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Empirical evidences of the deviations from Covered Interest Rate Parity

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INTRODUCTION

The global financial crisis of 2007-2008 has been the the worst economic disaster since the great depression in 1930. It began in the United States of America after a crisis in the real estate market triggered by the bursting of a real estate bubble (subprime crisis). The crisis gradually assumed a global character, driven by financial contagion mechanisms, and developed into a massive international banking crisis after the collapse of Lehman Brothers investment bank with devastating effects on the entire economic-financial system. One of the many and most considerable consequence that the crisis left behind is the main object of this paper which tries to examine the main causes and the consequences of deviations from the covered interest parity condition, which have emerged since the crisis. The covered interest parity (CIP) is the main conditions of equality in international finance, which states that the interest rate differential between two currencies in the money markets should be equal to the differential between the forward and spot exchange rates, otherwise risk-less profit arbitrage opportunities arise. In the fist chapter we will briefly present the concept of covered interest parity and the mostly used measure of the deviations, the cross currency basis, which is define as the discrepancy between the direct dollar interest rate from the cash market and the synthetic dollar interest rate from the swap market obtained by swapping the foreign currency into U.S. dollars (Dagfinn Rime, Andreas Schrimpf and Olav Syrstad paper,2017).

Thus, a currency basis different from zero implies sharp, systematic and persistent arbitrage opportunities in currency markets. Specifically, we will focus both on short term and long term cross currency basis using the Libor basis for short-term deviations and the spread on the Libor cross-currency basis swap for long-term CIP deviations. In the second chapter we will focus on the foreign exchange (FX) market, where the no-arbitrage condition is reasonably easy to test. However, The CIP condition fails to look after the transaction costs that may be largely catched by the market buying and selling quotes of exchange rates and interest rates (the Bid-Ask spread). Historically, many researchers such as Tailor (1989), have shown that covered interest parity held, both across countries and across time, leading to the belief that CIP is one of the few binding laws in economics (Falk Bräuning and Kovid Puria, paper 2017).

However, the second chapter of this paper reports also an empirical analysis conducted by Lucio Sarno, that provides real-time evidence on the frequency, size, duration and economic significance of arbitrage opportunities in the foreign exchange market. In the analysis, the deviations are calculated both for the case of “Ask” and “Bid”, in order to better understand when and for how long the deviations arise and check if it is possible to implement an arbitrage strategy and exploit these opportunities. Finally, in the third chapter we will examine the possible causes of these CIP deviations. We will start from the problem of credit risk and transaction costs focusing on Libor-based contracts. In order to check if the deviations persist even after we take away transaction costs we will build up two alternative risk-free currency basis: the REPO basis at short maturities and the Kfw basis at long maturities. Then, we will examine the problem of costly financial intermediation, specifically focusing on the leverage ratio, risk-weighted capital requirements and other banking regualtions implemented after the crisis. The other main element we consider in the analysis of the possible explanation of CIP deviations are the international imbalances that led to high customer currency hedging demand to sell high-interest-rate currencies and buy low-interest rate currencies in the foreign exchange forward and swap markets. Then, we will examine the CIP condition based on CIP condition based on IOER rates across major central banks, using an alternative basis, the IOER cross currency basis, as a measure of U.S. dollar funding costs. Finally, we will conclude our analysis with some general considerations on the CIP condition and on the results obtained.

CHAPTER I

THE COVERED INTEREST PARITY (CIP) AND THE CROSS CURRENCY BASIS

1.1 COVERED INTEREST PARITY AND UNCOVERED INTEREST PARITY

The most relevant conditions of equality in international finance are Uncovered Interest Parity (UIP), followed by Covered Interest Parity (CIP). The hypothesis of parity condition can be used to prove the efficiency of the market.

UIP explains a situation where the nominal interest rates, both domestic and foreign, are related to the spot exchange rate and the expected spot rate.

UIP can be expressed as follows:

$$(1+ i_t^d) = (1+i_t^f)\, E\, [S_t+_k] \,/\, S_t$$

where i_t^d and i_t^f are the nominal interest rate for the domestic(USD) and foreign currency (EUR) at time t. S_t is the nominal spot exchange rate (\$/€) at time t and E $[S_t+_k]$ is the expected spot exchange rate (\$/€) at time t+k.

This equation indicates how foreign-invested income should equal the domestic interest rate income. This is because the UIP condition implies that the higher (lower) interest rate currency should depreciate (appreciate) to compensate for the interest differential. In other words, the expected exchange rate at time t+k should be lower (higher) than the current spot rate, at time t. If so, the higher (lower) interest rate currency is at a forward discount (premium).

Rearranging the equation, this can be illustrated as:

$$E\, [S_t+_k] - S_t \,/\, S_t = i_t^d - \, i_t^f \,/\, 1+ i_t^f$$

From this hypothesis it is shown that the expected future exchange rate is consistent with the interest rate differential.

In that case, currency trading strategies are supposed to gain zero excess returns and investors should gain the same return on an investment in domestic currency as in foreign currency.
Investment strategies that rely on uncovered interest parity are uncertain for the investor. The exchange rate risk could be eliminated with the use of the forward market. Here is where the Covered Interest Parity comes into play. It permits investors to hedge foreign exchange risk, or unpredictable fluctuations in exchange rates, with the use of forward contracts. Ergo, the foreign exchange risk is considered to be covered.
To avoid arbitration, CIP is the right one. The fundamental philosophy of trading is to wage against it. The hedging of interests can be defined as a no-arbitrage relationship which implies postulating the implicit price of an FX swap. The CIP therefore argues that interest rates on two equal investments, that differ only in their currency denomination, should be similar after hedging the exchange rate risk. (Pinnington, James and Maral Shamloo paper,2016)
The CIP follows the following relation:

$$(1 + y^{\$}_{t,t+n})^n = (1 + y_{t,t+n})^n \frac{S_t}{F_{t,t+n}}$$

An example will clarify the meaning of this condition and explain why it must always be valid. Assume that $y^{\$}_{t,t+n}$ and $y_{t,t+n}$ denote the n-year risk-free interest rates in U.S. dollars and foreign currency (euro), respectively. The spot exchange rate S_t at time t is expressed in units of foreign currency per U.S. dollar: thus an increase in S_t indicates a depreciation of the foreign currency (euro) and an appreciation of the U.S. dollar._Moreover, assume that $F_{t,t+n}$ designates the n-year forward exchange rate in foreign currency per U.S. dollar at time t guaranteed by the forward contract. Now suppose that an investor in the US has to decide how to invest a dollar and choose between a domestic (US) or a foreign (Europe) investment. He could invest in the United States and earn $(1+y^{\$})^n$ after n years from now. Alternatively, he could first convert her U.S. dollar into S_t units of foreign currency and then invest them in Europe to obtain $(1 + y) S_t$ units of foreign currency n years from now. At time t+n he would reconvert these dollar cashbacks for $(1+y)^n$ US dollar guaranteed by the forward contract signed at time t. According to the no arbitrage CIP condition, the two investment strategies must offer the same payoff and, hence, the investor should be indifferent in choosing between them.

The CIP condition implies that any nominal interest rate gain of USD currency deposit over EUR foreign currency deposits, will be offset by the depreciation of the USD against the EUR as it is reflected in the forward premium.

Specifically,the forward premium, $\rho_{t,t+n}$, measures the relative difference between the forward rate and the current spot rate and is given by the formula:

$$\rho_{t,t+n} = \frac{Ft}{St} - \frac{St}{St}$$

Taking into account that premium are quoted as annualized percentages we should adjust the formula according to the lenght of the contract stipulated (n):

$$\rho_{t,t+n} \equiv \frac{1}{n}(f_{t,t+n} - s_t) = y_{t,t+n} - y^{\$}_{t,t+n}$$

Since 2008, global markets require a premium to borrow US dollars in global currency and interest rate markets and this is also oftenly observed across the major G-10 currencies. In summary, if any agent attempts to borrow simultaneously in US dollars and investing in another currency, forward FX markets would usually whip out that demand by making it more expensive to borrow dollars money than it is supposed to be given interest-rate differentials.

1.2 COVERED CROSS CURRENCY BASIS

The mostly used measure of the deviation from the covered interest parity condition is the cross currency basis. It come out during the Global Financial Crisis and has not vanished since then. (Borio, Claudio EV, et al. "Covered interest parity lost: understanding the cross-currency basis." - 2016). The meaning of a zero cross currency basis is that the CPI condition is valid.

Thus, a currency basis different from zero implies sharp, systematic and persistent arbitrage opportunities in currency markets.The cross-currency basis, $x_{t,t+n}$, expresses the spread between the direct U.S. dollar interest rate, $y^{\$}_{t.t+n}$, and the synthetic dollar interest rate, $y_{t,t+n} - \rho_{t.t+n}$, by exchanging the foreign currency interest rate into U.S. dollar employing FX forward fontracts.

The CIP is defined as

$$(1 + y^{\$}_{t,t+n})^n = (1 + y_{t,t+n})^n \frac{S_t}{F_{t,t+n}}$$

and it implicitly entails that the cross currency basis is equal to:

$$x_{t,t+n} = y^{\$}_{t,t+n} - (y_{t,t+n} - \rho_{t,t+n})$$

where

$$\rho_{t,t+n} \equiv \frac{1}{n}(f_{t,t+n} - s_t) = y_{t,t+n} - y^{\$}_{t,t+n}$$

expressed the forward premium or forward discount if the result is negative.

In case of a negative currency basis, the direct US interest rate is lower than the synthetic dollar interest rate and in order to gain a riskless profit equal to an annualized [x] of the trade notional, arbitrageurs may exploit the basis borrowing at the direct dollar free rate $y^{\$}_{t.t+n}$ and investing in the synthetic dollar risk-free rate $y_{t.t+n}$ and use a forward contract to exchange back the foreign currency into US dollars.

Conversely, in the existence of a positive cross currency basis, arbitrage is carried out by borrowing in the synthetic dollar interest rate and investing in the direct dollar risk-free rate.

1.2.1 SHORT TERM LIBOR CROSS CURRENCY BASIS

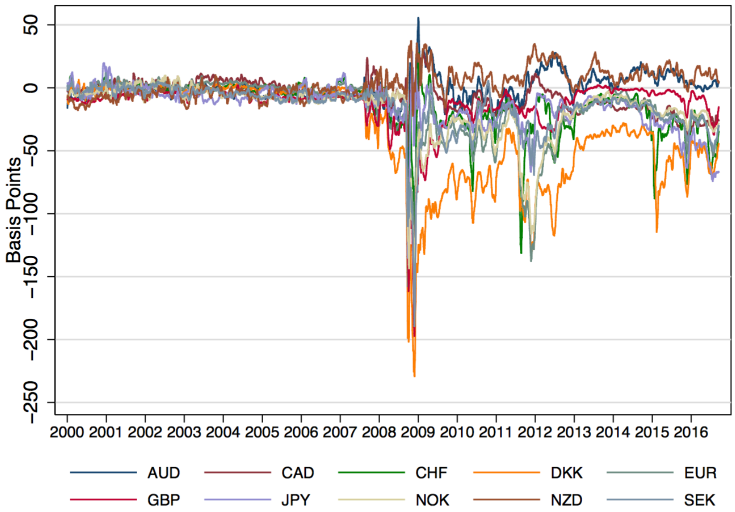
In this paper we focus on Libor rates, Intercontinental Exchange London Interbank Offered Rates, since Eurocurrency deposit rates situated in London have commonly been used as band of interest rates usefull to test the CIP condition.

Replacing the generic dollar and foreign currency interest rates of the general CIP equation, we come up with the following Libor bais:

$$x^{Libor}_{t,t+n} \equiv y^{\$,Libor}_{t,t+n} - (y^{Libor}_{t,t+n} - \rho_{t,t+n})$$

In the post-crisis period, since 2010, major currences experienced a the three-month Libor basis sistematically different from zero, contrasting the validity of the CIP condition as we can notice from the following graph:

Graph 1: Short-Term Libor-Based Deviations from CIP



SOURCE: Wenxin Du, Alexander Tepper, Adrien Verdelhan paper, 2016

1.2.2 LONG TERM LIBOR CROSS CURRENCY BASIS

At long maturities, the long-term CIP deviation based on Libor is calculated by the spread on the cross-currency basis swap.

A cross-currency swap is an over-the-counter derivative that involves an agreement between two parties to exchange periodically interest payments linked to floating rates (interbank rates) and to exchange a principal in two different currencies at the inception and the maturity of the swap. This concept can be better clarified using an example of a yen/us cross currency swap between 2 banks. Assume bank A receives one dollar in exchange of St yen from bank B at the inception of the swap.

At the j-th coupon date, Bank A pays a dollar floating cash flow equal to the three-month U.S. dollar Libor $y_{t+i}^{Libor,\$}$ on \$1 notional to Bank B and receives from Bank B the three-month yen Libor $y^{Libor,¥}$ on the notional amount , and the cross-currency basis swap spread $x_{t,t+n}^{xccy}$, which is pre-decided at the inception of the swap agreement. At maturity of the swap contract Bank B receives \$1 from Bank A in exchange of ¥S_t.

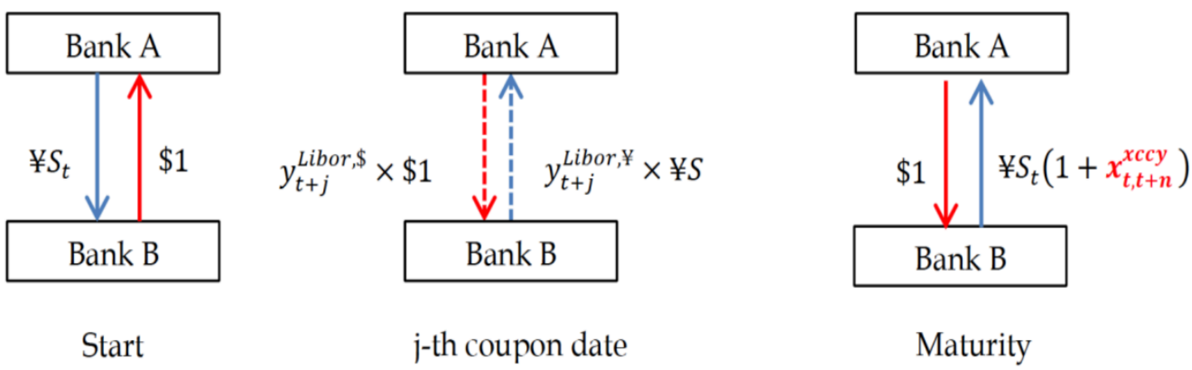
The spread on the cross-currency basis swap $x_{t,t+n}^{xccy}$, can be seen as the price at which the parties involved in the derivative contract are willing to exchange foreign currency floating cash flows against U.S. cash flows.

In order to not have arbitrage opportunities, the cross-currency basis swap rates are priced according to this equilibrium condition formula:

$$\left(1 + y_{t,t+n}^{\$,IRS}\right)^n = \left(1 + y_{t,t+n}^{IRS} + x_{t,t+n}^{xccy}\right)^n \frac{S_t}{F_{t,t+n}}$$

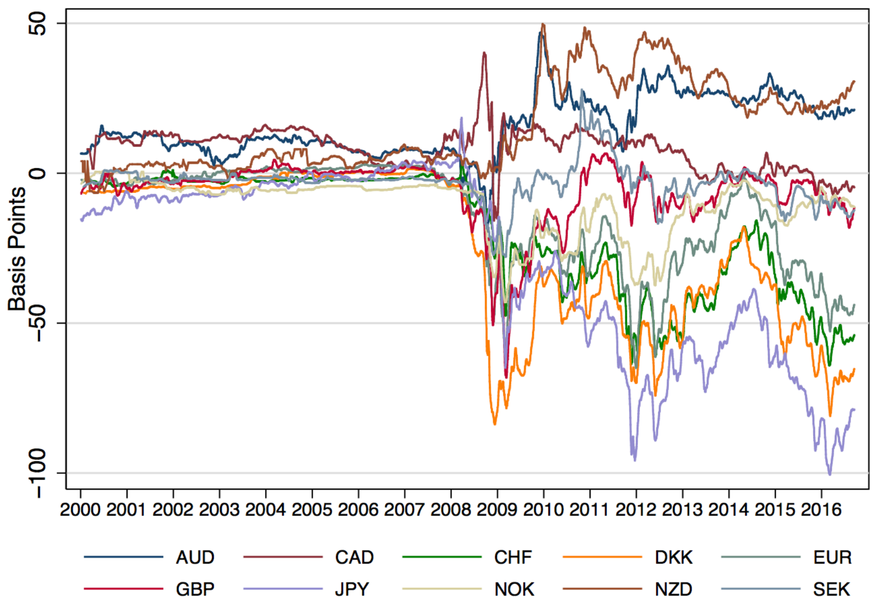
The yen/U. S dollar cross-currency $x_{t,t+n}^{xccy}$ has been often negative for some time.

In the case of a negative cross-currency bank B would pay an amount that is less than the yen libor rate and simultaneously earn an amount equal to the yen Libor rate by investing the yen it received at the inception from bank A. Doing so, Bank B would make a riskless and sure profit. Thus, as soon as the cross currency basis is not zero, one of the counterparties involved can benefit from the swap transaction.



The next graph plots the 10-day moving averages of the five-year Libor cross-currency basis, measured in basis points, for G10 currencies. We can clearly notice that, after the crisis, the Australian dollar and the New Zealand dollar exhibit the most positive bases, equal to 25 and 31 basis points on average, respectively, while the Japanese yen and the Danish krone showed up the most negative bases, equal to −62 and −47 basis points on average, respectively. The Swiss franc and the euro also experience very negative bases.

Graph 2: Long-Term Libor-Based Deviations from CIP



SOURCE: Wenxin Du, Alexander Tepper, Adrien Verdelhan paper, 2016

CHAPTER II
EMPIRICAL ANALYSIS OF CIP-BASED ARBITRAGE OPPORTUNITIES

2.1 ARBITRAGE IN THE FOREIGN EXCHANGE MARKET

In this chapter we examine empirically the existence of arbitrage in the foreign exchange market. An Arbitrage is a riskless opportunity to profit from situations of inconsistency in the price system. Agents gain a profit from the mispricing by combining purchase and sale transactions. Arbitrageurs buy the good on the market where the price is lower and re-sells it in the one where it is higher, profiting from the price difference. Economic theory tends to exclude the persistence of such situations; it would be the arbitrage's activity itself that eliminate them, augmenting the demand where the price is lower and the supply where it is higher, thus generating a tendency to rebalance prices.

Precisely, we focus on the foreign exchange (FX) market, where the no-arbitrage condition – the covered interest parity – is reasonably easy to test. the FX swap market has a daily trading volume exceeding USD 2 trillion (BIS, 2016). If the functioning of this crucial market is impaired, the relative prices of assets and debt across currencies will be distorted.

However, The CIP condition fails to look after the transaction costs. Nevertheless, such costs may be largely catched by the market buying and selling quotes of exchange rates and interest rates. Transaction costs that incurre when trading securities are reflected in the spread between the price the buyer paid (the bid price) and the price the dealer paid for a security (ask price). Intuitively, In the presence of transaction costs, the absence of arbitrage is characterized by two inequalities:

$$\frac{F_{t,t+n}^{bid}}{S_t^{ask}} \leq \frac{(1+y_{t,t+n}^{ask})^n}{(1+y_{t.t+n}^{\$,bid})^n} \quad \text{and} \quad \frac{F_{t,t+n}^{ask}}{S_t^{bid}} \geq \frac{(1+y_{t,t+n}^{bid})^n}{(1+y_{t,t+n}^{\$,ask})^n}$$

where $F_{t,t+n}^{ask}$ denotes the n-year outright forward exchange ask rate in foreign currency per U.S. dollar at time t, the variable S_t^{bid} is the spot exchange bid rate expressed in units of foreign currency per U.S. dollar at time t; the $y_{t.t+n}^{\$,ask}$ refers to n-year risk-free interest ask rates in US dollars and the $y^{bid}_{t.t+n}$ stands for n-year risk-free interest bid rates in the foreign currency. Conversely, the variables in the second equation are the opposite ask-bid rates. If the bid and ask forward rates satisfy the two inequalities, arbitrage cannot be reached neither by borrowing the domestic currency and lending the foreign currency, while hedging the currency risk with the forward contract, nor by doing the opposite transaction. During the crisis, the uncertain expectations about future exchange rate movements consistently increased hedging demand in the market of forward contracts. This enabled dealers to increase the fee charged on the forward contracts, that is the bid-ask spread. For this reason, large and persistent bid-ask spread persevered to exist, reflecting the increase in forwards demand. As a matter of fact, systematic and persistent deviations from CIP, that cannot be arbitraged away, came into play.

2.1.1 LITERATURE REVIEW

The literature showes up that, in the FX market, mispricing is negligible when we take transaction costs into account. The first one, in the litterature, who tested the no-arbitrage conditions in the FX market, is Taylor (1987). He doubted the evidence of CPI deviations because it was not based on contemporaneously real-time data of comparable domestic and foreign interest rates and spot and forward exchange rates. For this reason, it was not possible to know whether an apparent violation of the CIP truly could give rise to a profitable opportunity to be exploited by agents. In his analysis, Taylor (1987) used interest rate and exchange rate data points recorded roughly within 1 minute from each other. He obtained thosa data, in the 1985, by making calls to many London brokers every ten-minute, from the 9 in the morning to the 4.30 in the afternoon, over three days. Taylor found out that no profitable CIP arbitrage opportunity arose, providing strong evidence of the validity of CIP condition. Taylor's study may be thought to be inaccurate for several reasons. Firstly, the period of time in which data are observed may be to short. Secondly, he used quotes that were not strictly contemporaneous since quotes could change even during an interval of a minute. Furthermore, he made observations at ten-minute frequency, a relative low time tha does not permit to detect the patterns of possible deviations from CIP equilibrium condition. At that time, however, Taylor's research was one of the most accurate since there were no electronic markets yet. From that time other studies have been made, such as the ones of Rhee and Chang ore of aliber and juhl, that confirmed the absence of arbitrage opportunities.

2.2 DATA AND CALCULATION OF ARBITRAGE RETURNS

The most recent research on arbitrage opportunities in the foreign exchange market was made in 2004 by Lucio Sarno which employed Reuters trading systems to collect a wide amount of data on three major capital and foreign exchange markets. The major exchanges rates considered - USD/EUR, USD/GBP and JPY/USD - are investigated at four different maturities of 1 month, 3 months, 6 months and 1 year (Q. Farooq Akram, Dagfinn Rime and Lucio Sarno paper, 2008). In the analysis, we focus on swaps since they are traded in the interbank market much more widerly than forwards. Swaps are expressed in swap points, which are calculated as the spread between forward and spot exchange rates multiplied by specific decimals. Decimals are the smallest measure of exchange rates movements, called “pips”. Generally, spot exchange rates are quoted with four decimals, unlike the Japanese yen, for which two decimals are used. In other words, swap points, denoted by pips, are calculated by multiplying the difference between forward and spot exchange rates by 10^4, except for the japanese yen, where 10^2 is used. In our analysis, the “Base currency” corresponds to the foreign currency, while the “Quoting currency” corresponds to the domestic (d) currency. We seek for potential returns from CPI deviations by the comparison of reuters quoted swap points and the theoretical swap points we derive from calculations. The arbitrage returns obtained by CIP violations on the bid and ask side can be calculated as follow:

$$\mathrm{Dev}^{b}_{\mathrm{CIP}} = \left(F^{b} - S^{a}\right) \times 10^{4} - \frac{S^{a}\left(i^{a}_{d} \times \frac{D}{360} - i^{b}_{f} \times \frac{D}{360}\right)}{\left(100 + i^{b}_{f} \times \frac{D}{360}\right)} \times 10^{4}$$

$$\mathrm{Dev}^{a}_{\mathrm{CIP}} = -\left(F^{a} - S^{b}\right) \times 10^{4} + \frac{S^{b}\left(i^{b}_{d} \times \frac{D}{360} - i^{a}_{f} \times \frac{D}{360}\right)}{\left(100 + i^{a}_{f} \times \frac{D}{360}\right)} \times 10^{4}$$

In the formulas, the first right-hand side term represents the swap point quoted by Reuters, at a given maturity, while the second term expresses the swap point we derive from calculus for the same maturity. Since the interest rates are quoted on an annual basis we need to adjust them for maturites shorter that a year. In order to see if a CPI deviation is profitable, we need to check that the arbitrage returns are positive also after we subtract transaction costs. In our analysis, we consider profitable those deviations larger than 1/10 of a pip, that is the amount needed to cover at least brokerage and settlement costs.

2.3 FREQUENCY AND SIZE OF THE DEVIATIONS FROM CIP

In the analysis we are focusing on, the deviations are calculated both for the case of "Ask" and "Bid"; hence, either when funds are borrowed in the base currency (foreign currency) and lent in the quoting currency (domestic currency), or in the opposite transaction. The results from the calculations of CIP arbitrage opportunities, for the three major exchange rates at the four maturities taken into account, are summarized in the following two tables.

"Table 1" refers to the case in which both profitale and unprofitable observations are used, while "Table 2" reports results obtained by using only relevant observations. The profitable deviations are the ones that- for the reason we have precedently stated- are larger than 1/10 pips.

Table 1: Frequency and size of profitable and unprofitable CIP deviations

Exchange rate			a) All deviations					
			All dev.	Mean	*t*-value	Median	Ann. mean	Inter-quote time (s)
EUR	1M	Ask	2,037,923	−0.90	−4.2	−0.9	−11	2.9
		Bid	2,037,923	−1.00	−4.6	−1.0	−12	2.9
	3M	Ask	2,068,143	−2.67	−3.3	−2.7	−11	2.9
		Bid	2,068,143	−2.77	−3.7	−2.7	−11	2.9
	6M	Ask	2,309,197	−5.78	−3.1	−5.7	−12	2.6
		Bid	2,309,197	−5.31	−3.2	−5.3	−11	2.6
	1Y	Ask	2,560,419	−12.43	−2.9	−12.4	−12	2.3
		Bid	2,560,419	−10.64	−2.9	−10.6	−11	2.3
GBP	1M	Ask	2,445,312	−1.36	−2.5	−1.4	−16	2.4
		Bid	2,445,312	−1.72	−3.4	−1.7	−21	2.4
	3M	Ask	2,450,660	−4.06	−1.9	−4.1	−16	2.4
		Bid	2,450,660	−4.25	−2.0	−4.1	−17	2.4
	6M	Ask	2,594,610	−7.91	−2.3	−7.9	−16	2.3
		Bid	2,594,610	−9.43	−2.8	−9.3	−19	2.3
	1Y	Ask	2,746,288	−16.01	−2.6	−16.2	−16	2.2
		Bid	2,746,288	−17.85	−2.8	−17.4	−18	2.2
JPY	1M	Ask	804,885	−1.04	−3.4	−1.0	−12	7.3
		Bid	804,885	−1.02	−3.5	−1.0	−12	7.3
	3M	Ask	818,537	−2.66	−3.4	−2.6	−11	7.2
		Bid	818,537	−2.85	−3.3	−2.9	−11	7.2
	6M	Ask	838,047	−4.61	−2.9	−4.6	−9	7.0
		Bid	838,047	−5.69	−3.5	−5.6	−11	7.0
	1Y	Ask	892,242	−8.37	−2.3	−8.3	−8	6.6
		Bid	892,242	−13.42	−3.4	−13.6	−13	6.6

SOURCE: Lucio Sarno, Q. Farooq Akram, Dagfinn Rime, article of Journal of International Economics (2008).

NOTE: The column headed by "All dev." presents the number of all profitable and non-profitable deviations.

Table 2: Frequency and size of CIP profitable deviations

Exchange rate			b) Profitable deviations					
			Pa dev.	Share (%)	Mean	Median	Ann. mean	Inter-quote time (s)
EUR	1M	Ask	1975	0.10	0.26	0.24	3	2.7
		Bid	73	0.00	0.18	0.13	2	25.0
	3M	Ask	30,116	1.46	0.85	0.39	3	2.8
		Bid	3500	0.17	0.88	0.66	4	2.2
	6M	Ask	12,844	0.56	1.44	1.30	3	1.9
		Bid	8559	0.37	2.58	2.42	5	2.1
	1Y	Ask	21,495	0.84	5.33	4.69	5	2.0
		Bid	8966	0.35	3.29	2.14	3	2.2
GBP	1M	Ask	35,110	1.44	0.35	0.26	4	2.4
		Bid	16,835	0.69	0.69	0.68	8	2.8
	3M	Ask	57,523	2.35	2.13	1.40	9	2.5
		Bid	24,124	0.98	2.90	3.09	12	1.9
	6M	Ask	37,820	1.46	4.91	3.27	10	2.0
		Bid	5950	0.23	1.70	1.38	3	2.4
	1Y	Ask	37,987	1.38	9.09	7.38	9	2.0
		Bid	4593	0.17	4.52	2.35	5	2.5
JPY	1M	Ask	1545	0.19	0.37	0.15	4	13.8
		Bid	2068	0.26	0.23	0.18	3	6.2
	3M	Ask	491	0.06	3.86	3.00	15	10.5
		Bid	2891	0.35	1.83	1.72	7	15.6
	6M	Ask	718	0.09	4.71	0.90	9	15.0
		Bid	4140	0.49	1.45	1.25	3	2.8
	1Y	Ask	3403	0.38	6.21	2.00	6	10.9
		Bid	4358	0.49	3.50	3.26	4	4.6

SOURCE: Lucio Sarno, Q. Farooq Akram, Dagfinn Rime, article of Journal of International Economics (2008).

NOTE: the column "Pa dev." records only the number of profitable deviations bigger than 1/10 of a pip. The "Ann. mean" column reports annualized mean values of deviations written down in the "Mean" columns. Annualized values for the 1-month, 3-month and the 6-month maturities are obtained by multiplying the mean value by 12, 4 and 2, respectively. The "t-value" is simply the (period) mean value divided by the respective sample standard deviation. In this table the "Inter-quote time" is conditioned on the current deviation being profitable.

Table 1 shows that, in all of the cases, the mean return (average size) from CIP deviations is negative. The distribution is symmetric since the median returns are strictly closed to mean returns. Negative mean values indicate that the CIP-based arbitrage gives a negative profit. The conventional wisdom is that arbitrageurs eliminate any positive or negative deviation from the equilibrum condition, keeping the CIP hold on average. This result can be explained by the fact that, when fearing the possibility of arbitrage, market makers may make price offers more conservatively than CIP suggests to be on the safe side. However, the maximum point of distribution of average returns is not zero as it is required in order to not have arbitrage. Table 2 shows periodic returns that are annualized, reported in the “Ann. mean” column, since they are required to be comparable across different maturities. The column called “Pa dev” shows the number of profitable arbitrage opportunities on the total number of deviations (“All dev”), calculated for each exchange rate and maturity considered. We consider profitable deviations from CIP those deviations with values higher than 1/10 pip. The results suggest that there are many profitable arbitrage opportunities for all exchange rates, at most of the maturities. However, the share percentage of profitable deviations, that is, the number of profitable arbitrage opportunities on the total number of deviations, is extrimely low. The EUR shares go from zero to 1.5%, GBP shares range from 0.2% to 2.4%, and JPY shares go from 0.1% to 0.5%. When examining the annualized mean return from profitable arbitrage deviations, we find that returns value range from the EUR lowest returns of 2 pips at the one-month bid side to a maximum of 15 pips reached by the JPY at the three-month ask. The returns obtained show that there is no relationship between size and maturity. Furthermore, we use “inter-quote time” as the economic indicator of the pace of the market since it expresses the average time in seconds that elapses beetween two consecutive profitable deviations. The obtained results, written in the “Inter-quote time (s)” columns, highlight that the market has a very fast rhythm. New CIP deviations occur every 2/3 seconds in the case of the EUR and the GBP, and every 6/7 seconds in the case of the JPY, on average. These results show also that we have few profitable arbitrage opportunities in lending dollar funds with respect to the profitable opportunities we get when we lend funds in sterling, euro and yen. As a matter of fact, there are higher share of profitable arbitrage opportunities on the ask sides of EUR and GBP and on the bid side of JPY, as in the EUR/USD and GBP/USD exchange rates the base currencies are respectively the EUR and GBP while in the USD/JPY rate the base currency is the USD. This may be due to the reverse quoting convention of dollar per euro and sterling vs yen per dollar in Reuters systems. However, we don’t know exactly yet the reason why, in the sample analyzed, arbitrage opportunities emerge more frequently in case of dollar lending.

2.4 DURATION OF THE DEVIATIONS FROM CIP

The research of Lucio Sarnio reports also the duration of sequences of profitable deviations from the CIP condition. More specifically, Table 3 is a summary statistics report of the durations of clusters of profitable CIP deviations. A cluster is defined as a sequence of at least two consecutive profitable CIP deviations. The entries in the "Mean" column denote the average duration (mins) of the clusters, while those in the "Median" column refers to the median duration of the clusters. The "Q1" and "Q3" columns represent the first and the third quantiles of the duration of clusters, respectively. The "St dev" column reports sample standard deviations. It is evident that the number of sequences of profitable deviation, across exchange rates and maturities, goes from a minimum number of 8 clusters to a maximum number of 923 clusters. Most of these clusters do not last more than few minutes and frequently their average duration goes from 30 seconds to less than 4 minutes. The median values of the clusters are even lower: EUR mean values are less that one minute, GBP are no more than 1:43 minutes and in the case of JPY they are at most 4:34 minutes. Since high maturities are characterized by low inter- quote time and high market pace, it is normal that the values of the duration of clusters decreases in line with the maturity of contracts. Sample standard deviations of the clusters duration show up large variations in the duration of profitable CIP deviations. We notice that they can be either low or even higher than 10 minutes in some cases. However, the high standard deviations reported are potentially driven by relatively few outliers. As a matter of fact, the first and third quantiles in the last two columns of the following table indicate that duration is not particularly high even at these quantiles of the distribution of duration.

Table 3: Duration of clusters

Exchange rate			# Clusters	Mean	Stdev	Median	Q1	Q3
EUR	1M	Ask	55	1:35	1:56	0:49	0:18	2:05
		Bid	8	4:03	9:33	0:39	0:09	1:35
	3M	Ask	293	4:44	12:11	1:04	0:21	3:34
		Bid	81	1:36	2:01	0:57	0:26	2:14
	6M	Ask	419	0:57	1:29	0:26	0:12	1:01
		Bid	416	0:44	2:01	0:18	0:08	0:30
	1Y	Ask	660	1:06	2:33	0:23	0:11	1:07
		Bid	518	0:36	1:01	0:14	0:06	0:36
GBP	1M	Ask	339	4:11	10:46	1:30	0:25	4:00
		Bid	70	11:02	55:16	0:39	0:14	1:23
	3M	Ask	404	5:54	13:59	1:43	0:26	5:05
		Bid	86	8:47	4:23	0:37	0:11	1:59
	6M	Ask	554	2:18	8:34	0:25	0:10	1:09
		Bid	207	1:10	2:05	0:27	0:11	1:33
	1Y	Ask	923	1:20	4:17	0:19	0:09	0:55
		Bid	232	0:48	1:46	0:18	0:08	0:46
JPY	1M	Ask	38	10:14	13:36	4:34	2:52	10:45
		Bid	60	3:28	8:07	1:36	0:54	2:53
	3M	Ask	17	5:22	13:46	0:16	0:06	1:36
		Bid	103	7:32	15:51	3:01	2:05	9:12
	6M	Ask	52	3:15	8:45	0:27	0:10	2:07
		Bid	133	1:20	3:05	0:23	0:10	1:01
	1Y	Ask	415	1:20	4:36	0:29	0:13	1:04
		Bid	183	1:47	3:26	0:41	0:16	1:51

SOURCE: Lucio Sarno, Q. Farooq Akram, Dagfinn Rime, article of Journal of International Economics (2008)

Summarizing, we can conclude that the duration of profitable CIP deviations is relatively low on average but high enough to permit traders to exploit the arbitrage deviations. However, an arbitrage opportunity is not easy to exploit. An arbitrageurs must undertake three deals simultaneously or as fast as possible. It is very difficult to conclude all three deals without any changes in the price of one or more instruments, which make the arbitrage opportunity disappear. Nowadays, an arbitrageur can enter into many deals simultaneously thanks to Reuters electronic trading system.

2.5 TEST OF THE ECONOMIC SIGNIFICANCE OF CIP PROFITABLE DEVIATIONS

The analysis, we are focusing on, shows the existence of profitable deviations from the covered interest parity that can provide small gains. In order to check whether these deviations are economically significant and whether it is worth to exploit them, we need to know the exact trading volumes available in the markets. Unfortunately, this information is not publicly available. As a matter of fact, we don’t have any information on trades in the swap market. Neverthless, in order to have an upper bound on orders available for trading at CIP deviations, we can analyze the spot market, for which we have information on firm quotes and information on the number of trades. We can use the estimation of orders available for trade -the limit orders- to have an idea about the liquidity in the spot currency market. The higher the number of limit orders, the higher the liquidity in the market, the more volume is available for trading. The liquidity of the spot market may suggest how liquidity providers in these markets act in situations of profitable arbitrage opportunities.
In order to calculate the limit orders available, we need to know how much the spot exchange rate can deverge from the current level without eliminating the arbitrage opportunity. To do so, we assume that the interest rate and forward quotes stay unchanged and reformulate the expression for CIP deviations on the bid side and ask side as follow:

$$\left(F^b - \frac{\delta}{10^4}\right) \times \frac{100 + i_f^b \times \frac{D}{360}}{100 + i_d^a \times \frac{D}{360}} - S^a = \frac{Dev_{\text{CIP}}^b - \delta}{10^4} \times \frac{100 + i_f^b \times \frac{D}{360}}{100 + i_d^a \times \frac{D}{360}}$$

$$S^b - \left(F^a - \frac{\delta}{10^4}\right) \times \frac{100 + i_f^a \times \frac{D}{360}}{100 + i_d^b \times \frac{D}{360}} = \frac{Dev_{\text{CIP}}^a - \delta}{10^4} \times \frac{100 + i_f^a \times \frac{D}{360}}{100 + i_d^b \times \frac{D}{360}}$$

where δ = 1/10 of a pip, and F^b is the forward rate. The first term in first expression and the second term in second expression, represent the critical values,that is,the spot quote at which the profit from CIP arbitrage will be null; S^a and S^b are the best current ask and bid spot quotes,respectively. If the ask spot quote S^a is lower than the critical value defined by the first term in the first expression, there is a profitable arbitrage at the CIP bid side; Similarly, if the spot quote S^b is higher than the critical value defined by the second expression, we have a profitable arbitrage opportunity at the CIP ask side. Summing up, the critical values identify ask and bid spot quotes at which CIP deviations are worth to be exploited, at given interest rates and forward rates.

A statistic report, Table 4, presents the average and median numbers of limit orders at best spot prices when there are profitable arbitrage opportunities (whose values are higher than 1/10 of a pip).

Table 4: Number of limit orders and deviations' prices in the spot market

Exchange rate			a) Spot market limit order depth					b) Spot price deviations		
			Pa dev.	(i) Best depth		(ii) Total depth		Pa dev.	Mean	Median
				Mean	Median	Mean	Median			
EUR	1M	Ask	52	4.14	2	4.14	2	73	0.08	0.03
		Bid	1685	4.92	3	4.92	3	1975	0.16	0.14
	3M	Ask	3215	6.06	4	6.63	5	3500	0.78	0.56
		Bid	26,254	7.65	5	9.47	6	30,116	0.75	0.29
	6M	Ask	6789	6.78	4	10.30	8	8559	2.48	2.33
		Bid	10,529	5.62	3	7.64	5	12,844	1.34	1.20
	1Y	Ask	6969	6.36	4	9.72	8	8966	3.20	2.04
		Bid	17,519	7.34	4	13.36	11	21,495	5.23	4.59
GBP	1M	Ask	16,333	3.90	3	4.11	3	16,835	0.59	0.59
		Bid	34,257	4.17	3	4.22	3	35,110	0.25	0.16
	3M	Ask	23,437	5.73	4	10.95	9	24,124	2.82	3.01
		Bid	54,251	4.16	3	5.45	4	57,523	2.04	1.31
	6M	Ask	5426	3.94	3	5.28	4	5950	1.63	1.30
		Bid	34,442	4.11	3	8.11	6	37,820	4.87	3.21
	1Y	Ask	3967	4.47	3	7.62	6	4593	4.54	2.32
		Bid	32,940	4.25	3	8.26	6	37,987	9.24	7.50
JPY	1M	Ask	1885	3.65	2	3.67	2	2068	0.13	0.08
		Bid	1353	2.23	1	2.24	1	1545	0.27	0.05
	3M	Ask	2085	2.39	1	3.87	3	2891	1.74	1.63
		Bid	420	3.19	2	4.29	4	491	3.78	2.91
	6M	Ask	3838	5.58	4	8.34	7	4140	1.36	1.16
		Bid	525	2.78	2	3.98	2	718	4.66	0.80
	1Y	Ask	3602	3.32	2	5.97	5	4358	3.48	3.24
		Bid	2176	3.05	2	5.34	4	3403	6.25	1.94

SOURCE: Lucio Sarno, Q. Farooq Akram, Dagfinn Rime, article of Journal of International Economics (2008)

Specifically, Panel a) shows the average number of the limit orders that goes, more or less, from 3 to 7 and the median numbers of limit orders, which go from 1 to 5, at the best quotes. It is important to underline that the spot quotes can deverge from the best quotes without whiping out the arbitrage opportunities when the size of profitable deviations amounts to several pips. Therefore, in case of the existence of profitable arbitrage opportunities, the number of limit orders available would be higher than those available at the best quotes.

Panel b) shows the average sizes and median values of the difference between the current spot rate and the spot rate at wich there can be no arbitrage, expressed in pips. The deviations from the critical spot rates (in pips) are coherent with the sizes of the profitable deviations precedently founded: they are between 0.08 and 5.23 in the case of EUR, between 0.25 and 9.24 in the case of GBP, and between 0.13 and 6.25 in the case of JPY. The columns labeled “Pa dev.” shows the number of profitable deviations, while the rows “Ask” and “Bid” refer to the spot ask (bid) price needed in the bid (ask) CIP calculation.

As we notice from the table, profits gained by exploiting arbitrage opportunities can be economically significant. However, even if we do not have information about the size of the limit orders trading volume, we can make some conclusions. Looking at the frequency and size of profitable CIP deviations (reported in Table 2), and the depth of the market (reported in Table 4), we can conclude that every arbitrage strategy makes profits of a few pips that can accumulate sizable gains over time.

CIP arbitrage deviations are highly influenced by the pace of the market, as reflected in the inter-quote time, and in the volatility. When markets are very active, the amount of arbitrage opportunities is lower because the limit orders are posted frequently and the corresponding spot quotes are fastly changed. However, in some circustances, spot quote changes are not enough to eliminate profitable arbitrage opportunities. As reported in Table 5, the time that elapses between two consecutive posts of limit orders is around 1s in the case of EUR and GBP, and around 2s in the case of JP, while profitable CIP deviations can last from 30s to several minutes.

Table 5: median number of seconds beetween two spot quotes during CIP arbitrage

		EUR	GBP	JPY
1M	Ask	1	1	3
	Bid	4	1	2
3M	Ask	1	1	2
	Bid	1	1	3
6M	Ask	1	1	2
	Bid	1	1	1
1Y	Ask	1	1	2
	Bid	1	1	2

SOURCE: Lucio Sarno, Q. Farooq Akram, Dagfinn Rime, article of Journal of International Economics (2008)

NOTE: median time between two spot quotes in a profitable CIP arbitrage at the ask side and at the bid side. Sample based on Reuters quotes, February 13- september 300, 2004 between GMT 07:00 and 18:00 on weekdays.

2.6 CONCLUDING REMARKS

As the evidence from the research suggests, arbitrage opportunities may occur at any time and cannot be effortlessy forecasted. The theory of the CIP condition asserts that in a well-functioning market, any arbitrage condition would not hold continuously. However, the research analysed in this chapter shows that temporary arbitrage opportunities emerge in the major foreign exchange and capital markets. The size of CIP arbitrage opportunities for the three exchange rates (USD/EUR, USD/GBP, JPY/USD) observed at for different maturities (1m,3m,6 months and 1 year) can be economically significant. Furthermore, the duration of arbitrage opportunities is on average high enough to allow agents to take advantage of CIP deviations. At the same time, duration is low enough to suggest that before the Great Financial Crisis, in the markets arbitrage opportunities were fastly eliminated. As opposed to previous researches, the high speed of arbitrage documented in this chapter can reasonably represents the reason why such opportunities have been undiscovered until now. As a matter of fact, only if we use a data recorded at tick frequency for quotes of comparable domestic and foreign interest rates and spot and forward exchange rates, it is possible to identify the existence and measure the duration of a number of short-lived arbitrage opportunities.

CHAPTER III

POTENTIAL EXPLANATIONS OF THE CIP DEVIATIONS

3.1 CREDIT RISK AND TRANSACTION COSTS IN LIBOR-BASED CONTRACTS

Taking into consideration the common case in which there is a negative Libor basis in the yen/US dollars market, an arbitrageur would profit by borrowing dollars at the dollar libor rate and investing them in the yen market at the yen libor rate, meanwhile hedging the exchange risk by stipulating a forward contract to convert back yen into US dollars at maturity. However, this arbitrage strategy relies on the CIP condition without taking transaction costs into account. Spot and derivative contracts presents such costs, which can actually lower the effective returns. As a consequence, the actual U.S. dollars borrowing rate may be larger than the Libor rate the arbitrageur relies on. Furthermore, Libor rates are unsecured. there exists counterparty credit risk due to the cost of replacing the contract in case of counterparty default. (Niall Coffey Warren B. Hrung Asani Sarkar,paper 2009).

For this reason, the arbitrageur should be compensated for the credit risk by a risk premium when lending at the yen Libor rate, preventing, in this way, the risk of default on the loan. In the literature, the potential default risk is a valid explanation of the CIP deviations and it relies on cross-country differences in credit worthiness of different Libor panel banks. Therefore, the yen basis can be negative if the yen Libor is riskier than the U.S. Libor. However, the reasons of CIP deviations can not be merely addressed neither to credit risk nor to transaction costs. Significant and persistent violations of the CPI condition show up even after transaction costs and credit risk are eliminated.

3.1.1 REPO BASIS

At short maturities, we can eliminate the credit risk associated with Libor-based CIP building up an alternative currency basis measure with the use of collateral (GC) repo rates in U.S. dollars and foreign currencies. In a repurchase agreements contracts GC repo, the lender agrees on having a variety of Treasury and agency securities as collateral. Repo rates considered secured borrowing and lending rates since GC assets are of high quality and very liquid.

The general definition of the basis, we have previously mentioned in this paper, leads to the following repo basis:

$$x_{t,t+n}^{Repo} = y_{t,t+n}^{\$,Repo} - (y_{t,t+n}^{Repo} - \rho_{t,t+n}).$$

where $y_{t,t+n}^{\$,Repo}$ is the U.S. dollar GC repo rate and $y_{t,t+n}^{Repo}$ the foreign currency GC repo rate.

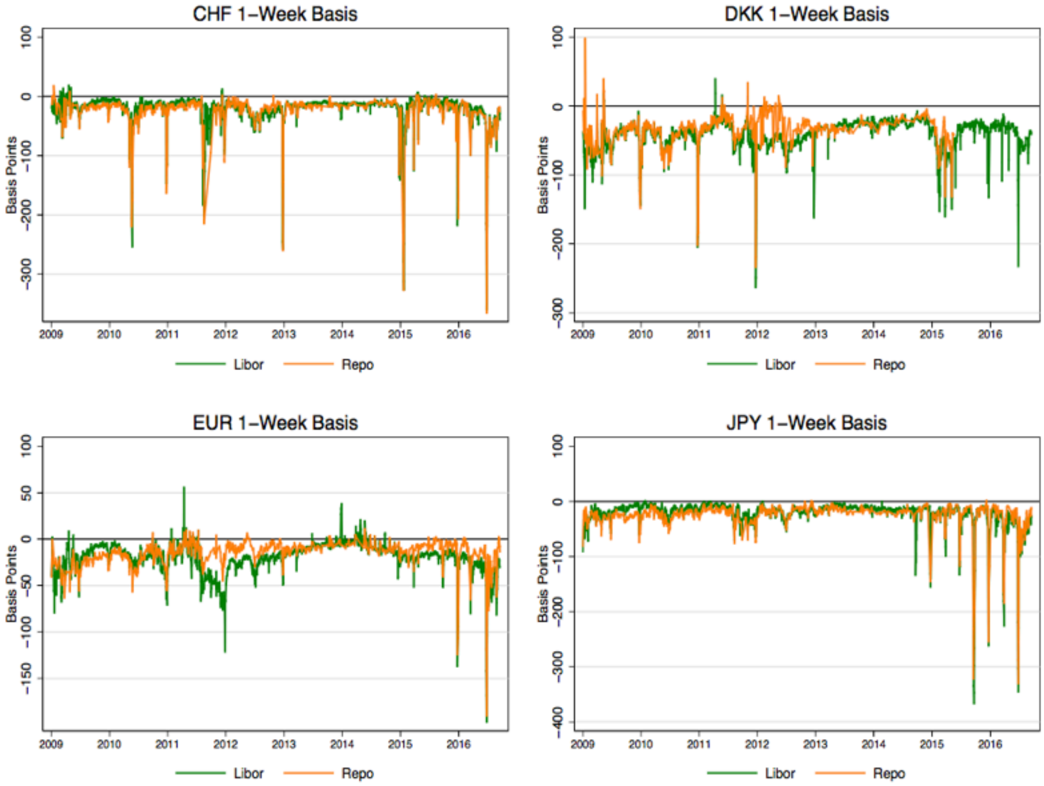
When the basis is not zero, arbitrageurs can profit by undertaking negative (π^{Repo-}) and positive arbitrage (π^{Repo+}) strategies expressed as following:

$$\begin{aligned}
\pi_{t,t+n}^{Repo-} &\equiv [y_{t,t+n,Bid}^{Repo} - (1/n) \times FP_{t,t+n,Ask}/S_{t,Bid}] - y_{t,t+n,Ask}^{\$,Repo}, \\
\pi_{t,t+n}^{Repo+} &\equiv y_{t,t+n,Bid}^{\$,Repo} - [y_{t,Ask}^{Repo} - (1/n) \times FP_{t,t+n,Bid}/S_{t,t+n,Ask}].
\end{aligned}$$

In the case of a negative basis, the arbitrageur would borrow at the U.S. dollar GC repo rate and lend in the foreign currency GC repo rate, hedging the exchange rate risk with the payment of a forward premium. Conversely, in case of a positive basis, the arbitrageur would borrow at the foreign currency rate and receive the forward premium, while investing in the U.S. dollar rate.

We examine the one-week Libor and repo basis for Swiss, Danish, Euro, Japanese, and U.S. repo markets from january 2009, at one-week horizon,to september 2016. In many istances, the Libor- and repo-based deviations from CIP are not able to be identified as distinct from each other as it is shown in the following graphs:

Graph: One-week Repo and Libor CIP deviations



SOURCE: Wenxin Du, Alexander Tepper, Adrien Verdelhan paper, 2016

NOTE: The green line refers to the one week Libor cross-currency basis and the orange line represents the one-week repo cross currency basis for the swiss Fran, Danish krone, euro and yen

From a summary statistic report, described in Table 1, we can see that mean and standard deviation of Libor- and repo-based bases are negative in all the cases. The Danish krone had the most negative mean repo basis, specifically of 43 basis points when Libor-based and 34 basis points when repo-based. The euro exhibits the least negative mean repo basis equal to 10 basis points with repo rates and 19 with Libor rates. For the Swiss franc, the Libor and repo rates deliver similar basis: 20 and 23 basis points. For the yen, the repo basis is 22 basis point while the libor basis is 17 basis points.

Table 1: one week Libor and GC repo basis

		Libor Basis Full Sample	Repo Basis Full Sample	Repo Basis Conditional neg.	Repo Arbitrage Profits
CHF	Mean	-20.2	-23.0	-23.4	14.1
	S.D.	(26.1)	(27.3)	(27.1)	(22.7)
	% sample			99%	85%
DKK	Mean	-43.4	-33.5	-35.3	18.7
	S.D.	(24.3)	(24.8)	(23.2)	(23.2)
	% sample			96%	67%
EUR	Mean	-19.1	-10.0	-12.8	9.1
	S.D.	(14.2)	(11.4)	(10.0)	(7.7)
	% sample			84%	57%
JPY	Mean	-16.9	-22.4	-22.4	14.4
	S.D.	(12.6)	(12.8)	(12.7)	(10.5)
	% sample			100%	95%

Notes: The first two columns report the annualized mean and annualized standard deviation for one-week Libor and GC repo basis by currency during the 01/01/2009–09/15/2016 period. The next column reports the same summary statistics conditional on observing a negative repo basis. For each currency, the last row of the panel reports the percentage of observations with a negative basis. The last column reports the arbitrage profits for the negative basis repo arbitrage provided that the arbitrage profits are positive after taking into account the transaction costs on the forward and spot exchange rates. Transaction costs are taken into accounts for the U.S. and Danish krone repo rates, but not for the Swiss franc, euro, and yen repo rates.

SOURCE: Wenxin Du, Alexander Tepper, Adrien Verdelhan paper, 2016

It is evident that short-term CIP deviations emerge even if we eliminate transaction costs and for interest rates that are free of credit risk. The fourth column of the table shows the net profits gained by arbitrageurs thanks to the negative basis arbitrage strategy. Even if we take transaction costs into consideration, the average annualized reached profits go from 9 to 19 basis points.

3.1.2 KfW BASIS

We turn now our attention to CIP deviations at long maturities, for which repo contracts do not exist. Anyhow, we can eliminate the credit risk associated with Libor-based CIP building up an alternative currency basis measure free from credit risk by making the comparison between direct dollar yields on dollar denominated debt and synthetic dollar yields on debt denominated in other currencies, having the same risk and the same years to maturity. Therefore, we focalize our attention on bonds supplied by the KfW, an AAA-rated German government-owned development bank, whose liabilities are entirely backed by the German government.

The general definition of the basis, we have previously mentioned in this paper, can also lead to the following KfW cross-currency basis:

$$x_{t,t+n}^{KfW} = y_{t,t+n}^{\$,KfW} - \left(y_{t,t+n}^{j,KfW} - \rho_{t,t+n}^{j}\right)$$

that is expressed as the difference between the cost of directly borrowing KfW in U.S. dollars and the synthetic borrowing cost of KfW in a foreign currency j. The $y_{t,t+n}^{\$,KfW}$ and $y_{t,t+n}^{j,KfW}$ represent the zero-coupon yields on KfW bonds nominated in U.S dollars and foreign currency j, respectively.

When the basis is not zero, arbitrageurs can profit by undertaking negative $\pi_{t,t+n}^{KfW-}$ and positive arbitrage $\pi_{t,t+n}^{KfW+}$ strategies expressed as follow:

$$\pi_{t,t+n}^{KfW+} \equiv (y_{t,t+n,Bid}^{\$,Kfw} - y_{t,t+n,Ask}^{\$,IRS}) - [(y_{t,t+n,Ask}^{j,KfW} - y_{t,t+n,Bid}^{IRS,j}) + x_{t,t+n,Bid}^{xccy,j}] - fee_{t,t+n}^{j}$$

$$\pi_{t,t+n}^{KfW-} \equiv [(y_{t,t+n,Ask}^{j,KfW} - y_{t,t+n,Bid}^{IRS,j}) - x_{t,t+n,Bid}^{xccy,j}] - (y_{t,t+n,Bid}^{\$,Kfw} - y_{t,t+n,Ask}^{\$,IRS}) - fee_{t,t+n}^{\$}$$

where $fee^{\$}_{t,t+n}$ and $fee^{j}_{t,t+n}$ denote the short-selling fee of the dollar and foreign currency bonds. In the case of a negative basis, the arbitrageur would invest in KfW bond denominated in foreign currency, pay the cross-currency swap to exchange cash flows denominated in foreign currency for U.S. dollars and short-sell the KfW bond denominated in U.S. dollars. In case of a positive basis, the arbitrageur would undertake the opposite arbitrage strategy.

We examine KfW bonds of similar maturity issued in different currencies, specifically, australian dollar, the Swiss franc, the euro and the japanese yen.

Table 2: KfW Basis and KfW CIP Arbitrage

		Basis full sample	Basis conditional	Pos. Profits ex. shorting fee	Pos. Profits 25 pct fee	Pos. Profits median fee
AUD	Mean	0.1	6.9	4.3	6.1	5.8
	S.D.	(11.5)	(6.1)	(4.2)	(3.1)	(3.4)
	% sample		57%	10%	4%	2%
CHF	Mean	-23.5	-24.3	15.0	5.6	15.2
	S.D.	(15.7)	(15.0)	(10.7)	(10.0)	(8.9)
	% sample		97%	72%	50%	33%
EUR	Mean	-13.6	-14.7	9.3	2.5	8.7
	S.D.	(9.7)	(8.8)	(6.7)	(6.9)	(5.4)
	% sample		94%	68%	34%	23%
JPY	Mean	-30.2	-30.8	21.6	13.1	20.2
	S.D.	(15.2)	(14.6)	(13.5)	(13.1)	(11.3)
	% sample		98%	90%	75%	63%

SOURCE: Wenxin Du, Alexander Tepper, Adrien Verdelhan paper, 2016

Table 2 reports the one-week KfW basis for Swiss, Danish, Euro, Japanese, and U.S. repo markets from 1/1/2009 to 08/31/2016 .The first column shows the annualized mean, annualized standard deviation and number of observations for the KfW basis, while the second column reports the same statistics data conditional on observing a positive KfW basis for the Australian Dollar (AUD) and a negative KfW basis for the Swiss franc (CHF), the euro (EUR), and the Japanese yen (JPY).The last row for each currency report says the percentage of observations having a negative basis.The third column reports the profit that can be gained by undertaking a positive basis arbitrage strategy in case of the Australian Dollar and a negative basis arbitrage strategy for Swiss franc, the euro, and the Japanese yen. The negative basis arbitrage strategy would provide positive profits by going long in yen, euro, Swiss franc KfW bonds and going short in dollar KfW bonds. The positive arbitrage strategy would consist in going long in Australian Dollars and going short in all other currencies considered.

The profits are gained considering bid-ask spreads on swaps and bonds, but not the short-selling costs of KfW bonds. The last two columns shows the profits net of the cost of shorting KfW bonds.

These costs are assumed to be equal to the 25th (50th) percentile of the shorting costs for KfW bonds of the corresponding currency on the same trading date. The evidence suggets that long-term CIP deviations emerge and they can give rise to significant arbitrage opportunities that offer positive profits even if we take into account the bid-ask spreads of bonds and swaps and the bond short-selling costs.

3.2 INTERNATIONAL IMBALANCES

An important element to be considered in the analysis of the possible explanation of CIP deviations are the international imbalances. Speculative practices, such as the carry trade, cause high customer demand for investments in high-interest-rate currencies and a large supply of savings in low-interest rate currencies. This misalignment leads to customer currency hedging demand to sell high-interest-rate currencies and buy low-interest rate currencies in the foreign exchange forward and swap markets. The increased demand for forward and swap contracts put upward pressure on the forward and swap exchange rate, causing it to deviate from the level implied by interest rate differentials and the spot exchange rate. The problem is that financial intermediaries provide currency hedging but do not want to carry the exchange rate risk. To achieve that, financial intermediaries can hedge the currency risk of their forward and swap positions in the cash market by buying low interest rate currencies and selling high interest rate currencies. The profit per unit of notional equals the absolute value of the cross- currency basis and it represents the cost of capital associated with the trade.

3.3 COSTLY FINANCIAL INTERMEDIATION

Before the global financial crisis, the validity of the CIP condition was strengthen by the continuous activities of global banks aimed at arbitraging funding costs. However, since the crisis, banks' balance sheet costs, associated with arbitrage and market making activities, highly increased because of the implementation of post-crisis bank regulations. The effect of further regulation constraints on banks has spread to other non regulated entities, causing the increase in the cost of leverage for the whole financial system. In the next pages of this section we will focus on relevant banking regulations and on how they affect the CIP arbitrages opportunities.

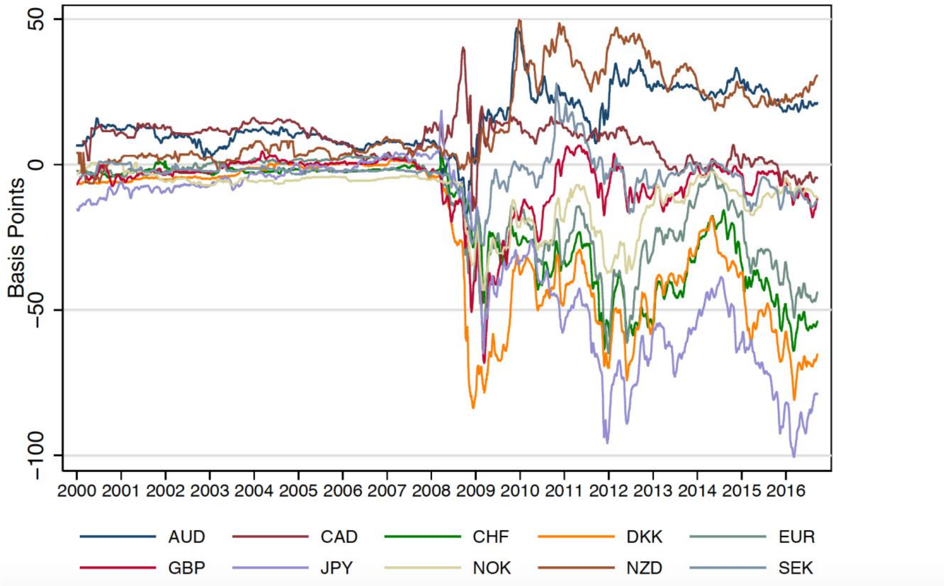
3.3.1 LEVERAGE RATIO

First of all, non-risk-weighted capital requirements are predominantly relevant for short-term CIP arbitrage. Non-risk-weighted capital requirements, or leverage ratio, existed also before the crisis but they have been strenghtened since then. The leverage ratio says the minimum amount of capital banks are required to hold against all on balance-sheet assets and off balance- sheet exposure. However, it doesn't take into consideration the degree of risk and hence it is considered a reasonable explanation to short-term CIP deviations. The required leverage ratio became higher after the crisis. The required ratio for US banks increased up to 6%. Before the crisis, the leverage ratio was not required for foreign banks but after Basel III, the leverage ratio became 3%. The leverage ratio requirement is likely to limit banks' balance sheet activities since banks need at least a certain number of cross-currency basis point to be willing to enter in trade. The minimum amount of basis points required woud be equal to the rates of return on capital multiplied by the required leverage ratio. As a matter of fact, many of the arbitrage opportunities that were shown previously, may not be attractive enough for banks that became reluctant to perform this activity after the crisis.

3.3.2 RISK-WEIGHTED CAPITAL REQUIREMENTS

Since the global financial crisis, also Risk-weighted Capital Requirements are more severe in order to reduce the risk of insolvency. The capital requirement represents the minimum amount of capital that must be held by banks against risk-weighted assets (RWA), that is, according to the risk level of each type of bank asset. Specifically, Tier 1 capital ratio, that before the crisis was 4%, increased to a range of 9.5%–13% and the total capital ratio increased from 8% to a range of 11.5%–15% under Basel III after the crisis. The main component of the RWA calculation for a CIP trade is the 99% Value-at-Risk (VaR) on 10-business-day holding period returns. The higher volatility of the cross-currency basis after the crisis, consequenty increased the estimation of the RWA it-self. After the crisis the basis is different from zero, as it shoud be according to the CIP condition. The post-crisis higher volatility is evident in the following graph, that reports the average movements of the five-year Libor cross-currency basis, measured in basis points, over 10-business days for G10 currencies.

Graph: Five-year Libor cross-currency basis



SOURCE： Wenxin Du, Alexander Tepper, Adrien Verdelhan paper, 2016

However, RWA capital constraints are relevant only for fong-term CIP arbitrages because one-week arbitrage opportunities present zero Value-at-Risk.

Furthermore, an additional measure of VAR adjusted for the stress period is introduced in the United States under Basel II.5 in January 2013.

Table 1 reports the increase in capital requirements against a five-year Libor CIP trade in recent years. The first column reports the 99% VaR measure for the trade based on the 10-business- day holding period; the VaR is annualized. Before the crisis the VaR was lower than 5%. During the peak of the crisis, the VaR measure reached the 20% and remained significantly high since then. The second column shows the SVaR, which is equal to the VaR in 2009. The third column shows the minimum total capital ratio for U.S. banks. Finally, the fourth column presents the total capital charges against the CIP trade. It is obtained by multiplying the sum of VaR and SVaR by the minimum capital ratio and scaling by a factor of 12.5 times 3, as specified by the Basel rules.

Table 1: U.S. Banks Capital Requirements Against a Five-year Libor CIP Trade

Year	VaR	SVaR	Capital Ratio	Capital Charge (% of notional)
2000	4.87%		8%	0.56%
2001	3.34%		8%	0.39%
2002	3.65%		8%	0.42%
2003	3.64%		8%	0.42%
2004	3.12%		8%	0.36%
2005	2.07%		8%	0.24%
2006	1.92%		8%	0.22%
2007	3.26%		8%	0.38%
2008	19.21%		8%	2.22%
2009	20.28%		8%	2.34%
2010	12.03%		8%	1.39%
2011	12.78%		8%	1.47%
2012	14.39%		8%	1.66%
2013	8.94%	20.28%	8%	3.37%
2014	6.43%	20.28%	11.50%	4.44%
2015	9.20%	20.28%	11.50%	4.88%

SOURCE: Wenxin Du, Alexander Tepper, Adrien Verdelhan paper, 2016

Capital charges against the five-year CIP trade that, before the crisis, were lower than 0.4% increased to more than 4% of the trade notional after the implementation of both Basel II.5 and Basel III. In other words, before the crisis banks could trade a volume 250 times bigger than their equity when undertaking CIP arbitrage activities; after the crisis, they can trade an amount 25 times bigger than their equity. In conclusion, the RWA appears not to be relevant for short-term CIP arbitrage, while representing a importat issue for long-term CIP arbitrage.

3.3.3 OTHER BANKING REGULATIONS

Finally, other banking regulations have also reduced banks' willingness to engage in CIP arbitrage. The over-the-counter derivatives reform required higher capital and higher minimum margin for cross-currency swaps, consequently increasing the capital needed to undertake the CIP arbitrage. Furthermore, the Basel III, other than risk-weighted and no-risk weighted capital requirements, established also the Liquidity Coverage Ratio, which requires banks to keep High Quality Liquidity Assets (HQLA) against potential cash outflows during the 30- day stress period.

The effects of this regulatory reforms on banks spreaded also to other-regulated institutions, such as hedge funds, for which the cost of leverage highly increased. The reason lies in the fact that hedge funds obtain funds from their prime brokers, which are regulated institutions and in order to sell the CIP strategy, they need to significantly increase the size of the arbitrage strategy to make their clients willing to buy it. Since capital requirements faced by primer brokers are more severe, their borrowing costs may increase considerably.

In conclusion, banks, main potential arbitrageurs, becomes unwilling to undertake arbitrage strategies since post-crisis regulatory requirements increased the cost of CIP trade.

Furthermore, in the following pages we will show that CIP deviations are larger when the banks' balance sheet costs are higher, specially towards quarter-end financial reporting dates.

3.4 QUARTER-END EFFECT ON THE LEVEL OF CIP DEVIATIONS

Usually financial intermediaries experience greater balance sheet constraints at the end of quarters due to quarterly regulations. Since the global financial crisis, as the banking regulation augmented, quarter-end balance sheet constraints became more relevant. More specifically, the Leverage Ratio requirement represents an important constraint for the short-term CIP arbitrage trade and it is disclosed at least on the quarter-end basis. The effect of quarter ends dynamics on CIP deviations was tested by Wenxin Du, Alexander Tepper and Adrien Verdelhan. They showed that CIP deviations are deeper at the end of the quarters than at any other point in time especially since the global financial crisis and since 2015, the year in which European Leverage Ratio Delegated Act,

requiring a point-in-time quarter-end leverage ratio for european banks, bacame effective. (Wenxin Du, Alexander Tepper, Adrien Verdelhan paper, 2016).
They made a difference-in-difference test for the one-week contract, expressed by the following linear regression:

$$\begin{aligned}|x_{1w,it}| &= \alpha_i + \beta_1 QendW_t + \beta_2 QendW_t \times Post07_t + \beta_3 QendW_t \times Post15_t \\ &+ \gamma_1 Post07_t + \gamma_2 Post15_t + \epsilon_{it},\end{aligned}$$

where $|x_{1w,it}|$ is the absolute value of the one-week basis for currency i at time t, α_i is a currency fixed effect. $Post07_t$ is an dummy variable that equals 1 if the trading date t is in or after 1/1/ 2007 and equal zero otherwise, and $Post15_t$ is an dummy variable equal 1 after 1/1/2015 and 0 otherwise. The $QendW$ is an dummy variable that equals 1 if settlement date for the contract, traded at t, is within the last week of the current quarter and zero if the maturity date is within the following quarter. The regression is estimated on the daily sample from 01/01/2000 to 09/15/2016 on one week Libor, OIS and repo bases. The coefficients β_2 captures the change in the quarter-end effect in the post-crisis 2007-2016 sample compared to the quarter-end effect in the 2000–2006 pre-crisis sample, and the coefficient β_3 captures the additional changes in the quarter-end effect during the past two years relative to the post-crisis average effect. They also tested the quarter-end effect for the monthly CIP deviation in a similar way:

$$\begin{aligned}|x_{1m,it}| &= \alpha_i + \beta_1 QendM_t + \beta_2 QendM_t \times Post07_t + \beta_3 QendM_t \times Post15_t \\ &+ \gamma_1 Post07_t + \gamma_2 Post15_t + \epsilon_{it},\end{aligned}$$

where $QendM_t$ is a binary variable indicating if the settlement date and maturity date of the monthly contract spans two quarters. In the following table we can see the results of their regression.

Table 2: Quarter-End Effects of the Level of CIP Deviations (2000-2016)

Panel A	(1) 1w Libor	(2) 1w OIS	(3) 1w Repo	(4) 1m Libor	(5) 1m OIS	(6) 1m Repo
$QendW_t$	1.585*	2.446	6.624**			
	(0.963)	(2.851)	(2.675)			
$QendW_t \times Post07_t$	9.545***	11.23***	22.42***			
	(1.297)	(3.191)	(3.864)			
$QendW_t \times Post15_t$	37.30***	31.35***	38.48***			
	(2.257)	(3.406)	(7.014)			
$QendM_t$				-0.523	-0.397	0.331
				(0.598)	(1.407)	(1.928)
$QendM_t \times Post07_t$				4.748***	4.419**	13.01***
				(0.822)	(1.748)	(2.689)
$QendM_t \times Post15_t$				7.561***	8.154***	1.792
				(1.371)	(2.493)	(5.620)
$Post07_t$	11.00***	18.33***	21.71***	12.64***	13.55***	22.00***
	(1.036)	(2.737)	(2.301)	(1.062)	(2.057)	(2.587)
$Post15_t$	4.344***	4.838*	-8.259**	6.228***	5.795**	3.026
	(1.602)	(2.554)	(4.000)	(1.706)	(2.828)	(5.449)
Observations	32,102	22,664	9,921	41,577	31,765	9,262
R-squared	0.168	0.101	0.112	0.200	0.129	0.162

SOURCE: Wenxin Du, Alexander Tepper, Adrien Verdelhan paper, 2016

Columns 1, 2 and 3 consider the one-week CIP deviations based on Libor, OIS, and repos. The slope coefficients β_2 and β_3 are positive and statistically significant across all three instruments meaning that there is a quarter end effect post crisis.

The quarter-end CIP deviation relative to the mean deviation in the rest of the quarter is on average 10 to 22 basis points higher in the post-2007 sample than over the pre-2007 sample for the one-week contracts.

Furthermore, compared to the post-2007 sample, the quarter-end weekly CIP deviation increases by another 30-40 basis points on average since January 2015. Columns 4, 5 and 6 consider the one-month CIP deviations. Still, the coefficients β_2 and β_3 are always positive and statistically significant except in one case. For CIP deviation based on Libor and OIS rates, the month-end deviation relative to the rest of the quarter is on average 4 to 5 basis point higher post-crisis than the level pre-crisis and increases by another 8 basis point in the post-2015 sample. For one-month repo, even though β_3 is not significant, β_2 is highly significant. Moreover, the coefficients on $QendW$ and $QendM$ are very small and largely insignificant meaning that there is very little quarter end effect before 2007.

3.4.1 QUARTER-END EFFECT ON THE TERM STRUCTURE OF CIP DEVIATION

The quarter-end balance sheet constraints have also some effects on the term structure of the basis. Has been shown that the one-week basis increases significantly as the one-week contract crosses quarter ends and one-month basis becomes significantly larger as the one-month contract crosses quarter ends. On the other hand, since a three-month contract always shows up in one quarterly report regardless of when it is executed within the quarter, we should not expect isolated price movement one week or one month prior to the quarter end. Thus, the quarter-end balance sheet constraint has effects on the term structure of the basis.

More specifically, the difference between three-month and one-month CIP deviation $(ts_{t,3M-1M} \equiv |x_{t,3M}| - |x_{t,1M}|\ )$ is expected to drop significantly once the one-month contract crosses the quarter-end. At the same time, the difference between one-month and one-week CIP deviation $(ts_{t,1M-1W} \equiv |x_{t,1M}| - |x_{t,1W}|\ )$ is expected first to increase significantly as the one-month contract crosses the quarter end and then decreases significantly once the one-week contract crosses the quarter end. Wenxin Du, Alexander Tepper and Adrien Verdelhan confirmed the characteristics previously observed with these panel regressions:

$$\begin{aligned} ts_{t,3M-1M} &= \alpha_i + \beta_1 QendM_t + \beta_2 QendM_t \times Post07_t + \beta_3 QendM_t \times Post15_t \\ &+ \gamma_1 Post07_t + \gamma_2 Post15_t + \epsilon_{it}. \end{aligned}$$

This regression used the difference between one-month and one-week CIP deviation $ts_{t,3M-1M}$ based on Libor, OIS and repo. Results are reported in the following table:

Table 3: one-month and one-week CIP deviation based on Libor, OIS and repo.

	(1) ts^{Libor}_{3M-1M}	(2) ts^{OIS}_{3M-1M}	(3) ts^{Repo}_{3M-1M}	(4) ts^{Libor}_{1M-1W}	(5) ts^{OIS}_{1M-1W}	(6) ts^{Repo}_{1M-1W}
$QendM_t$	0.565	0.565	0.565			
	(0.414)	(0.414)	(0.414)			
$QendM_t \times Post07_t$	-2.390***	-2.390***	-2.390***			
	(0.567)	(0.567)	(0.567)			
$QendM_t \times Post15_t$	-9.476***	-9.476***	-9.476***			
	(0.934)	(0.934)	(0.934)			
$\mathbb{I}_{QendM_t=1,QendW_t=0}$				-0.625	0.543	0.827
				(0.577)	(1.315)	(1.020)
$\mathbb{I}_{QendM_t=1,QendW_t=0} \times Post07_t$				4.242***	2.392	8.270***
				(0.773)	(1.466)	(1.505)
$\mathbb{I}_{QendM_t=1,QendW_t=0} \times Post15_t$				12.76***	11.05***	19.84***
				(1.226)	(1.426)	(3.635)
$QendW_t$				-3.217***	-3.782**	-5.618***
				(0.809)	(1.743)	(1.525)
$QendW_t \times Post07_t$				-1.404	-5.725***	-8.307***
				(1.085)	(1.950)	(2.353)
$QendW_t \times Post15_t$				-33.39***	-25.22***	-77.10***
				(1.849)	(2.057)	(6.177)
$Post07_t$	5.925***	5.925***	5.925***	0.843	-0.524	1.087
	(0.553)	(0.553)	(0.553)	(0.657)	(1.097)	(0.912)
$Post15_t$	-2.591***	-2.591***	-2.591***	0.444	1.594	5.516**
	(0.890)	(0.890)	(0.890)	(1.022)	(1.030)	(2.160)
Observations	41,553	41,553	41,553	32,045	22,491	7,337
R-squared	0.104	0.104	0.104	0.095	0.091	0.131

SOURCE: Wenxin Du, Alexander Tepper, Adrien Verdelhan paper, 2016

From the the table we can notice that the coefficient β_1 is small and insignificant, and β_2 and β_3 are both significantly negative. Compared to the pre-crisis sample, in the post crisis sample the $ts_{t,3M-1M}$ is 2.4 basis point lower relative to its mean in the rest of the quarter when the one-month contract crosses the quarter ends. In the post-2015 sample, the quarter-end effect corresponds to another 9.5 basis point reduction in $ts_{t,3M-1M}$ compared to its post-crisis mean. The remaining three columns show similar tests for $ts_{t,1M-1W}$:

$$
\begin{aligned}
ts_{t,1M-1W} \quad = \quad & \alpha_i + \beta_1 \mathbb{I}_{QendM_t=1,QendW_t=0} + \beta_2 \mathbb{I}_{QendM_t=1,QendW_t=0} \times Post07_t \\
& + \beta_3 \mathbb{I}_{QendM_t=1,QendW_t=0} \times Post15_t + \beta_4 QendW_t + \beta_5 QendW_t \times Post07_t \\
& + \beta_6 QendW_t \times Post15_t + \gamma_1 Post07_t + \gamma_2 Post15_t + \epsilon_{it},
\end{aligned}
$$

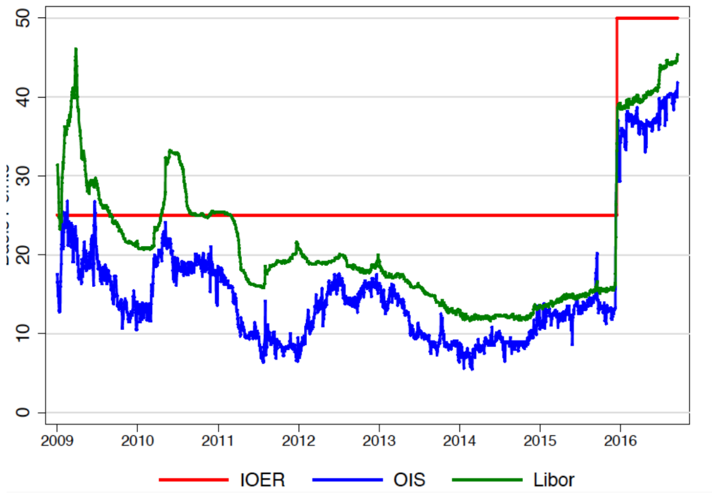
The variable $\mathbb{I}_{QendM=1,QendW=0}$ equals 1 if a one-month contract traded at t tt crosses the quarter end, but the one-week contract traded at t does not cross the quarter end. As expected, the coefficients β_2 and β_3 are significantly positive while β_5 and β_6 are significantly negative, which suggests that the difference between one-month and one-week CIP deviation first increases as the once-month contract crosses the quarter end, but the one-week contract does not, and then decreases as the one-week contract crosses the quarter end. Like in the previous results we can observe that these quarter-end effects are larger in the post-crisis period and especially since 2015. In summary, consistent with the key role of banks' balance sheets on quarter-end reporting dates, we find that CIP deviations are systematically higher for contracts that cross quarter- end reporting dates post the crisis.

3.5 CIP CONDITION BASED ON IOER RATES ACROSS MAJOR CENTRAL BANKS

During the great financial crisis, major central banks implemented unconventional monetary policies, which brought global depositary institutions to have held large amounts of excess reserves at major central banks. As we know, the interest rate paid on excess riserves, the IOER, is decided by the central bank. In the united states the IOER is frequently higher that interest rates paid in private money market, such as the Fed Fund rate. This is explained by the fact that there are government-sponsored enterprises (GSEs), for example, Federal Home Loan Banks, that not having the IOER deposit facility, lend at rates below the IOER in the Fed Fund market. This causes the so-called "IOER-Fed Fund arbitrage" exploited by depositary institutions with IOER deposit facility, that borrow from the GSEs at fed fund rate and deposit this money as excess reserves, profiting in this way from the IOER-Fed Fund spread. Furthermore, such strategy is risk-free as central bank cash is risk-less.

The IOER is always greater than the one-week OIS rate (overnight swap interest rates) since 2009 and higher than the one-week Libor rate since 2012, as it is evident from the following graph:

Graph: Short-Term Libor-Based Deviations from CIP



SOURCE: Wenxin Du, Alexander Tepper, Adrien Verdelhan paper, 2016

The IOER-Fed Fund/Libor spreads can be considered a fair measure the balance sheet costs associated with the Leverage Ratio and the Liquidity Coverage Ratio for depository institutions that undertake risk-free arbitrage strategies. Specifically, the spread represents the cost of leverage for foreign banks and, in addition to the leverage ratio, it includes also the deposit insurance fees paid on wholesale funding for US banks.

Thus, the IOER basis may reflects the cost of funding dollar positions by borrowing foreign currency and converting it into dollars through an FX swap. (Linda S. Goldberg, Craig Kennedy, and Jason Miu paper, 2011).

We consider the IOER a proxy for the U.S. dollar "funding" cost after taking into consideration balance sheet constraints and wholesale dollar funding costs. Therefore, in addition to the the Libor and OIS cross-currency basis as a measure of U.S. dollar funding costs, we use an alternative basis based, the IOER cross currency basis. It refers to the basis obtained by funding in the U.S. dollar interest rate on excess reserves (IOER) and investing at the foreign IOER.

Table 4: One-week Libor-based, OIS-based and IOER-based basis

Currency	Libor basis	OIS basis	IOER basis
CHF	-21.4	-36.8	-25.2
	(28.6)	(36.9)	(32.0)
DKK	-41.3	-29.1	-33.8
	(22.7)	(23.6)	(25.2)
EUR	-19.8	-22.9	-15.5
	(16.6)	(15.8)	(14.7)
JPY	-22.3	-26.5	-26.6
	(28.7)	(30.7)	(29.1)
Total	-26.1	-28.3	-24.7
	(26.2)	(27.8)	(26.7)

SOURCE: Wenxin Du, Alexander Tepper, Adrien Verdelhan paper, 2016

NOTE: Means and standard deviations of the one-week cross-currency basis for the Swiss franc (CHF), the Danish Krone (DKK), the euro (EUR), and the Japanese yen (JPY). The sample period is 01/01/2009-09/15/2016.

From a summary statistic report in Table the IOER basis is 8 basis points, the Libor basis is 26 basis points and the OIS basis is -28 basis points, on average. As we expected, since the IOER basis takes into account bank balance sheet costs related to the Leverage Ratio and the Liquidity Coverage Ratio, the CIP condition based on IOER rates across major central banks hold significantly better than the CIP conditions based on private money market instrument. In conclusion, CIP deviations can be mitigated once we take into account the balance sheet cost associated with Leverage Ratio and the Liquidity Coverage Ratio and wholesale dollar funding.

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CONCLUSION

In this paper we have examined persistent and systematic failure of the CIP conditions after the financial crisis of 2007-2008. We have showed that in the post-crisis period, since 2010, both the three-month Libor basis and the five-year Libor cross-currency basis, have been sistematically different from zero for G10 major currencies. Furthermore, thanks to the empirical analysis of Lucio sarno we have provided evidence that short-lived arbitrage opportunities emerge in the major foreign exchange and capital markets. Specifically, the size of CIP arbitrage opportunities for the three exchange rates (USD/EUR, USD/GBP, JPY/USD) observed at for different maturities (1m,3m,6 months and 1 year) can be economically significant. Moreover, we have seen that the duration of arbitrage opportunities is on average high enough to allow agents to take advantage of CIP deviations. At the same time, duration is low enough to suggest that before the Great Financial Crisis arbitrage opportunities were fastly eliminated. Finally, we have showed that these arbitrage opportunities can not be merely explained by credit risk and transaction cost but that they are caused by the costly financial intermediation and international imbalances in funding supply and investment demand across currencies. We have demonstrated that CIP deviations are systematically higher at the quarter ends post crisis reporting dates, reflecting the impact of higher balance sheet costs due to the implementation of post crisis bank regulations. Finally, consistent with the potential explanations, we have showed that CIP deviations can be mitigated once we take into account the balance sheet cost associated with Leverage Ratio and the Liquidity Coverage Ratio of wholesale dollar funding since the IOER rates across major central banks hold significantly better than the CIP conditions based on private money market instrument.

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