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PARITY: THEORY AND EVIDENCE**

Alfred Wong, David Leung and Calvin Ng

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Risk-adjusted Covered Interest Parity: Theory and Evidence^{*}

Alfred Wong^{}**

Hong Kong Monetary Authority

and

David Leung

Hong Kong Monetary Authority

and

Calvin Ng

Hong Kong Monetary Authority

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Abstract

We extend the theory of covered interest parity (CIP), aligning the different risks involved in uncollateralized money market transactions and collateralized foreign exchange (FX) swap transactions, which underscore CIP deviations in times of elevated uncertainty. We postulate that the swap dealer behaves as if he tries to filter out the counterparty risk embedded in money market rates in pricing FX swaps. Our results suggest that he does so not only during turbulent times but also under normal market conditions. The extended theory also uncovers a simple way to disentangle counterparty and liquidity risk premiums embedded in money market rates.

Keywords suggested:

Covered interest parity, CIP deviation, forward rate, exchange rate, Libor-OIS spread, counterparty credit risk, funding liquidity risk, FX swap

JEL Codes suggested:

F31, F32, G15

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^{**} Corresponding author's email: alfred_yt_wong@hkma.gov.hk

1. Introduction

It has long been established in economic and finance literature that in general covered interest parity (CIP) holds but uncovered interest parity (UIP) does not.¹ However, the CIP departure for practically all currencies vis-à-vis the US dollar during the global financial crisis (GFC) in 2007 and 2008 caught many by surprise. The US dollar interest rate quoted in bank funding markets deviated significantly from that implied in the foreign exchange (FX) swap market (Chart 1).² Baba and Packer (2009), Coffey et al (2009), and Genberg et al (2011) argue that the deviations were largely caused by a sharp increase in counterparty credit risk in the interbank money market during the GFC, while Hui et al (2011) and Mancini-Griffoli and Ranaldo (2011) attribute the phenomenon to mainly a rise in funding liquidity risk.

The explanations offered by these authors are all linked to some unusual market circumstances that occurred during the GFC, which should gradually disappear after the crisis as financial markets return to normalcy.³ However, considerable CIP deviations, though scaling back significantly from their peaks registered during the GFC, have persisted. While counterparty credit risk and liquidity funding risk in the interbank money market, as reflected in the spread between the London interbank offered rates (Libor) and its respective overnight index swap (OIS), have remained elevated (Chart 2), it is puzzling to see the CIP deviations sustained given the substantial profitable arbitrage opportunities. What is the economics behind the violation of such a long-established and well-tested theory? This question is the key motivation of this study.

The puzzle prompts us to go back to first principles in studying the phenomenon: how the prices of the variables in the CIP condition are determined and, in particular, what risk premiums are possibly built into these prices, especially in light of the timing of the occurrence of the deviations. In doing so, we

¹ UIP postulates that the interest rate differential between two currencies should be equal to the expected changes in the exchange rate. Hence, cross-currency arbitrageurs are exposed to exchange rate risks. Generally speaking, UIP does not hold well empirically. For a review of empirical work on UIP, see Lewis (1995), Engel (1996) and Aggarwal (2013).

² The derivation of the CIP deviation is fully explained in Sections 3 and 4. The data used in drawing it are detailed in Section 5.

³ An unusual market circumstance popularly described in the literature occurs when a general dollar funding shortage arises from a group of financial institutions failing to obtain dollar funding in the money market to finance the operations of their US conduits (Baba and Packer, 2009) or from financial institutions in general coming under pressure to hoard dollars to prepare for their own funding needs or to meet regulatory requirements (Hui et al, 2011).

find that the key lies in the difference between the risks involved in money market transactions and those in FX swap transactions: transactions in the money market are uncollateralized and hence unsecured, while those in the FX swap market are effectively collateralized. We hasten to add that recognizing this difference is not new but no one has pointed out that this is what renders the parity condition invalid.

To put it simply, the parity condition is basically an equation that has the ratio of the forward to spot exchange rate of two currencies on one side and the interest differential between the two currencies on the other. An FX swap transaction, which is a combined spot and forward FX transaction, is essentially a collateralized transaction but the interest differential is calculated based on the interest rates drawn from two uncollateralized money markets. Obviously the parity condition cannot be expected to hold when counterparty risk is perceived to be significant by market participants. In case this occurs, one simple way of equalizing the two sides of the equation is to remove the counterparty risk premium from the money market rates. In our view, this is exactly what the FX swap dealer does in setting the forward rate for any FX swap transaction.

Hence, in light of the different nature of the transactions, we modify the theory of CIP by incorporating into the parity condition the relevant risk premiums that are embedded in the prices of the foreign and domestic financial instruments. In this extension—which can be referred to as the risk-adjusted version of the theory—asymmetric reappraisal of the risks involved in interbank lending between two countries is what causes the CIP deviations under the traditional version. Since counterparty and liquidity risks tend to rise in times of uncertainty, these deviations were particularly acute during the GFC. However, as we shall see, the risks exist all the time in the money market as reflected in the data and our empirical results show the FX swap market always tries to separate the two.

As mentioned, past studies have already linked the phenomenon of CIP deviations to the surge in counterparty risk during the GFC. However, our theory differs significantly from theirs in explaining the mechanism of how the surge causes the deviations. Most of these studies argue that the surge screens certain financial institutions out of the money market, creating a dollar shortage at the benchmark interest rate (e.g., Baba and Packer (2009), McGuire and von Peter (2012)). The resulting

excess demand forces these market participants to resort to the FX swap market for obtaining dollar funding, causing the market to charge a premium over what is implied by the interest differential between two money markets to compensate for the additional risk. Based on their conjecture, the CIP deviation, which can be interpreted as an FX swap market premium, will persist as long as the money market remains uncleared. We concur with these studies that counterparty risk is the culprit. However, we believe that the money market is always cleared, i.e., there is no shortage of, or excess demand for, funding. As the money market and the FX swap market are in equilibrium, there are no market forces to drive away the deviations. Financial institutions can always choose between the money market and the FX swap market to borrow from. Those who opt for the latter do so voluntarily and at a discount from the money market rate for placing an equivalent amount of fund in another currency as collateral. The decision depends on how the borrower weighs between borrowing at a higher interest rate in the money market, and a lower rate in the FX swap market but incurring an opportunity cost, that of having the same amount of fund in another currency.

The fact that CIP departure is not entirely a crisis phenomenon means that any attempt to answer the question should not be confined to examining what occurred in crisis periods as in most previous studies (including, but not limited to, Baba and Packer (2009) and Genberg et al (2011) and Hui et al (2011)). Hence, we study a much longer period starting from the beginning of 2002 to the end of 2015. In a bid to investigate how the financial markets behave during tranquil and turbulent times, we examine the period as a whole and also break it down into two sub-periods: before and after the onset of the GFC. The latter sub-period, characterized by elevated counterparty and liquidity risks (Chart 2), encompasses not only the GFC but also the European sovereign debt crisis and several bouts of market turbulence triggered by, for example, multiple rounds of quantitative easing measures of major central banks between 2009 and 2012, and the taper tantrum in 2013. Three European currency pairs vis-à-vis the US dollar, namely, the euro, the British pound and the Swiss franc, come under scrutiny in this study.⁴ All these currencies have an active Libor market. In our estimation, the currency pairs are examined separately and also under the same panel.

⁴ These currency pairs are among the most traded ones, covering approximately 70% of the global FX market turnover, according to the latest issue of Triennial Central Bank Survey of Foreign Exchange and Derivatives Market Activity published by the Bank for International Settlements (BIS). In the BIS definition, global foreign market turnover covers activities in the spot market, forward market and markets for other FX-related derivatives.

In essence, this paper argues that risks must be properly accounted for in two distinctly different types of financial market transactions involved in the CIP condition. The empirical evidence found in this study, which encompasses long periods of tranquil and turbulent periods, shows that the so-called CIP departure is not a phenomenon pertaining only to economic or financial crisis, but also one that reflects that financial markets are always vigilant about counterparty and liquidity risks involved in borrowing or lending. Due to the ways in which transactions are conducted, the money market is concerned with both counterparty risk and liquidity risk while the FX swap market only the latter. Therefore, as counterparty risk gets elevated in turbulent times, CIP deviation becomes noticeable. However, it is important to note that the existence of the deviation does not imply profitable arbitrage opportunity; it merely represents the difference in the prices to pay to borrow in the domestic and foreign money markets for their respective counterparty risk taken by the lender.

In the literature, the distinction between counterparty and liquidity risks can be traced back to the theoretical exposition put forward by Brunnermeier and Pedersen (2008), which was followed by a heated debate about the shares of the two risk premiums embedded in the Libor-OIS spread (McAndrews et al (2008), Michaud and Upper (2008), Sarkar (2009), Acharya and Skeie (2011), Garleanu and Pedersen (2011) and Gefang et al (2011)). As the extension of the theory suggests that the FX swap market acts almost like a risk screening device that can strip off the counterparty risk premium from the money market rate, this allows us to estimate econometrically the shares of the two risk premiums. Hence, this paper also contributes to the literature by introducing a new and simple way of separating the two risk premiums embedded in money market transactions, a task that has been widely recognized to be extremely difficult. We estimate that, on average, counterparty risk premium accounts for 27% of the total risk premium (i.e., the Libor-OIS spread) embedded in the foreign money market rates under study and 29% in the US money market rate prior to the GFC. The shares of funding liquidity risk premium are 73% and 71% respectively. The share of counterparty risk premium increases sharply to 81% in the foreign money markets but falls to 18% in the US money market during and after the crisis. The share of funding liquidity risk premium falls to 19% overseas but rises to 82% in the US.

In the next section we provide a brief review of the relevant literature. Section 3 outlines the formulation of the risk-adjusted version of CIP and discusses the difference between the prediction of the theory of risk-adjusted CIP and the common conjecture put forward by previous studies in analyzing CIP deviations. We specify the econometric model for estimation in Section 4. Section 5 elaborates the data used for the analysis. Section 6 reports the empirical findings. Our conclusion is in Section 7.

2. Literature Review

A key feature of the empirical literature on the validity of CIP prior to the GFC is that researchers tend to dichotomize between tranquil and turbulent periods. In relatively tranquil markets, the empirical findings on major currencies are generally consistent with CIP.⁵ Departures from CIP are explicable by political risk, transaction costs, capital control, taxes, measurement errors due to non-synchronous data and various types of capital market frictions (Branson (1969), Aliber (1973), Frenkel and Levich (1975), Levi (1977), Deardorff (1979), Dooley and Isard (1980), Clinton (1988), Frankel and MacArthur (1988), Akram et al (2008, 2009)). In most cases, the deviations are small, falling within a narrow band arguably consistent with CIP.⁶ Any deviations that are relatively larger or fall outside an allowable band tend to be short-lived, reflecting that FX markets are efficient and quick enough to eliminate significant arbitrage opportunities.⁷ In all, most studies support the theory of CIP and also give a sense that empirical evidence is likely to strengthen over time in view of increasing global capital mobility, international financial integration and rapid development of information technology.

At the same time, the literature has also recognized that financial markets behave drastically differently during turbulent periods such that they could significantly depart from CIP. For example, in a follow-up study, Frenkel and Levich (1977) found that the role played by transaction costs in accounting for the deviations in tranquil periods is not observed in the turbulent peg period of 1968-69 characterized by heightened financial uncertainty and political risk. Similarly, Taylor (1989) found evidence of significant departures from CIP during the floating of the sterling in 1972 and the introduction of the European

⁵ For a comprehensive survey of the literature, see Levich (2012).

⁶ Such a band is often referred to as a "neutral band" following French and Levich (1975).

⁷ For example, employing high frequency data in their investigation, Akram et al (2008, 2009) find that any such opportunities would last for only a few minutes.

Monetary System in 1979. However, except pointing out that CIP deviations could indeed occur and persist through protracted periods of time when market conditions were uncertain, there was little that economists could do until an important market came into being in the middle of 1990s. This market is the OIS market.

As the OIS is an interest rate swap in which a fixed rate is swapped against a pre-determined published index of an overnight reference rate for an agreed period of time, it provides a good barometer of counterparty and liquidity risks when measured against the market interest rate. For the US OIS market, the reference rate refers to the effective federal funds rate; for the euro and British pound OIS markets, the floating legs are the euro overnight index average and the sterling overnight index average respectively. At maturity, the party that supposedly ends up paying less interest will receive from the other party the difference between the fixed rate and the geometric average of the overnight rate over the term of the contract. Given that the notional principal is not exchanged and only the difference between the interest payments is settled at maturity, the OIS rate is considered as the best proxy for the risk-free rate.⁸ At the riskier end of the funding market, the Libor is the average interbank interest rate at which banks lend to each other on an unsecured or uncollateralized basis in London. The nature of the transactions means that the Libor is necessarily risk-embedded. That is, when a bank is in doubt of the creditworthiness of the other party or becomes more conscious of its own need for liquidity over the term of the loan, it will demand a higher interest rate on top of the risk-free rate to compensate for taking counterparty and liquidity risks.⁹ Hence, the difference between the Libor and OIS can serve as a proxy indicator of counterparty and liquidity risks in the money market.

The indicator has aided a number of researchers trying to explore the connection between CIP deviations, and counterparty and liquidity risks in the bank funding market during the GFC (e.g., Baba and Packer (2009), Coffey et al (2009), Mancini-Griffoli and Ranaldo (2011), Genberg et al (2011), Hui et al (2011)). More specifically, it is argued that in the depths of the crisis, particularly in the immediate aftermath of the collapse of Lehman Brothers in September 2008, elevated uncertainties about these

⁸ As the reference rate is often the key policy rate, it is also a measure of market expectations of the future path of the policy rate concerned.

⁹ Funding liquidity risk refers to the risk of being unable to obtain funding to meet financial obligations. It differs from market liquidity risk, which refers to the risk of being unable to convert assets to cash at market prices. However, the two are closely linked. For a detailed discussion, see Brunnermeier and Pedersen (2008).

risks resulted in severe dislocations of money markets, leading to a shortage of US dollars which was particularly acute among non-US financial institutions. As these institutions had difficulties in accessing the cash market for dollar funding, they resorted to FX swaps as an alternative channel, with the excess demand in this market transforming into a widening wedge between the interest rates implied by the FX swaps and in the cash market.

However, as we shall see in the next section, our theory differs significantly from their conjecture that turmoil in the money market spills over to the FX swap market (e.g., Baba et al (2008)), as financial institutions that are unable to borrow foreign currency funds in the money market (e.g., smaller European banks that could not obtain dollar funding in the eurodollar market) resort to borrowing in the FX swap market at a higher cost than benchmark money market rates. We argue that the markets are always in equilibrium and the emergence of CIP deviations merely reflects that the traditional version of CIP wrongly assumes the counterparty risks are the same or absent in money market and FX swap transactions. As long as counterparty risks remain, there will be CIP deviations. In our view, the problem of the past studies is that they attribute the deviations to disequilibrium in the money market. While this may sound plausible for crisis situations, it is difficult to reconcile with the phenomenon of sustained deviations when calm returns to financial markets.

3. The theory of risk-adjusted CIP

The theory of interest rate parity essentially says that movement of the exchange rate between two currencies is governed by the interest differential between the two countries concerned:

$$\frac{F}{S} = \frac{1+r}{1+q} \quad (1)$$

where S is the spot exchange rate, defined as the foreign currency value of one US dollar, F is the expected future spot exchange rate, and r the foreign interest rate and q the domestic interest rate. Equation (1) is sometimes referred to as a no-arbitrage condition because there is no profit to arbitrage

if the exchange rate moves exactly as dictated by the interest differential. If this condition—commonly referred to as UIP—holds, the investor would be indifferent between holding domestic and foreign currency assets. In reality, interest differential does not always dictate exchange rate movement and, hence, it is possible to make a profit, or a loss, with such an attempt.

However, the emergence of the forward market allows the domestic (foreign) investor to take a forward cover when buying the foreign (domestic) currency asset in a bid to take advantage of possibly a higher interest rate abroad (at home). He can do so by taking an FX swap, i.e., conducting a spot and forward FX transaction simultaneously.¹⁰ This enables him to convert his investment back to domestic (foreign) currency at the end of the investment horizon at an exchange rate determined today. In this case, the exchange rate risk incurred is said to be covered, i.e., eliminated. Equation (1) can therefore be referred to as CIP when F stands for the forward rate, rather than the expected future spot rate. This, if it holds, is also a no-arbitrage condition because there is no risk-free profit to make.

To understand why CIP does not seem to hold any longer, it is important to note that while exchange rate risk is covered in equation (1), counterparty and liquidity risks are not.¹¹ Since money market transactions entail counterparty and liquidity risks, let's rewrite (1) as

$$\frac{F}{S} = \frac{1 + r_f + (r - r_f)}{1 + q_f + (q - q_f)} \quad (2)$$

where r_f and q_f denote the foreign and domestic risk-free interest rate respectively such that $(r - r_f)$ and $(q - q_f)$ represent the sum of counterparty risk and liquidity risk premiums in the foreign and domestic money markets respectively.

In the traditional version of CIP, it is commonly assumed that the risks facing the investor are the same in the foreign and domestic money markets. However, even if this assumption is satisfied, CIP deviations can still arise if the ratios between the counterparty and liquidity risks are different in the two

¹⁰ An FX swap is essentially two parties entering into a contract in which each of them borrows a sum of money in a currency from, and simultaneously lends the same amount of money in another currency at the current exchange rate to, the other party; and they agree to repay each other at a fixed exchange rate on the day the contract expires.

¹¹ Counterparty risk is the risk that the borrowing bank fails to repay the loan and interest in full at the end of the term while liquidity risk is the risk that the lending bank gets caught short of fund during the term.

markets. The reason is that FX swap transactions entail practically no other risk except a relative liquidity risk. To see this, let's consider an FX swap as two banks of different countries lending to each other in their own currency.

From the perspective of both, the loan from the other party, which is in a foreign currency, is effectively taken as collateral. Hence, if the other party fails to repay the loan at the end of the term, they can sell the collateral to recoup their loss. In case this occurs, there could still be a loss if the exchange rate, which determines the domestic currency value of the collateral, does not move in their favor during the term.¹² However, unless the foreign currency depreciates sharply, any such loss is negligible compared to the case of an interbank loan default. Hence, the counterparty risk taken by either party in an FX swap transaction is minimal.

However, both parties still have to take a liquidity risk as they may be caught short of domestic liquidity during the term. But again they have the option of selling the collateral to meet any temporary need (and buying it back at the end of the term to fulfill their obligation). As in the case of the counterparty risk involved in FX swap transactions, there is also possibly a small exchange rate loss.¹³ But compared with an interbank loan, the key difference is that while each party runs a domestic currency liquidity risk, it receives a foreign currency liquidity premium.

In view of the way the FX swap works, we postulate that the swap dealer behaves as if he tries to filter out in the transaction both the foreign and domestic counterparty risk premiums embedded in the respective money market rates. He takes into consideration only the difference between the foreign and domestic liquidity premiums in setting the interest differential that ultimately enters his forward rate calculation. Therefore, it is necessary to adjust the traditional version (2) of CIP by deducting the foreign and domestic counterparty risk premiums from their respective money market rates as follows:

$$\frac{F}{S} = \frac{1 + r - \alpha (r - r_f)}{1 + q - \beta (q - q_f)} \quad (3)$$

¹² This is attributable to the part of the term risk premium pertaining to the risk that the counterparty risk premium may have realization that differs from its expected amount (Hou and Skeie (2014)).

¹³ Like in the case of the counterparty risk, this potential exchange rate loss is the remaining part of the term risk premium. See the previous footnote.

where α and β , both of which lie between 0 and 1, denote the share of the counterparty risk premium in the total risk premium in the foreign and domestic money market respectively such that $(1 - \alpha)$ and $(1 - \beta)$ are the shares of the respective liquidity risk premium. Hence, this is equivalent to adding the foreign and domestic liquidity risk premiums to their respective risk-free rates:

$$\frac{F}{S} = \frac{1 + r_f + (1 - \alpha)(r - r_f)}{1 + q_f + (1 - \beta)(q - q_f)} \quad (4)$$

Equation (3) or (4) can also be rewritten as:

$$\frac{F}{S} = \frac{1 + \alpha r_f + (1 - \alpha)r}{1 + \beta q_f + (1 - \beta)q} \quad (5)$$

This suggests that removing counterparty risk premium from the money market rate or adding liquidity risk premium to the risk-free rate is the same as taking a weighted average of the risk-free interest rate and the risk-embedded money market rate, with the weights being the shares of the counterparty and liquidity risk premiums respectively. Compared to the traditional version, equation (3), (4) or (5), which can be referred to as the risk-adjusted version, essentially aligns the risks involved in the foreign and domestic money market transactions with those in the FX swap market transactions. Needless to say, in the absence of counterparty and liquidity risks in both the domestic and foreign money markets, these equations will converge to equation (1), the traditional version.

However, the emergence of counterparty and liquidity risks can cause departure from the traditional version. The departure is reflected in the deviation of the interest rate in the money market from the FX swap-implied interest rate. The latter can be obtained by calculating, from equation (1), the domestic interest rate using the ratio of the forward to spot exchange rate and the foreign interest rate:

$$q^* = \frac{S}{F}(1 + r) - 1 \quad (6)$$

Taking the natural logarithm of equation (6) and subtracting the prevailing domestic interest rate q from both sides yield the CIP deviation:

$$q^* - q \simeq r - q - (\ln F - \ln S) \quad (7)$$

which suggests that the deviation is approximately equal to the difference between the interest differential and the forward premium or discount.

Taking the natural logarithm of (3) and substituting it into (7) yield:

$$q^* - q \simeq \alpha (r - r_f) - \beta (q - q_f) \quad (8)$$

Hence, according to the risk-adjusted version, the CIP deviation essentially reflects the difference between the counterparty risks in the foreign and domestic money markets. When counterparty risk is greater in the foreign money market than in the domestic money market, the FX swap implied domestic interest rate will be higher than the domestic money market rate, and vice versa. In other words, a higher FX swap-implied interest rate for a currency than the respective money market rate implies that, in the FX swap, the party borrowing the currency is the one that is perceived to have a lower counterparty risk than the other party lending the currency.

This prediction runs counter to the story told by earlier researchers in the literature. In their story, European institutions, which are the dollar borrowers, are generally perceived to have high counterparty risk. Shut off by the cash market, they have no alternative but to resort to borrowing from US institutions in the FX swap market, paying a premium, hence resulting in an FX swap-implied dollar interest rate that is higher than the dollar money market rate (e.g., Hui et al (2011), Baba and Packer (2009), Fong, et al (2010)). However, according to the theory of risk-adjusted CIP, a higher FX swap-implied dollar interest rate suggests exactly the other way round, i.e., the party that borrows dollars is the one which is perceived to have a lower counterparty risk.

To see why the party who pays a higher FX swap-implied interest rate has a lower counterparty risk,

let's differentiate between FX swap-implied interest rate and implicit interest rate in the FX swap. As discussed earlier, an FX swap has two legs: borrowing a currency on the one hand and lending another currency on the other. In a dollar/euro FX swap, the dollar borrower is also the euro lender and the euro borrower is also the dollar lender. By implicit dollar interest rate, we refer to the interest rate pertaining to the dollar leg only. According to the theory, the dollar borrower (cum euro lender) pays a lower implicit interest rate in the FX swap (than the dollar money market rate) for his dollar loan. How much lower depends on how high the counterparty risk the dollar borrower is perceived to have.¹⁴ The higher his perceived counterparty risk, the larger the discount he will get for providing collateral to eliminate the risk for the lender. However, whether or not he will ultimately get an FX swap-implied dollar interest rate that is lower than the dollar money market rate also depends on the implicit interest rate he receives from lending his euros. If the other party, i.e., the euro borrower (cum dollar lender), is perceived to have a greater counterparty risk, then the implicit euro interest rate in the FX swap deal will be subject to a larger discount.¹⁵ In other words, the party that is perceived to have a comparatively lower counterparty risk will end up paying a higher FX swap-implied interest rate than the respective money market rate, as it receives a smaller discount from the money market rate than the other party does.

We hasten to add that the theory itself makes no reference to which country's institutions are likely to be the borrowers or lenders of a certain currency. For example, nothing is said about European institutions likely being dollar borrowers (and euro lenders) or US institutions dollar lenders (and euro borrowers). However, if European and US institutions are dollar borrowers (cum euro lenders) and dollar lenders (cum euro borrowers) respectively, then a higher FX swap-implied dollar interest rate would imply that European institutions must be perceived to have a relatively lower counterparty risk.

4. Model

The risk-adjusted version (5) suggests that the ratio of the forward to spot exchange rate is the

¹⁴ The counterparty risk of an average domestic currency (the dollar in this case) borrower is expected to be $\beta(q - q_f)$ based on equation (3), although the perceived counterparty risk differs significantly among individual borrowers in reality.

¹⁵ The counterparty risk of an average foreign currency (the euro in this case) borrower is expected to be $\alpha(r - r_f)$ based on equation (3).

difference between the weighted averages of the risk-free and risk-embedded interest rates in the domestic and foreign money markets. Taking the natural logarithm of equation (5) gives:

$$\ln F - \ln S \approx \alpha r_f - \beta q_f + (1 - \alpha) r - (1 - \beta) q \quad (9)$$

This suggests that the forward premium or discount is approximately equal to the counterparty-risk-weighted risk-free interest differential adjusted for the difference in the liquidity premium between the domestic and foreign money markets.

We estimate the equation (9) in its first difference form:

$$\Delta FP_t = \theta_0 + \theta_1 \Delta OIS_t^{FC} + \theta_2 \Delta OIS_t^{US} + \theta_3 \Delta Libor_t^{FC} + \theta_4 \Delta Libor_t^{US} + e_t \quad (10)$$

where Δ is the first difference operator, FP is the forward premium $\ln F_t - \ln S_t$, and the superscripts US and FC stand for US dollar and a foreign currency that serves as the funding currency in an FX swap. We take the first difference of the variables due to the presence of unit roots in the data. The risk-free rates and risk-embedded money market rates in equation (9) are respectively represented by OIS and Libor rates in equation (10). Based on the rationale underlying equation (9), the constant term θ_0 should be equal to zero; the coefficients θ_1 and θ_3 should lie between 0 and 1; the coefficients θ_2 and θ_4 should lie between 0 and -1; and e_t is the error term assumed to be independently and identically distributed with an expected value of zero. Additionally, the pair of coefficients θ_1 and θ_3 and the pair of coefficients θ_2 and θ_4 should sum to 1 and -1 respectively.

The model is estimated by means of ordinary least squares without and with the restrictions of $\theta_1 + \theta_3 = 1$ and $\theta_2 + \theta_4 = -1$ imposed on each pair of the currencies, and under the same panel such that all the currency pairs are estimated jointly and therefore the heterogeneities of individual economies can be taken into account in a single model.¹⁶

¹⁶ A fixed-effect panel data model is specified since there is no need to make a relatively strong assumption that the unobserved heterogeneity of individual economy is uncorrelated with the included variables.

5. Data

All data are daily, retrieved from Bloomberg. This study focuses on three major European currency pairs vis-à-vis the US dollar, namely, the euro, the British pound and the Swiss franc. All these currencies have an active Libor market (Hou and Skeie (2014)). Chart 3 shows the Libors of the US dollar, the euro, the British pound and the Swiss franc for the 3-, 6- and 12-month tenors, which broadly follow the same trend.¹⁷ While different tenors should not have a significant impact on the results *a priori*, we choose the 12-month tenor for our study as the Swiss National Bank targets the 3-month Libor, which renders any analysis of interest rate response to market forces difficult to interpret.¹⁸ The longest tenor is chosen also because it is less subject to any distortion caused potentially by (i) the effect of the 3-month Libor being targeted by the Swiss National Bank rippling up the yield curve; and (ii) the extremity of monetary conditions in the turbulent period that encompasses considerable quantitative easing and negative interest rates.

Generally speaking, compared to other empirical tests, data quality requirements for testing CIP validity are relatively more demanding, as minor differences can produce profitable arbitrage opportunities or cause an acceptable CIP deviation to fall outside the “neutral band” (Frenkel and Levich (1975)). Traditionally, since Keynes (1923), many studies have tried to identify the average deviation above which arbitrage becomes possible (e.g., Einzig (1961), Branson (1969)). In this regard, we admit that we may not have gone far enough in screening our data which may bear some minor deficiencies. First of all, our data are synchronized to a significant extent, but not totally. Libor data are their fixings at 11am London time. For the OIS rates, and the spot and forward exchange rates, there are market close data of New York, London and Tokyo available in Bloomberg. We choose those of Tokyo (20:00pm JST(GMT+9)), which match exactly the same time of the Libor fixing in London

¹⁷ For the euro, the money market rate used is actually Euribor instead of Libor as the former is more representative of the interbank borrowing rate in euro. The Euribor is based on the quotes of 24 banks, of which 20 are headquartered in the euro zone, two in European countries outside the euro zone, and two international banks. In comparison, the Libor euro is based on the quotes of 15 banks, with many of them being the London branches of banks headquartered in continental Europe. However, despite these differences, the two rates are largely the same, and estimation results using either series bear practically no differences.

¹⁸ The 3-month Libor has been an operational target of monetary policy of the Swiss National Bank since 1999. The Bank would make use of short-term repo transactions to influence the 3-month Libor to make sure it falls within its “operational target range”, which is currently set at -1.25% to -0.25%. This range was last revised on 15 Jan 2015, from the previous -0.75% to 0.25%. For details, see page 34 in *Swiss National Bank 92nd Annual Report 1999* and page 15 in *Swiss National Bank 108th Annual Report 2015*.

(11:00am BST(GMT+1) in spring and summer, and 11:00am GMT) during winter and spring, but Tokyo is ahead of London by an hour during summer and autumn.¹⁹ Second, these data are market quotes by contributing banks, which are not necessarily actual transacted prices. Hence, they might not be executable in practice, for example, for the purpose of taking arbitrage. Some studies emphasize the importance of using transacted data (Taylor (1989), Akram et al (2008) and Mancini-Griffoli & Ranaldo (2011)). Third, the Libor fixing is the reference rate calculated based on the quotes from a small group of large banks. Consequently, it is arguably not a market rate accessible by an average market participant for funding, especially at the peaks of financial crisis. Finally, the highly publicized Libor scandal, which broke out in 2012, casts further doubt over the benchmark interest rates. There are many possible allegations, which are all highly controversial (Hou and Skeie (2014)). Perhaps, the most widely-accepted one is that some of the contributing banks intentionally underreported the borrowing cost in order to enhance their image of financial soundness, particularly during the depths of the GFC. Nonetheless, despite these limitations, we believe that the overall quality of our data is good enough for the purpose of testing the validity of the risk-adjusted version of CIP in a general sense, instead of focusing on whether the deviations falls with a certain critical range.

The period under study runs from, subject to data availability, December 6, 2001 to December 31, 2015. Since the CIP deviations of all the currencies in this study strongly suggest that there are two distinct regimes before and after the GFC, we divide the sample period into two sub-periods, namely a tranquil period before the crisis and a turbulent period afterwards, so as to account for any structural break (Chart 1). The dividing line of the two regimes is August 9, 2007, the day on which BNP Paribas suspended redemptions for three of its investment funds, a landmark event that is widely regarded as the starting point of the ensuing turmoil in global financial markets (e.g., Hui et al (2011), Taylor and Williams (2009)).

The importance of the division of the period can also be seen from the perspectives of the sharply different characteristics of the forward premium (or discount). To do so, let's rewrite the definition of CIP deviation in equation (7) as:

¹⁹ London practices daylight adjustment while Tokyo does not.

$$\ln F - \ln S = (OIS^{US} - OIS^{FC}) + [(Libor^{US} - OIS^{US}) - (Libor^{FC} - OIS^{FC})] + (q^* - q) \quad (11)$$

such that the forward premium is decomposed into three components: the relative OIS rate of the US dollar to the foreign currency, the spread of the US dollar and foreign currency Libor-OIS spreads (referred to as the spread of spreads for short hereafter), and the CIP deviation. We plot equation (11) for the three pairs of currencies in Chart 4. As can be seen, in the tranquil period the forward premium was essentially an outcome of the risk-free interest differential of two countries, i.e., the difference between the US dollar OIS and the foreign currency OIS. As the Libor-OIS spread was so small for all the currencies, the spread of spreads was negligible. In this period any CIP deviation was also insignificant. However, it is clear that in the turbulent period the OIS differential can no longer fully explain the forward premium. And as the spread of spreads can also explain part of the rest of the forward premium, any component that remains unexplained can only be attributed to or simply called CIP deviation.

The descriptive statistics of all the variables are summarised in Table 1. It is obvious that the means and the variability of the Libor-OIS spreads for all currencies were significantly higher in the turbulent period than in the tranquil period. For example, the US Libor-OIS spread had a mean of 73 basis points during the turbulent period, almost a six-fold increase from the 13 basis points during the tranquil period.²⁰ Meanwhile, its standard deviation was 39 basis points in the turbulent period, more than an eleven-fold increase from the 3.4 basis points in the tranquil period. However, as a result of extraordinary monetary accommodation following the GFC, the means of the Libors and OISs of all the currencies were significantly lower in the turbulent period.

6. Empirical Findings

The estimation results of the model are presented in Table 2, with the upper panel for the unrestricted model and the lower panel for the restricted model. First of all, the constants for all the equations are very close to zero and insignificant, as expected. The coefficients of almost all the explanatory

²⁰ We have conducted the t-test and confirmed that the means and variances of the Libor-OIS spreads are statistically different.

variables including those in the panel equation are found to be highly significant for the whole sample period as well as for the two sub-periods. The only coefficient found to be insignificant is that of the euro Libor for the turbulent period but this is because the coefficient is very close to zero (as the coefficient of the euro OIS approaches unity). The signs of all the coefficients are correct, as predicted by the risk-adjusted version of CIP, i.e., positive for the foreign currency OIS and Libor, and negative for the US dollar OIS and Libor.

Another salient feature of the results is the size of the coefficients: all of them fall between zero and unity (one or negative one) except the coefficient of the euro OIS for the turbulent period which is marginally greater than one. Given that they represent the shares of counterparty risk and liquidity risk premiums in the total risk premium, it is interesting to see if the estimated coefficients of the OIS and Libor would sum to unity for each of the foreign currencies and the US dollar. Somewhat to our surprise, the results lend support to our thesis not only in the turbulent period but also in the tranquil period, i.e., before the GFC, as we thought that market participants would have generally been less vigilant about counterparty and liquidity risks.

We plot the sum of each pair of coefficients in Chart 5 for ease of reference. As can be seen, except for the Swiss franc for the turbulent period, all sum fairly close to unity. Based on the results of the panel regression, for the tranquil period the share of counterparty risk premium for the foreign currency is estimated at 26% and that of the liquidity risk premium 67%. The share of counterparty risk premium for the US dollar is estimated at 28% and that of the liquidity risk premium at 63%. For the turbulent period, the share of counterparty risk premium for the foreign currency rises to 86% while the share of the liquidity risk premium falls to 20%. On the contrary, the share of counterparty risk premium for the US dollar falls to 25%, while the share of the liquidity risk premium rises to 87%. These sums tend to be larger for the turbulent period, which may be attributable to the limited accessibility of the Libor funding to all market players and also underreporting of Libor. As these problems tend to intensify in times of market distress, the Libor may be understated to some extent during the turbulent period, hence possibly leading to a small upward bias on the coefficients.

In all, the results are highly consistent with what is predicted by the risk-adjusted version of CIP.

Despite the simplicity of the model, its explanatory power is very high, especially given that all the data are specified in first differences. For the tranquil period, the adjusted R^2 of the three currency pairs ranges from 0.79 to 0.87 with that of the panel being 0.82. Even for the turbulent period during which market fluctuations are much more volatile, the adjusted R^2 still falls within 0.52 to 0.60, with that of the panel being 0.55.

In light of the above results, we re-estimate the model, restricting the sum of each pair of the coefficients of OIS and Libor to unity with a view to improving the precision of the estimates. The results are reported in the lower panel of Table 2. As expected, the adjusted R^2 of the equations all reduces, but only very marginally, suggesting that the restrictions are sound and reasonable. Overall, the results retain essentially the same flavour, except that the estimates are now statistically more significant, possess the correct signs, and fall strictly between zero and one. The panel equation results show that for the foreign currency the share of the counterparty risk premium now stands at 27% in the tranquil period and hence that of the liquidity risk premium the remaining 73%; counterparty risk premium accounts for 81% of the total risk premium in the turbulent period and liquidity risk premium the remaining 19%. For the US dollar, the share of counterparty risk premium is 29% in the tranquil period and the share of liquidity risk premium 71%; counterparty risk premium constitutes 18% of the total risk premium and liquidity risk premium the remaining 82%.

In addition to the above unrestricted and restricted estimation, we have also estimated the model with three additional variables, namely, the domestic and foreign bank credit default swap (CDS) spreads, and FX implied volatility for two reasons. First, bank CDS spreads are a popular counterparty risk measure. Hence, in light of the well-known weaknesses of Libor (e.g., underreporting), it is possible that bank CDS spreads are better than Libor in capturing the effects of counterparty risk, especially for the turbulent period.²¹ Second, as discussed in Section 3, there is still arguably a small counterparty risk involved in FX swap transactions, i.e., the risk of a loss of value of the collateral, which can be proxied by the exchange rate risk. We find that these variables are significant only for the turbulent period but, even so, they add little to the explanatory power of the model.²² Hence, for simplicity, we

²¹ We follow Baba and Packer (2009) and Hui et al (2011) to take the average of the CDS spreads of some large banks in each market to the proxy the CDS spread for the market.

²² The results, not reported here, are available on request.

prefer keeping the original specification.

7. Concluding Remarks

In this paper we have outlined a general theory of CIP to explain the relationship among the spot exchange rate, the forward exchange rate and the interest differential between two countries under normal and turbulent market conditions.²³ This theory, put simply, says that the difference between the spot and forward exchange rates is determined by the counterparty-risk-free interest differential between two countries or the risk-free interest differential between two countries adjusted for their relative liquidity premium.

As evidenced by a vast amount of empirical literature, the traditional version of CIP, while well supported under normal market conditions, is proven to be insufficient in explaining the considerable deviations that have persisted through protracted periods of time characterized by relatively elevated market uncertainty. We argue that the deviations are by no means signs of a breakdown of the fundamental economic relationship between exchange rates and interest rates as governed by CIP, but merely reflect that the traditional version *per se* is inadequate in coping with the significant asymmetric reappraisal of counterparty and liquidity risks between countries that often arise in turbulent times. The key lies in the fact that the CIP condition tries to equate the prices set in money markets with those in foreign exchange (including FX swap) markets. Unfortunately these markets have distinctly different ways of conducting transactions and hence the pricing of their instruments necessarily entails different risks. It is useful to note that even if both the foreign and domestic money market instruments face the same total risk—a key assumption in the traditional version—there could still be CIP deviations if the composition of counterparty and liquidity risks in the foreign and domestic instruments is not the same.

The risk-adjusted version of CIP essentially calls for correct appropriation of risks to, or alignment of risks between, (the foreign and domestic) money markets and foreign exchange (including FX swap)

²³ The traditional version is a specific case in which there is little counterparty or liquidity risk in the market, i.e., when the market is in relatively tranquil times.

markets. Indeed, the empirical evidence obtained in this study strongly supports that the FX swap market, given the nature of its transactions, would discount the counterparty risk embedded in both the domestic and foreign money market rates in pricing the forward premium. This underscores the CIP deviation of the forward premium from the interest differential between the two money markets. However, the existence of the deviation offers no arbitrage opportunity, as it only represents the price to pay to borrow in the money market for the counterparty risk taken by the lender as compared to the FX swap market. Needless to say, those who can afford the collateral have the choice of borrowing at a lower rate in the FX swap market.

The theory of risk-adjusted version of CIP also has a by-product that adds to its contribution to the literature. There has been a highly contentious debate on whether counterparty or liquidity risk premium accounts for a larger proportion of the total risk premium embedded in the money market rate, and both sides recognize that the two are extremely difficult to disentangle. According to the risk-adjusted version, the pricing mechanism of the FX swap market effectively acts as a risk filter that can separate them. As suggested by the results of the restricted panel model, counterparty risk premium accounts for 27% of the total risk premium embedded in the foreign money market rates and 29% in the US money market rate during the tranquil period. This means that, under normal market conditions, liquidity risk premium accounts for the majority of the total risk premium. During the turbulent period most of the CIP deviation studies focus on, the share of counterparty risk premium increases sharply to 81% in the foreign money market but falls to 18% in the US money market. In other words, liquidity risk premium accounts for a much smaller share for the foreign money markets but a larger share for the US market in crisis periods. In light of these results, the answer is dependent on which market and under what market condition one refers to in determining which of the two risk premiums constitutes a greater proportion of the Libor-OIS spread.

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Table 1: Descriptive statistics of key variables**12-Month Forward Premium (%)**

	<i>Full Sample</i>					<i>Tranquil Period</i>					<i>Turbulent Period</i>				
	Mean	Max	Min.	S.D.	Obs.	Mean	Max	Min.	S.D.	Obs.	Mean	Max	Min.	S.D.	Obs.
Euro	-0.33	2.02	-2.83	1.15	4,431	-0.68	1.59	-2.83	1.39	2,240	0.03	2.02	-1.35	0.67	2,191
British pound	0.78	3.31	-0.94	0.97	5,213	1.00	3.31	-0.94	1.09	3,022	0.48	3.14	-0.51	0.67	2,191
Swiss franc	-1.84	0.47	-4.73	1.36	5,217	-2.59	-0.18	-4.73	1.28	3,026	-0.79	0.47	-2.36	0.54	2,191

12-Month Libor (%)

	<i>Full Sample</i>					<i>Tranquil Period</i>					<i>Turbulent Period</i>				
	Mean	Max	Min.	S.D.	Obs.	Mean	Max	Min.	S.D.	Obs.	Mean	Max	Min.	S.D.	Obs.
Euro	2.50	5.53	0.04	1.51	4,355	3.31	5.34	1.93	0.93	2,205	1.66	5.53	0.04	1.54	2,150
British pound	4.12	8.00	0.86	2.25	5,054	5.60	8.00	3.40	1.13	2,932	2.06	6.65	0.86	1.74	2,122
Swiss franc	1.37	3.98	-0.79	1.12	5,054	1.84	3.98	0.33	0.90	2,932	0.72	3.38	-0.79	1.07	2,122
US dollar	3.17	7.50	0.53	2.18	5,055	4.49	7.50	0.99	1.79	2,933	1.35	5.28	0.53	1.10	2,122

12-Month OIS (%)

	<i>Full Sample</i>					<i>Tranquil Period</i>					<i>Turbulent Period</i>				
	Mean	Max	Min.	S.D.	Obs.	Mean	Max	Min.	S.D.	Obs.	Mean	Max	Min.	S.D.	Obs.
Euro	2.10	5.28	-0.34	1.63	4,396	3.23	5.28	1.83	0.92	2,205	0.97	4.72	-0.34	1.37	2,191
British pound	2.75	6.30	0.24	2.15	3,914	4.69	6.30	3.25	0.66	1,723	1.22	6.19	0.24	1.62	2,191
Swiss franc	0.86	3.90	-1.03	1.12	3,954	1.55	3.90	0.22	0.97	1,764	0.31	2.91	-1.03	0.89	2,190
US dollar	1.63	5.68	0.07	1.78	3,656	3.12	5.68	0.83	1.63	1,465	0.63	5.04	0.07	1.01	2,191

12-Month Libor-OIS spread (bps)

	<i>Full Sample</i>					<i>Tranquil Period</i>					<i>Turbulent Period</i>				
	Mean	Max	Min.	S.D.	Obs.	Mean	Max	Min.	S.D.	Obs.	Mean	Max	Min.	S.D.	Obs.
Euro	38.2	235.2	-13.0	41.6	4,322	7.3	19.6	-13.0	2.5	2,172	69.5	235.2	17.8	39.1	2,150
British pound	52.5	317.2	3.8	50.3	3,798	13.1	23.6	3.8	2.9	1,676	83.6	317.2	19.9	48.1	2,122
Swiss franc	26.1	196.1	-21.3	28.1	3,846	7.0	40.8	-21.3	3.2	1,725	41.6	196.1	-17.1	29.8	2,121
US dollar	48.7	284.3	7.1	42.0	3,539	12.9	24.0	7.1	3.4	1,417	72.6	284.3	22.4	38.9	2,122

Note: The tranquil period covers December 6, 2001 to August 8, 2007, while the turbulent period August 9, 2007 to December 31, 2015. The full sample covers both periods.

Table 2: Estimation results

Unrestricted Model

	<i>Full Sample</i>				<i>Tranquil Period</i>				<i>Turbulent Period</i>			
	<u>EUR</u>	<u>GBP</u>	<u>CHF</u>	<u>Panel</u>	<u>EUR</u>	<u>GBP</u>	<u>CHF</u>	<u>Panel</u>	<u>EUR</u>	<u>GBP</u>	<u>CHF</u>	<u>Panel</u>
θ_0	0.0000 (0.0005)	-0.0001 (0.0004)	0.0000 (0.0006)	-0.0001 (0.0003)	-0.0001 (0.0003)	0.0000 (0.0003)	-0.0001 (0.0004)	-0.0001 (0.0002)	-0.0004 (0.0007)	-0.0003 (0.0007)	0.0002 (0.0009)	-0.0002 (0.0004)
θ_1	0.9128 *** (0.0217)	0.7835 *** (0.0166)	0.4640 *** (0.0189)	0.6723 *** (0.0111)	0.5243 *** (0.0228)	0.4865 *** (0.0224)	0.1619 *** (0.0129)	0.2594 *** (0.0096)	1.0224 *** (0.0294)	0.8395 *** (0.0232)	0.7410 *** (0.0307)	0.8627 *** (0.0160)
θ_2	-0.2369 *** (0.0243)	-0.3438 *** (0.0218)	-0.0921 *** (0.0277)	-0.1850 *** (0.0145)	-0.3482 *** (0.0277)	-0.4736 *** (0.0302)	-0.2007 *** (0.0356)	-0.2834 *** (0.0184)	-0.2886 *** (0.0333)	-0.3541 *** (0.0296)	-0.1463 *** (0.0367)	-0.2477 *** (0.0194)
θ_3	0.1640 *** (0.0322)	0.1130 *** (0.0183)	0.6565 *** (0.0319)	0.3051 *** (0.0150)	0.4256 *** (0.0249)	0.4392 *** (0.0270)	0.7564 *** (0.0244)	0.6664 *** (0.0133)	0.0146 (0.0590)	0.0767 *** (0.0250)	0.5778 *** (0.0501)	0.2016 *** (0.0223)
θ_4	-0.8549 *** (0.0239)	-0.6507 *** (0.0215)	-0.9038 *** (0.0280)	-0.8238 *** (0.0145)	-0.5814 *** (0.0287)	-0.4745 *** (0.0313)	-0.7015 *** (0.0380)	-0.6336 *** (0.0194)	-0.9044 *** (0.0314)	-0.6887 *** (0.0280)	-0.9499 *** (0.0356)	-0.8658 *** (0.0185)
R-squared	0.6260	0.6426	0.5329	0.5762	0.8513	0.8673	0.7912	0.8243	0.5991	0.5704	0.5173	0.5475
Adjusted R-squared	0.6255	0.6422	0.5324	0.5760	0.8508	0.8669	0.7906	0.8240	0.5983	0.5696	0.5163	0.5471
DW Statistics	2.0865	2.3089	2.2422	2.2029	2.8135	2.8085	2.7255	2.7741	2.0372	2.2459	2.2580	2.1735

Restricted Model

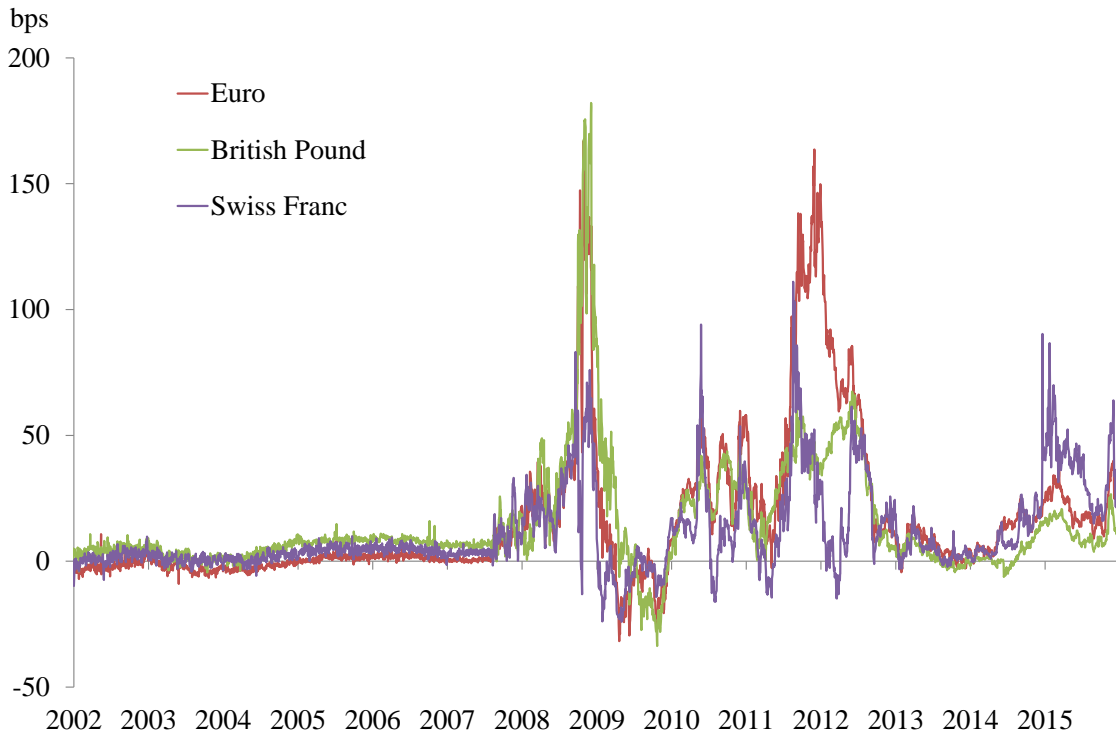
	<i>Full Sample</i>				<i>Tranquil Period</i>				<i>Turbulent Period</i>			
	<u>EUR</u>	<u>GBP</u>	<u>CHF</u>	<u>Panel</u>	<u>EUR</u>	<u>GBP</u>	<u>CHF</u>	<u>Panel</u>	<u>EUR</u>	<u>GBP</u>	<u>CHF</u>	<u>Panel</u>
θ_0	0.0000 (0.0005)	0.0000 (0.0004)	-0.0001 (0.0006)	-0.0001 (0.0003)	0.0000 (0.0003)	-0.0001 (0.0003)	0.0000 (0.0004)	0.0000 (0.0002)	-0.0001 (0.0007)	0.0000 (0.0006)	-0.0002 (0.0009)	-0.0001 (0.0004)
θ_3	0.1266 *** (0.0207)	0.1888 *** (0.0150)	0.5423 *** (0.0182)	0.3279 *** (0.0104)	0.4476 *** (0.0225)	0.5202 *** (0.0222)	0.8299 *** (0.0131)	0.7299 *** (0.0098)	0.0664 ** (0.0276)	0.1445 *** (0.0192)	0.3250 *** (0.0286)	0.1885 *** (0.0143)
θ_4	-0.8130 *** (0.0228)	-0.6583 *** (0.0207)	-0.9028 *** (0.0265)	-0.8208 *** (0.0137)	-0.6375 *** (0.0280)	-0.5122 *** (0.0304)	-0.8027 *** (0.0363)	-0.7078 *** (0.0188)	-0.8361 *** (0.0297)	-0.6783 *** (0.0265)	-0.9000 *** (0.0336)	-0.8177 *** (0.0175)
R-squared	0.6223	0.6372	0.5301	0.5760	0.8460	0.8637	0.7820	0.8178	0.5868	0.5660	0.5054	0.5434
Adjusted R-squared	0.6221	0.6370	0.5299	0.5758	0.8457	0.8635	0.7817	0.8176	0.5864	0.5656	0.5049	0.5431
DW Statistics	2.0769	2.3174	2.2274	2.2030	2.7990	2.8288	2.7378	2.7866	2.0131	2.2380	2.2102	2.1546

Note:

(i) ** and *** denotes statistical significance at the 5% and 1% levels.

(ii) The tranquil period covers December 6, 2001 to August 8, 2007, while the turbulent period August 9, 2007 to December 31, 2015. The full sample covers both periods.

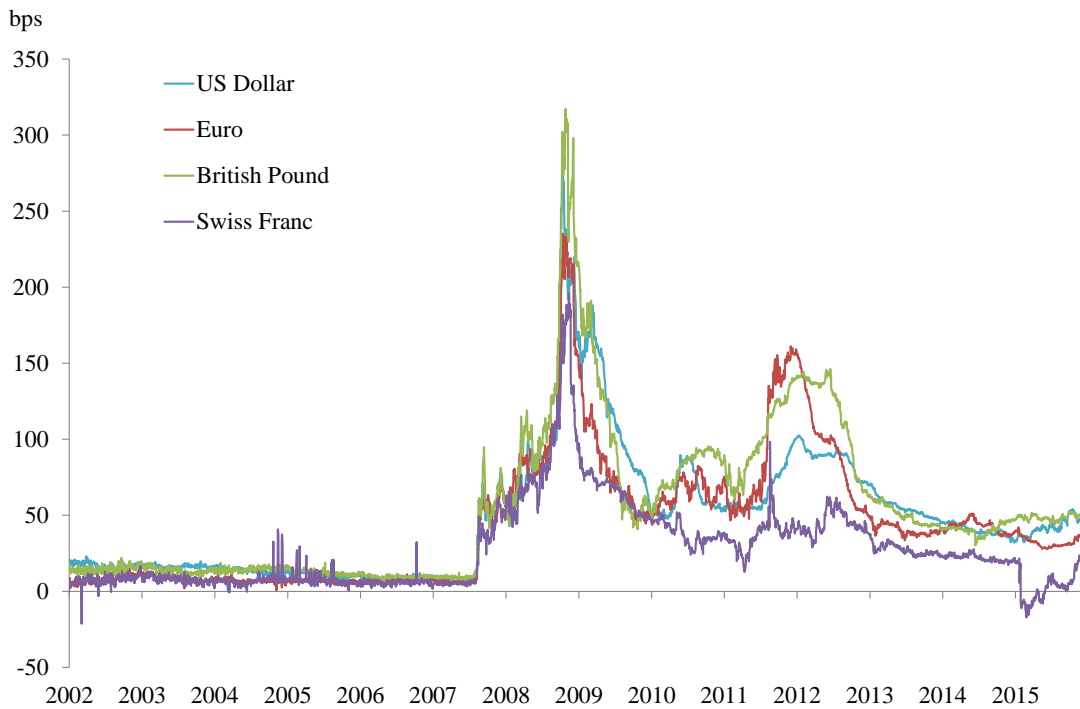
Chart 1: Deviation of FX swap-implied USD funding rate from USD Libor



Source: Estimates based on data drawn from Bloomberg

Note: The Libor and the FX swap-implied USD funding rates are based on a 12-month tenor.

Chart 2: Libor-OIS spreads

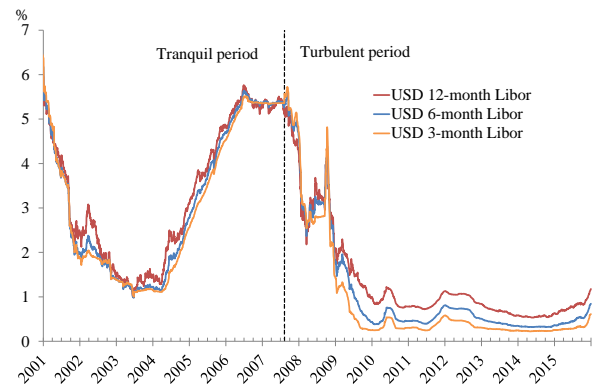


Source: Estimates based on data drawn from Bloomberg

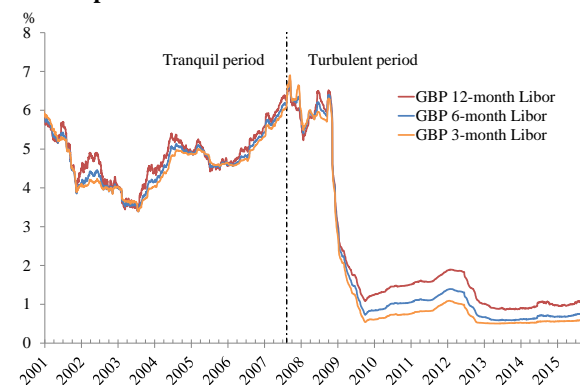
Note: The Libor and the OIS rates are based on a 12-month tenor.

Chart 3: London interbank offered rates

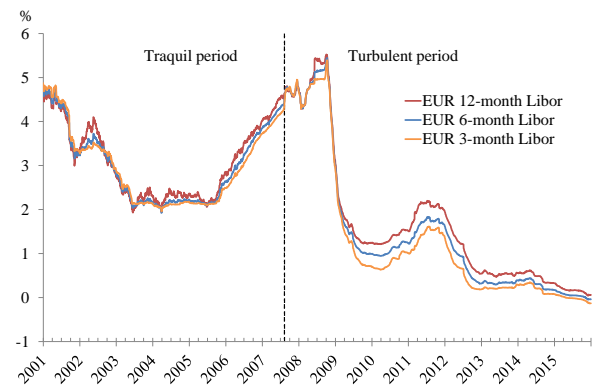
US dollar



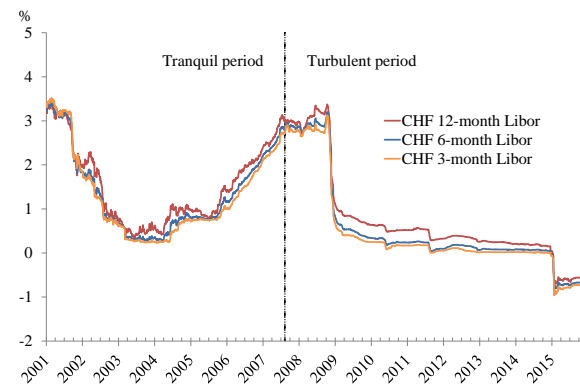
British pound



Euro



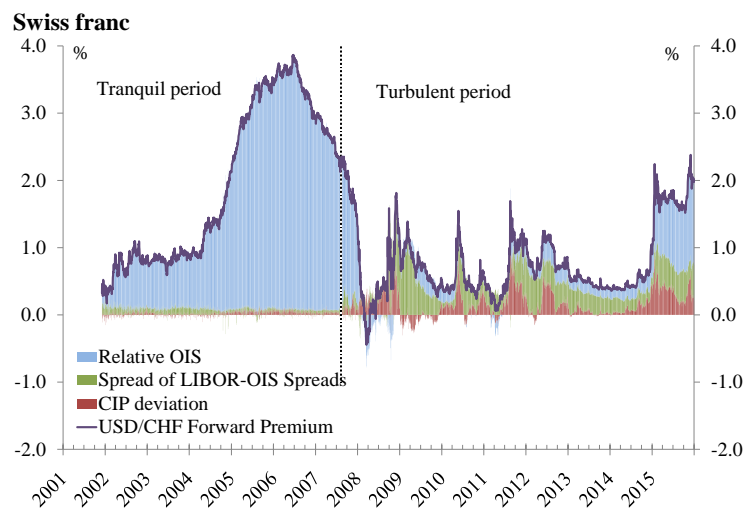
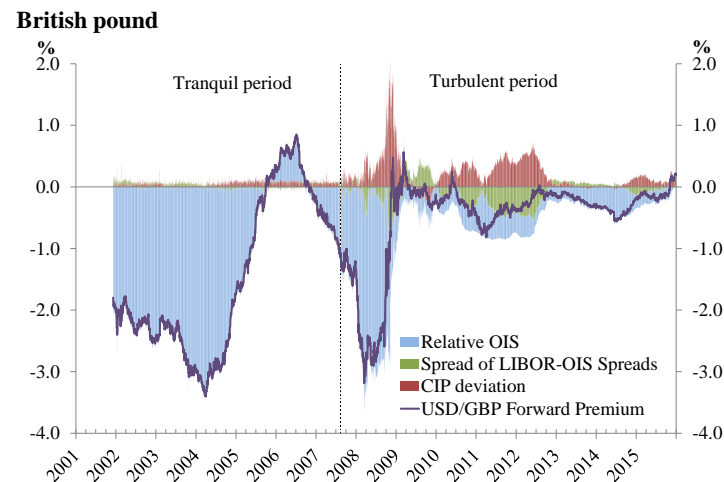
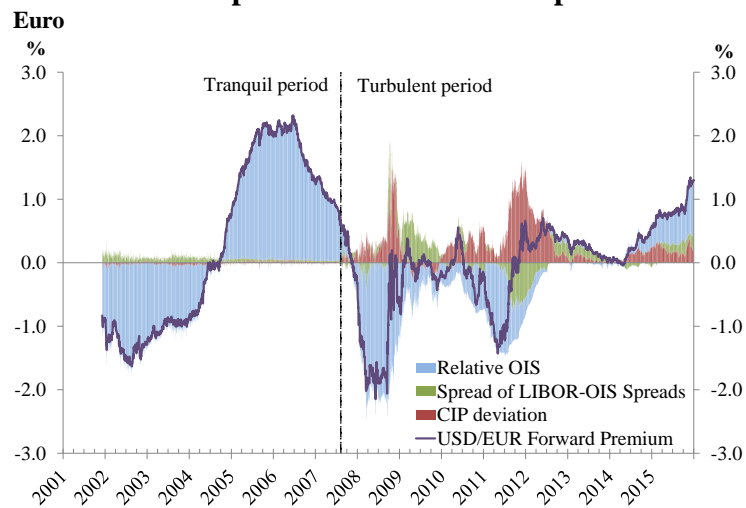
Swiss franc



Source: Bloomberg

Note: The tranquil period refers to December 6, 2001 to August 8, 2007, while the turbulent period August 9, 2007 to December 31, 2015.

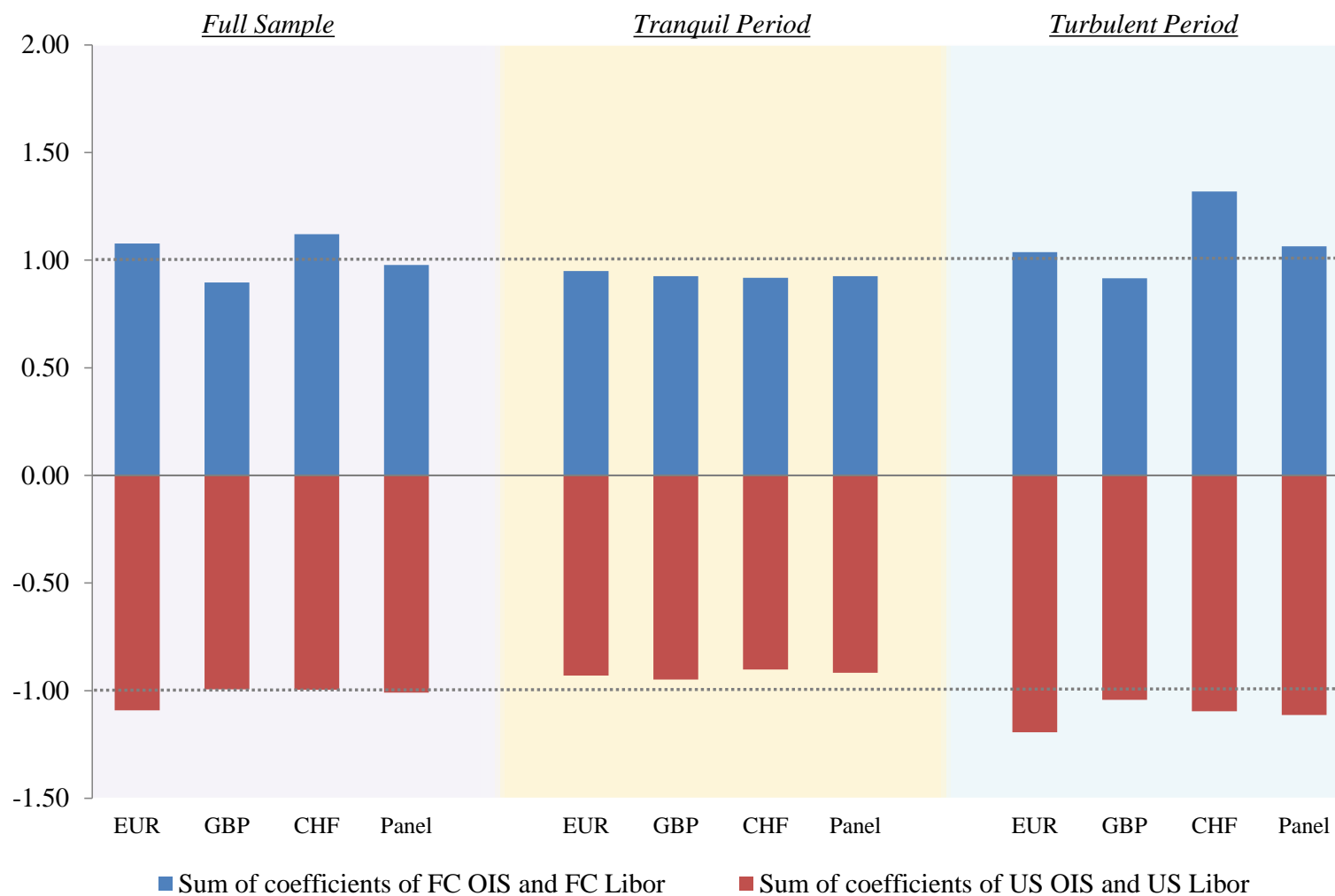
Chart 4: Decomposition of the forward premium vis-à-vis the US dollar



Notes:

- (i) The Libor and the swap implied rates are based on a 12-month tenor.
- (ii) The tranquil period refers to December 6, 2001 to August 8, 2007, while the turbulent period August 9, 2007 to December 31, 2015.

Chart 5: Sum of the coefficients of the Libor and OIS



Note: The tranquil period covers December 6, 2001 to August 8, 2007, while the turbulent period August 9, 2007 to December 31, 2015. The full sample covers both periods.