Empirical Explanation of Covered Interest Parity Deviations During Financial Crises

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ABSTRACT

My paper aims to analyze the 2008 financial crisis, when Covered Interest Parity (CIP) between the U.S. dollar and the euro appears to have deviated by hundreds of basis points to historically unprecedented levels. In existing literature, this deviation is attributed to heightened credit risk spreads and dollar liquidity premiums. However, my paper shows that the Term Fed Funds explain the majority of these observed market deviations. I thus argue that covered interest parity did not fail as an economic model, but rather that panel banks underreported their true borrowing rates in the London Inter-Bank Offered Rate (LIBOR) survey. Ultimately I conclude that LIBOR, which is linked to more than $90 trillion of financial derivatives, broke down as an accurate measure of true interest rates during the 2008 financial crisis.

Keywords: Covered Interest Parity, LIBOR, Term Fed Funds, Cross Currency Basis

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(1) Introduction

During the 2008 financial crisis, an unprecedented deviation appeared in Covered Interest Parity (CIP). CIP is an economic theory that relates the spot and forward exchange rates to the domestic and foreign interest rates. Historical data on foreign exchange markets shows that CIP is generally accurate to within a few basis points (bps) because it is based on a no-arbitrage pricing model. However, following the Lehman Brothers bankruptcy in September 2008, deviations of up to 260 bps appeared in the three-month term CIP when calculated using the U.S. dollar and euro currency pair and respective LIBOR interest rates.

This CIP deviation was observed and analyzed by Baba and Packer (2009) as well as Coffey, Hrung and Sarkar (2009). These papers found that heightened counterparty credit risk premiums and dollar liquidity premiums were statistically significant determinants of observed CIP deviations. The credit risk hypothesis implies that European banks and financial institutions were perceived to have a relatively higher probability of default compared to their U.S. counterparts. Since CIP operates on risk-free interest rates, a large difference between euro and dollar credit risk premiums could lead to deviations in CIP calculated using the London Inter-Bank Offered Rate (LIBOR). The dollar liquidity hypothesis argues that the demand for borrowing dollars through the forex markets exceeded the supply. Financial institutions around the world bid up the dollar interest rates implied in the forex markets to raise vital dollar liquidity as their asset values rapidly deteriorated during the financial crisis.
The purpose of my paper is to document the observed CIP deviation during the 2008 financial crisis and offer an alternative explanation. I use the same methodology as Baba, Packer and Nagano (2008) to calculate the dollar interest rates implied by CIP and compare them to quoted LIBOR. Furthermore, I introduce Cross Currency Basis (CCB) swaps to verify that the magnitude of the deviation was actually as severe as is implied by CIP. While existing literature focuses on credit risk and dollar liquidity premiums as explanations of observed CIP deviations, I argue that these reasons cannot sufficiently explain the full magnitude of the observed spread between CIP-implied rates and quoted LIBOR.

By analyzing an alternative measure of U.S. interest rates, the Term Fed Funds (TFF), I find that the biggest factor was in fact measurement error in LIBOR. When I use the TFF as a more appropriate and accurate measure of dollar interest rates, the majority of the observed CIP deviation disappears, especially in the longer 12-month term. Quoted by the largest interdealer broker, ICAP, the TFF rate is the best offer rate at which there are market participants actually willing to lend deposits at the Federal Reserve (Fed). However, dollar liquidity may not necessarily be found at the quoted LIBOR, because it is calculated based on a survey of sixteen panel banks that are asked to report the rate at which they could borrow funds. During periods of financial distress, the panel banks have an incentive to underestimate their reported borrowing rates because they want to appear more credit worthy to investors. Based on my analysis, I argue that LIBOR, tied to more than $90 trillion of financial derivatives, was underreported by at least 100 bps during the 2008 financial crisis.
(2) CIP and Cross Currency Basis Definitions

CIP calculates the forward exchange rate between two currencies based on the spot exchange rate and the risk-free interest rate in the dollar and foreign currency. An investor should be indifferent between the following two trades:

1. Exchanging euro into dollars today at the spot rate ($S_0$) and earning risk-free U.S. interest rates ($r$) for $t$ years.

2. Locking in a $t$-year EURUSD forward exchange rate ($F_t$) today and earning risk-free European interest rates ($\tilde{r}$) on the euro for $t$ years before exchanging euro for dollars at the secured forward rate.

The forward exchange rate must therefore take into account the interest rates on both currencies. Consequently, in order to set the above two trades equal, CIP implies the following well-known equations:

$$S_0 (1 + r)^t = F_t (1 + \tilde{r})^t$$

$$F_t = S_0 \left( \frac{1 + r}{1 + \tilde{r}} \right)^t$$

(1)

While historical data shows that CIP based on no-arbitrage pricing is a very precise economic model overall, small deviations of a few basis points (bps) may often be present due to perceived liquidity and credit risk premiums. A Cross Currency Basis (CCB) spread is used to represent the small adjustments that must be made to interest rates in order for CIP to hold perfectly. Defined as U.S. dollar flat, CCB spread is the number of bps that must be added to, or subtracted from, the foreign interest rate to set the actual market forward exchange rate equals the CIP-implied forward exchange rate.
Under normal circumstances, using risk-free interest rates, the CCB spread should be zero. A trader should be indifferent between exchanging a floating risk-free interest rate in the dollar currency for a floating risk-free interest rate in the foreign currency with a guaranteed forward exchange rate at expiration. The following sequence of trades demonstrates this example (Tuckman 2007, p.7):

1. Pay 1 euro for 1.5 dollars today.
2. Receive European risk-free interest rate on 1 euro and pay US risk-free interest rate on 1.5 dollars for a year.
3. Receive 1 euro and pay 1.5 dollars at expiration.

Paying 1 euro to receive the European risk-free interest rate for a year and receiving 1 euro at expiration is a fair trade. Similarly, receiving 1.5 dollars today, paying US risk-free interest rate on 1.5 dollars for a year and then paying 1.5 dollars at expiration is also a fair trade. If the European and US risk-free interest rates were different on the first day, CIP would account for this difference in the forward exchange rate. The CCB spread is therefore zero, because no bps are added to, or subtracted from, the European risk-free interest rate to equalize the euro and dollar side of the trade. Mathematically, in a simplified form, the CCB spread may be included in equation (1) as the variable (x) added to the foreign interest rate as follows:

\[
F_t = S_0 \left( \frac{1 + r}{1 + \tilde{r} + x} \right)^t
\]
Unfortunately, truly risk-free interest rates are difficult to measure; the US Treasury yields are considered to be the best approximation. Any other interest rate must therefore be higher as it carries a risk premium to the dollar US interest rate. The problem with implementing a no-arbitrage model based on government bond rates is that an arbitrage trader at a financial institution can only lend, but not borrow, at the same interest rate as government debt because the financial institution will inherently have more credit risk than the US government.

In order to solve this problem, the interest rate used in the no-arbitrage calculations is the London Inter Bank Offering Rate (LIBOR), the rate at which banks lend and borrow unsecured funds to and from each other. Arbitrage traders at the largest financial institutions can both borrow and lend at LIBOR (\(i\)), unlike the theoretical risk-free rate. However, compared to the risk-free rates, LIBOR (\(i\)) inherently carries a small credit risk premium (\(p\)).

\[
F_t = S_0 \left( \frac{1 + r}{1 + \tilde{r} + x} \right)^t = S_0 \left( \frac{1 + i - p}{1 + i - \tilde{p} + x} \right)^t
\]  

(3)

Individual financial institutions reporting LIBOR quotes (\(i\)) have a small probability of default, which is part of the LIBOR premium (\(p\)) over the risk-free rate (\(r\)).

Furthermore, the volume of funds available at a given LIBOR may be limited, so liquidity shortage may also increase the LIBOR premium over the risk-free rate.
Assuming that \((i)\) and \((p)\) are small, we can simplify the above equations as follows:

\[
\log \left( \frac{F_t}{S_0} \right) = t \log (1 + i - p) - t \log (1 + \tilde{i} - \tilde{p} + x)
\]

\[
\log (1 + i - p) \approx (i - p)
\]

\[
\log (1 + \tilde{i} - \tilde{p} + x) \approx (\tilde{i} - \tilde{p} + x)
\]

\[
\log \left( \frac{F_t}{S_0} \right) \approx \log \left( \frac{F_t - S_0}{S_0} \right)
\]

\[
\left( \frac{F_t - S_0}{S_0} \right) \approx t \left[ (i - p - \tilde{i} + \tilde{p} - x) \right]
\]

\[
\left( \frac{F_t - S_0}{S_0} \right) \approx t \left[ (i - \tilde{i}) + (\tilde{p} - p) - x \right]
\]

(4)

As long as the LIBOR premiums are small and almost equal for both the dollar \((p)\) and foreign \((\tilde{p})\) country, CIP based on LIBOR will be a close approximation for the actual forward rates and CCB spread will remain within a few bps of zero.
(3) Literature Review

The mathematical equations behind CIP and CCB swaps are derived in detail by Tuckman and Porfirio (2003) in the *Lehman Brothers Quarterly* on fixed income and liquid markets research. The article begins with a derivation of CIP based on risk-free interest rates, as presented in equation (1) above. In order to adapt the CIP equation (1) to use LIBOR instead of risk-free interest rates, the authors utilize CCB swaps to set different currency LIBOR payments fair against each other and money market basis swaps to take into account the LIBOR credit risk premium. Money market basis swaps exchange floating payments on one index for floating payments on another index; for example, a trader may pay 3-month LIBOR to receive the yield on 3-month risk-free Treasury bills plus a spread of 50 bps in exchange.

A CCB swap on two LIBOR rates may be deconstructed into the following three swaps: “a cross-currency basis swap of overnight, default-free rates; a money market basis swap of dollar LIBOR versus dollar, default-free overnight rates; and a money market basis swap of foreign LIBOR versus foreign, default-free, overnight rates” (Tuckman et al. 2003, p.4). A CCB spread arises from the latter two money market basis swaps. If the foreign LIBOR carriers more credit risk premium compared to the dollar LIBOR, then a stream of foreign LIBOR payments would be relatively more valuable. In order for two market participants to agree to the trade, a certain CCB spread must be subtracted from the foreign LIBOR to make it fair against the dollar LIBOR. A relatively high foreign LIBOR risk premium will therefore be associated with a negative CCB spread.
While the pricing theory on CIP and CCB is well established, few papers empirically analyze CIP deviations and CCB spreads during the 2008 financial crisis. Baba, Packer and Nagano (2008) are among the first to address the impacts on the forex markets in their paper on, “The spillover of money market turbulence to FX swap and cross-currency swap markets.” Their paper begins with an overview of how central banks in the U.S., Europe and Japan lowered interest rates in response to the economic crisis. At that time, spreads widened between unsecured LIBOR and Overnight Index Swaps (OIS), which are generally considered to be virtually risk-free. In a later paper, “A Black Swan in the Money Market,” Taylor and Williams (2009) conclude that rising counterparty credit risks and not liquidity shortage led to this widened LIBOR-OIS spread.

Baba, Packer and Nagano (2008) focus on forex CCB swaps, which are used to raise liquidity through a foreign currency, as explained above. They input the forward rate, spot rate and foreign LIBOR interest rate into the CIP equation (1) to calculate the forex swap-implied dollar interest rate, as follows:

\[
(1 + r)^t = \frac{F_t}{S_0}(1 + \tilde{r})^t
\]  
(5)

Applying their formula to market data, Baba at al. analyze a twelve month time period from January 2007 to January 2008, just prior to their publication in March 2008. Starting from August 2007, they find that the quoted dollar LIBOR is below the forex swap-implied LIBOR by about 40 basis points. Prior to August 2007, the two lines match almost exactly, verifying that CIP generally is an accurate model. A similar case is presented in the British pound and Japanese yen.
In their analysis, Baba et al. (2008) offer three possible explanations for why CIP might not hold during the crisis. Their first and main reason is that counterparty credit risk was disproportionately high on one side; European financial institutions were perceived as more risky compared to the U.S. financial institutions. Their second reason is that the dollar liquidity premium was elevated due to one-sided order flow; European financial institutions were struggling to find dollar funding due to dollar shortages in the uncollateralized LIBOR market. This could have led forex swap-implied dollar interest rates to exceed quoted dollar LIBOR. Their last reason is that LIBOR underestimated the true borrowing costs to the European financial institutions due to measurement error. Since LIBOR is a non-binding survey, the panel banks are not required to transact on the rates they report. During periods of financial distress, banks may therefore underestimate their true borrowing rates because they do not want to reveal information that would further increase their borrowing costs or cause a run on the bank.

Coffey, Hrung and Sarkar (2009) expanded upon the Baba et al. (2008) paper by using the same methodology to calculate forex-implied dollar interest rates over a longer time period from January 2007 to March 2009. Compared to the 40 bps deviations described by Baba et al. at the beginning of 2008, Coffey et al. find deviations of more than 200 bps in CIP following the Lehman Brothers bankruptcy in September 2008. Apart from the main EURUSD currency pair, Coffey et al. provide robust evidence of very similar CIP deviations in the five other most liquid dollar currency pairs, including Japanese yen, Swiss franc, British pound, New Zealand dollar and Australian dollar.
Coffey et al. (2009) empirically test two hypotheses as possible causes for the observed CIP deviations. The first hypothesis is that margin constraints and shadow costs of capital impede investors from arbitraging away CIP deviations. Under this hypothesis, the spread between mortgage-backed securities and Treasury repo rate is introduced as a proxy for tight margin conditions. The correlations show that dollar funding constraints are indeed statistically significant determinants of CIP deviations. Furthermore, the TED spread between LIBOR and Treasury yields also confirms that funding constraints are statistically significant. However, dollar funding constraints do not necessarily explain the full scope of the CIP deviation, as the correlation coefficients only range from about 0.22 to 0.50.

The second hypothesis is that a difference in the relative credit risk of non-U.S. and U.S. firms was also a determinant of the CIP deviations. The proxies for this hypothesis are the CDX investment grade index of Credit Default Swap (CDS) prices and the dispersion between the sixteen interest rates reported in the LIBOR survey. The empirical tests confirm that credit risk also played a statistically significant role in determining CIP deviations after the Lehman Brothers bankruptcy.

Coffey et al. expand their analysis further to address the effects of the unlimited Fed swap lines introduced to lend dollar funding to foreign central banks in response to the worsening market conditions after the Lehman Brothers bankruptcy. The authors find that when the Fed announced unlimited swap lines in October 2008, CIP deviations diminished by more than 55 bps on the following day. However, Coffey et al. do not address underestimated LIBOR as a possible determinant of CIP deviations in their paper.
Baba and Packer published a subsequent paper in December 2009 in the Journal of International Money and Finance, “Dislocations in the FX swap market before and after the failure of Lehman Brothers.” The authors decompose the domestic and foreign LIBOR used in CIP into the domestic and foreign OIS and LIBOR-OIS spreads. While Baba et al. (2009) test for the same counterparty credit risk and liquidity shortage hypotheses as Coffey et al. (2009), the distinction is that Baba et al. use an EGARCH model to analyze all their explanatory variables together. Baba et al. reach similar conclusions as Coffey et al. in that both heightened counterparty credit risks and global dollar funding shortages were found to be statistically significant determinants of the CIP deviations.

In their analysis, Baba et al. (2009) also assess the impact of central bank actions on the forex markets. They find that increases in the dollar swap lines offered by the Fed to other central banks successfully reduced CIP deviations, but only in the time period following the Lehman Brothers bankruptcy. Furthermore, auctions of funds with maturities longer than 28 days by the European, Swiss and British central banks also helped to ameliorate the severe global dollar funding shortages and thus reduced CIP deviations.

Even though Baba et al. (2009) acknowledge in one short paragraph that measurement error in the LIBOR survey could have caused it to be underestimated, the authors do not address this topic as a possible determinant of CIP deviations. In my paper, I will assess whether or not quoted LIBOR was underestimated through comparisons to forex-implied dollar rates and Term Fed Funds, an alternative market-based measure of Fed deposit rates.
On the topic of underestimated LIBOR, on May 29th, 2008, the Wall Street Journal (WSJ) published a study doubting the reliability of LIBOR. The dollar LIBOR is calculated by the British Bankers’ Association (BBA) through a survey of the borrowing rates of sixteen member panel banks; out of the reported values, the four highest and four lowest are removed, and the remaining ones are averaged to give the resulting measure of interest rates. I will go into more detail about the BBA method and survey in the analysis section. The WSJ compared the LIBOR quoted by each of the sixteen contributing panel banks in the WSJ to the interest rates implied by Credit Default Swaps (CDS). CDS rates are the cost of buying protection on the company’s debt; a buyer pays a certain percentage premium, which equals the probability of default, on a notional amount of debt that the seller insures, should the underlying company default.

The WSJ took the lowest reported quote in the dollar survey and subtracted the lowest CDS premium on the most credit worthy bank to obtain a base rate. For example, on April 16th, 2008, the lowest LIBOR reported to BBA was 2.72% by the member banks; the WSJ subtracted the cheapest CDS protection for Bank of Tokyo-Mitsubishi, which was 0.25%, to obtain a base rate of 2.47%. The WSJ then used the base rate and added the CDS cost for other banks to calculate their expected LIBOR. For example, Citigroup’s CDS cost 1.07% on that day, so its reported LIBOR should have been around 3.54%, but Citigroup reported a rate 0.82% lower at only 2.72%. Using its methodology and the BBA’s calculation of the average, the WSJ calculated its own LIBOR average for April 16th at 2.97%. This was almost 0.24% higher than the official quoted LIBOR at 2.73%.
The WSJ estimates that LIBOR is tied to more than $90 trillion of dollar-denominated mortgage loans, corporate debt and other financial contracts. If LIBOR were underestimated as much as the WSJ predicts it to be, it would mean an estimated $45 billion break on interest rates to debtors over the first four months of 2008. There are other possible explanations for the deviations: the LIBOR market for terms of more than three months may have measurement error as banks ceased the majority of longer-term lending to each other, and the CDS prices may be too inaccurate and volatile measures of default risk. While the study does not conclusively prove that the LIBOR is underreported, finance professors at London School of Economics and Columbia University agree that the study convincingly demonstrates that LIBOR is lower than it should be and surpasses thresholds for statistical significance of results.
(4) Measuring Deviations from CIP

The no-arbitrage pricing model is often considered to be the most accurate, as profit-driven market participants will compete away any discrepancies. CIP uses the no-arbitrage model to price forward exchange rates in the world’s most liquid forex market. With the forex markets trading on average more than $3 trillion in daily volume, abundant market participants will eliminate even minute market arbitrage discrepancies in milliseconds. CIP should therefore be a reliable and accurate model that reflects all available market information. However, according to the existing literature, even the no-arbitrage CIP model experienced major shocks and dislocations during the 2008 financial crisis.

The first objective of this paper is to compare quoted LIBOR to rates implied by CIP during the 2008 financial crisis. This is important in order to see how closely CIP holds historically and how interest rates deviated during the 2008 financial crisis. I will apply the same method as Baba et al. (2008) to calculate the forex implied LIBOR, using the most liquid euro and U.S. dollar currency pair (EURUSD). Starting with CIP, I rearrange equation (1) to obtain the CIP-implied rate \( r \) when I input the spot exchange rate \( S_0 \), forward exchange rate \( F_t \) and foreign interest rate \( \tilde{r} \), as follows:

\[
(1 + r)^t = \frac{S_0}{F_t} (1 + \tilde{r})^t
\]

\[
r = \left( \frac{S_0}{F_t} (1 + \tilde{r})^t \right)^{\frac{1}{t}} - 1
\]  

(6)
My source of data for the three input variables is Bloomberg. The spot exchange rate \( S_0 \) is obtained using the function EURUSD Curncy, the three-month forward exchange rate \( F_t \) comes from the function EUR3M Curncy (also EUR6M and EUR12M) and the function for the three-month foreign LIBOR \( \hat{r} \) is EE0003M Index (also EE0006M and EE0012M). Each of my three variables is available in a variety of terms \( (t) \), but I chose the following three terms \( (t) \) that are common for all of my data series: 3 months (3M), 6 months (6M) and 12 months (12M). Since equation (6) operates on terms \( (t) \) expressed in years, I will substitute \( t = \frac{1}{4} \) for 3M, \( t = \frac{1}{2} \) for 6M, and \( t = 1 \) for 12M.

The 3M term is the most liquid of the three maturities and should therefore be the most efficiently priced and contain the least measurement error. Figure 1 on the following page plots the BBA official quotes for dollar LIBOR as the blue solid line; the red dashed line is the CIP-implied rate, calculated using equation (6) above with the end of the month closing prices for EURUSD spot and 3M forward exchange rates, 3M euro LIBOR, and \( t = \frac{1}{4} \).

Prior to August 2007, CIP based on LIBOR was an accurate model for forex markets, as shown by the close overlap of the two rates in Figure 1. From January 2003 to July 2007, the spread between the two rates averaged only 1.4 bps with a 6.3 bps standard deviation. This means that the domestic or foreign interest rates in equation (1) only need small adjustments of a few bps in order for the forward exchange rate calculated through CIP to perfectly equal the forward exchange rate actually quoted in the forex market.
When the first signs of the subprime mortgage crisis emerged in August 2007, a spread developed between the BBA quoted LIBOR and the CIP-implied rate. This spread continued to widen until it reached a peak of 260 bps following the Lehman Brothers bankruptcy in September 2008. As the turbulence in financial markets slowly dissipated, the spread fell substantially through 2009. My data range is therefore focused on a time period from January 2007 to January 2010, a three-year span covering the duration of the financial crisis and centered on the Lehman Brothers bankruptcy in September 2008. Over my three-year data range, the spread averaged more than 41 bps with a 49 bps standard deviation.
The spread between BBA LIBOR and CIP-implied rate in Figure 1 is plotted as the black long-dashed line in Figure 2. This CIP-implied CCB spread must be added to euro LIBOR in order for CIP to hold perfectly. For example, in September 2008, CIP would hold if 260 bps were subtracted from the euro LIBOR, thus bringing the red dashed line down to the blue solid line in Figure 1; alternatively, CIP would also hold if 260 bps were added to dollar LIBOR, thus bringing the blue solid line up to the red dashed line in Figure 1. While either of these adjustments would produce a perfect overlap in Figure 1, the CCB spread is defined as dollar LIBOR flat – the spread that must be added to the foreign LIBOR to make it fair against the dollar LIBOR. Figure 2 therefore correctly shows the CIP-implied CCB spread as negative; the euro LIBOR minus 260 bps is fair against the dollar LIBOR.

![EURUSD 3M Cross Currency Basis](image)

*Figure 2*
Prior to August 2007, Figure 2 shows that CIP historically was a reliable economic model that held accurately in the forex markets. However, the CIP model started faltering in the following months and appeared to nearly break down in September 2008, when an unprecedented deviation of 260 bps occurred. The Lehman Brothers bankruptcy sent shocks throughout all markets as credit risks and volatility increased drastically due to heightened uncertainty about the solvency of most financial institutions. The forex market in particular is interesting to analyze during this period, because its participants are inherently exposed to interest rate, credit and currency liquidity risks at the same time.

To begin my analysis, the graphs on the left hand side of Figure 3 show the data for the 3M, 6M and 12M terms of BBA LIBOR and CIP-implied rates. The right hand side graphs plot the difference between these two interest rates, the CIP-implied CCB spread, as the black long-dashed line; the green dotted line shows the quoted CCB spread on CCB swaps. CCB swaps are real financial instruments traded in the forex markets by market participants to raise liquidity in a foreign currency. Through a CCB swap, a European bank can offer euro collateral to receive dollar collateral today, on which it would pay LIBOR; at the same time, it would receive euro LIBOR payments from the counterparty on the euro collateral, until both parties returned the collaterals at maturity. The quoted CCB spread is the number of bps that must be added to the foreign LIBOR in order for both counterparties to consider the deal to be fair. Since CCB swaps are historically quoted and traded in longer maturities of one to thirty years, data on the 3M and 6M contracts is only available for the last two years.
All three terms show that CIP-implied rates deviated significantly from BBA quoted LIBOR in September 2008. The deviation is the greatest for the short term 3M contracts, which are the most volatile and more heavily influenced by daily events. The one-time turmoil of the Lehman bankruptcy only left a smaller impact on the longer 12M contracts, as market participants expected market conditions to return closer to normal over the course of the next twelve months. Correspondingly, the CCB
spreads are negative for all three terms on the right hand side of Figure 3. Even though the quoted CCB spread is calculated against dollar LIBOR flat, it does not necessarily mean the deviation occurred on the euro side. For example, in order for CIP to hold in September 2008, the negative CCB spread in the 3M term suggests that either quoted euro LIBOR is 260 bps too high, or quoted dollar LIBOR is 260 bps too low, or some combination in-between.

The reason I included the quoted CCB spread, on actual CCB swaps, in my graphs was to confirm that the CIP-implied CCB spread actually deviated so drastically using another data series. The match between the CIP-implied and quoted CCB spread is the closest for the short term 3M. The liquidity is the highest in the 3M contracts, so I would expect them to be priced most accurately in the market. While the 6M and 12M terms also tell a consistent story of a negative CCB spread deviation around September 2008, the two lines diverge slightly in the subsequent months. The explanations for a divergence between the CIP-implied and quoted CCB spreads are beyond the scope of my thesis. I will focus on explaining events surrounding September 2008, where both quoted and CIP-implied CCB spreads show highly significant and consistent negative deviations. Going forward, my references to “CCB spread” will refer to the CIP-implied CCB spread, the difference between BBA quoted LIBOR and CIP-implied rates, as shown by the black long-dashed line in the right hand graphs of Figure 3. The CCB spread is therefore my measure of CIP deviations.
(5) Analysis of Observed CIP Deviations

The second objective of my paper is to analyze the causes of the observed CIP deviations described above. As presented by Baba et al. (2008), there are three possible reasons why a deviation from CIP may have occurred: credit risk premium, dollar liquidity premium or underreporting of LIBOR. Given that we know the CCB spread to be negative, each reason is only viable in explaining that either the dollar LIBOR is underestimated, or the euro LIBOR is overestimated, but not both.

First, the credit risk premium on euro LIBOR (\( \tilde{p} \)) may have increased substantially compared to the dollar LIBOR premium (\( p \)). This reason is best understood through equation (4), reproduced below:

\[
\left( \frac{F_t - S_0}{S_0} \right) \approx t\left[(i - \tilde{i}) + (\tilde{p} - p) - x\right]
\]

(4)

Since CIP operates on risk-free interest rates, it is only accurate if both the dollar (\( p \)) and euro (\( \tilde{p} \)) LIBOR premiums are small and equal so they cancel out in equation (4). Since the CCB spread (\( x \)) is negative, the credit risk argument is only valid in explaining a deviation on the euro LIBOR side as follows: the euro LIBOR premium (\( \tilde{p} \)) rose substantially compared to the dollar LIBOR premium (\( p \)), resulting in a significant positive difference in the two LIBOR premiums (\( \tilde{p} - p \)). Therefore, a CCB spread (\( x \)) must be subtracted from euro LIBOR to remove the excess credit risk premium in order for CIP based on risk-free interest rates to hold.

In existing literature, both Coffey et al. (2009) and Baba et al. (2009) found credit risk premiums to be statistically significant determinants of observed CIP deviations. While I do agree that an increased difference in euro and dollar LIBOR
premiums \((\hat{p} - p)\) explains part of the CIP deviation, it is unlikely to explain the full 260 bps deviation. At the end of September 2008, 3M euro LIBOR was quoted at 5.27%; subtracting the full CCB spread of 260 bps implies that euro LIBOR of 2.66% is fair against dollar LIBOR, quoted at 4.05%. It seems implausible that CIP and the forex markets would price euro interest rates lower than dollar interest rates by up to 1.4%; euro LIBOR at 2.66% would be almost halfway between the dollar LIBOR at 4.05% and the Treasury yield of 0.90%.

Furthermore, Figure 4 shows that fifteen out of the sixteen panel banks in the dollar and euro LIBOR surveys are the same (BBA 2010a). Each bank’s credit spread over the risk-free interest rate should be equally reflected in the bank’s dollar and euro LIBOR quotes. Unless investors somehow perceive the branch borrowing in euro to be less credit worthy than the branch borrowing in dollars, the credit risk premium difference between dollar and euro LIBOR \((\hat{p} - p)\) should be relatively small.

<table>
<thead>
<tr>
<th>Name of Bank</th>
<th>USD LIBOR (16)</th>
<th>EUR LIBOR (16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank of America</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Bank of Tokyo-Mitsubishi UFJ Ltd</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Barclays Bank plc</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Citibank NA</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Credit Suisse</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Deutsche Bank AG</td>
<td>X</td>
<td>X</td>
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<tr>
<td>HSBC</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>JP Morgan Chase</td>
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<td>Mizuho Corporate Bank</td>
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<td>WestLB AG</td>
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Figure 4
Second, a supply and demand imbalance for dollar liquidity may have caused the forex markets to price in a liquidity premium for dollars. The Lehman Brothers bankruptcy demonstrated the deadly consequences of high leverage and low dollar cash liquidity during a financial crisis. Financial institutions rushed to accumulate dollar liquidity to pad their balance sheets in order to protect themselves from potential bank runs. As financial institutions deleveraged, prices of assets in all markets, ranging from real estate to equities and commodities, plummeted and exacerbated the already dire situation.

Searching for more ways to source dollar liquidity, financial institutions turned to the forex markets. Through a CCB swap, a bank could offer to give up euro as collateral to receive dollar collateral immediately; the bank would then pay dollar LIBOR and receive euro LIBOR payments until the collaterals were returned at maturity. It is possible that the high demand for dollar liquidity greatly exceeded the supply, so banks started to pay a premium spread over dollar LIBOR in order to find counterparties who considered the trade to be fair. An alternative way of thinking about this spread is that banks were willing to pay dollar LIBOR on the dollar collateral they borrowed in exchange for only receiving euro LIBOR minus a spread on the euro collateral they lent out. This reasoning therefore provides a possible second explanation for the negative CCB spread seen in the forex markets.

However, if banks were truly borrowing in the forex market at a premium spread over LIBOR because of the shortage of dollar liquidity everywhere, then the banks should have reported this higher interest rate to the BBA in the LIBOR panel survey. If dollar LIBOR represented the true borrowing costs for financial institutions,
then there would be no need to add a spread to dollar LIBOR in the CCB swap market in order for both parties to consider the trade to be fair. This deviation would only occur if banks and institutions were actually borrowing dollars in the forex markets at a premium spread to the interest rates reported by the sixteen LIBOR panel banks as the official borrowing costs. If this were the case, LIBOR failed to be an accurate indicator of true borrowing costs in the economy; a spread was necessary to adjust LIBOR to an accurate level, because the LIBOR survey of the sixteen panel banks underreported true borrowing costs.

Third, following the credit risk and liquidity premium reasons, I would like to focus my main analysis on whether an underreported dollar LIBOR may explain the observed CIP deviations. I will compare the BBA quoted LIBOR and the CIP-implied rates to an alternative measure of interest rates, the Term Fed Funds (TFF). In order to better understand which interest rate accurately reflects true borrowing costs for banks it is of imperative to first understand how each series is calculated.

The British Banker’s Association (BBA) calculates the dollar and euro LIBOR daily by polling sixteen designated contributor panel banks on their uncollateralized borrowing rates. After BBA discards the four highest and the four lowest reported rates, LIBOR is calculated as an average of the middle eight borrowing rates. The banks are asked to report, “At what rate could you borrow funds, were you to do so by asking for and then accepting inter-bank offers in a reasonable market size just prior to 11 am?” (BBA 2010b). However, this definition can be problematic during periods of financial distress. When banks are worried about their liquidity and solvency, they may be inclined to underestimate their true borrowing rates. Since the individual
rates submitted by panel banks are released daily, no bank wants to be the one that consistently reports the highest borrowing rate in the LIBOR survey; this may give investors a perception that the bank is in financial trouble and could lead to a run on the bank. Furthermore, banks are not prohibited from talking to each other or interbank dealers before submitting their borrowing rates to BBA at 11:00AM London time; individual banks may therefore form expectations about what rates other banks will be reporting and adjust its reported rate lower accordingly. There is no obligation that the bank actually borrow or be able to borrow funds at the reported rate.

Term Fed Funds (TFF) are unsecured loans of bank deposits held at the Federal Reserve. If an individual bank does not have enough funds deposited at the Fed to meet its reserve requirements, it may borrow funds from another bank that has funds deposited at the Fed in excess of its reserve requirements. Most of the liquidity lies in loan terms under 90 days, though longer-term contracts up to one year are available. Data on TFF rates is provided on Bloomberg by the function GFED03M Index (also GFED06M and GFED12M). Bloomberg sources its data from ICAP, the largest inter-dealer broker in the world, headquartered in London. ICAP is one of the brokers that provide transaction data to the Fed for calculating the official effective overnight Fed Funds rate (Wrightson ICAP 2010). Speaking with ICAP representatives, they explained to me that the TFF data is driven based on market activity on their Fed Funds broker dealer desk (Hoban 2010). TFF data points re the best offers by financial institutions with the highest credit rating looking to lend their excess Fed deposits; they are not averages of actual deals on a particular day. The key difference between the BBA LIBOR and the TFF rates is that TFF quotes are actual
offers of dollar liquidity in the market; BBA LIBOR quotes are based on what interest rate the buyer (bid) side thinks they will be able to obtain dollar liquidity, but liquidity does not necessarily have to be present at that interest rate.

Figure 5 below shows the BBA quoted LIBOR and CIP-implied rate from Figure 1, but also adds the TFF rates as the green dotted line. The difference between the CIP-implied rate and the BBA quoted LIBOR is the CCB spread, my measure of CIP deviations, as shown by the black long-dashed line in Figure 3.

![USD LIBOR 12M Comparisons](image)

Figure 5

The most important observation on Figure 5 is the almost perfect overlap between the CIP-implied LIBOR and the TFF rates, especially in the months preceding and following the events of September 2008. The dollar interest rates implied by CIP are nearly identical to the TFF rates reported by ICAP, both of which reveal that true
dollar interest rates were significantly higher than the BBA quoted LIBOR. Based on this data in Figure 5, I argue that LIBOR panel banks actually underreported LIBOR during the financial crisis. Banks were almost certainly sourcing dollar liquidity at much higher interest rates closer to TFF rates, which were the best offers for dollar deposit loans seen by the largest interdealer broker. Given the significant role that interdealer brokers play in interest rate markets, it is unlikely that banks would be able to find dollar deposit liquidity at significantly lower interest rates than those seen by the world’s largest interdealer broker.

However, the LIBOR panel banks probably did not want to report their true high borrowing rates; they feared investors would judge them as risky and potentially insolvent, which could quickly spark a run on the bank. Following the Lehman Brothers bankruptcy, banks were extremely concerned about appearing credit worthy to their shareholders. For this reason, none of the sixteen panel banks wanted to be the one who consistently reported the highest borrowing rates in the LIBOR survey because of high credit risk premiums. Since there is no guarantee that dollar liquidity may be found at the reported LIBOR, TFF rates may be a more accurate indicator of true interest rates. TFF rates are real offers of dollar liquidity; there is a market participant willing to lend dollar deposits at the TFF rate.

Furthermore, it would be incorrect to argue that the full CCB spread between BBA quoted LIBOR and the CIP-implied rate may be explained by the bid/ask spread on dollar interest rates. ICAP representatives informed me that the bid/ask spread usually oscillates around 10 bps, but increased up to about 30 bps during the crisis. In comparison, the market 12M CCB spread was more than 140 bps in September 2008.
The LIBOR panel banks are supposed to report the interest rate offers at which they can borrow dollar funds; however, even if the panel banks reported their bids instead, the bid/ask spread by itself is too small to explain the CCB spread. I thus argue that the underreporting of borrowing rates cannot be attributed to the bid/ask spread, but rather was a deliberate action by the panel banks.

While the overlap between the CIP-implied rates and the TFF rates is not as strong in the 6M and 3M term contracts, shown in Figures 6 and 7 below, the data still supports my main argument that LIBOR is underreported.

Figure 6
Even in the 6M and 3M terms, the TFF explains the majority of the observed CIP deviations. The remaining gap of about 100 bps between the CIP-implied rate and the TFF rate may most likely be explained by the dollar liquidity premium. Any market participant can source dollar liquidity through the forex markets, but only U.S. banks may use TFF to meet their reserve requirements at the Fed. As financial institutions around the world, especially in Europe, rushed to the forex markets to raise dollar liquidity to cover their liabilities, they bought CCB swaps and bid up CIP-implied rates on dollars. Many of these foreign financial institutions were not eligible to borrow dollars through the TFF or other Fed programs, such as discount window lending or the Troubled Asset Relief Program. It is therefore reasonable that the CIP-implied rate may include a dollar liquidity premium over the TFF rate.
(6) Conclusion

The no-arbitrage CIP model was put to test by the explosion in credit risk premiums and the dollar liquidity shortage during the 2008 financial crisis. In my paper, I argue that credit risk and dollar liquidity premiums alone are unlikely to be large enough in magnitude to justify the full CIP deviations of up to 260 bps. Instead, I show that the majority of the alleged CIP deviation disappears when TFF rates are used instead of LIBOR. In the longer-term 12M contracts, the overlap between CIP-implied rates and the TFF rates is almost perfect; in the shorter-term contract, a small deviation still remains, which is attributable to the dollar liquidity premium.

My observations have two critical implications. First, they demonstrate that during the financial crisis the no-arbitrage based CIP did not necessarily fail as a model, but rather inaccurate LIBOR interest rates were used in the calculations that resulted in the observed CIP deviations. Second, they suggest that LIBOR breaks down as an accurate measure of interest rates during financial crises. The TFF rates are a more accurate indicator of true borrowing costs because they quote the best offers for dollar liquidity as seen by the world’s largest interdealer broker, ICAP. The difference between TFF rates and quoted LIBOR implies that the BBA panel banks underreported LIBOR by at least 100 bps in September 2008. Based on the WSJ’s estimate that LIBOR is linked to more than $90 trillion of financial derivatives, even a 100 bps inaccuracy in LIBOR could lead to misallocations of trillions of dollars between market participants. Further research should focus on confirming whether the remaining gap between the TFF rate and the CIP-implied rate is indeed the result of the dollar liquidity premium, especially in the shorter 3M and 6M terms.
(7) Bibliography


