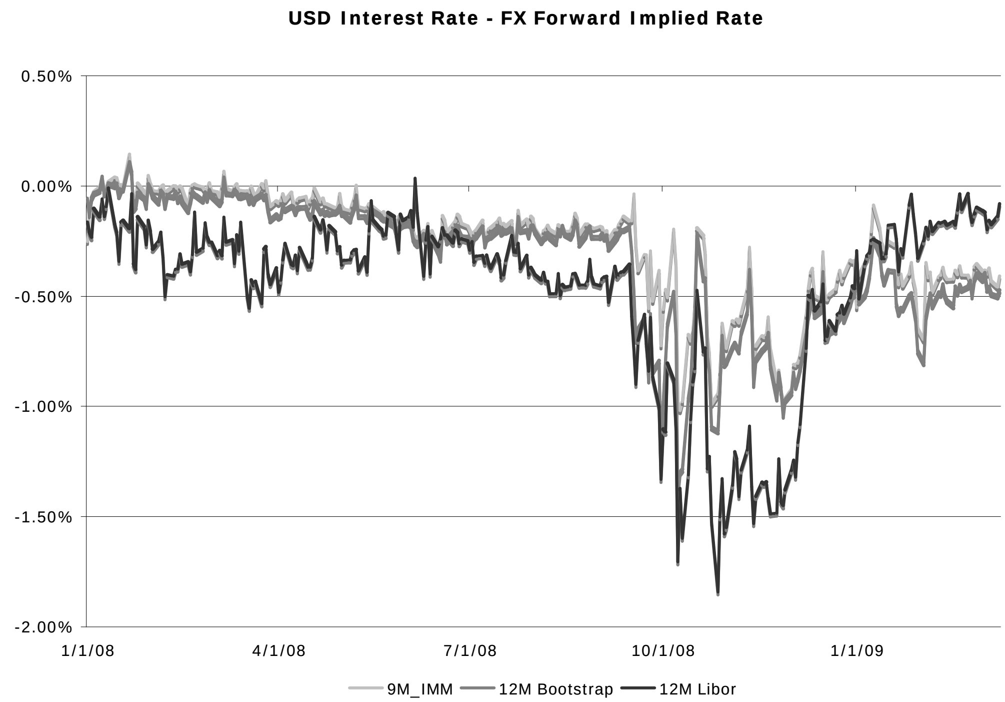
Question marks may surround the possibility of executing the transaction created in the data. First, obtaining forward quotes based on IMM dates may not find a liquid market in FX swaps, though as futures themselves serve as a hedging tool sufficient liquidity may exist. Counter to this point, however, is the observation that these arbitrage opportunities remain on dates very close to the IMM date, with high proximity to a generic 3-month trade. There is the further issue of the mark-to-market convention on IMM futures contracts, which brings volatility to the cash requirement to enter and maintain the trade and, as a result, impacts the expected arbitrage return. Outside of these concerns, the existence of a similar potential arbitrage opportunity is not experienced at any point in historical data currently available from Bloomberg.

A final problem with the actual efficiency of the futures based arbitrage relates to the fixed denominations required in futures contracts ($1,000,000 per Eurodollar future). This feature implies that the assumed ability to hedge all investments with futures, including compounding, is not practical in active trading. Even with these limitations, it is likely that some of the 50bp arbitrage could be captured through the trade.

VI. THE FUTURE OF RECONVERGENCE TO COVERED INTEREST PARITY

With evidence that deviations from Covered Interest Parity were commonplace across USD related currency pairs, the question arises as to how the relationship will re-establish itself. Given the current focus on bank de-leveraging and with counterparty risk remaining a significant concern, it seems likely that arbitrage will rely on methods that employ minimum cash outlays and minimal risk exposure.

Observed behavior at present is mixed and, from the findings in this paper, slightly counterintuitive. Given that as of March 2009 liquidity in long-dated unsecured markets is still considered tight, it would be expected that arbitrage opportunities would appear more prevalent with a longer-dated LIBOR transaction. However, the data suggest that following the divergence from parity, CIP has shown more progress in reestablishing itself with LIBOR rates than with futures based rates.



The deviations from CIP we observe in the foreign exchange market clearly reflect a spill-over of discrepancies between exchange traded interest rate futures and bank-specific LIBOR rates. The difference between the two rates appears to have stabilized over recent months, and could represent a form of term counterparty risk (with IMM Futures only exposing the investor to risk in 3 month periods at a time). Once more, the difference between covered arbitrage with IMM futures and LIBOR is such that the potential return is higher from a lower risk transaction. Given that to exploit the arbitrage opportunity we borrow in USD, the inflated cost of money in the US, partly related to counterparty risk being priced in to the rate, has reduced the return from the covered arbitrage.

VI. CONCLUSION

Academic studies examining Covered Interest Parity have generally shown that, during tranquil currency regimes and given data of a contemporaneous nature, Covered Interest Parity tends to hold within a narrow bound consistent with transaction costs. However, during periods containing significant turbulence, there is evidence of larger deviations where arbitrage appears possible for a short period of time.

This examination of data shows that since September 2008 breaches of Covered Interest Parity have been commonplace. Extended periods of arbitrage opportunities have been observed, with multiple methods of execution available to exploit the returns. The source of the deviations are closely tied to events in the U.S. banking and money markets, with the widening of arbitrage gains closely related to major financial events that raised bank counterparty risks and drained liquidity from the short-term money market.

In further analysis, it would be valuable examine the viability of executing the arbitrage transactions outlined in this paper. Observed prices in the financial markets since September 2008 have been variable in both scale and in the ability for trades to be executed at rates observed on screen. Though it is clear that we measured covered arbitrage opportunities in the FX markets, the actual returns to be made from these trades remain uncertain.

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APPENDIX A – THE BOOTSTRAPPED YIELD CURVE

The bootstrapped yield curve approach was originally included in the analysis to try to remove any significant counterparty risk being added for long-dated LIBOR contracts. The bootstrapped yield curve was constructed out to a minimum of one full year, as required to duplicate the LIBOR rates used in case 1.

The curve was constructed using the minimum possible number of cash rates (the number required to bridge to the first IMM futures contract), using the first four IMM contracts to derive all other prices. The rates used were:

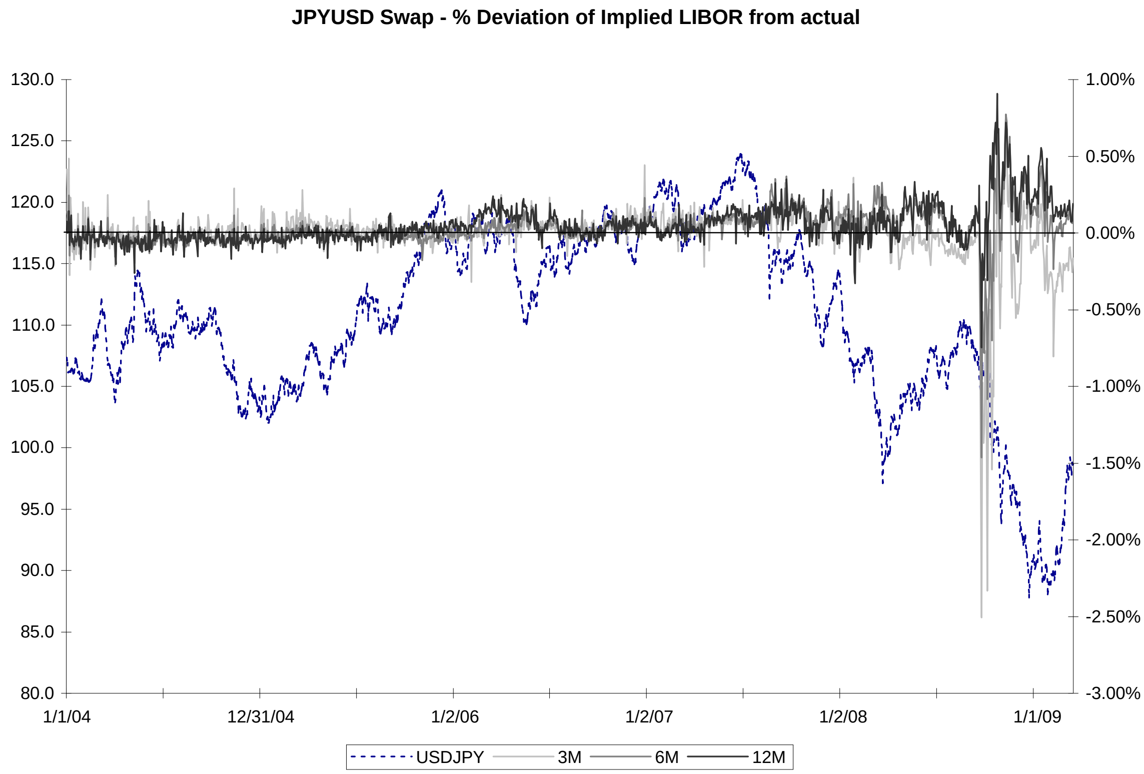
- Overnight (to interpolate when the first contract was within one week)
- 1, 2, 3 weeks
- 1 and 3 month LIBOR
- The first four IMM interest rate futures contracts

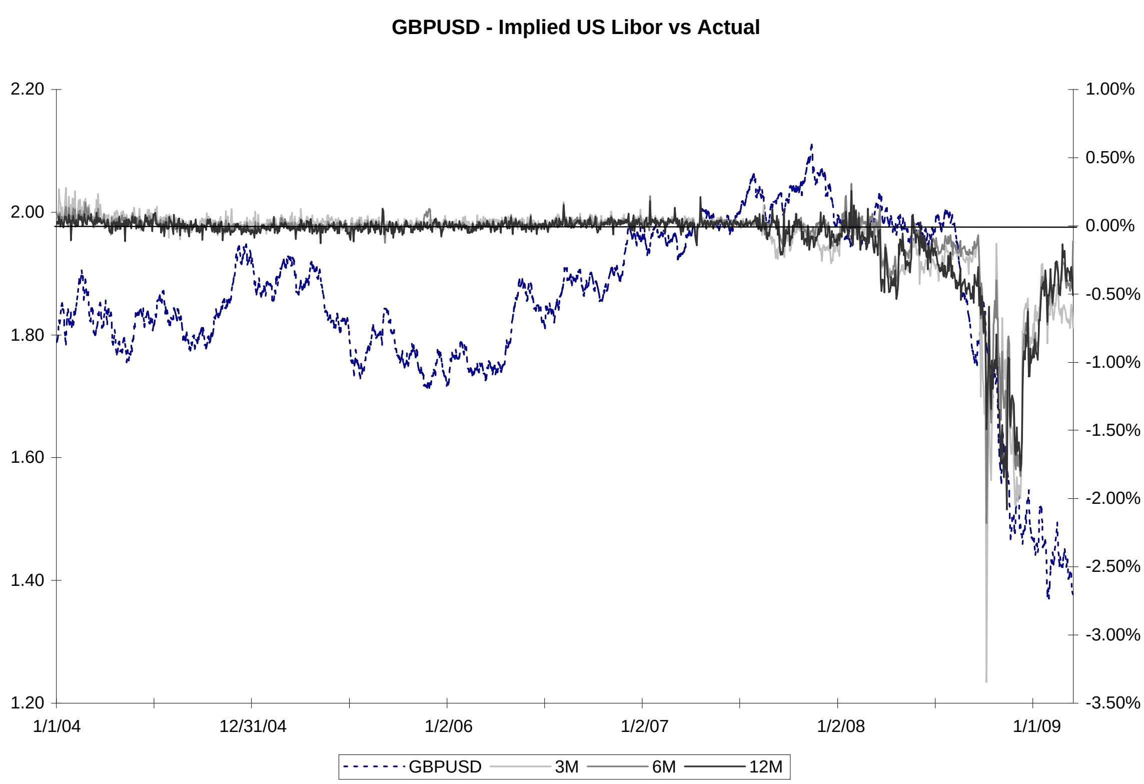
To calculate the 3, 6 or 12 month rate on any date there were typically two interpolations required, each of which was calculated using a linear spline. The interpolations were for the following two points:

- To calculate the "cash" rate required up to where the investor would be able to transfer into the interest rate obtained from the first interest rate. This rate was interpolated from the two closest cash rates available
- An interpolation to obtain a fair rate for a standard 6 or 12 month contract required the interpolation to create a fair rate between the IMM dates. In the case of a 3 month interpolated rate, this would be between the cash rate obtained, and the maturity date of the 3 month trade from the first IMM date.

The work from this calculation served more to confirm that the behavior observed from LIBOR rates was less a result of any concerns on term-related counterparty risk, as the divergences observed are almost identical.

APPENDIX B – CIP DEVIATION CHARTS FOR LIBOR TRADES





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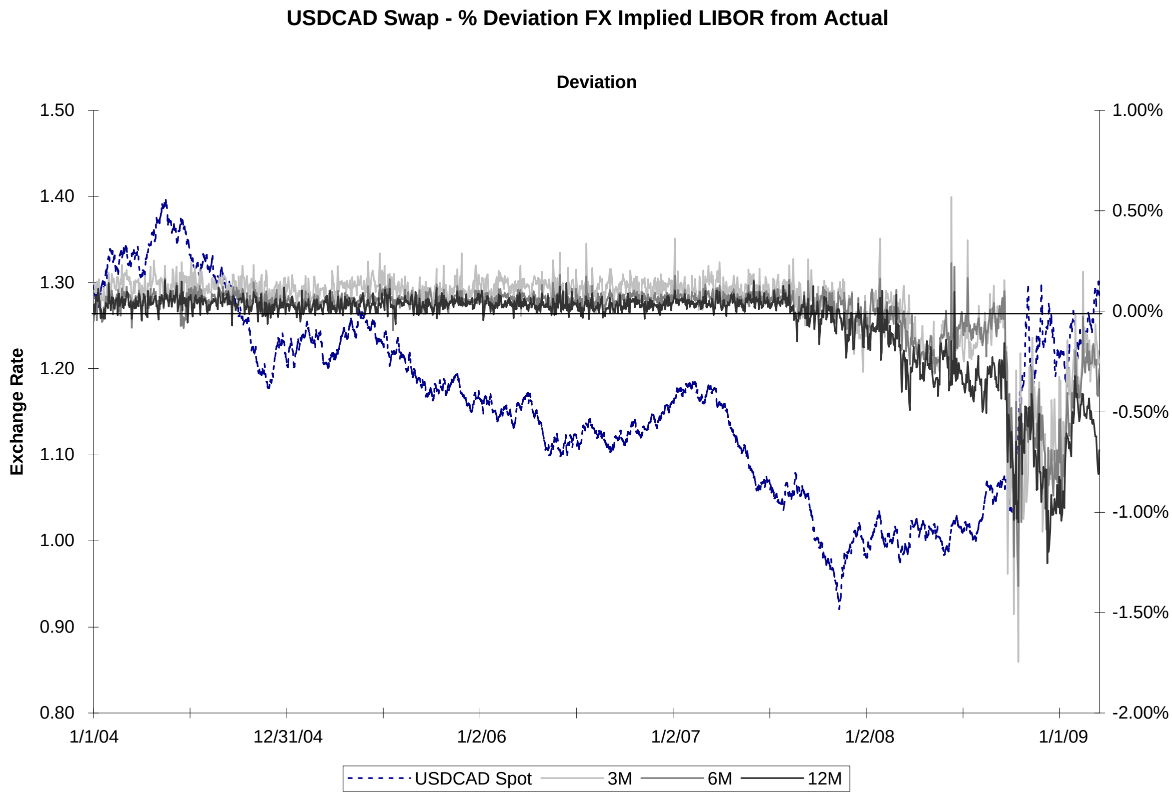
USDCAD Swap - % Deviation FX Implied LIBOR from Actual
Deviation
Exchange Rate
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
1.00%
0.50%
0.00%
-0.50%
-1.00%
-1.50%
-2.00%
1/1/04
12/31/04
1/2/06
1/2/07
1/2/08
1/1/09
USDCAD Spot
3M
6M
12M

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APPENDIX C – IMM BASED FUTURES ARBITRAGE

Starting with equation (2)

$$(1+r_b^A) \approx (1+\widehat{r}_b) = (1+r_t^B)\frac{F^B}{S^A} \tag{2}$$

For the IMM interest rate futures CIP, the calculation is most often a forward starting time-period. For a three-month interest rate futures calculation, this will be as follows:

$$(1+(1-(\frac{IMM1_b^A}{100}))) \approx (1+\widehat{r}_b) = (1+(1-(\frac{IMM1_t^B}{100})))\frac{F_{T=x+3}^B}{F_{T=x}^A} \tag{2a}$$

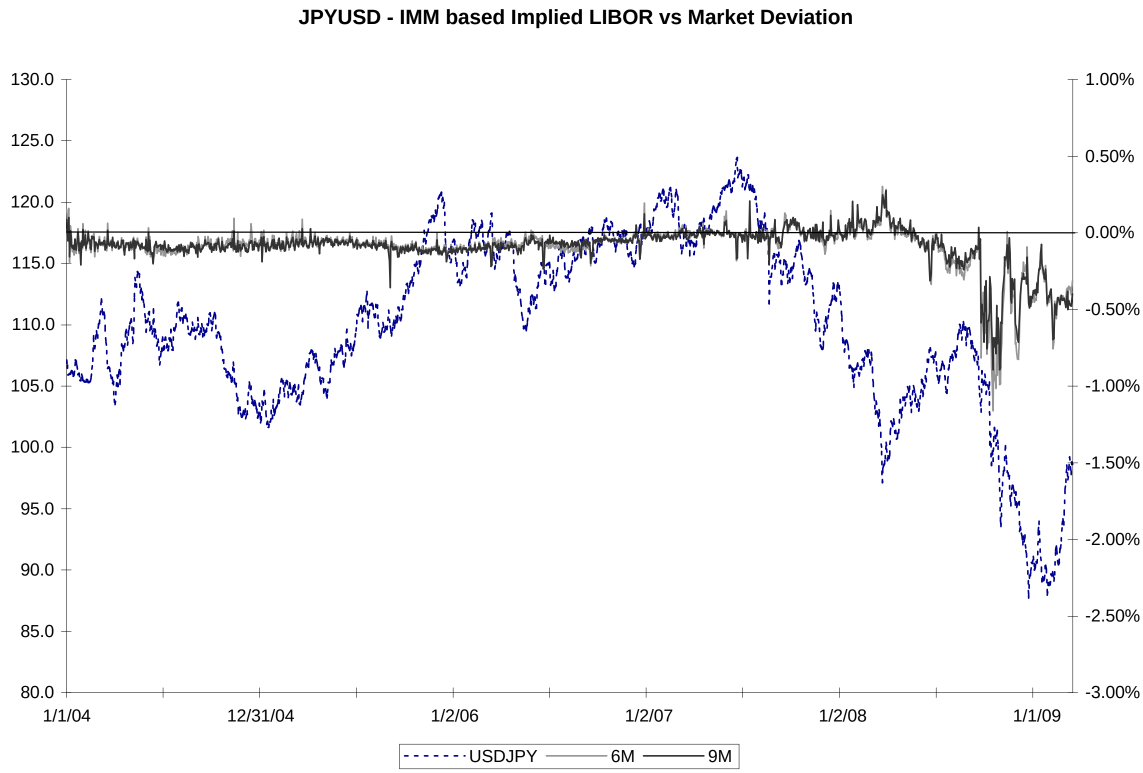
For the actual calculations in the paper, the IMM interest rate future values will have been compounded to create the 6 month and 9 month term rates. The equations, as per the main paper, for the 3-month calculation are as below.

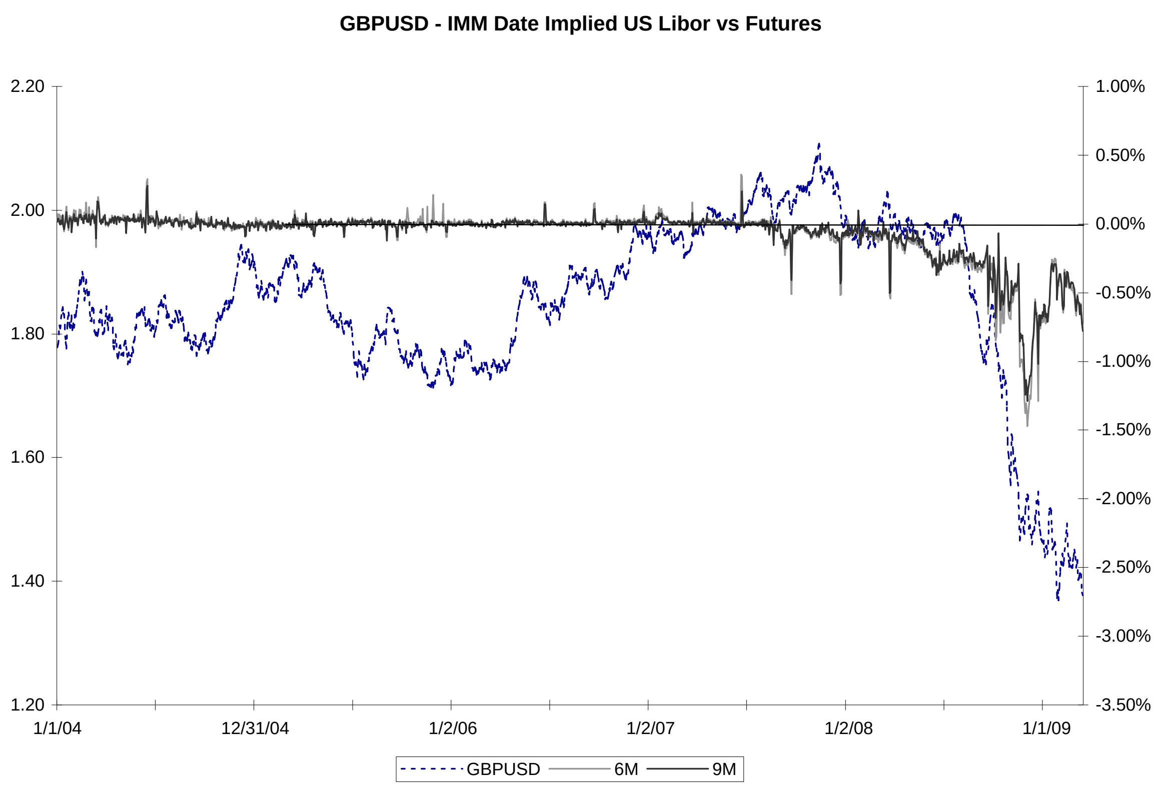
$$(1+((1-(\frac{IMM1_b^A}{100}))\times\frac{days_b}{daycount_b}) \approx (1+(\widehat{r}_b\times\frac{days_b}{daycount_b}) = (1+((1-(\frac{IMM1_t^B}{100}))\times\frac{days_t}{daycount_t})\times\frac{F_{T=x+3}^B}{S_{T=x}^A} \tag{3a}$$

$$\widehat{r}_b = ((1+((1-(\frac{IMM1_t^B}{100}))\times\frac{days_t}{daycount_t})\times\frac{F_{T=x+3}^B}{S_{T=x}^A})-1)\times(\frac{daycount_b}{days_b}) \tag{4a}$$

$$basis = (1-\left(\frac{IMM1_b^A}{100}\right)) - \widehat{r}_b \tag{5a}$$

APPENDIX D – CIP DEVIATION FOR IMM BASED FUTURES TRADES





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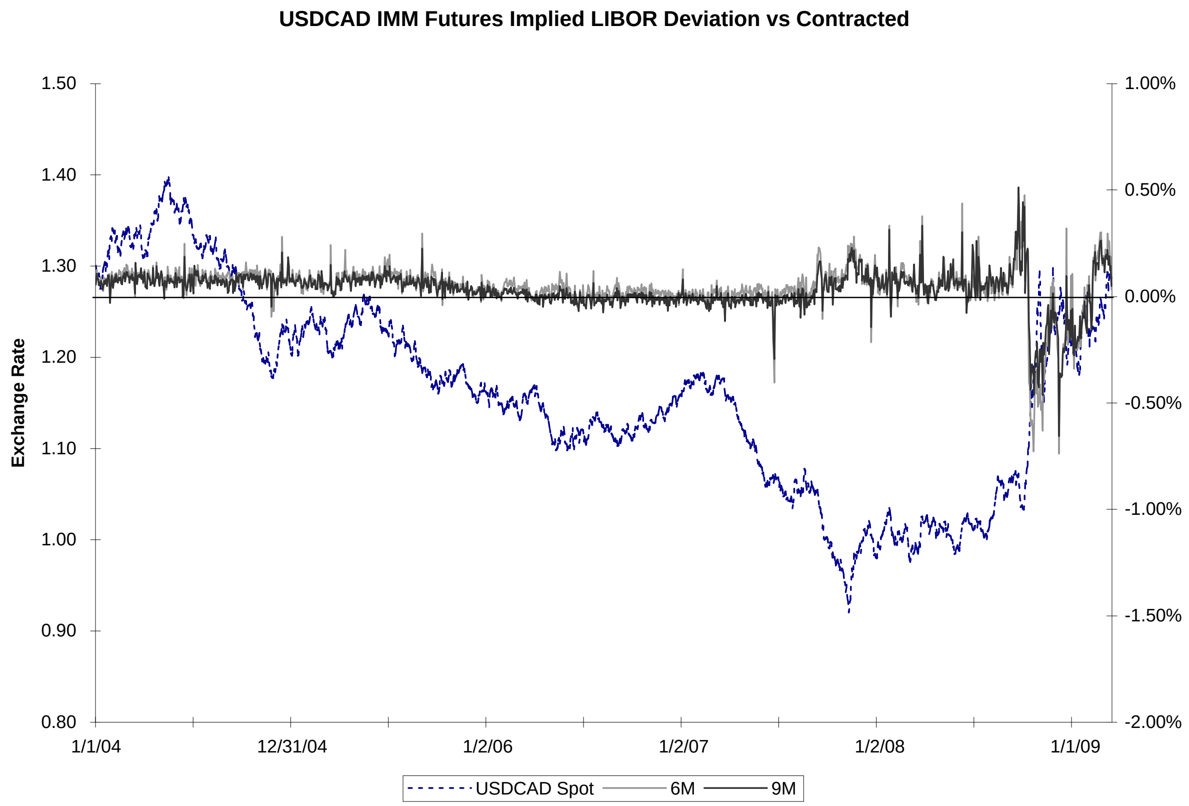
USDCAD IMM Futures Implied LIBOR Deviation vs Contracted
Exchange Rate
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
1.00%
0.50%
0.00%
-0.50%
-1.00%
-1.50%
-2.00%
1/1/04
12/31/04
1/2/06
1/2/07
1/2/08
1/1/09
USDCAD Spot
6M
9M

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