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Investigating the cross currency basis in EURUSD and EURGBP

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No. 227

**Investigating the cross currency basis in
EURUSD and EURGBP**

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Abstract

The fundamental premise upon which the pricing of major FX derivatives rests is the Covered Interest Parity (CIP), and a violation is seen as a reflection of potential capital market inefficiencies. CIP postulates that FX forward prices simply reflect the interest rate differential between the two currencies. This has been the case before the global financial crisis. During the 2008 financial and 2011 European debt crises, market prices deviated significantly from the theoretical CIP-implied prices, and the deviations persist at noticeable levels until present.

This paper documents and analyzes the pronounced nature of the *EURUSD* and *EURGBP* CIP violations from 2007 to 2019. We explain the basis in terms of five driving factors: credit risk differential, funding liquidity differences, measurement error, hedging demand imbalance, and new constraints to arbitrage. Furthermore, we carry out a term structure analysis, showing the varying dynamics of CIP violations across maturities and over time. Lastly, we test a statistical approach to adjust the interest rate differential formula bringing the theoretical prices closer to market (i.e., reducing CIP deviation).

Key words: cross-currency basis, covered interest parity, CIP deviation, EURUSD basis, EURGBP basis, FX swaps, FX forwards, cross-currency basis swaps

JEL classification: E30, E42, E44, G15

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Content

| | |
|--|----|
| 1. Introduction..... | 4 |
| 2. An overview of concepts | 5 |
| 2.1 Forwards | 5 |
| 2.2 Foreign exchange swaps | 6 |
| 2.3 Cross currency basis swaps | 7 |
| 3. Literature on Covered Interest Parity (CIP) deviations | 8 |
| 4. General analysis of the cross currency basis | 10 |
| 4.1 Short-term CIP deviation in FX swaps and forwards..... | 10 |
| 4.2 Long-term CIP deviation in cross currency basis swaps..... | 12 |
| 5. The determinants of the cross currency basis | 13 |
| 5.1 Credit risk differential | 13 |
| 5.2 Funding liquidity differences | 16 |
| 5.3 Measurement error..... | 18 |
| 5.4 Hedging demand and diverging monetary environment | 19 |
| 5.5 Regulation and capital constraints in exploiting arbitrage | 21 |
| 6. Term structure of the cross currency basis | 22 |
| 7. Pricing implications | 23 |
| 7.1 Pricing adjustment | 24 |
| 7.2 Back test results | 25 |
| 8. Conclusion | 27 |
| Bibliography | 29 |

1. Introduction

The fundamental premise upon which the pricing of major foreign exchange (FX) derivatives rests is the Covered Interest Parity (CIP) condition. A violation is seen as a reflection of potential capital market inefficiencies, as well as an opportunity for arbitrageurs to lock in a riskless profit. CIP – named by researchers the “bedrock of international economics” – postulates that FX forward prices simply reflect the interest rate differential between the two currencies. This was the case before the global financial crisis. However, during the 2008 financial and 2011 European debt crises, market prices deviated significantly from the theoretical CIP prices, and the deviations continue to persist at noticeable levels.

The increased usage of FX and cross currency basis (XCCY) swaps in the past decade and the overall scale of FX derivatives – globally the second largest over-the-counter (OTC) derivatives market¹ – make the understanding of CIP deviations highly relevant. A reconciliation of the theoretical prices with the market not only presents trading opportunities for arbitrageurs or speculators but is also important for treasury operations with underlying business needs. These include banks (hedging their balance sheet FX risk), corporates (raising funds, hedging their cash flows, or managing their liquidity with a global approach), and investors (seeking FX-hedged yield enhancement).

Numerous studies have been undertaken to explain the drivers of CIP deviations (hereafter “cross currency basis” or simply “basis”). Baba and Packer (2008) and Coffey et al. (2009) linked the *EURUSD* basis during the financial crisis to the short-term interbank credit risk differences and the *USD* funding shortage. Similar factors are believed to have driven the basis during the European debt crisis (Bottazzi et al. (2012), Leonhardt et al. (2015)). What has puzzled practitioners and researchers is the persistence of the basis after these crises, when short-term strains in the market had eased. Borio et al. (2016) and Liao (2016) identified one-sided hedging demand and new constraints to arbitrage as the main drivers from 2014 onwards. The former is driven by the diverging monetary policies around the world, whereas the latter is a function of the new rules that have limited the ability of market players to clear the market.

Although there is extensive research on the causes of the basis, two crucial research gaps still exist. First, there is little work on the pricing implications of the basis determinants. The existing papers identify the drivers of the basis both qualitatively and empirically. However, researchers have stopped short of taking the next step and adjusting the classic interest rate differential formula as to bring the theoretical prices of FX forwards, as well as FX and cross currency basis swaps, into line with, or at least close to, market prices. Wong and Zhang (2018) are among the few authors to propose a basic credit risk adjustment to the pricing formula by statistically separating credit and funding liquidity risks embedded in the interbank benchmark rates. On the whole, researchers have overlooked the basis term structure (i.e., varying levels of CIP

¹ *USD* 95.8 trillion in outstanding notional amount, and *USD* 2.6 trillion in gross market value (BIS, 2018).

deviations in different tenors). Borio et al. (2018) are among the few to study the term structure of the basis in terms of its determinants.

This paper expands the literature by establishing a better understanding of the causes of the basis, contains a discussion of the term structure, and indicates possible pricing implications. The objective is threefold. First, we provide a general analysis of the short- and long-term bases for *EURUSD* and *EURGBP* pairs through a study of their drivers. Second, we take an in-depth look into the term structure of the basis for the same currency pairs. Lastly, based on the empirical findings of Wong and Zhang (2018), we present a test of a statistical approach to adjust the interest rate differential formula for pricing 3-month *EURUSD* FX swaps. This paper also includes an examination of the adjustment method through back tests in terms of bringing the theoretical prices closer to market.

We document the pronounced nature of the *EURUSD* and *EURGBP* bases during the global financial and European debt crises, as well as their persistence after the crises. We explain the basis in terms of five driving factors: credit risk differential, funding liquidity differences, measurement error, hedging demand imbalance, and new constraints to arbitrage. The term structure analysis indicates that the 3-month basis was the highest during the two crises, as were the short-term credit and funding liquidity strains. The longer-term basis (1 to 10 years) was comparatively insignificant during the two crises but increased substantially after 2014 to some degree following the diverging monetary policy of the euro area compared to that of the US and the UK. Finally, we demonstrate in a back test that a statistical adjustment to the interest rate differential formula reduces the distance of the theoretical 3-month *EURUSD* FX swap price to market by 36%. This result is in line with the notion among market participants that the basis has increasingly become a risk factor on its own, being more a function of supply and demand than of arbitrage.

2. An overview of concepts

2.1 Forwards

The forward exchange rate is based on the no-arbitrage principle and is calculated with the following formula:

$$F_T = S_0 \cdot \frac{(1 + r_q \cdot \frac{D}{Tr_q})}{(1 + r_b \cdot \frac{D}{Tr_b})} \quad \text{Equation (1)}$$

where F_T and S_0 are the forward and spot rates, respectively. The term to the right side of S_0 represents the so-called interest rate differential, where r_q is the nominal interest rate for the quoted currency (e.g., *USD* in the *EURUSD* pair), r_b denotes the nominal interest rate for the base currency (e.g., *EUR* in the *EURUSD* pair), and D represents the maturity of the forward

contract. T_{r_q} and T_{r_b} reflect the day count convention for the interest rate in quoted and base currencies, respectively.²

The derivation of Equation (1) is based on the no-arbitrage concept, whereby, in an efficient market, one should not be able to lock in a guaranteed profit without taking any risks. Suppose that a European investor wants to invest *EUR* 100 for a period of one year and have euros in the end. For an easier conceptual understanding we are using full years and disregarding deviating day count conventions, the two alternatives are:

A) Direct investment

- invest euros at *EUR* interest rate r_b and receive $EUR\ 100 \cdot (1 + r_b)$ in one year.

B) Synthetic investment

- convert *EUR* 100 to *USD* in the spot market, receiving $USD\ 100 \cdot S_0$;
- enter into a zero-cost forward contract, locking in the forward exchange rate F_T ;
- invest $USD\ 100 \cdot S_0$ at *USD* interest rate r_q and receive $USD\ 100 \cdot S_0 \cdot (1 + r_q)$ in one year;
- convert $USD\ 100 \cdot S_0 \cdot (1 + r_q)$ back to *EUR* in one year at F_T and receive $\frac{EUR\ 100 \cdot S_0 \cdot (1 + r_q)}{F_T}$.

In the absence of arbitrage, both direct and synthetic returns should be the same, implying

$$EUR\ 100 \cdot (1 + r_b) = \frac{EUR\ 100 \cdot S_0 \cdot (1 + r_q)}{F_T}$$

Solving for F_T yields the forward price in Equation 1. If the market forward price is lower than the theoretical F_T , arbitrageurs could borrow in *EUR*, convert it to *USD* in the spot market, invest the *USD*, cover the exchange rate risk with a forward, and gain a riskless profit. In the presence of such arbitrage opportunities, the forces of supply and demand are believed to ensure that the market forward rate is in line with the theoretical forward rate derived from the classic interest rate differential formula.

2.2 Foreign exchange swaps

Through FX swaps, one entity can exchange a currency at a spot rate while simultaneously agreeing to exchange back at maturity at a forward rate. Structurally, it can be seen as a combination of both spot and forward contracts.³ Furthermore, FX swaps are mainly short term, with highest liquidity applying to tenors of up to one year. Figure 1 shows the basic structure of an FX swap.

² As a matter of convention, D/T_r varies by currency and market type (money market vs. capital market).

³ The markets quote FX swaps as “swap points”, $F_T - S_0$ in pips, where F_T is the forward rate and S_0 is the spot rate. One pip is 1/10000 of the exchange rate (that is, the fourth decimal point in the quoted number).

Among users of FX swaps are corporate treasuries seeking to hedge their FX operations. Typically, a treasury separates the forward into a spot and a FX swap component. On the one hand, this maximizes the chance for natural hedges in the spot component. On the other hand, it is easier to time the transactions and understand the different risks involved.

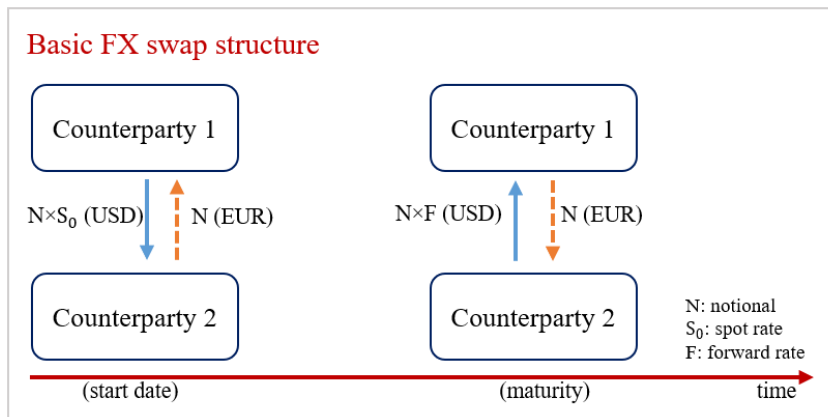


Figure 1: Basic FX swap structure

Unlike outright forwards that involve an exchange of currencies only at maturity, parties in an FX swap exchange the notional amounts in the beginning, effectively making the arrangement secured and almost eliminating the counterparty risk. However, there is still a small risk involved in FX swaps as far as the mark-to-market valuation is concerned.

2.3 Cross currency basis swaps

While FX outright forwards and FX swaps are utilized mainly for short maturities, market participants use cross currency basis (XCCY) swaps for maturities of more than 1 year (and generally up to 30 years). Figure 2 demonstrates the cash flows involved in an XCCY swap.

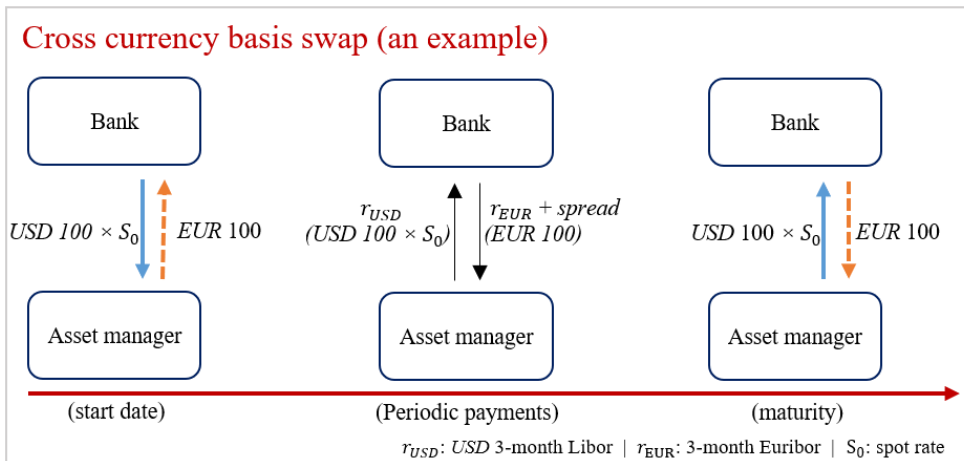


Figure 2: Cross currency basis swap (example)

The counterparties exchange the notional amounts in the beginning at the spot rate, effectively making an XCCY swap a secured arrangement. The asset manager pays $EUR\ 100$ and receives $USD\ 100 * S_0$ from the bank, thereby obtaining synthetic USD funding. During the tenor of the contract, periodic payments are made based on certain benchmarks. In this example, the asset manager pays a 3-month USD Libor rate, while the bank pays 3-month Euribor rate plus a spread. Note that the spread can be either positive or negative, and the market convention for quoting the spread depends on the currency pairs. In a $EURUSD$ XCCY, the USD leg pays USD Libor flat rate, and the spread is added to the EUR leg. The EUR leg is flat in a $EURGBP$ XCCY swap. At maturity, the counterparties exchange back the notional amounts, again at the spot exchange rate S_0 .

3. Literature on Covered Interest Parity (CIP) deviations

Covered Interest Parity (CIP) is among the most recognized concepts in international finance. Keynes is known to have first explained the CIP concept in 1923, leading to the classical no-arbitrage pricing of FX forwards, FX swaps, and XCCY swap. In addition, CIP stipulates that the FX forward premium should simply reflect the interest rate differential between the two currencies (see Equation 1), provided that the two funding securities in two different currencies meet the comparability criteria: equal maturity and similar liquidity, as well as political and default risks (Akram et al. (2008), Frenkel and Levich (1975)). Additionally, Coffey et al. (2009) highlighted the importance of correct measurement of CIP inputs and the availability of arbitrage capital in order for CIP to hold.

However, CIP must not be confused with the Uncovered Interest Parity (UIP). The former is a pricing concept based on the no-arbitrage replication principle, while the latter postulates a prediction for future spot price. UIP is beyond the scope of this paper.

For most currencies, CIP held incredibly well (i.e., there is no cross currency basis) before the 2008 financial crisis. Starting in 2008, market participants realized substantial CIP violations both in the short end (FX forwards and swaps) and the long end (XCCY swaps). Baba and

Packer (2008) were the first ones to document large CIP deviations in the literature. They calculated implied *USD* Libor rates based on the classic interest rate differential formula and compared them to the actual *USD* Libor from August 2007 to September 2008, recording a deviation of as high as 40 basis points in September 2017. They explained the effect by the *USD* funding shortage arising from credit risk differentials between the two currencies. Due to the *USD* funding shortage in the interbank market, European financial institutions without a natural dollar deposit base but with high levels of *USD* assets turned to the FX swap market. On the other hand, *USD* providers started hoarding the currency, squeezing the supply of direct and synthetic *USD* funding.

In a two-hypotheses setting, Baba and Packer (2008) highlighted relative credit default swap CDS differentials between banks of the US and the euro area as significant in explaining the CIP deviation. Additionally, the dollar auctions of the European Central Bank (ECB) - supported by swap lines from the Federal Reserve (Fed) - aimed at fighting the dollar shortage were found to have reduced the volatility of CIP deviation.

Coffey et al. (2009) expanded on Baba and Packer's (2008) work, analyzing the period right after Lehman's default. While the *USD* funding squeeze drove the CIP deviation in the period leading to the default of Lehman, credit risk clearly dominated as the driver in the post-Lehman period.

A number of studies have been conducted to assess the violations of CIP during the European debt crisis, focusing on the FX swap and XCCY swap levels for the *EURUSD* pairs. Bottazzi et al. (2012) documented the decrease in the level of CIP deviations following the peak of the financial crisis, as well as the subsequent increase during the 2011-2012 European debt crisis. They identified the credit risk of banks as a common factor driving CIP deviation in both the global financial crisis and the European debt crisis.

Leonhardt et al. (2015) carried out a statistical analysis of CIP deviations during the global financial crisis, the European debt crisis, and the period in between. Compared to Baba and Packer (2008), the authors conducted a volatility-based econometric analysis, concluding that the volatility of forward premiums (forward minus spot rate) is significantly impacted by the volatility of FX forward bid-ask spreads and the risk in the interbank market.

Overall, the studies described above have pointed to funding liquidity, counterparty risks, and the overall pressures in the interbank markets as potential drivers of the basis. However researchers and practitioners are puzzled by the significant persistence of CIP deviations after the two crises, when markets had already recovered.

Borio et al. (2016) are among the first researchers to carry out a post-crisis study of the CIP deviations. Their study involves the *USDJPY*. Here, the key drivers of the basis are found to be the increased hedging demand and the new constraints on arbitrage activity. The former comes from loose monetary policy in Japan, leading to US corporations issuing *JPY* bonds and using XCCY swaps to convert to *USD*. Additionally, the Japanese banks' own needs to fund their

USD assets through swaps decreased their role as arbitrage players who would otherwise decrease the mispricing. By using quantifiable proxies and covering a period of 2007 to 2015, the authors established the significant explanatory power of hedging demand and arbitrage constraints on the increased levels of CIP violations.⁴ They further documented quarter-end spikes in the basis, indicating a decreased level of arbitrage activity at quarter ends due to the banks' reporting needs on regulatory ratios and potential quarter-end window-dressing activities.

Liao (2016) analyzed the post-crisis CIP deviations for the *EURUSD* pair and similarly identified the diverging monetary policies of the ECB and the Fed, the US money market reform of 2016, and the increased difficulty of carrying out arbitrage as key drivers.

Borio et al. (2018) are among the few researchers to analyze the term structure of CIP violations – the level to which long-term deviations differ from short-term deviations. The authors' Principle Component Analysis demonstrates that the level of the CIP deviations is driven by hedging demand imbalances between the two currencies, while the slope is mainly affected by temporary interbank strains in terms of credit risk and funding shortages. For the *EURUSD* pair, the authors found that 76% of the variance in the CIP deviation is explained by the level factor; the rest is mainly attributable to the slope factor. However, it is very difficult to interpret these factors economically. The authors also reported that, during the financial crisis, the CIP deviation was much higher for short-term instruments than for long-term XCCY swaps. The post-crisis period of 2014 to 2018 demonstrates a U shape, indicating a small deviation at the short end, a larger deviation in certain middle points of the term structure, and again a small deviation at longer tenors (all in negative terms).

4. General analysis of the cross currency basis

4.1 Short-term CIP deviation in FX swaps and forwards

Short-term CIP violation is broadly defined as the difference between the market price of FX swaps or forwards and the theoretical price as calculated with the classic interest rate differential formula. One can also assess the CIP deviation by looking at the actual interbank benchmark rate and comparing it to the theoretically implied interest rate. In line with existing literature (Baba and Packer (2008), Coffey et al. (2009), Mancini-Griffoli and Ranaldo (2011), Choi et al. (2016), Liao (2017)), we used the following formula to capture the *EURUSD* short-term CIP deviation:

$$EURUSD \text{ CIP deviation}_{3M} = r_{q,3M} - \left[\frac{\left(\frac{F_{3M}}{S_0} \cdot \left(1 + r_{b,3M} \cdot \frac{D}{Tr_b} \right) - 1 \right) \cdot Tr_q}{D} \right] \quad \text{Equation (2)}$$

⁴ Hedging demand proxies used: net *USD* claims of Japanese banks, US companies' *JPY* bond issues, and Japanese insurance companies' *USD* bond portfolios. Arbitrage constraint proxy used: Repo spreads in the US and Japan.

The second term on the right side of Equation 2 represents the implied interbank benchmark rate in the quoted currency (*USD* Libor in *EURUSD*) and was derived by rearranging Equation 1. The first term on the right side is the actual *USD* Libor.

As can be seen in Figure 3, the short-term CIP deviation had been close to zero prior to the financial crisis, meaning both the FX swap implied *USD* Libor and the actual *USD* Libor rates were the same, as CIP would predict. During the global financial crisis, the basis became significantly negative, reaching 250 (negative) basis points in September 2008. Negative basis means that the Libor rate implied by the market FX swap rates is higher than the Libor rate in the interbank market. During the financial crisis, it became significantly more expensive to borrow dollars synthetically through the FX swap market than directly in the interbank market.

This phenomenon was observed again during the European debt crisis though at a smaller magnitude. At its peak, the CIP deviation reached approximately minus 150 basis points, making synthetic dollar funding costlier. Following the European debt crisis, in late 2013, when markets had already calmed and credit restraints eased, the basis returned to the zero territory. However, from late 2014 onwards, the basis drifted back to negative territory and stayed there. This was a surprise for market observers, who had previously believed that the phenomenon was merely a crisis-related development.

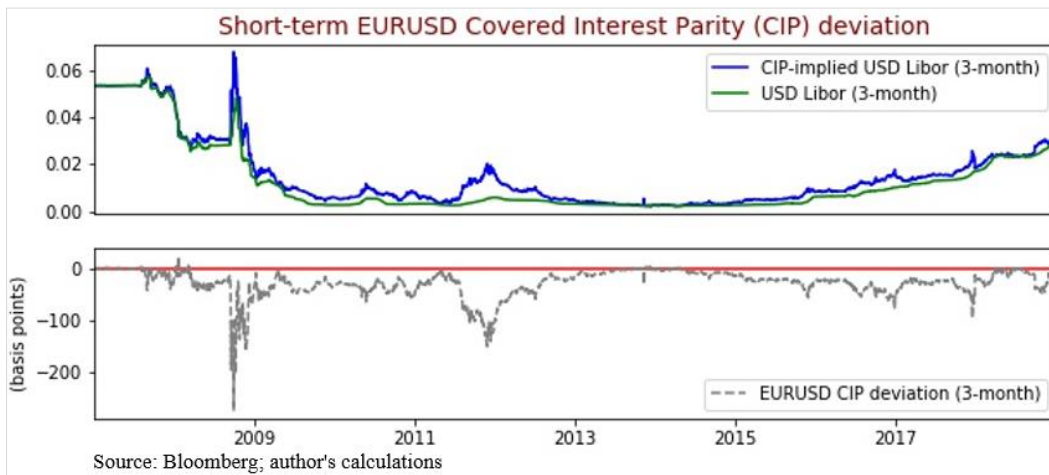


Figure 3: Short-term *EURUSD* Covered Interest Parity (CIP) deviation

As for the *EURGBP* pair, we define the short-term CIP deviation as the difference between actual *EUR* Libor and the *EUR* Libor rate implied by the interest rate differential formula. Accordingly, the following formula applies:

$$EURGBP\ CIP\ deviation_{3M} = r_{b,3M} - \left[\frac{\left(\frac{S_0}{F_{3M}} \cdot \left(1 + r_{q,3M} \cdot \frac{D}{Trq} \right) - 1 \right) \cdot Tr_b}{D} \right] \quad \text{Equation (3)}$$

The second term on the right side of Equation 3 represents the implied interbank benchmark rate in the base currency (*EUR* Libor in the *EURGBP* pair) and was derived by rearranging Equation 1. The first term on the right side is the actual *EUR* Libor.

Figure 4 illustrates the short-term basis for the *EURGBP* pair. Again, there were significant spikes during the two crises. During the European debt crisis, in particular in November 2011, the basis became as wide as 132 (positive) basis points, reflecting a lower cost of synthetic *EUR* funding than in the interbank market (or put another way, a higher cost of synthetic *GBP* funding). However, the *EURGBP* basis opens in the other direction during the 2008 – 2009 period, reaching over 75 (negative) basis points, and reflecting market conditions where the cost of synthetic *EUR* funding was higher than in the interbank markets. The post-crises persistence of CIP deviation also applies.

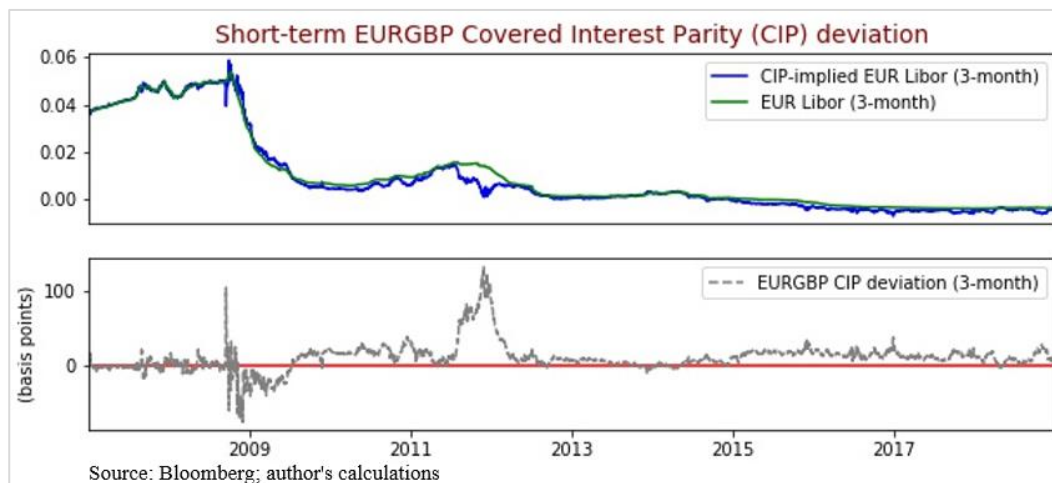


Figure 4: Short-term EURGBP Covered Interest Parity (CIP) deviation

4.2 Long-term CIP deviation in cross currency basis swaps

The long-term CIP deviation can be directly observed in the market through the quoted XCCY swap spreads. Theoretically, CIP should ensure that a XCCY swap trades without a spread. That is, a simple exchange of Euribor against *GBP* Libor or Euribor against *USD* Libor should be fair. A negative XCCY spread for the *EURUSD* pair and a positive XCCY swap spread for the *EURGBP* pair reflect higher synthetic funding costs compared to the benchmark in *USD* and *GBP*, respectively.⁵

Practically, however, the basis has been anything but zero since the start of the global financial crisis. As seen in Figure 5, the *EURUSD* 5-year XCCY swap spread (one of the most liquid instruments) has increased significantly in the negative direction around the times of the global financial and European debt crises, reaching the peaks of negative 61 and negative 67 basis points, respectively. Shortly after reverting to zero in mid-2014, the basis opened again and has persisted until the present time. Similar observations apply to the *EURGBP* pair.

⁵ Recall that by convention the quoted spread is on the *EUR* and *GBP* legs for *EURUSD* and *EURGBP* pairs, respectively.

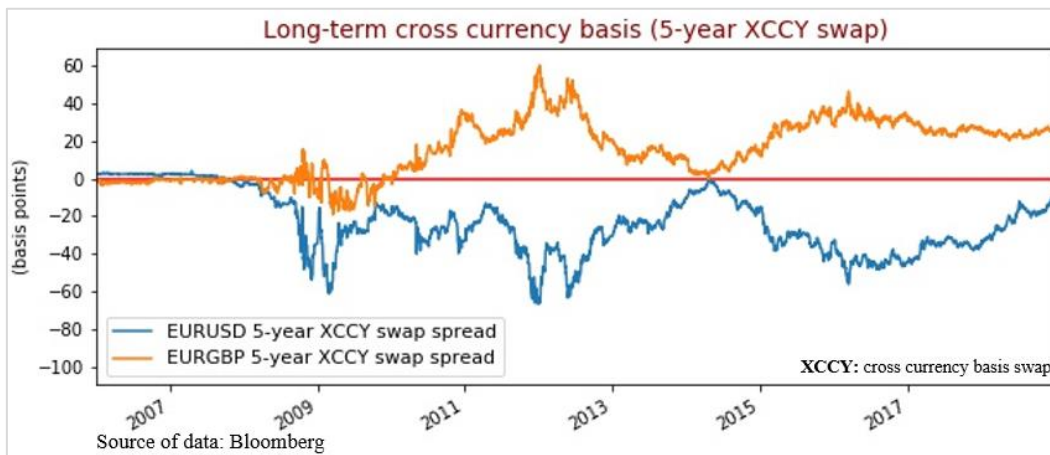


Figure 5: Long-term cross currency basis swaps (5-year XCCY swaps)

5. The determinants of the cross currency basis

5.1 Credit risk differential

One of the main determinants of the CIP deviations since the start of the financial crisis is the difference in credit risk embedded in the interbank benchmark rates. There is a strong consensus among researchers that CIP should hold if the two interbank market securities used in the replication are similar in all aspects except for currency (Aliber (1973), Frenkel and Levich (1975), Dooley and Isard (1980), Akram et al. (2008)). Until 2008, interbank lending was considered risk free, leading dealers to quote FX swap rates calculated by simply looking at the Libor rates. However, post-2008 Libor rates have considerable credit risks embedded, which makes it incorrect to use them in the classic interest rate differential formula without adjustment.

Seen from another perspective, FX swaps are close to secured transactions since the principles are exchanged at initiation. Euribor and Libor are unsecured. Unless the embedded credit risk is similar in the interbank benchmark rates, there will be a difference between the theoretical and market FX swap rates. In the case of XCCY swaps, two counterparties borrow from each other in two different currencies in a secured way, given the exchange of notional amounts at the start. If the unsecured 3-month Euribor has a higher embedded credit risk than unsecured 3-month *USD* Libor, the implicit Euribor would not be fair against the *USD* Libor. Hence, the Euribor leg needs to be adjusted down for the XCCY swap to trade fair (Wong and Zhang, 2018).

The key is to understand that one reason that CIP does not hold is simply due to the fact that Libor (or Euribor) rates in different currencies differ in respect to credit risk.

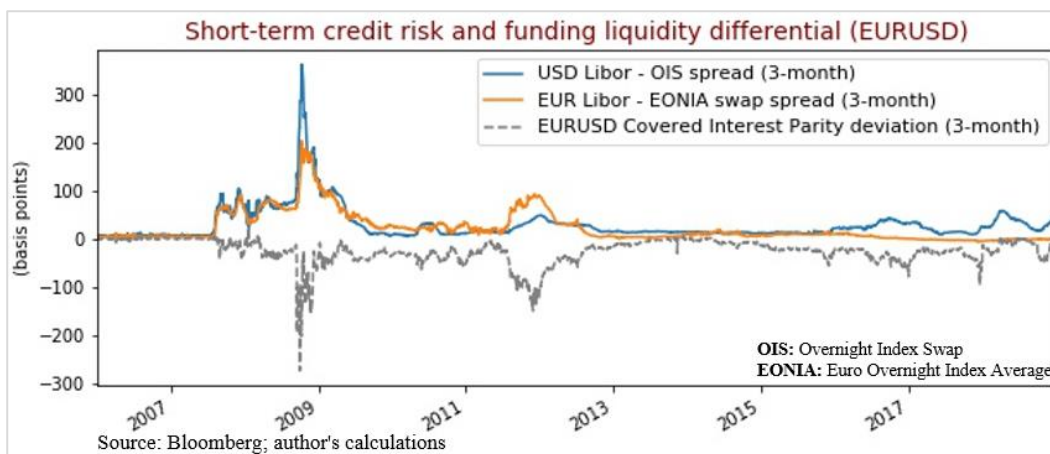


Figure 6: Short-term credit risk and funding liquidity differential (EURUSD)

The 3-month *USD* Libor – OIS (Overnight Interest Rate Swap) spread is considered to be a proxy for the implicit credit risk. As the OIS is secured and does not include a payment of the notional amount, it is considered almost risk free. Therefore, the difference in the Libor rates with the same tenor can be considered as the implicit credit risk (compare section 5.2 and 7.1 for funding aspects). In the euro environment, the OIS is defined as a European Overnight Index Average (EONIA) swap. We plotted the implicit credit risk of the two currencies and the CIP deviation in Figure 6.⁶ Both *USD* Libor – OIS and *EUR* Libor – EONIA swap spreads had been zero before the crisis, meaning that interbank benchmark rates were practically seen as risk free. Furthermore, both spreads exhibited significant widening during the two crises, especially during the global financial crisis. Most important is the gap between the two spreads, which we refer to as the short-term credit risk differential. One can observe that the 3-month *EURUSD* CIP deviation typically becomes larger as the differential widens. This finding is in line with the argument that diverging credit risks in interbank benchmark rates lead to an XCCY basis. Similar observations can be made for the *EURGBP* pair in Figure 7.

⁶ OIS (Overnight Index Swap) rate is generally seen as the risk-free rate by market participants since it is based on overnight rates. EONIA (Euro Overnight Index Average) swap and Sonia (Sterling Overnight Index Average) swap are equivalent rates for *EUR* and *GBP* currencies, respectively. *USD* Libor minus OIS, *EUR* Libor minus EONIA swap, and *GBP* Libor – Sonia swap reflect both credit and funding liquidity risk. We focus on the credit risk aspect in this sub-section.

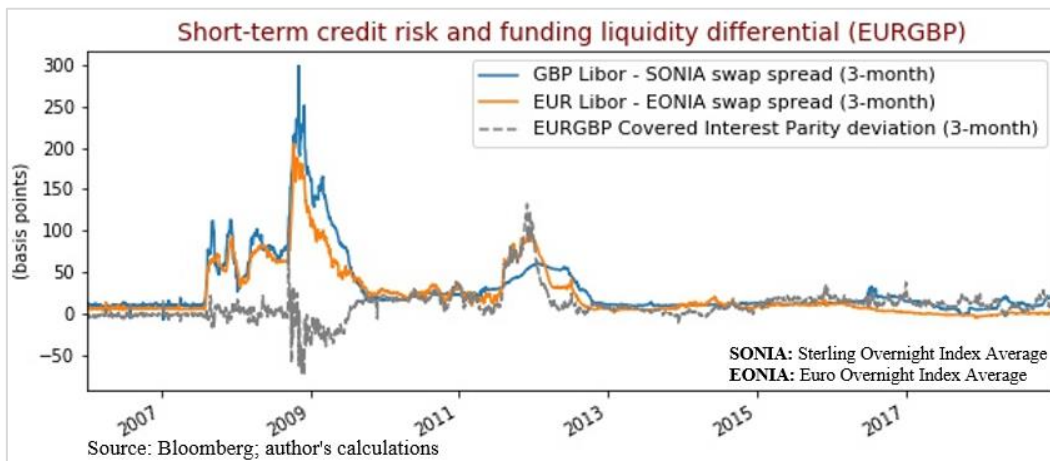


Figure 7: Short-term credit risk and funding liquidity differential (EURGBP)

Libor minus OIS mainly reflects credit but also funding liquidity risk for short-term interbank lending. The spread is relevant for analyzing short-term CIP deviations. Although the spread is also relevant for understanding the XCCY swap spread, the maturity of the instrument does not fit. Therefore, the longer maturity of CDS seems to be the better proxy. Using the average CDS spread of the banks in the euro area and comparing it to the US and the UK CDS enables us to better understand the long-term credit risk dynamics and also isolate credit risk from funding liquidity risk.

Figure 8 displays the credit risk differential based on CDS levels. As expected, the difference between credit risk of the euro-area and US banks increased substantially during the European debt crisis, which also parallels the widening of the 5-year XYCC swap spread for the *EURUSD* pairs. Interestingly, even if the long-term credit risk differential in the 2008 period is negative (meaning riskier US banks than euro-area banks), the XYCC swap spread is not positive (contrary to what one would expect). This is a phenomenon specific to *USD* and is due to the funding liquidity shortage (cf. Section 5.2).

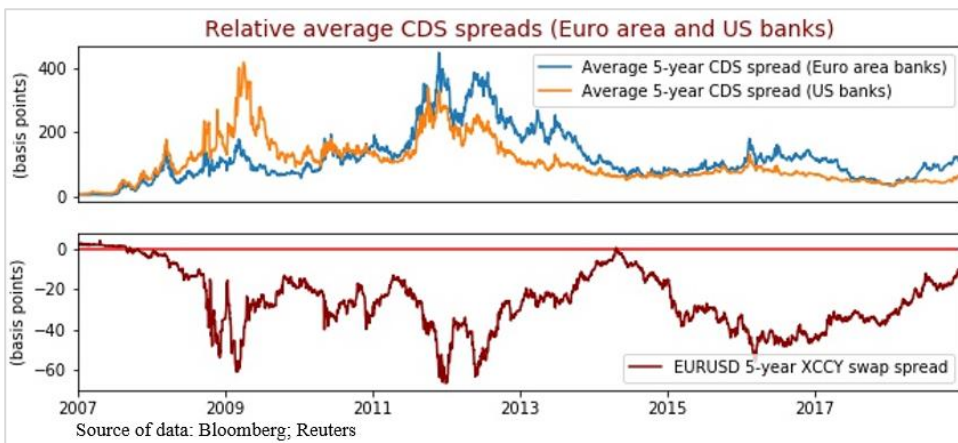


Figure 8: Relative average CDS spreads (Euro area and US banks)

The movement of the long-term credit risk differential of the UK and euro-area banks closely follows the XYCC swap spread in the *EURGBP* pair during both the financial and European debt crises (Figure 9). During the financial crisis, when the British banks faced higher credit risk and borrowing costs, the *GBP* leg was adjusted down (negative spread) and vice versa during the European debt crisis when the long-term credit risk differential was positive.

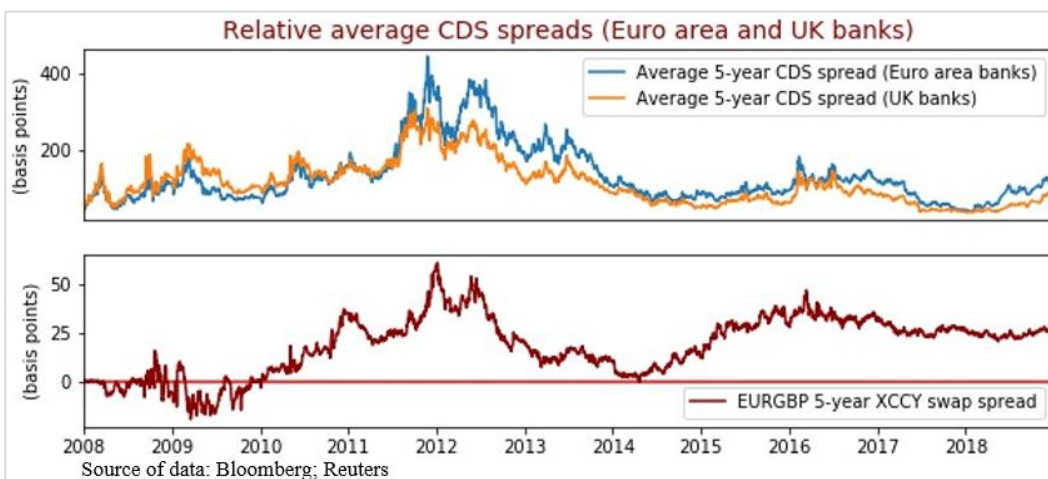


Figure 9: Relative average CDS spreads (euro-area and UK banks)

5.2 Funding liquidity differences

Another reason for the appearance and persistence of CIP deviations is the funding shortage in one of the currencies involved in an FX or XCCY swap. Both Baba and Packer (2008) and Coffey et al. (2009) highlighted that the deviation from CIP condition during the crisis was partly due to the *USD* funding shortage. American financial institutions, fearing losses from their mortgage and credit products, started hoarding *USD*. European banks, on the other hand, had significantly increased their *USD*-denominated assets prior to the crisis, from *USD* 2 trillion in 1999 to over *USD* 8 trillion in 2007 (Baba et al., 2009). With the *USD* funding dried up in the interbank market and given lack of natural *USD* deposit base, European banks increasingly turned to synthetic funding through FX and XYCC swaps.

Although it is difficult to separate funding liquidity from credit risk, the following arguments can help us to understand the funding aspect. As discussed in Section 5.1, the higher credit risk of British banks compared to European banks resulted, as expected, in *GBP* trading with a negative spread against *EUR* in the *XCCY* swap. As there was no funding shortage in either currency, this aspect did not seem to be important for this currency pair.

This is considerably different for *XYCC* swaps concerning *USD* against most European currencies. In this case, it is likely that an important reason for *USD* trading with a positive spread against the euro despite the credit risk differential is due to the global funding shortage of *USD* during the global financial crisis.⁷

Another way to understand the impact of the funding liquidity on the CIP condition is to study the *USDCAD* pair. Terajima et al. (2010) found that the CIP deviation for *CAD* in the *USDCAD* case was not as large in magnitude as that for *EUR* or *GBP* given that the Canadian banks had a stable *USD* deposit base, which even increased following the collapse of Lehman brothers as clients moved away from American banks.

In discussing credit risk differential as one the determinants of the basis (Section 5.1), we referred to Libor – OIS as a proxy for credit risk, cautioning, however, that there is a funding liquidity aspect as well. If the Libor – OIS spreads purely reflected credit risk, then one way to get closer to the market forward rates would be to use the risk-free OIS rates in the classic interest rate differential formula. This approach would then address the issue of different credit risks embedded in the interbank benchmark rates of different currencies. To do so, one can change Equation 1, which is based on Libor rates, as follows:

$$F_T = S_0 \cdot \frac{(1 + OIS_q \cdot \frac{D}{Tr_q})}{(1 + OIS_b \cdot \frac{D}{Tr_b})} \quad \text{Equation (4)}$$

In line with the methodology employed by Bottazzi et al. (2012) and Du et al. (2017), we calculated the 3-month *EURUSD* CIP deviation as the difference between the actual OIS rate and the theoretical OIS rate calculated with a rearranged form of Equation 4. As seen in Figure 10, there is still a noticeable CIP deviation. Therefore, it is reasonable to conclude that funding liquidity is an important component in this context (cf. section 7.2).

⁷ Actually, *USD* traded flat against *EUR* minus a spread. We mention *EUR* flat vs. *USD* plus a spread in this instance for comparison to the *EURGBP* pair. Both views are identical; it is a matter of quoting convention.

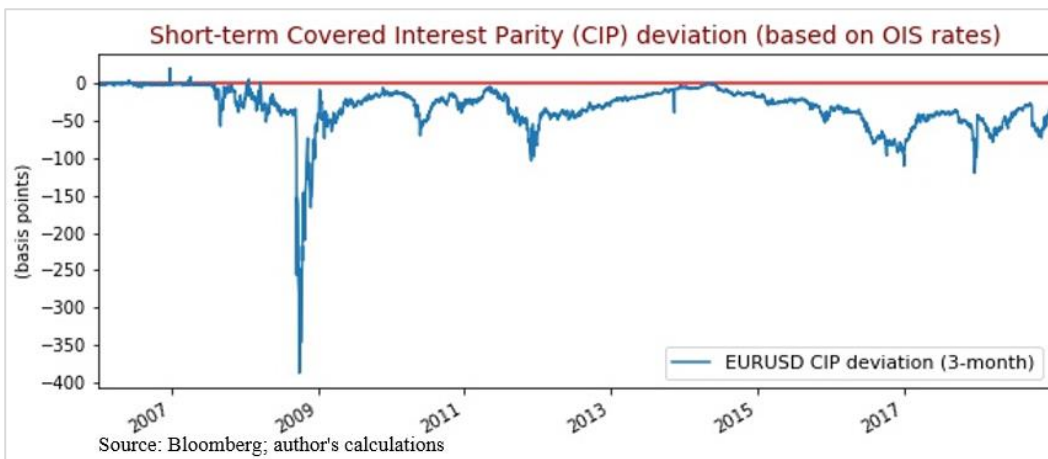


Figure 10: Short-term Covered Interest Parity (CIP) deviation (based on OIS rates)

5.3 Measurement error

In Section 5.1, we discussed the credit risk levels embedded in Libor rates and highlighted that CIP deviations will exist as long as the risk implicit in Libor rates varies across currencies. In this section, we discuss why Libor may not reflect the actual credit risk of the participants in the FX or XCCY swap markets.

To start with, Libor rates are reported by a pre-determined set of major banks and, if reported correctly, are supposed to reflect the average unsecured borrowing costs of these banks. However, the borrowing costs within the Libor panel vary. Additionally, there are other banks, asset managers, hedge funds, and corporates (each with different credit characteristic), and the quoted FX swap rates or XCCY swap spreads would actually reflect a CIP relationship based on the risk nature of a wider set of market participants not only Libor panel banks.

Even given the above issues with Libor rates, one cannot attribute the appearance and persistence of CIP deviations following the financial crisis to measurement error alone. We calculated CIP deviation (i.e., actual *USD* Libor minus the CIP-implied *USD* Libor) by using Euribor instead of *EUR* Libor in the interest rate differential formula. This approach ensures, to some extent, that the borrowing costs of a wider set of euro-area market participants would be considered. The upper half of Figure 11 compares Euribor to *EUR* Libor, and the lower half plots the CIP deviation based on Euribor against the CIP deviation based on *EUR* Libor. Clearly, CIP deviations exist under both measures and co-move closely.

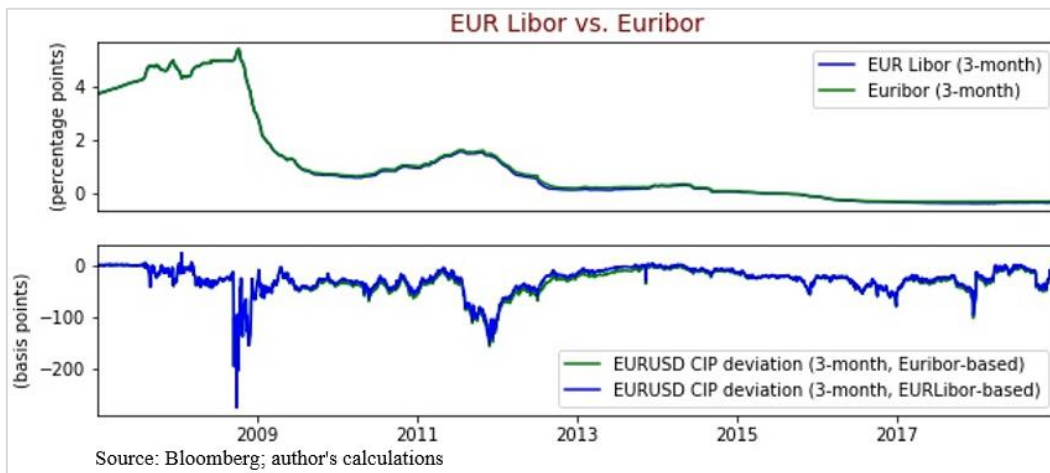


Figure 11: Covered Interest Parity deviation (based on EUR Libor vs. Euribor)

Lastly, while the measurement error in Libor bears some significance in CIP deviation calculations, it is not critical in explaining CIP deviations. The pressure on the short-term CIP deviation can be observed even if one completely ignores the interbank benchmark rates and simply looks at the FX swap market itself. As seen in Figure 12, the FX swap bid-ask spread noticeably widened during the two crises, underlying the phenomenon that the FX swap market itself became illiquid, further magnifying the CIP deviations, irrespective of what benchmark rate one uses in the theoretical interest rate differential formula.

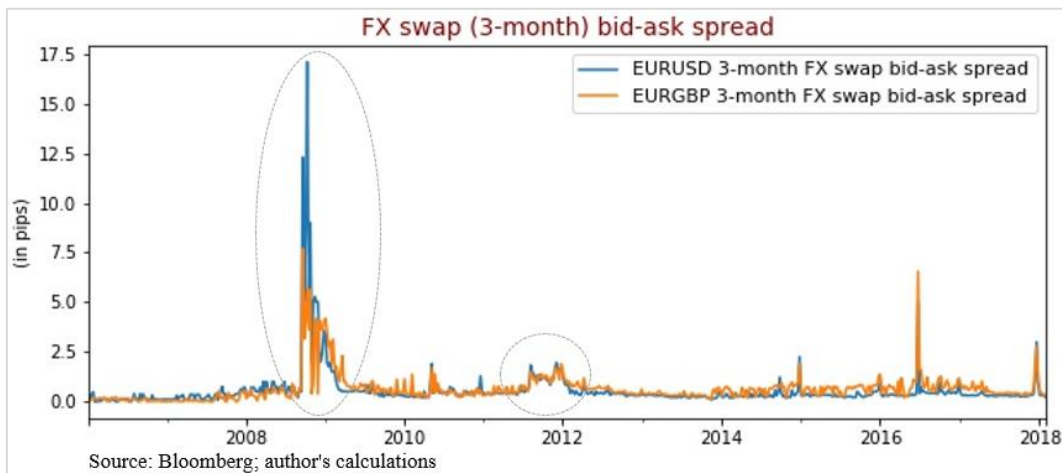


Figure 12: FX swap (3-month) bid-ask spread

5.4 Hedging demand and diverging monetary environment

Researchers have thoroughly documented CIP deviations during the global financial crisis and the European debt crisis and investigated the related determinants. What is surprising is the persistence of the CIP deviations after the crises when the factors short-term credit and liquidity risk were no longer a major concern in the markets. Researchers and practitioners have identified a global hedging demand imbalance and diverging monetary policies as potential

causes of CIP deviation after the two crises (Borio et al. (2016), Liao (2016), Baran and Witzany (2017), Borio et al. (2018)).

Relative to the Fed and the Bank of England (BoE), the ECB took a number of aggressive steps in its monetary policy stance starting from June 2014 when deposit facility rates were lowered to -0.10%, ultimately reaching -0.40% in March 2016. The Quantitative Easing (QE) program initiated in March 2015 further contributed to the loose euro-area monetary policy, resulting in lower yields across different assets and maturities.

This development led to euro-area banks, insurance companies, and pension funds seeking higher-yield foreign assets, as well as to foreign entities raising funds opportunistically in the euro market, where they face tighter credit spreads. Borio et al. (2016) documented that, since the start of the ECB's bond-purchasing program, *EUR* corporate credit spreads have decreased in relation to those of *USD*. Both the foreign assets of euro-area entities and the *EUR* funding of foreign entities are typically hedged through FX derivatives.

For instance, a euro-area insurance company would be on the *USD* demand side of the XCCY swap if it wanted to invest in *USD* assets and hedge the FX risk simultaneously. A US corporate would also be on the *USD* demand side as it borrows *EUR* in the capital markets and exchanges this money for *USD* through the XCCY swap. Accordingly, one would observe a hedging imbalance in terms of more demand for *USD*.

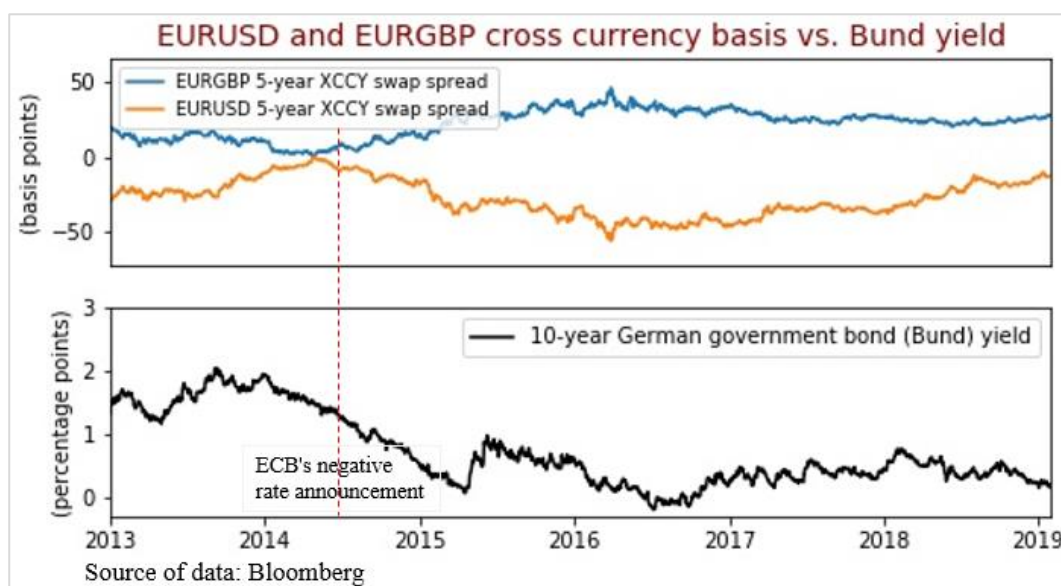


Figure 13: *EURUSD* and *EURGBP* cross currency basis vs. *Bund* yield

In broad terms, one can look at the 10-year German government bond (*Bund*) yields as an indicator of the euro area's loosening monetary policy starting from mid-2014. As seen in Figure 13, both the *EURUSD* and *EURGBP* 5-year XCCY swap spreads started to widen in mid-2014, closely coinciding with the decline of the *Bund* yield.

Baran and Witzany (2017) considered the central bank balance sheet ratio as another proxy for diverging monetary policies. From 2012 to mid-2014, when the ECB's balance sheet shrunk

relative to those of the Fed and the BoE, the tightening of the XYCC swap spreads can be observed, followed by widening from mid-2014 onwards.

5.5 Regulation and capital constraints in exploiting arbitrage

The details of regulatory developments concerning FX forwards, FX swaps, and XCYY swaps are beyond the scope of this paper. However, to understand the CIP deviation after the crises, it is crucial to highlight some of the restrictions that have limited the ability of market participants (in particular banks) from clearing the markets through arbitrage.

Du et al. (2018) emphasized Basel III's leverage ratio as an important change in regulation that has made it difficult to carry out CIP arbitrage. Even if short-term FX arbitrage trade by design does not involve significant market risk, it does expand the balance sheet and hence affects the overall leverage ratio. Unless the CIP deviation is large enough to provide an attractive return, banks take a precautionary approach. The authors documented spikes in the *USDJPY* CIP deviation at quarter-ends, reflecting the fact that banks potentially window dress their balance sheets at quarter-end reporting dates by reducing their CIP arbitrage activities. Other regulatory factors are the overall tighter capital requirements (even for risk-weighted assets) under Basel III, stricter rules on the proprietary trading activities of banks, as well as the increased margin requirements in the FX derivatives markets. Finally changes in interest taxation influence the pricing.

In addition to addressing the arbitrage activities of the banks, regulation has also affected the hedging activities of institutional investors. The European Union's Solvency II Directive, in place since 2016, has tightened the requirement for EU and UK insurance companies to use XCCY swaps with longer dates to maturity for hedging their open FX positions. The 2016 US money market reform, on the other hand, has decreased foreign banks' access to wholesale *USD* funding. Liao (2016) assessed the EU Directive and the US money market reform to be among the drivers of CIP deviation in different currencies.

Corporates, asset managers, and insurance and pension funds do not engage in pure round-trip arbitrage, and they carry out FX swaps or XCCY swap trades to gain funding advantages or to cover their FX exposure. We also highlighted, in Section 5.4, that the diverging monetary environment has led to one-sided demand pressure on FX derivatives involving *EURUSD* and *EURGBP* pairs, thereby magnifying CIP deviations. The natural players to take the other side of the trade and clear the markets through a round-trip arbitrage would be banks and hedge funds. The latter have a limited capacity to act due to a lack of access to cheap funding sources, as well as a high expected return on capital (Rime et al., 2017). Banks face stricter regulatory and internal risk management rules and have consequently reduced their arbitrage activity. Given their business needs to fund through FX and XCCY swaps, they are in fact seen by Liao (2016) as net contributors to CIP deviation and not as major arbitrageurs. The overall impact is ultimately the persistence of CIP deviation after the crises.

6. Term structure of the cross currency basis

Regarding their term structure, CIP deviations or XYCC swap spreads demonstrate two features. There is a noticeable slope, and the slope behaves differently at different points in time. Figure 14 illustrates the term structure for the *EURUSD* pair as of February 2019 (the most recent data point), December 2016 (a point of increased monetary policy divergence), December 2013 (post-crisis normalized markets), November 2011 (the European debt crisis peak), and September 2008 (the global financial crisis peak). We took the basis calculated with Equation 2 in Section 4.1 for the 3-month tenor, while the other tenors are market XCCY swap quotes (Figure 14).⁸

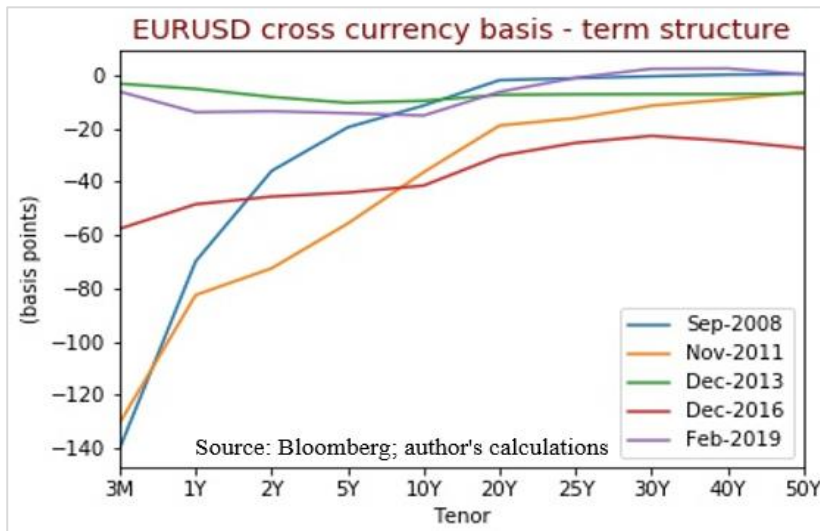


Figure 14: *EURUSD* cross currency basis – term structure

- The term structure during the two crises is concave and upward sloping, meaning the short-end negative basis is significantly larger than the long-end. The tenors beyond 20 years show a comparatively small CIP deviation.
- After the European debt crisis (as of December 2013), the term structure is flat and close to zero, reflecting a negligible CIP deviation at all tenors.
- The line makes a noticeable shift downwards in 2016, with both ends of the curve going further into negative area.
- As of February 2019, a rough U curve can be observed, with no or very small deviations at the 3-month tenor, a moderate negative basis in the 1-year to 10-year tenors, followed by negligible deviation beyond 20-year tenors. In fact, the 30-year and 40-year tenors have a small positive basis.

Two key qualitative assessments can be made as to the behavior of the basis term structure. First, the high level and fluctuation of the 3-month basis during the two crises can be attributed

⁸ For the purposes of consistency in term structure analysis, given that Euribor is the reference rate in a *EURUSD* and *EURGBP* XCCY swap, we use Euribor as the interbank benchmark rate in Equation 2 for calculating short-term CIP deviation.

to the crisis-specific, short-term strains, as well as to credit and liquidity strains. Second, if there is a hedging demand imbalance causing CIP deviation after the crises, the impact should be most noticeable on commonly used instruments and highly liquid tenors. As of February 2019, the basis was the highest in 1-year to 10-year tenors, and according to Barnes (2017), these are the most liquid tenors. Tenors beyond 20 years are not as liquid and do not face hedging demand pressure. This is consistent with Figure 14, as longer tenors are in line with CIP both during the crisis and non-crisis periods.

These observations are helpful in understanding the different determinants of the basis in different phases of the market. The basis of the 3-month tenor had its maximum during the two crises due to the short-term credit and funding liquidity strains. After the crises, it became comparatively insignificant because the market turned to a more normal environment. The basis of 1-year to 10-year tenors was not significant during the two crises and became significant only since 2014, following the development of the hedging demand imbalance. The observation that tenors of 20 years and beyond demonstrated minor CIP deviations both during and after the crises was to be expected, as short-term market strains and hedging demand imbalance are concentrated on other tenors.

Figure 15 illustrates the term structure of the basis for the *EURGBP* pair, from 3 months to 20 years. Patterns comparable to that of *EURUSD* basis term structure can be observed.

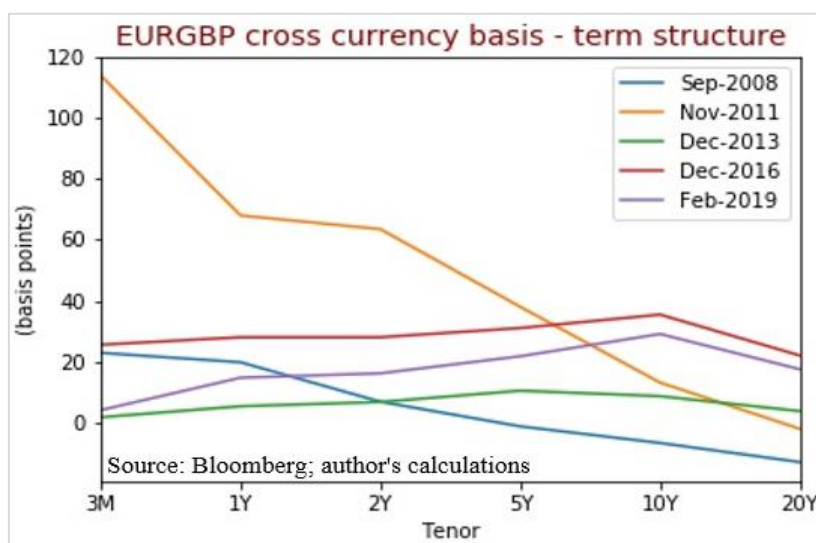


Figure 15: EURGBP cross currency basis – term structure

7. Pricing implications

To calculate FX forward rates before the global financial crisis, market participants could simply use the spot rate and the interest rate differential of unsecured interbank benchmark rates. Moreover, for XCCY swaps, interbank benchmark rates could be used without any major adjustment as reference rates. Accordingly, the CIP relationship in Equation 1 held well, and as shown in Section 4, the market prices were fairly in line with the theoretical prices.

Since the financial crisis, market participants could not use the classic interest rate approach anymore, and the fundamental relationship behind the formula no longer held. While many researchers have attempted to explain the determinants of the CIP deviation qualitatively and through general regressions, very few have considered approaches to adjusting the interest rate differential formula to bring the theoretical CIP-based prices closer to those observed on the market.

In this section, we consider the work of Wong and Zhang (2018), who proposed a way to adjust the classic interest rate differential formula. We followed Wong and Zhang's (2018) approach to statistically adjust the formula and calculate the 3-month CIP deviation. Afterwards, we conduct a back test and compare the results to the actual CIP deviation without adjustments.

7.1 Pricing adjustment

When discussing the determinants of the basis, we highlighted that the difference in credit risk embedded in the Libor rates of the two currencies is one of the key drivers of CIP deviation (Section 5.1). For CIP, the Libor rates should bear at least a similar credit risk. While the Libor rates were seen as risk free prior to the financial crisis, market participants started to attach varying credit risk levels from 2007 onwards, which meant Libor rates could no longer be used in the CIP equation. One solution is to use the risk-free OIS rates instead; however, as Figure 10 indicates, there is still a noticeable CIP deviation when OIS is input into the interest rate differential formula.

The Libor – OIS spread has not only a credit risk but also a funding liquidity component. Wong and Zhang (2018) argued that using OIS rates in the interest rate differential formula is incorrect, as it strips Libor off from both components. The authors proposed using the Libor rates without the credit but with a funding liquidity component.

Consider two parties buying a floating rate note from each other in different currencies. In this case, each party would be exposed to the default risk of the other. An FX swap can be represented by the two floating rate notes except that principles are exchanged at the initiation. Effectively, this equates to secured lending. Therefore, the credit risk component is neutralized, but the funding liquidity component is still present. Both parties in the FX swap arrangement assume the liquidity risk of the respective currency they are lending. Wong and Zhang (2018) statistically determined the share of credit and liquidity components in the Libor – OIS spread (Table 1). For the period from 9/2009 to 6/2017, they found a liquidity component of 23% for the euro and 82% *USD*, respectively.

| Libor-OIS split | <i>EUR</i> Libor – Eonia | <i>USD</i> Libor – <i>USD</i> OIS |
|------------------------|--------------------------|-----------------------------------|
| Liquidity component | 22.83% | 82.04% |
| Credit risk component | 77.17% | 17.96% |

Source: Wong and Zhang (2017); data sample period: 09/2009 to 06/2017

Table 1: Libor-OIS split

Afterwards, Equation 1 was adjusted only for the credit component.

$$F_T = S_0 \cdot \frac{(1 + (r_q - \alpha) \cdot \frac{D}{T_{r_q}})}{(1 + (r_b - \beta) \cdot \frac{D}{T_{r_b}})} \quad \text{Equation (5)}$$

Alpha and *beta* denote the credit risk adjustment of the interbank benchmark rate in the quoted and base currencies. Supposing a *USD* Libor – OIS spread of 1% in the *EURUSD* case with a credit risk component of 1/5, then one would use 0.2% for *alpha*. Similarly, *beta* would reflect the credit risk component in the *EUR* Libor – Eonia spread.

Of course, one has to recognize the major problem with such a statistical approach. It is based on regressions, which are dependent on historical data and do not respond to recent economic changes.

7.2 Back test results

We conducted a back test on the 3-month *EURUSD* CIP deviation based on FX swaps using Equation 6, which reflects the difference between the actual *USD* Libor and CIP-implied *USD* Libor rates.

$$EURUSD \text{ CIP deviation}_{3M} = r_{q,3M} - \left[\left[\frac{\left(\frac{F_{3M}}{S_0} \cdot \left(1 + (r_{b,3M} - \beta) \cdot \frac{D}{T_{r_b}} \right) - 1 \right) \cdot T_{r_q}}{D} \right] + \alpha \right] \quad \text{Equation (6)}$$

Table 2 provides a comparison of the back test results for the 3-month *EURUSD* CIP deviation between the classic interest rate differential approach (Equation 2) and the adjusted approach (Equation 6) based on the credit/liquidity split of Wong and Zhang (2018; Table 1).

| 3-month <i>EURUSD</i> CIP deviation (average absolute deviation, daily) | Adjusted pricing (Wong and Zhang's (2018) approach) | Classic pricing (Interest rate differential formula) |
|---|---|--|
| Full sample period (01/2008 to 2/2019) | 20.89 bp <i>(12 bp improvement)</i> | 32.51 bp |
| Financial crisis (1/2008 to 12/2010) | 18.05 bp <i>(25 bp improvement)</i> | 42.89 bp |
| European debt crisis (01/2011 to 12/2013) | 19.17 bp <i>(20 bp improvement)</i> | 38.73 bp |
| Post-crises period (01/2014 to 2/2019) | 23.56 bp <i>(0 bp improvement)</i> | 23.53 bp |

Sources: Bloomberg; author's calculations

Table 2: 3-month *EURUSD* CIP deviation (pricing comparison, back test)

The adjustment based on Wong and Zhang's (2018) empirical findings brings the theoretical prices closer to the observed market prices, reducing the average CIP deviation by 12 bp for the full comparison period (2008 to 2019).⁹ However, the improvement of 20/25 bp only appeared during the crises. The adjustment failed to quantitatively capture the different post-crisis determinants of the CIP deviation focusing on hedging demand imbalance and arbitrage constraints.

Figure 16 plots the 3-month *EURUSD* CIP deviations, comparing the adjusted pricing approach to the classic interest rate differential pricing without adjustment.

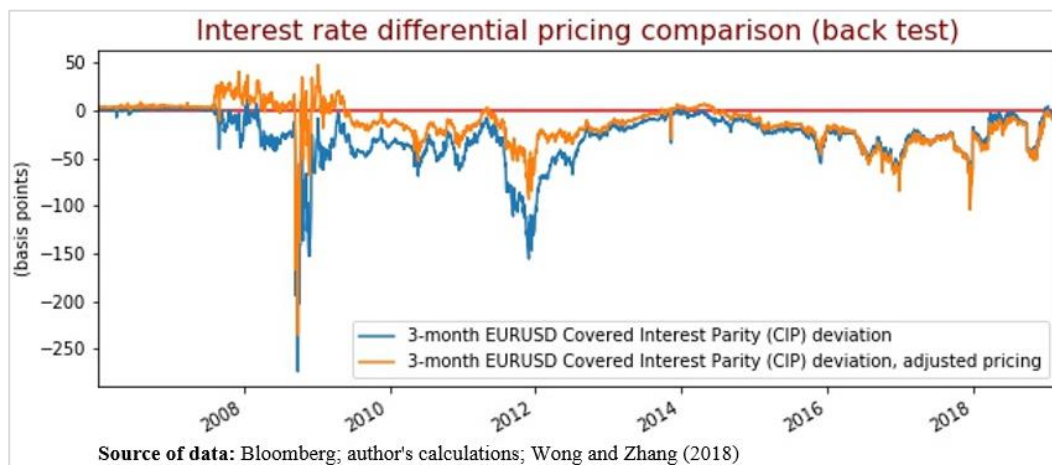


Figure 16: Short-term *EURUSD* CIP deviation (pricing comparison, back test)

⁹ Note that while the actual *EURUSD* CIP deviations are always negative, the deviations based on the adjusted interest rate differential formula include both positive and negative values, making it necessary to use absolute values in taking the average.

8. Conclusion

In this paper, we documented the deviation from the covered interest parity (CIP) for the short- and long-term cross currency basis of *EURUSD* and *EURGBP* from 2008 to 2019. The basis was particularly pronounced during the global financial and European debt crises but also persisted on a lower level after the crises. Our paper focuses on five factors: credit risk differential, funding liquidity differences, measurement error, hedging demand imbalance, and new constraints for arbitrage.

The term structure analysis revealed that the 3-month basis was the highest during the two crises, which is in line with the short-term credit and funding liquidity strains. The longer-term basis was comparatively insignificant during that time period but increased substantially after 2014, partially following the diverging monetary policy of the euro area compared to that of the US and the UK.

Before the financial crises, the benchmark interest rates were considered to be risk free, and CIP calculation led to prices very close to those on the market. One reason for the CIP breakdown was the impact of the financial crises, as the credit risk component of the benchmark became apparent. Unfortunately, using OIS to achieve identical credit components for both parties did not lead to convincing results. The OIS approach stripped both the credit and liquidity component from the rates. However, the liquidity component should not be adjusted.

Wong and Zhang (2018) proposed a statistical approach to adjust CIP only for the credit component. Using their approach for *EURUSD* in a 2008 to 2019 back test, we found that the adjustment reduces the 3-month CIP deviation by 36%. However, the back test performance was poor after the crisis. This is evidence that, in this period, hedging demand imbalance and regulatory changes, making arbitrage more costly, were driving factors for CIP violations.

Overall, to our knowledge, a pricing approach to replace CIP does not exist. Therefore, the currency forward market is, to some extent, independent of interest rates. Therefore, it should also be considered separately in risk management. During a crisis, the liquidity and the credit components are particularly important. In normal market conditions, monetary policy, the hedging imbalance, and regulatory limits on arbitrage seem to be the drivers.

Looking ahead, the measurement problem may become a crucial aspect. As the Libor and Euribor benchmark rates are replaced, the differences in rates are likely to increase. As the new *USD* benchmark is collateralized (and the European rates will probably not), the difference between them will grow. To better understand the movements of the cross currency swap basis and the deviation of FX swaps from CIP, all five drivers have to be observed. Credit risk differentials are, to some extent, quantifiable. The funding liquidity differences can only be incorporated using statistical approaches and typically adjust too slow to market changes. To our knowledge, there is no approach to include measurement error, hedging demand imbalance, or regulatory constraints on arbitrage in a model that is able to duplicate market prices.

On the one hand, pricing in the FX forward market has become more complicated. On the other hand, it provides companies a wide variety of funding alternatives, as costs can vary substantially between currencies as a function of the credit spread and cross currency swap basis.

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