Cross-Currency Basis*

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Abstract

The cross-currency basis measures the deviation from the covered interest parity condition. It emerged during the Global Financial Crisis and has not disappeared since then. We show that the existence of the basis implies large, persistent, and systematic arbitrage opportunities in currency markets for major currencies. The cross-currency basis is highly correlated with nominal interest rate levels in the cross-section and in the time series. These findings are at odds with a frictionless global funding market, but point to key frictions in financial intermediation and their interactions with global imbalances during the post-crisis period.

Keywords: currency swaps, covered interest parity, dollar funding.

JEL Classifications: E43, F31, G15

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1 Introduction

The foreign exchange (FX) forward and swap market is one of the largest and most liquid derivative markets in the world with a total notional amount outstanding equal to $61 trillion and an average daily turnover equal to $3 trillion (BIS 2013, 2014). The cornerstone of FX forward and swap pricing, presented in all economics and finance textbooks, is the covered interest parity (CIP) condition. This simple no-arbitrage condition is taught in every class in international finance at the undergraduate and graduate levels. It simply states that the log difference between the forward and spot exchange rates should be equal to the difference in risk-free nominal interest rates across countries. In this paper, we show that the CIP condition is systematically violated among G10 currencies since the Global Financial Crisis (2007-2009). Furthermore, we show that the existence of potential arbitrage opportunities implied by CIP violations point to key frictions in financial intermediation and their interactions with global imbalances between savings and investment across countries during the post-crisis period.

We define the cross-currency basis of a foreign currency vis-à-vis the U.S. dollar as the deviation from the CIP condition between the foreign currency and the U.S. dollar. The foreign currencies in this paper include the Australian dollar (AUD), the Canadian dollar (CAD), the Swiss franc (CHF), the Danish krone (DKK), the euro (EUR), the British pound (GBP), the Japanese yen (JPY), the Norwegian krone (NOK), the New Zealand dollar (NZD) and the Swedish krona (SEK).

In particular, the basis is defined as the difference between direct dollar interest rate and the synthetic dollar interest rate by swapping the foreign currency into the U.S. dollar. A positive (negative) cross-currency basis means that the direct dollar interest rate is higher (lower) than the synthetic dollar interest rate. In the case of perfect capital mobility and perfect substitutability between U.S. and foreign interest rates, CIP should hold by no arbitrage and the cross-currency basis should be equal to zero. This was indeed the case prior to the Global Financial Crisis. Before 2007, the CIP condition held very well for London
Interbank Offer Rates (Libor), and the Libor cross-currency basis was very close to zero. During the Global Financial Crisis, the Libor cross-currency basis was significantly different from zero as the interbank markets became impaired and arbitrage capital was limited. More interestingly, the Libor cross-currency basis has been persistently different from zero since the Global Financial Crisis for many G10 currencies across different maturities, even during normal times many years after the crisis.

We first show that contrary to the conventional belief, credit risk differentials between Libor rates and other issues specific to the Libor market cannot explain away CIP deviations. In particular, the cross-currency basis exists beyond Libor for secured General Collateral repurchase (GC repo) rates at short maturities and bonds issued by Kreditanstalt für Wiederaufbau (KfW), which are default-free as they are fully guaranteed by the German government. In the absence of credit risk, GC repo and KfW bases give rise to risk-free arbitrage opportunities. A dollar arbitrageur can earn risk-free positive profits by going long in repo rates or KfW bonds denominated in low interest rate currencies, such as EUR, CHF, DKK and JPY, hedging foreign currency cash flows against the U.S dollar using foreign exchange (FX) swaps, funded by shorting U.S. dollar repos or U.S. dollar-denominated KfW bonds.

In addition, we generalize the CIP condition for bond yields of the same risky issuer denominated in different currencies. Using a panel including global banks, multinational non-financial firms and supranational institutions, we show that the issuer-specific basis has also been persistently different from zero. We note that there is a large cross-sectional dispersion in the issuer-specific basis across different types of issuers. Relative to the synthetic dollar rate by swapping foreign currency interest rates, foreign banks generally borrow the U.S. dollar directly at higher costs, whereas U.S. banks and supranational institutions generally borrow the U.S. dollar directly at lower costs.

Furthermore, we document a systematic relationship between the cross-currency basis of a foreign currency vis-à-vis the U.S. dollar and the nominal interest rate of the foreign
currency across currencies and over time. In the cross-section, the post-crisis mean basis is high for currencies with high nominal interest rates (such as AUD and NZD), and low for currencies with low nominal interest rates (such as CHF, EUR, DKK and JPY). This implies that currencies with higher nominal interest rates actually have lower synthetic dollar interest rates using FX swaps than currencies with lower nominal interest rates. The cross-sectional pattern holds for a constellation of interest rates including Libor, overnight index swap (OIS) rates, Treasuries, and bonds issued by KfW and other multinational issuers and global banks. From the perspective of a long-short arbitrageur, arbitrage opportunities exist for going long in low interest rate currencies, funded by shorting high interest rate currencies and swapping FX exposure, the exact opposite direction of the unhedged carry trade that goes long in high interest rate currencies and short in low interest rate currencies.

In the time series, we show that shocks to nominal interest rate differentials are significant drivers of the cross-currency basis over time. Using intradaily over-the-counter quotes of the euro/dollar cross-currency basis from a major European bank, we show that changes in the cross-currency basis around the release of European Central Bank (ECB)’s monetary policy decisions and the following press conferences are highly positively correlated with changes in the yield differential between German bunds and the U.S. Treasuries around the same event window.

The persistence of the cross-currency basis and its relationship with the nominal interest rate post crisis are quite puzzling, as the arbitrage opportunities implied by the basis are at odds with a frictionless global funding market. We show that our empirical findings can be explained by the interaction between costly financial intermediation and global imbalances in savings and investment opportunities across countries. The cross-currency basis can persist because the financial intermediaries requires excess returns to provide FX swap liquidity. Meanwhile, the global imbalance implies countries with low interest rates (such as Japan and Switzerland) have an oversupply of domestic savings relative to investment opportunities and countries with high interest rates (such as Australia and New Zealand) have an undersupply
of savings relative to investment opportunities. In other words, the excess supply of funding decreases in the nominal interest rate. As a result, banking sectors in the respective regions demand FX swaps for swapping funding in low interest rate currencies to high interest rate currencies to close the funding gap. The FX swap maker trades in the opposite direction to the banks, and hedges the FX exposure of the swap position in the cash market by going long in low interest rate currencies and short in low interest rate currencies, earning exactly the absolute value of the cross-currency basis. The lower the nominal interest of the funding currency vis-à-vis the U.S. dollar, the higher the excess demand for swapping the funding from low to high interest rate currencies, and the more negative is the cross-currency basis of the foreign currency vis-à-vis the U.S. dollar.

This work is closely related to several strands of the literature. There has been an extensive literature on the failure of the CIP condition during the Global Financial Crisis and the European Debt Crisis (for example, Baba et al. (2008, 2009); Coffey et al. (2009); Griffolli and Ranaldo (2011); Bottazzi et al. (2012); Ivashina et al. (2015)). These papers all focus on CIP deviations based on short-term money market instruments. The authors argue that a severe dollar funding shortage in the presence of limits to arbitrage attributed to the large cross-currency basis during the crisis. The severe dollar shortage during the crisis led to coordinated international policy response, notably the establishment of the Fed swap lines with various foreign central banks, which significantly reduced the magnitude of the cross-currency basis during the peak of Global Financial Crisis (Baba and Packer (2009); Goldberg et al. (2011) and McGuire and von Peter (2012)). We contribute to this literature by pointing that the existence of the cross-currency basis is not just a crisis phenomenon. In addition, we point out significant differences in the relative premium or discount of the dollar funding across currencies and across issuer types.

Furthermore, our work complements the recent work by Gabaix and Maggiori (2015) in identifying imperfect substitutability across currencies and linking to the imbalance in global savings and investment. The cross-sectional dispersion in the the cross-currency is
also related to the geography of risk capital as documented in Buraschi et al. (2015). Our work also fits into a large literature on global liquidity and the role of global banks in transmission funding shocks across countries (for example, Cetorelli and Goldberg (2011, 2012); Correa et al. (2012); Shin (2012); Bruno and Shin (2015)). Finally, the existing literature on margin-based asset pricing (for example, Garleanu and Pedersen (2011)) and preferred habit investors (Vayanos and Vila (2009); Greenwood and Vayanos (2014)) provide a framework for us to understand the persistence of the basis and its relationship with the nominal interest rates.

The paper is organized as follows. Section 2 defines the cross currency basis and presents the persistent failure of the textbook Libor CIP condition since the Global Financial Crisis. Section 3 shows that the cross-currency basis also exists for secured interest rates, such as GC repo rates and bond yields for KfW and unsecured rates for the same multi-currency issuer. Section 4 identifies nominal interest rate differentials as one key driver of the cross-currency basis in both cross sections and time series the post-crisis period. Section 5 explains the persistence of the basis and its relationship with the nominal interest rate. Section 6 concludes.

2 Cross-Currency Basis and Failure of Textbook CIP

2.1 Definition of the Cross-Currency Basis

We define cross-currency basis as the deviation from the CIP condition. Let \( y_{t,t+n} \) denote the \( n \)-year U.S. dollar interest rate and \( y_{t,t+n} \) denote the \( n \)-year foreign currency interest rate. In addition, we let \( S_t \equiv \log(s_t) \) denote the spot exchange rate defined as units of foreign currency per U.S. dollar and \( F_{t,t+n} \equiv \log(f_{t,t+n}) \) denote the \( n \)-year outright forward exchange rate for foreign currency per U.S. dollar at time \( t \). Finally, we use \( x_{t,t+n} \) to denote
the $n$-year cross-currency basis between foreign currency and the U.S. dollar, such that

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

In logs, we have

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

where $\rho_{t,t+n} \equiv \frac{1}{n}(f_{t,t+n} - s_t)$ is referred to as the $n$-year forward forward premium. Therefore, the cross-currency basis, $x_{t,t+n}$, measures the difference between the direct U.S. dollar interest rate, $y^S_{t,t+n}$, and the synthetic dollar interest rate, $y_{t,t+n} - \rho_{t,t+n}$, by the swapping foreign currency interest rate in the U.S. dollar using FX forwards. From the perspective of global funding, a negative cross-currency basis $x_{t,t+n}$ suggests there is a premium of getting access to the direct dollar funding, as it is cheaper than the synthetic dollar funding by swapping foreign currency funding into the U.S. dollar.

We first state the CIP condition for the risk-free interest rates in the foreign currency and the U.S. dollar in the following proposition.

**Proposition 1.** In a frictionless financial market, if $y^S_{t,t+n}$ and $y_{t,t+n}$ are both default-free and the FX swap is free from counterparty risk, and then we must have $x_{t,t+n} = 0$.

**Proof.** Proposition 1 holds by no arbitrage. In the case of a negative basis, the dollar arbitrageur can earn risk-free profits equal to an annualized $|x|$ percent of the trade notional by funding in the direct dollar risk-free rate, and investing in the synthetic dollar risk-free rate by swapping the foreign currency risk-free rate into the dollar using FX forwards. The cash flow diagram of this CIP arbitrage strategy is summarized in Figure 1. In the case of a positive basis, the opposite arbitrage strategy of funding in the synthetic dollar risk-free rate and investing in the direct dollar risk-free rate would also yield an annualized risk-free profit equal to $x$ percent of the trade notional. \hfill $\blacksquare$
2.2 Failure of Textbook Libor-Based CIP

Historically, London Interbank Offer Rates (Libor) reflect the interest rates at which banks borrow from each other, and have been used as the textbook money market instrument to test the CIP condition. We use the term “Libor” loosely to refer to unsecured interbank borrowing rate, which can be determined by local interbank panels rather than British Banker Association (now Intercontinental Exchange) Libor panels. At short maturities less than one year, CIP violations can be computed using Libor rates and FX forward and spot rates. At the longer maturities (typically one year or greater), CIP violations based on Libor are directly quoted as spreads on cross-currency basis swaps. We document persistent failure of Libor-based CIP after 2007 for G10 currencies at short and long maturities.

2.2.1 Short-Term Libor Cross-Currency Basis

By replacing dollar and foreign currency interest rates with Libor in Equation 1, we can define the Libor basis as

\[
\begin{align*}
x^{\text{Libor}}_{t,t+n} &\equiv y^{\text{Libor}}_{t,t+n} - (y^{\text{Libor}}_{t,t+n} - \rho_{t,t+n}).
\end{align*}
\] (2)

where \(\rho_{t,t+n} \equiv \frac{1}{n}(f_{t,t+n} - s_t)\). In practice, since forward points are often quoted with a higher level of precision that outright forwards, we can compute the forward premium \(\rho_{t,t+n}\) directly from forward points. We define forward points \(FP_{t,t+n}\), such that

\[F_{t,t+n} = S_t + FP_{t,t+n}.\]

Thus, the forward premium can be obtained as follows:

\[
\rho_{t,t+n} \approx (1/n)FP_{t,t+n}/S_t.
\]
We obtain daily FX spot rates and forward points from Bloomberg using London closing rates for G10 currencies. Mid-rates (average of bid and ask rates) are used for benchmark basis calculations. Daily Libor/interbank fixing rates are also obtained from Bloomberg.

Figure 2 shows 3-month Libor basis for G10 currencies between 2000 and 2015. Panel A of Table 1 summarizes mean and standard deviations of Libor cross-currency basis by periods. As we can see from both Figure 2 and Table 1, the 3-month Libor basis was very close to zero for all G10 currencies before 2007. During the Global Financial Crisis (2007-2009), there were large deviations during the peak of crisis around the Lehman bankruptcy, with basis reaching negative 200 to negative 300 basis points. In the aftermath of the GFC since 2010, the 3-month Libor basis has been persistently different from zero. There is cross-sectional dispersion in the level of the basis post crisis among G10 currencies, with AUD and NZD having on average positive basis, and CHF, DKK, EUR, JPY, NOK and SEK having on average negative basis below negative 20 basis points. Among the G10 currencies, DKK has the most negative 3-month Libor basis post crisis, with mean basis equal to negative 61 basis points, at stark contrast to its pre-crisis mean equal to 1 basis point.

2.2.2 Long-Term Libor Cross-Currency Basis

To measure long-term Libor cross-currency basis, we follow the same definition for Libor basis as given by Equation 2. The long-term Libor interest rates $y^S_{t,t+n}$ and $y^Libor_{t,t+n}$ can be obtained from fixed-for-floating interest rate swap rates, and the long-term forward premium $\rho_{t,t+n}$ can be obtained from a combination of interest rate swaps and the cross-currency basis swap. In this subsection, we will demonstrate that the long-term cross-currency Libor basis is equal to the spread on a traded derivative contract called cross-currency basis swap. Similar to the three-month basis, the long-term Libor basis was very close to zero for all G10 currencies before 2007. Since 2007, long-term Libor basis started diverging from zero and remained significantly different from zero in the post-GFC period.
A cross-currency basis swap involves exchanges of floating Libor cash flows in two different currencies at each coupon date, and an exchange of principal in two different currencies at the inception and the maturity of the swap. The spread on the cross-currency basis swap gives the price at which swap counterparties are willing to exchange foreign currency floating cash flows against U.S. Libor cash flows. Figure 3 gives a cash flow diagram for the JPY/USD cross-currency swap on $1 notional between Bank A and Bank B. At the inception of the swap, Bank A receives $1 from Bank B and gives away ¥$t. At the j-th coupon date, Bank A pays a dollar floating cash flow equal to $y_{t+j}^{\text{Libor,$}}$ percent on the $1 notional to Bank B, where $y_{t+j}^{\text{Libor,$}}$ is the 3-month U.S. dollar Libor at time $t+j$. In return, Bank A receives from Bank B a floating yen cash flow equal to $(y_{t+j}^{\text{Libor,$}} + x_{t,t+n}^{\text{cxy}})$ on the ¥$t notional, where $y_{t+j}^{\text{Libor,$}}$ is the 3-month yen Libor at time $t+j$, and $x_{t,t+n}^{\text{cxy}}$ is the cross-currency basis swap spread – pre-determined at the inception of the swap transaction.

To see how the spread on the cross-currency basis swap directly translates into deviation from long-term Libor-based CIP condition, we let $y_{t,t+n}^{\text{IRS}}$ denote the n-year U.S. dollar interest rate swap to swap fixed dollar cash flows into floating dollar Libor cash flows and $y_{t,t+n}^{\text{IRS}}$ denote the n-year foreign currency interest rate swap to swap fixed foreign currency cash flows into foreign currency Libor cash flows. Then the long-term forward premium to hedge foreign currency against the U.S. dollar is given by

$$\rho_{t,t+n} = y_{t,t+n}^{\text{IRS}} + x_{t,t+n}^{\text{cxy}} - y_{t,t+n}^{\text{IRS}}. \quad (3)$$

The cash flow diagram for Equation 3 is given by Figure 4. Intuitively, an investor can take three steps to swap fixed foreign currency cash flows into a fixed U.S. dollar cash flows. First, she pays the foreign currency interest rate swap, $y_{t,t+n}^{\text{IRS}}$, to swap fixed foreign currency cash flows into floating foreign currency Libor cash flows. Second, she pays the cross-currency basis swap, $x_{t,t+n}^{\text{cxy}}$, to swap floating foreign currency Libor into U.S. dollar Libor cash flows. Third, she receives the U.S. interest rate swap, $y_{t,t+n}^{\text{IRS}}$, to swap floating dollar U.S. Libor
cash flows into fixed U.S. dollar cash flows. Once we have the long-term forward premium \( \rho_{t,t+n} \), the long-term Libor basis is given by

\[
\begin{align*}
\pi_{t,t+n}^{Libor} &= y_{t,t+n}^{Libor} - (y_{t,t+n}^{Libor} - \rho_{t,t+n}) \\
&= y_{t,t+n}^{IRS} - [y_{t,t+n}^{IRS} - (y_{t,t+n}^{IRS} + \pi_{t,t+n}^{xccy} - y_{t,t+n}^{IRS})] \\
&= \pi_{t,t+n}^{xccy}.
\end{align*}
\]

Therefore, the long-term Libor basis is exactly equal to the spread on the cross-currency basis swap.

We obtain data on cross-currency basis swaps from Bloomberg. Figure 5 shows the 5-year Libor basis for G10 currencies between 2000 and 2015. Panel B of Table 1 summarizes mean and standard deviations of the 5-year Libor cross-currency basis by periods. As we can see from both Figure 5 and Table 1, before 2007, the 5-year Libor basis was slightly positive for AUD, CAD and NZD and negative for all the other currencies, but all basis was close to zero. The 5-year Libor bases started diverging away from zero in 2008, and reached their sample peak during the European debt crisis in 2012. The Libor bases narrowed in 2013 and early 2014, but started widening again in the second half of 2014. In the post-GFC sample, AUD and NZD have the most positive basis with the mean equal to 25 and 33 basis points, respectively. JPY and DKK have the most negative basis with the mean equal to negative 56 and negative 42 basis points, respectively. CHF and EUR also have very negative basis, with the mean below negative 25 basis points.

### 2.2.3 Credit Risk in the Libor CIP Arbitrage

Leaving the indicative nature of Libor and possible Libor manipulation aside, there is one important issue with the Libor market: Libor rates are unsecured and composition of the Libor banks are different across currencies. Therefore, the existence of the Libor cross-currency basis can potentially reflect different credit worthiness of different Libor panel
banks, rather than frictions in the global financial market (Tuckman and Porfirio (2004)). However, we do not find credit risk to be a significant driver for Libor cross-currency basis for G10 currencies in the post-crisis period with the exception of EUR.

To see this, suppose that the mean credit spread for the yen Libor panel is given by \( s_{t}^{JPY} \) and the mean credit spread for the U.S. dollar Libor panel is given by \( s_{t}^{USD} \). Let \( y_{t}^{*}^{JPY} \) and \( y_{t}^{*}^{USD} \) be risk-free rates in the yen and the U.S. dollar, respectively. Therefore, the Libor cross-currency basis of the yen vis-à-vis the U.S. dollar is given by the difference between credit risk in dollar and yen Libor panels as follows:

\[
\begin{align*}
\Delta x_{t}^{JPY/USD,Libor} & = (y_{t}^{*}^{USD} + s_{t}^{USD}) - (y_{t}^{*}^{JPY} + s_{t}^{JPY} - \rho_{t}^{JPY/USD}) \\
& = [y_{t}^{*}^{USD} - (y_{t}^{*}^{JPY} - \rho_{t}^{JPY/USD})] + (s_{t}^{USD} - s_{t}^{JPY}) \\
& = s_{t}^{USD} - s_{t}^{JPY},
\end{align*}
\]

where the bracket in the second equation equals zero by Proposition 1. Therefore, the yen basis can be negative if the yen Libor panel is riskier than the U.S. Libor panel.

We can directly test the whether credit risk differential is a driver of the Libor cross-currency basis by running the regression of changes in the Libor basis \( \Delta x_{t}^{i,Libor} \) on changes in the mean credit spread differentials between banks on the dollar Libor panel and the interbank panel of currency \( i \):

\[
\Delta x_{t}^{i,Libor} = \Delta (s_{t}^{USD} - s_{t}^{i}) + \epsilon_{it}.
\]

We use monthly changes in 5-year Libor cross-currency basis swaps and 5-year credit default swap spreads (CDS) of banks since 2009. The regression results for the post-crisis period between are given in Table 2. As we can see, in all sample currencies, changes in CDS spread do not have significant effects on changes in the Libor basis, except for EUR. Therefore, the
credit spread differential does not seem to be an important driver for the Libor cross-currency basis of G10 currencies in the post-crisis period except for EUR.¹

3 Cross-Currency Basis Beyond Libor

In this section, we document the existence of the cross-currency basis post crisis beyond Libor. First, we construct the general collateral (GC) repo rate basis, which uses the secured rates. We find that the repo cross-currency basis is persistently negative for JPY, CHF and DKK. Second, we examine the cross-currency basis for bonds issued by KfW in G10 currencies, which are fully backed by the German government and considered default-free. We show the KfW basis is also significantly different from zero for EUR, CHF and JPY. Third, we show the cross-currency basis for individual risky issuers, including global banks, multinational non-financial firms and supranational institutions. The issuer-specific basis exists post crisis and exhibits large cross-sectional dispersion across issuers.

3.1 GC Repo Basis

At short maturities, one way to eliminate credit risk associated with Libor CIP is to use secured borrowing and lending rates from the repo markets. We use general collateral (GC) repo rates in the U.S. dollar and foreign currencies to construct an alternative cross-currency basis measure. A GC repo refers to a repurchase agreement in which the cash lender is willing to accept a variety of Treasury and agency securities as collateral. Since GC assets are high quality and very liquid, GC repo rates are driven by supply and demand of cash, as opposed to supply and demand of individual collateral assets.

¹The credit spread differential has a much more significant effect on the cross-currency basis of emerging market currencies.
Given the U.S. dollar GC repo rate $y_{t,t+n}^{\text{Repo}}$ and the foreign currency GC repo rate $y_{t,t+n}^{\text{Repo}}$, we can define the GC repo basis (repo basis) as the CIP violation based on GC repo rates:

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

Since the bulk of repo transactions are concentrated at very short maturities, we compute the repo basis at the one-week horizon. We focus on CHF, DKK, EUR and JPY due to the availability of GC repo rates and large Libor basis since the GFC.

For the U.S. repo rates, we use intradaily data from Thomson Reuters Tick History, which gives bid and ask quotes for U.S. dollar term repos. We compared Tick History mid rates with daily GC repo quotes from JP Morgan (obtained from Morgan Markets), one of the only two clearing banks to settle tri-party U.S. repo markets. The difference between the two series is negligible. EUR GC repo rates are obtained from JP Morgan. CHF and DKK repo rates are obtained from Bloomberg, and JPY repo rates are obtained from Bank of Japan and Japan Securities and Dealer Association. We note that we only have separate bid and ask spreads for USD and DKK repos.

We plot the one-week Libor and repo basis for CHF, DKK, EUR and JPY since 2009 in Figure 6. The repo basis tracks the Libor basis very closely for CHF and JPY, and remain negative throughout the sample. For DKK and EUR, the repo basis was closer to zero than the Libor basis during the peak of the European Debt Crisis, but also tracks the Libor basis very closely. Columns 1 and 2 of Table 3 summarize the mean and standard deviation of Libor and repo basis during 2009-2015. DKK has the most negative mean repo basis equal to -43 basis points, and the EUR has the least negative mean repo basis equal to -10 basis points. Column 3 reports summary statistics for the repo basis conditional on a negative basis. We can see that the repo basis is negative almost all the time for CHF, DKK and JPY and is negative 85 percent of time for EUR.
A non-zero repo basis naturally gives rise to a potential risk-free arbitrage opportunity. A negative basis arbitrage requires the investor to borrow at the U.S. dollar GC repo rate and go long in the foreign currency GC repo rate, while paying the forward premium to hedge foreign currency exposure. A positive basis arbitrage does not oppose, borrowing at the foreign currency rate, receiving the forward premium, and investing in the U.S. dollar rate. We assume the transaction cost for each step of the arbitrage strategy is equal to one half of the posted bid-ask spread. Then, the arbitrage profits under the negative and positive arbitrage strategies, denoted by $\pi_{Repo}^-$ and $\pi_{Repo}^+$, are as follows:

$$
\pi_{t,t+n}^{Repo-} \equiv [y_{t,t+n,Bid} - \frac{1}{n} \times FP_{t,t+n,Ask}/S_{t,Bid}] - y_{t,t+n,Ask}^{\$}\ Repo
$$

$$
\pi_{t,t+n}^{Repo+} \equiv y_{t,t+n,Bid}^{\$}\ Repo - [y_{t,Ask}^{Repo} - \frac{1}{n} \times FP_{t,t+n,Bid}/S_{t,t+n,Ask}].
$$

Column 4 of Table 3 summaries the arbitrage profits from the negative basis arbitrage strategy provided that the ex-ante profits positive. We note that we are missing the half repo bid-ask spreads for CHF, EUR and JPY. The one-week repo arbitrage generate profits equal to 9 to 18 basis points after taking into transaction costs. The arbitrage profits are positive for the majority of the sample.

### 3.2 KfW Basis

GC repo contracts do not exist at long maturities. At the long term, we construct an alternative long-term cross-currency basis by comparing direct dollar yields on dollar denominated debt and synthetic dollar yields on debt denominated in other currencies of the same risk-free issuer. We focus on bonds issued by KfW, a German government-owned development bank, with all its liabilities fully backed by the German government. More details on the KfW bond market can be found in Schwartz (2015).

For simplicity of exposition, we consider a world with zero-coupon yield curves and swap rates. In practice, detailed calculations involving coupon bearing bonds can be found in the
appendix. Following our definition for cross-currency basis in Equation 1, we define the KfW cross-currency basis as the difference between the direct borrowing cost of the KfW in the U.S. dollar and the synthetic borrowing cost of the KfW in other currency $j$:

$$x_{t,t+n}^{KfW} = y_{t,t+n}^{KfW} - (y_{t,t+n}^{j,KfW} - y_{t,t+n}^{IRS,j}),$$

(4)

where $y_{t,t+n}^{KfW}$ and $y_{t,t+n}^{j,KfW}$ give the zero-coupon yield on KfW bonds denominated in the U.S. dollar and foreign currency $j$, respectively. We define the z-spread of the bond $j$, $s_{t,t+n}^{j}$, as the spread of the bond yield over the Libor interest rate swap rate in the respective currency. Using the z-spread definition and Equation 3, we can decompose the KfW basis as the z-spread differentials between bonds denominated in the U.S dollar and foreign currency $j$ and the Libor cross-currency basis swap:

$$x_{t,t+n}^{KfW} = (s_{t,t+n}^{KfW} - y_{t,t+n}^{IRS}) - (y_{t,t+n}^{j,KfW} - y_{t,t+n}^{IRS,j} + x_{t,t+n}^{zccy,j}).$$

(5)

If the long-term global capital markets are perfectly frictionless, we should expect $x_{t,t+n}^{KfW} = 0$, or the cross-currency Libor basis to be completely offset by the z-spread differential. \(^2\)

Intuitively, if the yen Libor has a higher credit risk than the U.S. dollar Libor, the yen/dollar cross-currency basis should be negative, because the synthetic yen Libor swapped into the U.S. dollar should be higher than the dollar Libor to compensate investors for higher credit risk associated with the yen Libor. However, the z-spread of the KfW yen bond over the yen Libor should be lower than the z-spread of the KfW dollar bond over the dollar Libor.

\(^2\)An alternative way to understand the basis is note that:

$$x_{t,t+n}^{KfW} = (s_{t,t+n}^{KfW} - s_{t,t+n}^{j}) = s_{t,t+n}^{KfW} - s_{t,t+n}^{j},$$

where $s_{t,t+n}^{j}$ gives the synthetic dollar spread of the bond $j$ over the U.S. dollar Libor interest rate swap. So the KfW basis measures the difference between the direct dollar borrowing cost, $s_{t,t+n}^{KfW}$, and the synthetic dollar borrowing cost, $s_{t,t+n}^{j}$, both measured as spreads over U.S. Libor interest rate swap rates.
The net result is that the KfW cross-currency basis should be independent of the differences across dollar and foreign currency Libor markets.

Figure 7 displays the KfW cross-currency basis for AUD, CHF, EUR and JPY. We can see that for the three currencies with negative Libor basis post crisis (CHF, EUR and JPY), the KfW is also negative and tracks the Libor basis very closely. In the case of AUD, the Libor basis is significantly positive post crisis, but the KfW basis is closer to zero. The mean of the KfW basis by currency during 2009-2015 is summarized in Column 1 of Table 4. The mean post-crisis KfW basis is very close to zero for AUD (0.8 basis points) and is significantly negative the other three currencies (-21.4 basis points for CHF, -15.2 basis points for EUR and -35.1 basis points for JPY). Column 2 reports summary statistics for the basis conditional on a positive basis for AUD, and negative basis for CHF, EUR and JPY. We can see that CHF, EUR and JPY have negative KfW basis for more 94% percent of the sample.

A non-zero KfW basis also potentially gives rise to rise to a risk-free arbitrage strategy for the fixed long-term investment horizon. In the case of a negative KfW basis, the arbitrage strategy would be to invest in the KfW bond denominated in the foreign currency, pay the cross-currency swap to swap foreign currency cash flows into the U.S. dollar, and short-sell the KfW bond denominated in the U.S. dollar. In the case of a positive KfW basis, the arbitrage strategy would be the opposite. The arbitrage profits of these strategies would be equal to the absolute value of the basis minus the transaction cost of the strategy. Therefore, arbitrage profits under the negative and positive arbitrage strategies, denoted by $\pi_{t,t+n}^{KfW-}$ and $\pi_{t,t+n}^{KfW+}$, are as follows:

\[
\begin{align*}
\pi_{t,t+n}^{KfW-} &= [(y_{t,t+n,Ask} - y_{t,t+n,Bid}) - x_{t,t+n,Bid}] - ((y_{t,t+n,Ask} - y_{t,t+n,Bid}) - \text{fee}_{t,t+n}^J) \\
\pi_{t,t+n}^{KfW+} &= (y_{t,t+n,Bid} - y_{t,t+n,Ask}) - [(y_{t,t+n,Ask} - y_{t,t+n,Bid}) + x_{t,t+n,Bid}] - \text{fee}_{t,t+n}^J.
\end{align*}
\]
where $fee_{t,t+n}^8$ and $fee_{t,t+n}^j$ denote the short-selling fee dollar and foreign currency bonds, respectively.

We obtain all bid and ask prices for bond and swap rates from Bloomberg. Since interest rate swaps and cross-currency swaps are very liquid derivatives for G10 currencies, the total swap transaction cost is on average about 5 basis points since 2009. We obtain KfW shorting costs from transaction-level data provided by Markit Securities Finance (formerly known as Data Explorer). As a negative basis arbitrage requires shorting the KfW USD bonds, Figure 8 shows the 25 percentile, median and 75 percentile of shorting costs for USD bonds issued by the KfW. There is significant cross-sectional dispersion in terms of shorting costs across transactions. During the peak of the Global Financial Crisis, the 25 percentile and median shorting costs were negative, which reflects demand for U.S. dollar cash or U.S. Treasury collateral. Post crisis, the median shorting cost fluctuates around 15 basis points.

Columns 3-5 in Table 4 reports summary statistics for positive arbitrage profits netting transaction costs for the positive basis arbitrage for the AUD and the negative basis arbitrage for CHF, EUR and JPY. Column 3 takes into account bid-ask spreads on swaps and bonds, but excludes bond short selling costs. We can see that the negative basis arbitrage strategy yields positive profits for CHF, EUR and JPY for the majority of the sample. The positive arbitrage strategy for AUD yields positive profits only for 15 percent of the sample. Columns 4 and 5 take into account additional shorting costs associated with the arbitrage strategy under the assumption of 25 percentile and median shorting costs based on transaction data, respectively. The negative basis arbitrage strategy yields positive profits between 30 to 50 percent of the sample for CHF and EUR, and around 80 percent for JPY. The positive basis arbitrage only yields profits for less than 10 percent of the sample for AUD after taking into account additional shorting costs. Therefore, after taking into account transaction costs, the magnitude of the KfW basis is generally within the arbitrage bound for AUD for a long-short arbitrageur, but can have frequent violations of the arbitrage bound for CHF, EUR and JPY.
3.3 Issuer-Specific Basis for Risky Issuers

In addition to testing the CIP condition based on risk-free rates, we can generalize the CIP condition based on defaultable rates in the following proposition.

**Proposition 2.** *In a frictionless market, if \( y^S_{t,t+n} \) and \( y_{t,t+n} \) correspond to yields on defaultable bonds with the same default probability and recovery rates, as long as the exchange rate process and the default process are independent, we must also have \( x_{t,t+n} = 0 \).*

*Proof.* See the proof of Proposition 1 in Buraschi et al. (2015) or Proposition 2 in Du and Schreger (Forthcoming).

The same default and recovery rates hold for bonds of the same issuer under the pari passu clause. In the case of correlated and currency risk, Du and Schreger (Forthcoming) give a simple calibration as follows. Assume that the foreign currency depreciates against the U.S. dollar by \( \alpha \) percent in the event of default compared to the non-default state, and the U.S. dollar bond yield is equal to \( y^*_{t} + s_{t} \), where \( y^*_{t} \) is the risk-free rate in the U.S. dollar. Then the synthetic dollar yield by swapping a foreign currency bond into the U.S. dollar should be equal to \( (1 - \alpha)s_{t} + \rho_{t} + y^*_{t} \). For corporate issuers in G10 currencies, a corporate default is unlikely associated with large swings in exchange rate. Suppose \( s_{t} = 100 \) basis points and \( \alpha = 5\% \), and then the CIP for the corporate issuer would deviate \( \alpha s_{t} = 5 \) basis points.

Using the more generalized version of the CIP condition for risky issuers in Proposition 2, we can also use corporate bond yields in different currencies to test the CIP condition even if the issuer is not default-free. As for the KfW basis, we define the issuer-specific basis for any issuer \( k \) as follows:

\[
x^k_{t,t+n} = y^S_{t,t+n} - (y^i_{t,t+n} - \rho^i_{t,t+n}),
\]

where \( y^S_{t,t+n} \) denotes dollar bond yield of issuer \( k \) and \( y^i_{t,t+n} \) denotes the bond yield of currency \( j \) issued by the same issuer \( k \). We choose a large panel of multi-currency issuers including
global banks headquartered in Australia, euro area, Japan, Switzerland, United Kingdom and United States, multinational non-financial firms (General Electric and Tokyo) and supranational organizations (European Investment Bank and the World Bank). We construct the issuer-specific basis by matching dollar and foreign currency bonds of issuer $k$ by the same maturity year and seniority. All data on bond yields in the secondary market are from Bloomberg.

Figure 9 shows issuer specific bases for AUD, CHF, EUR and JPY across different issuers, together with the Libor cross-currency basis, and Figure 10 shows the median issuer-specific basis of all sample issuers. Although the median issuer-specific basis has been closer to zero than the Libor basis, there has been a large cross-sectional dispersion in the basis across issuers since the Global Financial Crisis.

We can see that the sign of the cross-currency basis for each currency depends on the specific issuer. In particular, U.S. banks, KfW and supranational institutions on average have lower U.S. dollar borrowing costs than the synthetic dollar borrowing costs, whereas foreign banks have higher U.S. dollar borrowing costs than synthetic dollar borrowing costs. We note that during the peak of the Global Financial Crisis and the European debt crisis, the direct dollar borrowing costs of foreign banks can be 100 to 300 basis points higher than the synthetic dollar borrowing costs from borrowing in foreign currency and swap into the U.S. dollar, whereas the direct dollar funding costs for General Electric, U.S. banks, KfW and supranational institutions remained lower than the synthetic dollar cost from borrowing in foreign currency. The significant gap in funding costs across currencies can potentially explain why foreign banks heavily relied on funding in their local currencies and then swapping into the U.S. dollar rather than borrowing directly in the U.S. dollar markets. For U.S. domiciled entities and AAA-rated agencies and supranationals, it is more advantageous to borrow directly in the U.S. dollar from the pure funding cost perspective.
4 Cross-Currency Basis and Interest Rate Differentials

In this section, we first show a significant cross-sectional relationship that the cross-currency basis is positively correlated with the level of nominal interest rates. The relationship holds for Libor, OIS, Treasuries, bonds issued by KfW and other multinational issuers. In the time series, we show that changes to the foreign and U.S. nominal interest rate differential due to monetary policy surprises around the monetary policy are also correlated with significant changes to the basis.

4.1 Cross-Sectional Pattern

In this subsection, we document a robust cross-sectional relationship between nominal interest rates and various types of cross-currency basis. We find that low interest rate currencies tend to have most negative bases and high interest rate currencies tend to have less negative basis or positive bases. The cross-sectional pattern holds across Libor, OIS, Treasuries, KfW and other multinational bonds. Therefore, for a long-short arbitrageur, there exist arbitrage opportunities for going long in low interest rate currencies, short in high interest rate currencies with the currency risk hedged using FX swaps. The direction of the arbitrage trade is exactly the opposite of the conventional unhedged carry trade of going long in high interest rate currencies and short in low interest rate currencies. For mutlinational issuers, the cross-sectional pattern has a robust funding cost implication that on the FX-hedged basis, currencies with high nominal interest rates are cheaper funding currencies, and currencies with higher nominal interest rates are more expensive funding currencies.

In Figure 11, we plot the mean cross-currency basis on the y-axis and nominal interest rates for the various types of interest rates on the x-axis between 2010 and 2015. The two panels on the first row show that the Libor cross-currency basis is positively correlated with Libor rates at short and long maturities. The relationship is particularly strong at long maturity, with the correlation between 5-year Libor bases and Libor rates equal to 89
percent for G10 currencies. By contrast, the mean CDS spread of the interbank panel is only -33 percent correlated with the 5-year Libor basis.

In addition, we examine that cross-sectional differentials in synthetic dollar borrowing costs for KfW. Since the KfW bond yield is not observed for all currencies at all tenors on each trading date. We obtain the mean KfW basis by running a fixed effect regression controlling for the trading date and tenor over the 2010-2015 sample,

\[
\hat{s}_{t,t+n}^{KfWj} = \sum_{j \neq USD} \beta_j^{KfW} D_j + \alpha_{t,n},
\]

where \(\hat{s}_{t,t+n}^{KfWj}\) denotes the synthetic dollar spread of a \(n\)-year KfW bond denominated in currency \(j\) over U.S. Libor interest rate swap of the corresponding maturity, \(D_j\) is a dummy indicating currency \(j\), and \(\alpha_{t,j}\) is a tenor-date pair fixed effect. Since the U.S. dollar-denominated bonds are the omitted category in the regression. The minus coefficient \(-\beta_j^{KfW}\) on currency dummy \(D_j\) gives the mean KfW basis for currency \(j\). As shown in the middle left panel of Figure 11, we note that the KfW basis is also strongly correlated with the nominal KfW bond yields. For KfW, we note that all mean KfW basis is in the negative territory, which suggests that the KfW has funding costs advantage in the U.S. dollar over all other G10 currencies. AUD, and NZD are the cheapest funding currencies after the USD, despite of their high nominal yields, and JPY and CHF are the most expensive funding currencies even though their nominal yields are among the lowest.\(^3\)

Moreover, we can generalize the the KfW regression to estimate mean basis across issuers:

\[
\hat{s}_{t,t+n}^{kj} = \sum_{j \neq USD} \beta_j D_j + \alpha_{t,n,k},
\]

\(^3\)We note that DKK is not included in the plot as the KfW issuance of DKK-denominated bonds is close to zero, and there are no secondary market pricing information on DKK-denominated KfW bonds in Bloomberg.
where \( s_{k,j}^{t,t+n} \) denotes the synthetic dollar spread of an issuer \( k \)'s \( n \)-year bond denominated in currency \( j \) over U.S. Libor interest rate swap of the corresponding maturity, and \( \alpha_{t,j,k} \) is a tenor-date-issuer fixed effect. We include the following issuers with diverse funding currency mix in our regression: European Investment Bank, World Bank, the four largest Australian banks (Commonwealth Bank, Westpac, Australia and New Zealand Banking Group and National Australia Bank), Citi, JP Morgan, Goldman Sachs and General Electric. The middle right panel of Figure 11 shows the multinational basis is again highly positively correlated with nominal yield differentials. For both the KfW and multinational basis, we can see that the gap between the most expensive and the cheapest funding currency is about 30 to 40 basis points, which is smaller than the 100 basis point cost differentials between AUD and JPY based on Libor, but remain economically significant nevertheless.

Finally, we examine the the synthetic average dollar borrowing based OIS rates and Treasury yields across currencies. We define the OIS basis as

\[
x_{t,t+n}^{OIS} = y_{t,t+n}^{OIS} - (y_{j,t,t+n}^{OIS} - \rho_{t,t+n}^{j}),
\]

where \( y_{t,t+n}^{OIS} \) denotes the \( n \)-year U.S. dollar OIS rate and \( y_{j,t,t+n}^{OIS} \) denote the \( n \)-year OIS rate in currency \( j \).\(^4\) The bottom left panel shows the pattern for the three-month OIS rates. Again, the average synthetic dollar overnight funding costs are the lowest for AUD and NZD with the most positive OIS basis and highest for CHF, DKK and JPY with the most negative OIS basis. As shown in the bottom right panel of Figure 11, the same pattern also holds for the Treasury basis, which is defined as

\[
x_{t,t+n}^{Tres} = y_{t,t+n}^{Tres} - (y_{j,t,t+n}^{Tres} - \rho_{t,t+n}^{j}),
\]

where \( y_{t,t+n}^{Tres} \) denotes the yield on the \( n \)-year U.S. Treasury and \( y_{j,t,t+n}^{Tres} \) denote the yield on the \( n \)-year Treasury of country \( j \) denominated in currency \( j \) at time \( t \). Thus, on the

\(^4\)We omit NOK as there is no OIS traded for NOK.
FX-hedged basis, Australian and New Zealand government bonds have the lowest synthetic dollar yields and Swiss and Japanese government bonds have the highest synthetic dollar yields.

4.2 Time Series Pattern

In the time series, the nominal interest rate differential between foreign currency and the U.S. dollar also acts as a significant driver for the cross-currency basis. As the nominal interest rate is the primary monetary policy instrument, we use an event-study approach to identify unexpected shocks to nominal interest rates around monetary policy decisions and then study the effects of these interest rate shocks on the basis.

In particular, we look at intradaily changes in the cross-currency basis and changes in the yield differential between German Bunds and U.S. Treasuries around ECB’s monthly releases of monetary policy decisions of the Governing Council and following press conferences hosted by the ECB president since 2010. Our starting time is 5 minutes before the release of the monetary decision, usually at 1:45 pm CET, and our ending time is 105 minutes after the release of the statement to allow for the one-hour press conference, usually taking place between 2:30 pm CET and 3:30 pm CET. By choosing such a narrow event window, we are able to attribute the movements in the cross-currency basis and government yields to monetary policy shocks from the ECB.

We use intradaily data from Thomson Reuters Tick History. For German bunds and U.S. Treasuries, we use 2-year benchmark bond prices. For the cross-currency basis, we use OTC quotes for Euribor/U.S. Libor cross-currency at 1-year maturity from one major European bank.\textsuperscript{5} To test the corollary, we regress the changes in the cross currency basis around the \(i\)-th monetary policy announcement (\(\Delta x_i\)) on the changes in the German bund and U.S.

\textsuperscript{5} Cross-currency bases at tenors longer than one year is not quoted frequently enough for our event study. The three-month cross-currency basis was not actively traded as separate derivative product until 2012. Our results are robust to using the three-month basis since it becomes separately quoted.
Treasury yield differentials around the same event window \( (\Delta y_{i}^{GE} - \Delta y_{i}^{US}) \):

\[
\Delta x_{i} = \alpha + \beta (\Delta y_{i}^{GE} - \Delta y_{i}^{US}) + \epsilon_{i}.
\]

We expect that \( \beta > 0 \).

Figure 12 confirms the hypothesis that \( \beta > 0 \). We can see that changes in the euro/dollar basis around ECB monetary policy announcements is strongly positively correlated with changes in the German bund and U.S. Treasury yield differential. The regression result with robust standard errors is shown as follows:

\[
\Delta x_{i} = 0.024 + 0.150^{***} (\Delta y_{i}^{GE} - \Delta y_{i}^{US}).
\]

(0.056) (0.025)

The coefficient on the interest rate differential is equal to 0.15 with the t-statistic equal to 5.88. Therefore, a 10 basis point reduction in the German bund/U.S. Treasury 2-year yield differential due to accommodative monetary policy of the ECB leads to 1.5 basis point widening in the 1-year euro/dollar Libor cross-currency basis.

5 Explanations for Persistent and Systematic Basis

The persistence of the basis post-crisis and the relationship with the nominal interest is at odds with a frictionless financial market, but can be explained by increased costs financial intermediation and their interactions with global imbalances. In particular, the basis can persist because the CIP arbitrage has become balance sheet-intensive post crisis, and arbitrageurs require excess returns to offset the cost of arbitrage capital. Furthermore, the systematic relationship between the basis and the nominal interest rate sheds light on the magnitude and direction of currency hedging demand as a result of global imbalances in savings and investments across currencies. In particular, as a result of search-for-yield and
carry trade activities, there is an over demand of investments in high interest rate currencies, and an over supply of funding in low interest rate currencies. Financial arbitrageurs trade against these global imbalances, going short in high interest rate currencies and going long in low interest rate currencies, earning positive excess returns.

In this subsection, we use a simple reduced-form framework with capital constraint financial intermediary and interest-elastic supply of funding to explain the persistence of the cross-currency basis post the crisis and the positive relationship between interest rates and the basis. The key assumption we maintain is that the excess supply of funding in currency $i$ over currency $j$ in the global financial market is decreasing in the nominal interest rate differential $y^i - y^j$:

$$d_{i,j} = -\kappa (y^i - y^j).$$

Therefore, there is positive excess supply for funding $i$ relative to $j$ if $y^i > y^j$, negative excess supply for $j$ if $y^i > y^j$ and zero excess demand if $y^i = y^j$. This assumption is consistent with the empirical fact that countries with high nominal interest rates (Australia and New Zealand) have negative net international investment positions and are importers of capital, whereas countries with low nominal interest rates (Japan and Switzerland) have positive net international investment positions and are exporters of capital (Lane and Milesi-Ferretti (2007)). Furthermore, we assume that the funding and investment are channeled through the global banking centers, which demands FX hedging of assets and liabilities to some extent. Therefore, the funding gap for high interest rate currencies translate into demand for FX swaps to swap funding from low interest rate currencies to high interest rate currencies.

An FX swap market maker takes the opposite direction of the trade to clear the FX swap market, such that

$$a_{i,j} + d_{i,j} = 0$$

The swap maker does not take any unhedged FX risk. To do so, it must hedge the FX exposure in the cash market by going long in high interest rate currencies, and short in low
interest rate currencies. The profit per unit of notional is equal to

$$
\pi = \begin{cases} 
    \rho_{i,j} - (y^i - y^j) = x_{i,j} & \text{if } y^i \geq y^j \\
    (y^i - y^j) - \rho_{i,j} = -x_{i,j} & \text{if } y^i < y^j 
\end{cases}
$$

We further assume that the financial intermediary needs to set aside a haircut $h|\alpha_{i,j}|$ in capital, proportional to the swap position $|\alpha_{i,j}|$ and then FX dealer’s budget constraint becomes

$$
I = W - h \sum_{i,j} |\alpha_{i,j}|.
$$

We assume a concave production function $f(I)$. Then we can derive the following proposition.

**Proposition 3.** For a positive hair cut $h > 0$, the cross-currency of a foreign currency vis-à-vis the U.S. dollar increases in the foreign currency interest rate.

**Proof.** We fix currency $j$ to be the U.S. dollar. The optimality condition is given by

$$
f'(W - h|\alpha_{i,s}|) = \begin{cases} 
    x_{i,s}/h & \text{if } y^i \geq y^s \\
    -x_{i,s}/h & \text{if } y^i < y^s 
\end{cases}.
$$

By the implicit function theorem, we have

$$
\frac{\partial x_{i,s}}{\partial y^i} = -\frac{hKf''(W-ha_{i,s})}{1/h} > 0.
$$

The intuition behind the proposition is the lower the interest rate, the higher the excess demand to swap foreign currency funding into the U.S. dollar funding. A capital constrained arbitrageur charges higher excess returns for doing the opposite of the trade.
6 Conclusion

In this paper, we show that the CIP condition has failed persistently since the Global Financial Crisis for a constellation of interest rates including Libor, OIS, repo, Treasuries, bond yields of KfW and other risky issuers. Furthermore, the deviation from the CIP condition, or the cross-currency basis, is highly correlated with nominal interest rates across currencies and over time. As a result, currencies with higher nominal interest rates tend to have lower synthetic dollar interest rates on the FX-hedged basis. In the presence of costly financial intermediation and global imbalances in funding and investment, we show that the basis can persist and vary systematically with the nominal interest rate.
References


Appendix

For each individual bond issued by KfW denominated in currency $j$, we denote the coupon rate of an $n$-year bond by $c$, paid $q$ times per year. The principal is paid at the maturity time $t+n$. The price of the bond in currency $j$ is equal to

$$P_{t,n}^j = \frac{n}{q} \sum_{i=1}^{n/q} c \left(1 + \frac{y_{t+t+\tau}^{j,YTM}}{1 + y_{t+t+\tau}^{j,YTM}}\right)^{\tau} + \frac{1}{(1 + y_{t+t+\tau}^{j,YTM})^n},$$

where $y_{t+t+\tau}^{j,YTM}$ is the yield to maturity of the bond in currency $j$. We first compute the z-spread of bond over the Libor interest rate swap rate of the respective currency. Using the term structure of zero-coupon interest rate swap rates $y_{t+t+\tau}^{j,IRS}$ in currency $j$, the z-spread of the bond in currency $j$, $s_{t,t+n}^j$, is given as by the following equation:

$$P_{t,n}^j = \frac{n}{q} \sum_{i=1}^{n/q} c \left(1 + \frac{y_{t+t+\tau}^{j,IRS}}{1 + y_{t+t+\tau}^{j,IRS} + s_{t,t+n}^j}\right)^{\tau} + \frac{1}{(1 + y_{t+t+\tau}^{j,IRS} + s_{t,t+n}^j)^n},$$

To compare z-spreads in different currencies, we use the term structure of the cross-currency basis swaps to convert all floating benchmarks to the U.S. dollar Libor, and define synthetic spread of bond in currency $j$ over the U.S. dollar Libor, $\tilde{s}_{t,t+n}^j$, by

$$P_{t,n}^j = \frac{n}{q} \sum_{i=1}^{n/q} c \left(1 + \frac{y_{t+t+\tau}^{j,IRS} + x_{t+t+\tau}^{xcby} + \tilde{s}_{t,t+n}^j}{1 + y_{t+t+\tau}^{j,IRS} + x_{t+t+\tau}^{xcby} + \tilde{s}_{t,t+n}^j}\right)^{\tau} + \frac{1}{(1 + y_{t+t+\tau}^{j,IRS} + x_{t+t+\tau}^{xcby} + \tilde{s}_{t,t+n}^j)^n}.$$

Therefore, the KfW basis between the U.S. dollar and currency $j$ is defined as

$$x_{t,t+n}^{KfW,j} \equiv \tilde{s}_{t,t+n}^j - s_{t,t+n}^j,$$

which gives the difference between the direct dollar borrowing cost, $s_{t,t+n}^j$, and the synthetic dollar borrowing cost, $\tilde{s}_{t,t+n}^j$, both measured as spreads over U.S. Libor interest rate swap rates.
Table 1: Summary Statistics for Libor Cross-Currency Basis (basis points)

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<td>(9.6)</td>
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<td>(6.8)</td>
<td>(15.1)</td>
<td>(9.0)</td>
<td>(2.9)</td>
<td>(8.7)</td>
<td>(7.8)</td>
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<tr>
<td>SEK</td>
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<td>-7.2</td>
<td>-0.5</td>
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<td></td>
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<td>(5.7)</td>
<td>(33.6)</td>
<td>(12.9)</td>
<td>(1.0)</td>
<td>(7.9)</td>
<td>(8.1)</td>
</tr>
<tr>
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<td></td>
<td>-2.5</td>
<td>-21.7</td>
<td>-19.7</td>
<td>0.6</td>
<td>-8.2</td>
<td>-11.6</td>
</tr>
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<td></td>
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<td>(6.0)</td>
<td>(36.6)</td>
<td>(26.0)</td>
<td>(6.0)</td>
<td>(20.5)</td>
<td>(29.4)</td>
</tr>
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Notes: This table shows mean Libor basis for G10 currencies by periods in basis points. Standard deviations are shown in the parentheses.
Table 2: Credit Spread Differentials and the Libor Cross-Currency Basis

<table>
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<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
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</tr>
<tr>
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<td></td>
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<tr>
<td>NOK</td>
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<td></td>
<td></td>
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<tr>
<td>SEK</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>∆(cds_{USD} - cds_{i})</td>
<td>-0.0191</td>
<td>-0.0324</td>
<td>0.382</td>
<td>0.00937</td>
<td>0.277***</td>
<td>-0.419</td>
<td>-0.136</td>
<td>-0.0776</td>
<td>-0.0626</td>
</tr>
<tr>
<td></td>
<td>(0.0550)</td>
<td>(0.0304)</td>
<td>(0.423)</td>
<td>(0.0871)</td>
<td>(0.0434)</td>
<td>(0.519)</td>
<td>(0.295)</td>
<td>(0.0617)</td>
<td>(0.0665)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.245</td>
<td>-0.312</td>
<td>-0.0462</td>
<td>0.737</td>
<td>0.857</td>
<td>0.633</td>
<td>-0.216</td>
<td>0.444</td>
<td>0.345</td>
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<tr>
<td></td>
<td>(0.593)</td>
<td>(0.380)</td>
<td>(0.937)</td>
<td>(1.090)</td>
<td>(0.756)</td>
<td>(0.733)</td>
<td>(1.006)</td>
<td>(0.618)</td>
<td>(0.611)</td>
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<td>Observations</td>
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<td>64</td>
<td>64</td>
<td>64</td>
<td>64</td>
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<tr>
<td>R-squared</td>
<td>0.003</td>
<td>0.033</td>
<td>0.025</td>
<td>0.000</td>
<td>0.422</td>
<td>0.021</td>
<td>0.008</td>
<td>0.026</td>
<td>0.018</td>
</tr>
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</table>

Notes: This table shows regression results of monthly changes in the 5-year Libor cross-currency basis on monthly changes in mean 5-year CDS spreads differential between U.S. dollar Libor panel and the interbank panel of currency i. The sample period is January 2009 to April 2014. Robust standard errors are in the parenthesis, *** p<0.01, ** p<0.05, * p<0.1.
Table 3: One-week Libor/Repo Basis and Repo CIP Arbitrage Strategy Profits, 2009-2015 (basis points)

<table>
<thead>
<tr>
<th></th>
<th>(1) Libor Basis Full Sample</th>
<th>(2) Repo Basis Full Sample</th>
<th>(3) Repo Basis Conditional neg.</th>
<th>(4) Repo Arb. Profits Positive Profits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
<td>Count</td>
<td>% sample</td>
</tr>
<tr>
<td>CHF</td>
<td>-20.2</td>
<td>(26.1)</td>
<td>655</td>
<td>99%</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>(27.3)</td>
<td>655</td>
<td>85%</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>(27.1)</td>
<td>648</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>(22.7)</td>
<td>556</td>
<td></td>
</tr>
<tr>
<td>DKK</td>
<td>-43.4</td>
<td>(24.3)</td>
<td>655</td>
<td>96%</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>(24.8)</td>
<td>655</td>
<td>67%</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>(23.2)</td>
<td>630</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>(23.2)</td>
<td>437</td>
<td></td>
</tr>
<tr>
<td>EUR</td>
<td>-19.1</td>
<td>(14.2)</td>
<td>693</td>
<td>84%</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>(11.4)</td>
<td>693</td>
<td>57%</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>(10.0)</td>
<td>584</td>
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</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>(7.7)</td>
<td>396</td>
<td></td>
</tr>
<tr>
<td>JPY</td>
<td>-16.9</td>
<td>(12.6)</td>
<td>686</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>(12.8)</td>
<td>686</td>
<td>95%</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>(12.7)</td>
<td>685</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>(10.5)</td>
<td>651</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Count</td>
<td>(12.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>% sample</td>
<td>(10.5)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Columns 1 and 2 report the mean and standard deviation for one-week Libor and GC repo basis by currency during 2009-2015. Column 3 reports summary statistics conditional on a negative repo basis. Column 4 reports arbitrage profits for the negative basis repo arbitrage provided that the arbitrage profits are positive after taking into account the transaction costs.
<table>
<thead>
<tr>
<th></th>
<th>Basis full sample</th>
<th>(2) Basis conditional</th>
<th>(3) Pos. Profits ex. shorting fee</th>
<th>(4) Pos. Profits 25 pct fee</th>
<th>(5) Pos. Profits median fee</th>
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</thead>
<tbody>
<tr>
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<td>0.8</td>
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<td></td>
<td>S.D.</td>
<td>(13.5)</td>
<td>(7.2)</td>
<td>(4.8)</td>
<td>(4.1)</td>
</tr>
<tr>
<td></td>
<td>Count</td>
<td>1610</td>
<td>943</td>
<td>245</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>% sample</td>
<td>59%</td>
<td></td>
<td>15%</td>
<td>7%</td>
</tr>
<tr>
<td>CHF</td>
<td>Mean</td>
<td>-21.4</td>
<td>-23.4</td>
<td>15.6</td>
<td>12.1</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>(17.1)</td>
<td>(15.4)</td>
<td>(11.7)</td>
<td>(10.2)</td>
</tr>
<tr>
<td></td>
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<td>1496</td>
<td>1082</td>
<td>723</td>
</tr>
<tr>
<td></td>
<td>% sample</td>
<td>94%</td>
<td></td>
<td>68%</td>
<td>45%</td>
</tr>
<tr>
<td>EUR</td>
<td>Mean</td>
<td>-15.2</td>
<td>-16.5</td>
<td>10.3</td>
<td>7.1</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
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<td>(8.7)</td>
<td>(6.8)</td>
<td>(5.5)</td>
</tr>
<tr>
<td></td>
<td>Count</td>
<td>1624</td>
<td>1527</td>
<td>1253</td>
<td>710</td>
</tr>
<tr>
<td></td>
<td>% sample</td>
<td>94%</td>
<td></td>
<td>77%</td>
<td>44%</td>
</tr>
<tr>
<td>JPY</td>
<td>Mean</td>
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<td>-35.1</td>
<td>24.8</td>
<td>19.6</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>(14.1)</td>
<td>(14.1)</td>
<td>(12.9)</td>
<td>(11.6)</td>
</tr>
<tr>
<td></td>
<td>Count</td>
<td>927</td>
<td>927</td>
<td>889</td>
<td>814</td>
</tr>
<tr>
<td></td>
<td>% sample</td>
<td>100%</td>
<td></td>
<td>96%</td>
<td>88%</td>
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</table>

Notes: Column 1 reports the mean, standard deviation, and count for the KfW basis by currency for the full sample from 2009 to 2015. Columns reports conditional summary statistics only for positive KfW basis for the AUD and negative KfW basis for CHF, EUR and JPY. Column 3 reports summary statistics for arbitrage profits provided that the profits remain positive after taking into account the bid-ask spreads of bonds and swaps (positive basis arbitrage strategy for AUD and negative basis arbitrage strategy for CHF, EUR and JPY). Column 4 reports summary statistics for arbitrage profits provided that the profits remain positive after taking into account the bid-ask spreads of bonds and swaps and the 25 percentile of shorting costs for KfW bonds of the corresponding currency on the same trading date. Column 5 reports the summary statistics for positive arbitrage profits after taking into account the bid-ask spreads of bonds and swaps and the median shorting costs for KfW bonds.
Figure 1: Cash Flow Diagram for CIP Arbitrage with a Negative Basis \((x_{t,t+1} < 0)\).

Notes: This figure plots the cash flow exchanges of going long in JPY and short in USD, with the JPY cash flows fully hedged by FX swaps.

\[
\begin{align*}
\text{USD Lender} & \quad 1 \text{ USD} \quad \text{USD Arbitrageur} \\
\text{USD Arbitrageur} & \quad S_t \text{ JPY} \quad \text{FX Forward Dealer} \quad (1 + y_{t,t+1})S_t \text{ JPY} \\
\text{FX Forward Dealer} & \quad (1 + y_{t,t+1})S_t/F_{t,t+1} \text{ USD} \\
\text{USD Lender} & \quad 1 + y_{t,t+1} \text{ USD} \\
\text{JPY Borrower} & \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad 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Notes: This figure plots 10-day moving averages of the 3-month Libor cross-currency basis for G10 currencies.

Figure 2: 3-Month Libor Cross-Currency Basis (basis points)

Notes: This figure plots the cash flow exchanges of going long in JPY and short in USD, with the JPY cash flows fully hedged by FX swaps.

Figure 3: Cash Flow Diagram for JPY/USD Cross-Currency Basis Swap

Notes: This figure plots cash flow exchanges of the of a standard yen/dollar cross-currency basis swap.

Figure 4: Cash Flow Diagram for Long-Term Forward Premium

Notes: This figure shows that the long-term forward premium is equal to the zero fixed-for-fixed cross-currency swap rate. The zero-coupon fixed-for-fixed cross-currency swap for G10 currencies can be constructed using the following three steps: (1) paying a zero-coupon foreign currency fixed for floating interest rate swap indexed to the foreign currency Libor; (2) paying a zero-coupon foreign currency-Libor for USD-Libor cross-currency basis swap; and (3) receiving a USD fixed for floating interest rate swap. By summing up cash flows of the three steps, all floating cash flows are canceled and we are left exchanges of fixed cash flows at the inception and maturity of the swap in two currencies.
Figure 5: 5-Year Libor Cross-Currency Basis (Basis Points)

Notes: This figure plots the 10-day moving average of the 5-year cross-currency basis swap spreads for G10 currencies.
Figure 6: One-week Repo and Libor Cross-Currency Basis (basis points)

Notes: The green line plots the 1-week Libor cross-currency basis and the orange line plots the 1-week repo cross-currency basis.
Figure 7: KfW Cross-Currency Basis (basis points)

Notes: The red line plots the KfW cross-currency basis. The red line plots the difference in z-spreads over interest rate swap rates of the respective currency between U.S. dollar and foreign currency denominated KfW bonds. The green line plots the Libor cross-currency basis. All U.S. dollar and foreign currency KfW bonds are matched by the maturity year.
Notes: This figure shows the 25 percentile, median and 75 percentile of fees across all transactions for shorting U.S. dollar denominated KfW bonds. Data Source: Markit Securities Finance
Figure 9: Issuer-Specific Cross-Currency Bases for Multi-currency Issuers

Notes: The figure shows issuer-specific cross-currency bases, together with the Libor cross-currency basis. All bonds for the same issuer are matched by the maturity year and seniority.
Figure 10: Median Issuer-Specific Cross-Currency Basis

Notes: The figure shows median issuer-specific cross-currency basis, which is the sum of the median z-spread differential and the Libor cross-currency basis.
Figure 11: Cross-Sectional Variations in Currency Basis (2010-2015)

Notes: This figure shows the cross-currency relationship between various cross-currency bases on the y-axis and nominal interest rates on the x-axis. The top two panels plot the relationship for Libor at 3-month and 5-year. The middle two panels plot the relationship for KfW and average multinational issuers. The bottom two panels plot the relationship for 3-month OIS rates and 5-year Treasuries. The correlation between cross-currency bases and nominal interest rates for each interest rate instrument are indicated in the title of each panel.
Notes: This figure plots intraday changes in the 2-year German bund and U.S. Treasury yield differential around the ECB monetary policy announcement on the x-axis and intraday changes in the 1-year euro/dollar cross-currency basis around the same time on the y-axis. All intra-daily data are from Thomson Reuters Tick History. The sample period is from January 2010 to October 2015.