Covered Interest Parity Violations, Debt Overhang and Funding Value Adjustments*

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Abstract

Deviations from covered interest rate parity have been large and persistent since the 2007-08 global financial crisis. This means that the cost of borrowing the U.S. dollar in the money market differs from the cost of borrowing dollars synthetically using the forward swap market. We provide evidence that covered interest rate parity deviations are related to higher funding costs faced by dealers after the crisis. We argue that these costs stem from dealers' debt overhang.

Keywords: exchange rates, covered interest rate parity (CIP), market microstructure, stochastic discount factor

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1 Introduction

The covered interest parity (CIP) condition states that the return to lending a dollar in the U.S. money market should be the same as the return to lending a foreign currency and swapping (forward) the proceeds into dollars. Prior to the 2007-08 global financial crisis (GFC), deviations from covered interest parity tended to be small for major currency pairs.[1] During the turbulent episodes of the GFC and the European Debt Crisis sharp and persistent deviations from CIP were observed.[2] Even during relative calm periods of the post-GFC era, however, large and persistent deviations from CIP have continued to be observed.[3] We find evidence that these deviations from CIP are related to debt overhang costs borne by foreign exchange dealers' shareholders. When these debt overhang costs are sufficiently large, if dealers' actions are aligned with shareholders' interests, CIP arbitrage becomes unattractive.

The cross-currency LIBOR basis is a commonly used measure of the CIP deviation between the U.S. dollar (USD) and a foreign currency. When it is more expensive to borrow a dollar outright than it is to borrow foreign currency and swap the future obligation to dollars, the basis is positive. When it is cheaper to borrow the dollar outright than synthetically, the basis is negative. When the basis is zero, CIP holds. Consistent with the literature, we find that, since the onset of the GFC, the cross-currency basis has generally been large and negative for several European currencies, the British pound, and the Japanese yen (see Figures 1 and 2).[4] In the case of the euro, for example, this suggests an arbitrage opportunity is available whereby an investor could, at zero cost, pocket the cross-currency basis by borrowing in dollars, and simultaneously lending in euros, with the proceeds swapped to dollars.

We link the observed order-of-magnitude increase in CIP deviations to the substantial increase in debt overhang costs that has also been observed since the onset of the GFC. This is no mere coincidence, as Andersen et al. (2019) argue that these increased costs have reduced dealers' willingness to expand their balance sheets to exploit investment opportunities arising in financial markets. Andersen et al. (2019) state that these costs are equivalent to the funding valuation adjustments (FVAs) that dealers apply when reporting the values

[1] Early research on CIP, such as Deardorff (1979), Callier (1981), and Clinton (1988), largely concluded that CIP holds in the data. More recently Burnside et al. (2006) documented only small and infrequent deviations from CIP in the period prior to the GFC for a set of major currencies.

[2] See, for example, Baba et al. (2008), Baba et al. (2009), Baba and Packer (2009) and Bottazzi et al. (2012).

[3] See, for example, Du et al. (2018) and Rime et al. (2022).

[4] The cross-currency basis has been positive for the New Zealand dollar and mixed, depending on horizon, for the Australian and Canadian dollars.

of their swap books. To understand FVAs, imagine a situation where a dealer issues debt denominated in U.S. dollars (USD) while simultaneously purchasing a treasury security with the same market value.[5] While this transaction has no apparent effect on the dealer's net asset position, the action by the dealer is not neutral with respect to its shareholders if it faces a credit spread over the U.S. treasury rate. Lenders to the dealer receive this credit spread because they stand to take a loss in the state of the world in which the dealer defaults. The proceeds they receive in the non-default state must compensate for that loss. The bank's shareholders receive the reverse (negative) payoff in the non-default state of the world. Yet, for them, there is no corresponding positive payoff if the dealer defaults. In this example, if the dealer carries through with the transaction—which, as Andersen et al. (2019) point out, it might do for regulatory reasons—it should mark down the value of its balance sheet by an FVA equal to its risk-neutral survival probability times the net payout in the survival state. In this example, were it not for, say, a regulatory incentive, the bank would not undertake the investment because of this FVA.

Similarly, transactions undertaken by a foreign exchange dealer are subject to debt overhang costs. These stem from the dealer's risk of default, as well as from the risk of counterparty default. For example, a dealer might undertake a trade to exploit an apparent deviation from CIP. A dealer might lend New Zealand dollars and swap the proceeds to USD, if the return to doing so exceeds the dealer's borrowing rate in the commercial paper market. However, this transaction is subject to FVAs that reflect the fact that the bank's shareholders receive no payoff if the dealer defaults, and a likely negative payoff if the counterparty defaults. Andersen et al. (2019) conjecture that the magnitude of these FVAs may turn what looks like an arbitrage opportunity into a risk-neutral expected loss for the dealer's shareholders. Supporting this view, we provide empirical evidence that CIP deviations are related to the debt overhang costs faced by dealers. We do this in two ways. First, we follow Andersen et al. (2019) to obtain approximate measures of shareholders' costs when dealer banks engage in CIP arbitrage. We show that these costs are quantitatively large enough to rationalize the survival of significant deviations from CIP. Second, we show that variation over time in the size of CIP deviations appears to be significantly related to the size of dealer banks' borrowing spreads.[6]

It is important to note that, in this paper, we do not study whether CIP arbitrage was profitable over a given period, rather it is to shed lights on why dealers did not take advantage

[5] This example is the same as the one given in Andersen et al. (2019)'s introduction. They provide a more general discussion of FVAs for a variety of investment opportunities. See also Hull and White (2014).

[6] We believe ours is the first paper to provide this kind of empirical evidence that debt overhang costs pose significant costs that affect CIP. A related paper, Fleckenstein and Longstaff (2020), provides evidence that these costs are significant in the interest rate futures market.

of an arbitrage opportunity.

An active emerging literature has investigated CIP deviations throughout the post-GFC period. Du et al. (2018) were among the first to document them. They observe that arbitrage opportunities appear to exist at very short horizons (overnight and one-week), and argue that their findings are difficult to reconcile with limits-to-arbitrage models, such as Shleifer and Vishny (1997), because these models rely on long-term market risk. Instead, they argue that post-GFC regulatory reforms—in particular, leverage ratio requirements—had a critical impact on deviations from CIP because they raised banks' funding costs. To support their argument, they show that CIP deviations become sharper around quarter-end financial reporting dates implying that these deviations are related to leverage ratio costs and dealers' balance sheet capacity. However, this leaves open the question of whether dealers' balance sheet capacity more generally affects CIP deviations.

We complement Du et al. (2018) in several ways. Our empirical evidence covers a much longer period, and does not depend on a regulatory reporting date argument. It suggests that Du et al.'s findings are just the tip of the iceberg, as debt overhang costs seem to have constrained dealers at all times since the GFC. We also complement Du et al. (2018) by providing empirical evidence that debt overhang costs are important in markets when trades are executed via REPO and IOER markets rather than at LIBOR. One might expect that FVAs are less important in REPO markets given the reduced credit risk as a result of collateral. Our results, however, suggest the existence of significant costs for dealers in arbitraging CIP in this market as well. As discussed, REPO and IOER CIP basis arbitrage rely on balance sheet expansion which needs to be financed either by additional equity or debt implying debt overhang costs (see the discussion in Duffie and Krishnamurthy, 2016). Additionally to this, Rime et al. (2022) show that REPO arbitrage involves a shadow cost which is related to the difference in quality between USD and foreign currency collateral, due to flight-to-quality considerations. Our basic findings are robust to using these rates. In sum, we provide strong empirical evidence that debt overhang costs, in addition to leverage ratio costs, significantly constrain dealers.

In related work, Cenedese et al. (2021) exploit the introduction of the U.K. leverage ratio framework in January 2016, to investigate the relationship between the leverage ratio of U.K. dealer banks and the cross-currency basis. Their data set uses contract-level data, so they are able to observe that the same counterparty faces a range of currency bases that appear to be systematically related to the leverage ratios of the different banks. They show that dealers charged, on average, an extra premium of 16 basis points in response to the new regulations. They also observe a decrease in the amount of synthetic dollar borrowing after the introduction of the leverage ratio framework, consistent with the notion that dealers' balance sheet capacity and intermediation activity have both declined. Their evidence supports Du et al. (2018) and it is consistent with our results pointing towards higher rigidity on dealers' balance sheets following the GFC.

An important paper related to ours is Fleckenstein and Longstaff (2020). They document that dealers' balance sheet rigidity (proxied by the funding basis, that is the difference between uncollateralised and risk free borrowing rates) is associated to derivatives' mispricing of interest rate futures with respect to the cash market. They consider different motivations for dealers' balance sheet rigidity—leverage ratios, debt overhang costs, and capital regulations—and conclude that their proxy for balance sheet rental costs only explain part of the futures basis. Our paper complements these results but with an important difference, we focus on CIP bases and FVAs. We use different measures of CIP deviations and show that our proxy for FVAs seems important in understanding the cross-currency basis in different markets.

Recently, Rime et al. (2022) show that once we measure CIP bases using proper unsecured funds such as commercial paper, CIP deviations are smaller and only attractive to relatively few well-capitalised banks. Their evidence points towards a higher degree of balance sheet rigidity imposed by actual funding costs, and, in this respect, their evidence is consistent with what we document. However, the main focus of our paper is to ask whether arbitraging CIP deviations, even for well-capitalized banks, is beneficial for shareholders, as well as explaining variation over time in the apparent incentive to arbitrage. Our analysis focuses on the role of FVAs, which are related to funding costs, in making CIP arbitrage less beneficial for shareholders.

Borio et al. (2018) argue that size and persistence of CIP violations after 2014 can be explained by the hedging-related demand for dollars, and the tighter limits to arbitrage faced by dealers after the financial crisis. Lower balance sheet capacity since the GFC has decreased the supply of dollars available for a CIP-arbitrage trade's dollar swap market leg. Combined with the increasing demand for dollars outside the U.S., it has widened the CIP basis and made it more persistent. Borio et al. (2018) do not investigate the factors driving the hedging demand and its cost.

Avdjiev et al. (2019) show a triangular relationship between cross-currency deviations, USD strength and cross-border bank lending in dollars. An appreciation of the USD increases the cost of dealers' intermediation and reduces dealers' balance sheet capacity. It reduces the supply of dollars and increase the cross-currency basis. The appreciation of the dollar increases the value of liabilities relative to assets and, consequently, the shadow price for dealers' intermediation in supplying dollars. They propose a model explaining these features and rationalizing the observed CIP deviation and why this is larger for funding currencies and smaller for investment currencies.

2 CIP and the Cross-Currency Basis

CIP is a no-arbitrage condition stating that investors should be indifferent between borrowing USDs outright in the domestic wholesale market and borrowing them synthetically via the swap market. The synthetic method involves borrowing a foreign currency, say euros, and swapping the resulting euro obligation for a USD-denominated one via a cross-currency swap. If the two positions have the same credit quality, one would expect them to have the same USD cost.

To formalize the CIP condition, let $y^D_{t,t+n}$ be the annual interest rate for borrowing USD for n years in the wholesale market. Let $y_{t,t+n}$ be the equivalent interest rate for borrowing foreign currency units (FCUs). Let S_t be the spot exchange rate at time t, and let $F_{t,t+n}$ be the n-year forward exchange rate at time t, both measured as USD per FCU. An investor who borrows one USD in the wholesale market owes $(1 + y^D_{t,t+n})^n$ USD after n years. An investor who borrows an equivalent amount of FCUs, i.e. $1/S_t$ FCUs, would owe $(1 + y_{t,t+1})^n/S_t$ FCUs after n years. If the investor buys that many FCUs forward, the investor effectively swaps the FCU obligation for a dollar one valued at $(1+y_{t,t+1})^n F_{t,t+n}/S_t$ USD. In both cases, the amount borrowed is equivalent to one USD, and the future dollar obligations are known in advance, so the CIP condition says they should be equal:

$$\text{CIP:} \qquad (1 + y^D_{t,t+n})^n = (1 + y_{t,t+1})^n \frac{F_{t,t+n}}{S_t} \tag{1}$$

The CIP condition can be expressed approximately in logarithmic terms:

$$y^D_{t,t+n} \approx y_{t,t+n} + \frac{1}{n}(f_{t,t+n} - s_t) = y_{t,t+n} + x_{t,t+n}, \tag{2}$$

where $f_{t,t+n} = \ln F_{t,t+n}$ and $s_t = \ln S_t$, and $x_{t,t+n} = \frac{1}{n}(f_{t,t+n} - s_t)$ is the n-year forward premium expressed as an annual rate.

The n-year cross-currency basis $z_{t,t+n}$ is defined as

$$z_{t,t+n} \equiv y^D_{t,t+n} - (y_{t,t+n} + x_{t,t+n}). \tag{3}$$

If CIP holds, $z_{t,t+n} = 0$. More generally, if there are departures from CIP, the cross-currency basis measures the difference between the cost of borrowing USD in the wholesale market and the cost of borrowing USD synthetically.

We analyze CIP deviations for the G10 currencies vis-a-vis the USD at two horizons

(3-month and 5-year).[7] The spot and forward exchange rates we use are from Bloomberg using the London closing rate.

Figures 1 and 2 show weekly data on the 3-month and 5-year Libor-based deviations from CIP, as measured by the cross-currency basis. Table 1 provides summary statistics. As both the charts and summary statistics indicate, CIP deviations were small before 2008, typically less than 20 basis points in absolute value. A significant change occurred during the GFC, actually beginning in the latter part of 2007, with the range of observed CIP deviations widening sharply. For most currencies, the CIP basis was much larger and negative, on average, in the latter part of our sample. The AUD and NZD were exceptions to this rule, with both bases shifting towards smaller negative or more positive values in the latter part of our sample. As is clear from the charts, these large deviations from CIP have persisted throughout the period after the GFC. These findings align with what is documented in the literature.[8]

The the LIBOR-OIS spread is a commonly-used proxy for short-term funding costs in the banking sector as a whole. In Figure 3 we show Libor-OIS spreads across different maturities. At horizons between one month and one year, the LIBOR-OIS spread rose dramatically during the GFC and remained elevated thereafter, when compared to the pre-GFC period. So banks' short-term borrowing costs have increased significantly. A bank's CDS spread provides a direct measure of its long-term funding costs. In Figure 4 we show the 5-Year CDS spread averaged across two sets of banks used in this study. Banks' CDS spreads increased sharply in the 2008–09 period and again in 2011-13, but even in the 2014–2020 period they remained substantially higher than in the period prior to 2008.

In Table 2, we report some summary statistics for the measures of funding costs shown in Figures 3 and 4. Consistent with the above discussion, there was a significant increase in banks' funding costs from 2008 forward. The average 5-Year CDS spread increased nearly 100 basis points, from 21 to 115, while the Libor-OIS spread average 15 basis points prior to 2008, and 32 afterwards.

At face value, the data in Figures 3 and 4 and Table 2 are consistent with our conjecture that higher funding costs after the GFC have introduced an important friction in how dealers manage their balance sheets.[9] Furthermore, these data, together with the simultaneous increase in measures of the cross-currency basis, hint that these balance-sheet frictions may play an important role in driving CIP deviations. Banks that take shareholder interests into

[7] The G-10 currencies are 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 krona (NOK), the New Zealand dollar (NZD), and the Swedish krona (SEK).

[8] See, for example, Borio et al. (2018), Du et al. (2018), and Avdjiev et al. (2019).

[9] This evidence is also discussed in Rime et al. (2022).

account may be reluctant to engage in the types of arbitrage trades that would reduce the cross-currency bases observed in the data.

3 Debt Overhang and Dealer Credit Spreads

As we have seen, after the GFC dealer banks experienced sharply increased costs with their borrowing rates deviating sharply from risk free rates. When dealers borrow to finance asset purchases, the spread over the risk free rate represents a debt overhang cost to shareholders. When dealers account for these costs in their balance sheets they are referred to as funding value adjustments (FVAs). Since the GFC dealers have increasingly used FVAs in their accounting statements [Hull and White (2014)].

To see why debt overhang and FVAs are relevant when thinking about violations of CIP, it is instructive to review an example provided by Andersen et al. (2019).[10] In their example, a hypothetical dealer considers an arbitrage trade where it borrows USD in the commercial paper (CP) market, and then lends in the euro CP market, with the euros swapped back to USD. In this example, the marked-to-market profit from the trade is simply the negative of the CIP basis for each dollar the bank borrows; i.e. $-z$ in the notation of equation (3). If the cross-currency basis is negative the trade appears to be attractive. However, from the shareholder perspective the expected payoff from this trade is smaller than $-z$ if the dealer and counterparty have a risk of default. Andersen et al. (2019) suggest that the dealer will apply an FVA to this trade that is equal to the spread at which it borrows over the risk free rate. In their example, the credit spread is 35 basis points, while the CIP basis is -25 basis points, so from the shareholder perspective the value of the bank's equity is reduced by 10 cents for every 100 USD the bank borrows. A dealer acting in shareholders' interest would not execute the trade.

The basis of the argument in Andersen et al. (2019) can be understood in a simple setup, where, for convenience, we assume that the risk free USD interest rate is zero.[11] A dealer bank is assumed to have a risk-neutral survival probability q. If the bank defaults, its lenders are assumed to be able to recover a fraction $0 \leq \kappa < 1$ of the value of their loans. Therefore, the bank can borrow at the rate r, where

$$1 = q\,(1 + r) + (1 - q)\kappa(1 + r). \tag{4}$$

As shown in the appendix, when the probability of default is small

$$r \approx (1 - q)\,(1 - \kappa)\,. \tag{5}$$

[10] The discussion in Andersen et al. (2019) applies, more generally, to a wide variety of financial instruments, but they provide a specific example relevant for CIP deviations.

[11] Andersen et al. (2019) provide a numerical example consistent with the description than follows.

Now, imagine a CIP arbitrage trade in which the dealer bank borrows 1 USD at the rate r, and lends an equivalent amount of euros, swapped back to dollars, at the synthetic interest rate, $r^S > r$. Assume that the counterparty also has a risk-neutral survival probability q, with the survival or failure of the dealer and counterparty being independent events. As in the case of the dealer, if the counterparty defaults the dealer is assumed to recover only the fraction κ of the loan amount.

In this example, if both the dealer and the counterparty survive, which happens with probability q^2, the payoff to shareholders has a present value of $r^S - r$. If only the dealer bank survives, which happens with probability $q(1-q)$, the present value of the payoff to shareholders is $\kappa(1+r^S) - (1+r)$. If the dealer bank fails the shareholders receive zero. Thus, the risk-neutral expected value of the trade to shareholders is

$$\begin{aligned} \pi &= q^2 \left[(1+r^S) - (1+r)\right] + (1-q)q\left[\kappa(1+r^S) - (1+r)\right]. \\ &= q\left\{\left[q + (1-q)\kappa\right](1+r^S) - (1+r)\right\} \end{aligned} \tag{6}$$

As shown in the appendix, when the probability of default is small

$$\pi \approx (r^S - r) - r. \tag{7}$$

Thus, if the bank's risk premium is sufficiently large—i.e., if $r > r^S - r$—the bank will not undertake CIP arbitrage if it considers shareholder interests. In any case, considering FVAs, alone, we can think of typical dealer credit spreads as a benchmark for the size of the CIP basis that can persist in the foreign exchange market.

As Andersen et al. (2019) point out, the relevance of FVAs is separate from the costs imposed by banks' regulatory capital requirements. Leverage ratio requirements (LRR) impose an additional cost that can also be taken into account, but they argue that this cost is relatively small compared to r in their quantitative example. As discussed in Duffie (2022), the model in Andersen et al. (2019) can also be used to estimate the impact of the LRR cost on the return for banks' equity holders. Under the LRR a bank must finance at least a fraction c of a new investment with new equity and $1-c$ with debt. Per unit of funding, the marginal cost of an asset to shareholders due to the LRR is

$$c(1 - q - \text{FVA}), \tag{8}$$

where FVA represents the funding value adjustment that would be applied in the absence of the LRR. In the numerical example, above, FVA $\approx r$ and $q \approx 1$ so the LRR cost to shareholders is roughly equal to cr.[12] Thus, for a relative small value of c the LRR cost is

[12] Note that given that the LRR is binding the bank can conduct a CIP trade only if it retires an amount equal to c of unsecured debt and issues an equal amount of equity.

considerably smaller than the FVA that applies in the absence of the LRR.[13]

In the previous example, the FVA that applied to the CIP arbitrage trade could be proxied by the dealer's credit spread. The calculation of FVAs in practice is more complex and is not within the scope of this paper. However, most banks tend to link their FVAs to their own cash bonds or even asset swap spreads on unsecured debt and many others link FVAs to their own 5 Year CDS spread.[14] Consistent with this industry practice, in the analysis that follows, we proxy banks' FVAs by their own 5 Year CDS spread.[15] This choice is also partially motivated by the fact that we have available data on banks unsecured debt over the same sample period.

Table 3 explores individual banks' incentives to engage in CIP arbitrage in the latter part of our sample (Jan. 4 2008 to Jan 3 2020). In Panel A, we use each bank's 5-year CDS spread as a proxy for the FVA that it would apply to a CIP trade. Then, using equation (8), we calculate the marginal cost of the LRR framework that would apply to each bank. The sum of these terms is shareholders' perception of the total funding cost of the trade. These costs can then be compared to average 5-year CIP deviations for various currencies, which are shown in Panel B. Notably, the total annualised funding cost to shareholders (Panel A) are generally much larger in magnitude than the CIP deviations over the same period (Panel B). It is also notable that for all our banks, the leverage costs related to the post-2018 regulatory framework, although economically significant, are much smaller than the FVA itself.[16]

4 Banks Funding Costs and the Cross-Currency Basis

In the previous section, we saw that borrowing costs for banks rose sharply during the GFC and have remained elevated since then. We also saw that, since 2008, these premia, which proxy for banks' FVAs, have been quantitatively significant compared to the size of apparent departures from CIP observed in the LIBOR market. These higher funding costs make debt overhang a plausible explanation, on top of regulatory costs, for the persistent departures from CIP in this period. In the next sections, motivated by the simple theory reviewed in the previous section, we drive deeper into the question of whether debt overhang, as manifested in banks' funding costs, is related to CIP. In doing so, we do not claim to provide causal evidence, but rather, we focus on studying the correlation between funding costs and the

[13] In the United States $c = 0.06$. So, in the numerical example, the LRR cost is between 2 and 3 basis points, as compared to the FVA of 35 basis points.

[14] For more details, see Becker (2020).

[15] Our empirical findings are similar if we use 1 Year CDS spreads.

[16] Leverage ratio costs are relevant. Our suggestion, here, is that post-2008 regulations on leverage cannot fully explain the different bases reported in the literature, amongst them CIP basis. See also Fleckenstein and Longstaff (2020).

cross-currency basis. To do so, we explore the time-series relationship between the CIP basis and dealer funding costs. Our empirical approach is similar to that in Avdjiev et al. (2019).

Following the main literature cited earlier, in Section 4.1 we start with our benchmark case, where we study CIP deviations in the LIBOR market, the main wholesale funding market for banks over our sample period. Thereafter, in Section 4.2, we extend our analysis to departures from CIP that are observed in REPO and IOER markets. The reason for studying CIP deviations in this markets and how they relate to debt overhang is twofold. First, take as an example the REPO market. One would think that debt overhang would be significantly mitigated by moving trading from an unsecured funding market (such as LIBOR) to a secured one (such as REPO). Our results suggest that this is not the case. Additional to the regulatory costs discussed by large part of the literature (see our earlier discussion), our results point in the direction that an additional friction, debt overhang, could be at work.

Dealers acting as intermediaries, provide immediacy to clients by temporarily absorbing their net trade demands. Dealers have funding requirements for carrying and hedging these inventories. Within a "no-arbitrage" pricing world, one would assume that dealers finance any net cash funding requirements for their market-making positions and related hedges at risk-free market interest rates. Practically, dealers often need to fund their cash requirements from the treasury of the bank at a rate which is higher and can be proxied by the the bank's credit spread (FVA). This cost could be even higherm as the dealer's funding cost might also reflect, amongst the other things, the type of collateral supplied. By studying CIP deviations in other markets, we aim to call the attention of the reader on how pervasive debt overhang considerations have become. We believe ours is the first paper to emphasize and document this.

4.1 The LIBOR Market

We first consider the following panel model:

$$\triangle z_{it} = \alpha_i + \beta \triangle y_t + \gamma \triangle D_t + \eta' C_{it} + \epsilon_{it}, \tag{9}$$

where z_{it} is the cross-currency basis for currency i with respect to the USD, α_i is a currency fixed effect, y_t is the typical credit spread for banks, D_t is the log of the Federal Reserve Board (FRB) U.S. trade-weighted broad dollar index, and C_{it} is a vector of additional, possibly country-specific, control variables.[17] For the latter, we use the log-change of the bilateral exchange rate between country i and the U.S., the change in the borrowing rate

[17] A positive change of D_t means dollar appreciation.

spread between country i and the U.S., and the change in the logarithm of the VIX index.[18]

4.1.1 Long-Term CIP Basis

We first consider long-term 5-year CIP deviations. Table 4 shows results from estimating equation (9), with y_t being measured using the average 5-year CDS spread across twelve major U.S. and European banks. For the borrowing spread between country i and the U.S. we use 10-year government bond rates. The sample consists of weekly data from Jan 4 2008 to Jan 3 2020. We introduce the variables other than Δy_t one-by-one, with the final column of the table providing corresponding estimates for an earlier, pre-crisis, sample period (Jan 03 2003 to Dec 30 2006).

In every case, except in the pre-crisis sample period, our estimate of β is negative and highly statistically significant. This suggests that when banks' credit spreads increase, the higher FVAs that they apply reduce their capacity to intermediate CIP arbitrage, leading to a larger (negative) basis.

The coefficients on the dollar index are also negative and highly significant across all the specifications, as found in Avdjiev et al. (2019) using daily and quarterly data over a different time period. Avdjiev et al. (2019) argue that this indicates that the strength of the dollar proxies for the shadow price of bank leverage.

Unlike Avdjiev et al. (2019), we find the coefficient on the log-change of the bilateral exchange rate between country i and the USD to be negative and statistically significant.

Our estimate of the coefficient on the 10-year government yield spread is positive and significant, as in Du et al. (2018) and Avdjiev et al. (2019), suggesting that the nominal interest rate differential is an important driver of the CIP basis.

Finally, the estimated coefficient on the change of the VIX index is negative, but statistically insignificant.

The final column of the table shows results using the sample period prior to the GFC. In this case, all of our estimated coefficients are statistically insignificant, with one exception: the coefficient on the change of the VIX index is positive and statistically significant.

In Appendix Table 12, we repeat the analysis in Table 4 with y_t measured as the the average 5-year CDS spread for only the six U.S. banks in our sample. Appendix Table 13 repeats the analysis using only the six European banks in our sample. The results in Tables 12 and 13 are very similar to those in Table 4, with one exception. When we only use U.S. banks to measure the average credit spread, the coefficient on the change in the VIX is negative and becomes statistically significant.

[18] VIX is the ticker symbol for the Chicago Board Options Exchange's CBOE Volatility Index, a measure of expected stock market volatility.

Overall, our results suggest that debt overhang, as reflected in banks' funding costs, and FVAs, are important in explaining variation in the size of CIP deviations after the GFC.

4.1.2 Short-Term CIP Basis

The long term CIP bases discussed in the previous section, are retrieved directly from cross currency swaps at the 5yr horizon (Du et al. 2018). One might question whether the evidence, presented there, suggesting that CIP deviations are related to debt overhang, only reflects special costs associated with providing U.S. dollar liquidity in the longer-term swap market (commitment of capital, greater hedging costs etc., as discussed by Borio et al. 2018). To consider this possibility, we next study short-term 3-month CIP deviations. Table 5 shows results from estimating equation (9), with y_t being measured using the average 5-year CDS spread across twelve major U.S. and European banks. For the borrowing rate spread between country i and the U.S. we use 3-month LIBOR rates. The sample consists of weekly data from Jan 4 2008 to Jan 3 2020. We introduce the variables other than Δy_t one-by-one, with the final column of the table providing estimates in an earlier, pre-crisis, sample period (Jan 3 2003 to Dec 30 2006).

With respect to the estimates of β, the results are qualitatively similar to what we observed for long-term CIP deviations. The estimated coefficient on the change of the CDS spread is negative and statistically significant, but larger in magnitude than before. When banks' credit spreads widen, CIP deviations become more negative.[19] The estimated coefficients in column [4] of Table 5 suggest that, on average, a 100 basis point increase in the average bank's credit spread is associated with a larger (more negative) CIP deviation of about 23 basis points. In the pre-GFC period, the change of the CDS spread still has a negative coefficient but it is statistically insignificant.

In sum, our empirical evidence points to the relevance of dealers' funding costs in explaining the large CIP deviations after the GFC, both in terms of magnitudes and in terms of how they vary over time. Prior to the GFC, it would appear that FVAs were largely irrelevant in determining CIP deviations, which, of course, were smaller in magnitude.

4.1.3 Time Series Analysis

In this section we take a country-by-country time series approach to studying variation in CIP deviations. We consider the following variant of equation (9):

$$\triangle z_{it} = \alpha_i + \beta_i \triangle y_t + \gamma \triangle D_t + \eta' C_{it} + \epsilon_{it}, \tag{10}$$

which we estimate for each country i.

[19] We have also used one-year CDS spreads to measure y_t and have found qualitatively similar results.

Table 6 shows the results for weekly data. The results are broadly consistent with what we found with our panel analysis. For most countries, the coefficient on Δy is negative and statistically significant in most cases, and many of the estimated coefficients are quite close to the value we obtained by imposing the panel restriction. Overall, our results for individual currencies seem to confirm that FVAs are important in explaining CIP deviations.

4.2 CIP Deviations in Other Markets

We now extend our results by studying CIP deviations in markets where credit risk is very small but nevertheless arbitraging CIP deviations is capital intensive for dealers. We provide evidence suggesting that debt overhang costs are relevant in these markets as well, and prevent dealers from engaged in CIP arbitrage. We focus on two important markets. In the first case, we consider an investor who borrows in the U.S. REPO market and invests (lends) in the foreign currency REPO market. In the second case, we consider a dealer who borrows at the U.S. Federal Reserve's IOER rate and lends in either the foreign currency REPO or foreign currency LIBOR market.

4.2.1 General Collateral REPO Market (GREPO): Institutional Background

A REPO combines the sale of security (say, a Treasury security) with a commitment by the seller to purchase it back at a higher price on an agreed date while receiving funds over the intervening period. Therefore, broadly speaking, a REPO is similar to a collateralised loan. In a GREPO, the collateral can be any variety of Treasury or other related securities. REPO intermediation rests on the intermediation of safe securities such as Treasury securities and as a consequence carries very little risk.

Consider the following example of REPO intermediation where a dealer receives collateral say, \$100 dollar Treasury security in exchange for \$100 in cash (we do not consider haircuts in this example). In a "matched-book" REPO, the dealer would use the same collateral to borrow from a money market fund. If the REPO intermediation is not matched, the dealer will have to purchase the collateral in the market, generally by writing commercial paper using its own capital.

Therefore, a "matched book" REPO is neutral with respect to the dealer's balance sheet, as long as the dealer recovers the funding costs plus a spread for the intermediation, and therefore it carries no debt overhang costs for the dealer.

Suppose now that the dealer faces a capital requirement (say, the LRR), implying that it will need to set \$5 capital against this trade. In this case, the REPO intermediation is no longer neutral with respect to the dealer's balance sheet as the regulatory cost must be financed, either by issuing new equity or new debt. In either case, this cost will need be sustained by equity holders, implying debt overhang. These examples show that the intermediation of safe assets such as U.S. Treasury REPOs can be capital intensive even if the risk involved is small, while it only improves the position of the bank's unsecured legacy creditors.[20] Furthermore, compared to the example just discussed, as we discuss below, REPO CIP arbitrage is more capital intensive.

4.2.2 REPO-Based CIP Deviations

We measure the REPO basis as in Du et al. (2018).[21] We focus on the 3-month REPO basis, and use only three currencies due to data availability. We employ the Swiss franc (CHF), Danish krone (DKK) and Japanese yen (JPY). We study weekly data from Jan 4 2008 to Jan 3 2020.[22]

Tuckman and Porfirio (2003) argue that credit risk may explain non-zero cross-currency basis swap spreads. In contrast, Du et al. (2018) report large cross-currency bases in the post-GFC period when these are measured using REPO rates, but they discount the role of credit (default) risk as a driver of CIP deviations. Our results suggest that since REPO intermediation is capital intensive, making dealers' balance sheets non-neutral with respect to CIP arbitrage, it implies relevant debt overhang costs.[23] Finally, Rime et al. (2022) show that REPO CIP arbitrage carries a shadow cost, which is approximately equal to the difference between higher quality U.S. collateral and foreign collateral (the U.S. assets having flight-to-safety value). This shadow cost would be additional to the dealers' balance sheet costs that we have already discussed.

REPO-based CIP bases are showed in Table 7. These bases are large and in line with the empirical evidence in Du et al. (2018). Why do dealers do not trade given these apparent arbitrage opportunities? We conjecture that arbitraging REPO CIP deviations carries debt overhang costs for dealers' shareholders.

In Table 8, we estimate equation (9) using repo-based cross-currency bases as the left-hand-side variable. The right-hand-side variables remain the same as before. As in the previous sections, we measure debt overhang costs using the average 5-year CDS spread of the major dealers. We report separate results for U.S. and European dealers, as well as considering all banks.

As Table 8 indicates, debt overhang costs appear to remain important to understand CIP

[20] See, also, a related discussion in Andersen et al. (2019).

[21] The method is similar to the one described earlier, with the repo rates in each currency replacing the LIBOR rates in equation (3). For details, please refer to Du et al. (2018).

[22] We do not include the euro as the data available starts from 2011.

[23] Refer to the discussion in this paper as well as Duffie and Krishnamurthy (2016). Also, note that REPO CIP is not a matched book as discussed in the example above as it implies receiving a collateral which cannot be used in US REPO market and therefore the dealer, in general, will need to finance it with her own capital.

deviations in REPO markets. The estimated coefficient suggests that a 100bp increase in U.S. dealers' spread leads to a 40bp increase in the magnitude of the REPO cross-currency basis (i.e. it becomes more negative). The dollar index is not significant. LIBOR differentials are always highly significant and positive. This is consistent with Du et al. (2018) pointing towards the relevance of nominal interest differentials as drivers of the basis. Finally, the VIX is always significant but positive for U.S. dealers while negative for European dealers. These findings are in line with an emerging literature that focuses on a broad range of (safe) asset classes, for example Treasury and REPO matched book intermediation. For example, Duffie and Krishnamurthy (2016) show that bid-ask spreads for repo matched-book intermediation must be widened dramatically to overcome debt overhang costs.

4.2.3 CIP Deviations and IOER Rates

The second example we study involves using the Federal Reserve's IOER rate in place of the USD REPO rate. The IOER rate is a policy instrument used to influence other short term rates, and is paid by the Fed to banks holding excess reserves. These reserves are highly liquid assets for the banks and are as safe as Treasury securities.

Duffie and Krishnamurthy (2016) show that the IOER has been consistently above market rates, including REPO rates. They suggest that this spread could be attributed to debt overhang costs related to LRRs, but they do not provide direct supporting evidence. The reason why balance sheet constraints could be the main driver of the spread between market and IOER rates is that arbitraging this spread is completely risk free, and therefore it can only be explained by forces related to a dealer's balance sheet rigidity. Furthermore, as discussed in Copeland et al. 2024, large dealers are highly dependent on the level of reserves at the Fed, and they find a strong empirical relationship linking funding market rates and reserves of the largest banks. In this sense, the spread of IOER over market rates is, effectively, a measure of balance sheet costs for the typical dealer.

Du et al. (2018) use the spread between market and IOER rates as a proxy for balance sheet constraints (mainly LRR) and suggest that these account for one-third of the CIP deviations. We follow Du et al. (2018) and assume that a hypothetical dealer engages in CIP arbitrage by reducing her own excess reserves on the margin, in order to carry out a loan in the foreign REPO (LIBOR) market while hedging currency risk. As we show in the appendix, if we suitably modify the theoretical argument in Section 3, if the IOER rate is denoted by r^F, the risk-neutral expected value of the trade to shareholders is

$$\begin{aligned} \tilde{\pi} &= (r^S - r) - r - q(r^F - r), \\ &= (r^S - r^F) - \underbrace{[r - (1-q)(r^F - r)]}_{\text{FVA}}. \end{aligned} \tag{11}$$

Two points are notable. First, when $r^F > r$, the expected payoff to shareholders is smaller than for LIBOR arbitrage. Second, when the naive payoff is measured as $r^S - r^F$ and $r^F > r$ the FVA that applies to the trade is smaller than in the LIBOR case, but only by a small amount if the default probability is small.

Du et al. (2018) report large CIP deviations for different cross currency bases (IOER-LIBOR, IEOR-REPO, and more). We show that, indeed, debt overhang is important for understanding IOER-based CIP deviations.

We study weekly CIP IOER-REPO cross-currency bases for the period October 10 2008 to January 3 2020 for the same currencies as in the previous section (CHF, DKK and JPY).[24] Table 7 shows summary statistics. The IOER-bases are generally smaller in magnitude (less negative) than the 3-Month REPO bases, which is not surprising in that IOER rates are generally higher than REPO rates. Du et al. (2018) find similar results, although they use a different (shorter) sample.

Are debt overhang costs associated with IOER-based CIP deviations? We estimate equation 9 using 5-year CDS spreads to proxy for debt overhang costs. Our results are found in Table 9. There is a strong and significant association between CIP deviations and funding spreads: a 100 basis point increase in U.S. dealers' credit spread is associated with an almost 50 basis point increase in the magnitude of the cross-currency basis.

Overall, our results provides an interesting explanation to IOER-based CIP deviations on top of what discussed in Du et al. (2018). Debt overhang costs have become pervasive and persistent affecting a variety of markets—not just LIBOR markets—and not only at the ends of quarters.

5 Debt Overhang and Intermediary Constraints

In the previous sections, we have discussed, in the context of CIP deviations, that debt overhang costs are pervasive and affect different markets. In this section we study whether debt overhang costs are associated with some sort of intermediary net worth. We conjecture that debt overhang costs (or at least proxies for them) co-move with intermediary wealth. In doing so, we follow Adrian et al. (2014), who discuss broker-dealer leverage as a measure of intermediary constraints, and He et al. (2017) who focus on intermediary equity value.

He et al. (2017) argue that the equity-capital ratio is a key measure of dealers' marginal value of wealth. When a dealer suffers a negative shock, its risk bearing capacity decreases, its equity-capital ratio decreases and its marginal utility increases. At the same time the

[24] We have also studied IOER-LIBOR and IOER-OIS where we have more currencies and results are very similar. These results are available upon request.

dealer's leverage increases, implying that leverage is countercyclical. He et al. (2017) use the New York Fed's primary dealer list to construct data on the aggregate capital ratio (this is the sum across the dealers).

Adrian et al. (2014) use broker dealers' leverage (total financial assets over net worth), which is just the reciprocal of the equity capital ratio used by He et al. (2017) as a measure of intermediary net worth. Adrian et al. (2014), in contrast to He et al. (2017), show that leverage is procyclical. That is, when the dealer is hit by a negative shock, its marginal utility of wealth increases and dealers' leverage falls.

Figure 5 shows He et al.'s capital ratio and the 5-Year CDS spread before and after the GFC.[25] We use monthly data to mitigate noise, spanning the pre-crisis (Jul 2002 to Jan 2006) and post crisis (Jan 2008 to Jan 2020) periods. Although the data do not refer exclusively to the twelve dealers used in this paper, they also contain information on the same dealers we study here.[26]

The two series are negatively correlated, but the correlation is much much more strongly negative in the period after 2008. This suggests that debt overhang costs are more relevant, and have become more significant since 2008. In the latter period, consistent with our earlier discussion, when debt overhang costs increase, the dealer's capital ratio declines sharply. Or, equivalently, the marginal value of dealer's wealth is high, signaling bad times.

In Figure 6 we replace the equity capital ratio and consider leverage as an alternative measure of dealers' wealth. We plot leverage against the CDS spread over the same sample period as above. We also report the correlation coefficients before and after 2008. The correlation is now positive and (again) much higher after 2008. The positive correlation suggests that debt overhang costs increase with leverage.[27]

Taken together Figures 5 and 6 suggest that debt overhang costs are associated with negative shocks to intermediary wealth (bad-times), lower dealer capital ratios and high degrees of dealer leverage.

If debt overhang costs are related to equity holders' wealth, this might also be reflected in the equity market valuations. We consider this case below.

We employ the following panel regression:

$$\triangle P_{it} = \alpha_i + \beta_1 \Delta CDS_t + \beta_2 \triangle I_t^m + \varepsilon_{it} \tag{12}$$

[25]The capital ratio data are available at Zhiguo He's website: https://zhiguohe.net/data-and-empirical-patterns.

[26]We have also collected data for each of our dealers from Bloomberg and constructed the same measures. The data is only available at quarterly frequency from 2007, therefore much less observations available. We have obtained very similar results.

[27]This countercyclical intermediary leverage is consistent with He et al. (2010) and He et al. (2017).

where $\triangle P_{it}$ is the change in stock market price of bank i at time t, $\triangle CDS_t$ is the change of average CDS spread for the dealers used in this study, $\triangle I_t^m$ is the change of the S&P-500 market index.[28]

Table 10 shows the empirical results. We add one right hand side variable at the time.[29] In Columns (1) and (2), we see that debt overhang costs to shareholders are associated with a decline in equity prices. This result is consistent with debt overhang costs affecting intermediary wealth via a reduction in equity prices.

6 Conclusion

We have shown that that debt overhang appears to have become a significant factor preventing dealers from arbitraging CIP deviations after the 2008 GFC. Our findings are robust to measuring the cross-currency basis in a variety of ways, using LIBOR, REPO and IOER rates.

We did this in two ways. One was to simply assess the magnitude of the CIP deviations observed in the data and to compare them to the risk premia at which dealer banks can borrow, which are a reflection of debt overhang. These risk premia are good proxies for the FVAs that banks use to value their swap books when engaging in CIP arbitrage. If the FVA associated with a potential trade exceeds the CIP basis, then a dealer acting in its shareholders interest will avoid the trade. Thus large departures from CIP can persist when banks face significant debt overhang.

Our second approach was to show that the magnitude of CIP deviations has a significant empirical association with changes in the bank's risk premia. This association has been strong since the GFC, but was much weaker prior to it, when CIP deviations and risk premia were both much smaller.

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[28] Results are similar when we use the CDS spread of the individual banks as the right hand side variable rather than the cross-sectional average.

[29] These results are also robust to alternative specifications including controls.We do not report them to safe space.

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Table 1: Summary Statistics for the Cross-Currency Basis

	(A): 3-month CIP			(B): 5-year CIP		
Currency	Full Sample	Up To 2007	From 2008	Full Sample	Up To 2007	From 2008
AUD	-4.4	-10.2	-1.9	18.3	8.6	22.3
	[14.5]	[5.31]	[16.4]	[10.2]	[2.3]	[9.5]
CAD	-12.7	0.8	-18.5	4.4	9.2	2.3
	[14.9]	[7.0]	[13.6]	[9.4]	[4.7]	[10.1]
CHF	-11.4	8.5	-20.0	-23.8	-2.0	-32.9
	[22.2]	[5.8]	[21.2]	[18.8]	[0.8]	[14.8]
DKK	-40.0	-1.5	-56.6	-32.3	-0.9	-45.4
	[37.6]	[10.0]	[32.7]	[24.4]	[1.7]	[16.2]
EUR	-18.7	-2.8	-27.9	-18.6	1.3	-27.0
	[25.9]	[6.9]	[25.7]	[17.0]	[1.2]	[13.1]
GBP	-13.9	-7.3	-16.7	-5.70	0.6	-8.32
	[18.8]	[5.5]	[21.6]	[11.2]	[1.3]	[12.4]
JPY	-12.9	8.9	-22.3	-38.3	-1.3	-53.7
	[21.0]	[9.3]	[17/4]	[30.4]	[3.2]	[22.2]
NOK	-24.8	-7.0	-32.4	-11.6	-5.2	-14.3
	[24.6]	[8.4]	[25.3]	[8.9]	[0.8]	[9.3]
NZD	-0.4	-12.7	4.9	20.8	5.1	27.4
	[14.0]	[6.9]	[12.9]	[13.7]	[2.2]	[10.8]
SEK	-18.3	-4.2	-24.3	-4.5	-2.0	-5.5
	[19.9]	[7.9]	[20.4]	[7.2]	[0.7]	[8.4]
Average	-19.7	-2.8	-23.3	-9.1	1.3	13.5
	[21.3]	[7.30]	[20.7]	[15.1]	[1.90]	[12.70]

Note: This table presents the mean and standard deviation (in square brackets) of the cross-currency basis, measured in basis points. The data are sampled weekly. For 3 Month CIP, the "full sample" period is Jan 3 2003 to Jan 3 2020. The "up to 2007" period is Jan 3 2003 to Dec 30 2007. The "from 2008" period is Jan 4 2008 to Jan 3 2020.

Table 2: Banks' Credit Spreads

	5Y-CDS Spread			
	All Banks	U.S. Banks	European Banks	3M Libor-OIS
Full Sample	87	89	85	27
	[69.22]	[70.55]	[74.2]	[32.1]
Up to 2007	21	28	14	15
	[11.3]	[13.4]	[9.4]	[16.7]
From 2008	115	115	115	32
	[64.5]	[69.0]	[69.3]	[36.0]

Note: This table presents the mean and standard deviation (in square brackets) of major dealer banks in the U.S. and Europe as well as the 3-Month Libor-OIS spread. The data are sampled weekly. The "full sample" period is Jan 3 2003 to Jan 3 2020. The "Up to 2007" period is Jan 3 2003 to Dec 30 2007. The "From 2008" period is Jan 4 2008 to Jan 3 2020.

Table 3: Shareholder Funding Costs and Cross-Currency Bases From 2008

Panel A: Average shareholder costs of CIP trades							
	U.S. Banks				European Banks		
	5Y-CDS (bp)	LRR (bp)	Total annualised funding costs (bp)		5Y-CDS (bp)	LRR (bp)	Total annualised funding costs (bp)
JPM	79	5	84	BNP	90	3	93
MS	155	9	164	GLE	111	3	114
WFC	77	5	82	BARC	105	3	108
C	131	8	139	NWG	135	4	139
BAC	118	7	125	ACA	105	3	108
GS	129	8	137	SAN	142	4	146

Panel B: Average cross-currency bases			
Currency	5Y CIP (bp)	Currency	5Y CIP (bp)
AUD	22.3	GBP	-8.32
CAD	2.3	JPY	-53.7
CHF	-32.9	NOK	-14.3
DKK	-45.4	NZD	27.4
EUR	-27.0	SEK	-5.5

Note: Panel A calculates shareholders' perceived funding costs at major dealer banks using the framework described in Section 3. The list of banks is provided in the Appendix. For each bank the funding cost is the sum of the FVA (as proxied by the 5-year CDS spread) and the LRR cost (calculated as in Section 3). Panel B computes the average of the 5-year cross-currency basis for ten major currencies. For both panels, the sample period is Jan 4 2008–Jan 3, 2020.

Table 4: Explaining Variation in the 5-Year Cross-Currency Basis

	Post-GFC Sample				Pre-GFC Sample
RHS variable	[1]	[2]	[3]	[4]	[5]
Δy	-0.05***	-0.05***	-0.05***	-0.05***	-0.02
	(0.009)	(0.009)	(0.009)	(0.009)	(0.019)
ΔD		-0.38***	-0.38***	-0.36***	0.05
		(0.090)	(0.091)	(0.094)	(0.030)
Δ spot rate			-0.34***	-0.28***	-0.02**
			(0.100)	(0.030)	(0.006)
Δ yield spread				1.75***	-0.06
				(0.638)	(0.177)
Δ log of VIX				-0.31**	0.33***
				(0.133)	(0.089)
Obs	6270	6270	6270	6270	2080
R^2	0.08	0.09	0.09	0.09	0

Note: This table presents estimates of equation (9), which is

$$\triangle z_{it} = \alpha_i + \beta \triangle y_t + \gamma \triangle D_t + \eta' C_{it} + \epsilon_{it},$$

where z_{it} is the 5-year cross-currency basis for currency i with respect to the USD, α_i is a currency fixed effect, y_t is the average 5-year CDS spread for twelve U.S. and European banks, D_t is the log of the Federal Reserve Board (FRB) U.S. trade-weighted broad dollar index, and C_{it} is a vector of the following control variables: the log-change of the bilateral exchange rate between country i and the the U.S., the change in the 10-year government bond spread between country i and the U.S., and the change in the logarithm of the VIX. The sample period is weekly data from Jan 4 2008 to Jan 3 2020. The Post-GFC period is Jan 4, 2008 to 3 Jan 2020. The Pre-GFC period is Jan 3 2003 to Dec 30, 2006. Columns 1–4 show estimates for the Post-GFC period with right-hand-side variables being introduced sequentially. Column 5 shows results for the Pre-GFC period. White heteroskedasticity consistent standard errors are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 5: Explaining Variation in the 3-Month Cross-Currency Basis

	Post-GFC Sample				Pre-GFC Sample
RHS variable	[1]	[2]	[3]	[4]	[5]
Δy	-0.23***	-0.23***	-0.23***	-0.23***	-0.04
	(0.040)	(0.040)	(0.040)	(0.040)	(0.043)
ΔD		0.08	0.08	-0.18	0.16
		(0.234)	(0.233)	(0.213)	(0.105)
Δ spot rate			0.33***	0.23*	-0.27***
			(0.087)	(0.136)	(0.053)
Δ LIBOR spread				-24.8***	-11.2***
				(3.933)	(2.344)
Δ log of VIX				8.8***	2.2
				(2.190)	(2.250)
Obs	6270	6270	6270	6270	2080
R^2	0.08	0.08	0.08	0.13	0.02

Note: This table presents estimates of equation (9), which is

$$\triangle z_{it} = \alpha_i + \beta \triangle y_t + \gamma \triangle D_t + \eta' C_{it} + \epsilon_{it},$$

where z_{it} is the 3-month cross-currency basis for currency i with respect to the USD, α_i is a currency fixed effect, y_t is the average 5-year CDS spread for twelve U.S. and European banks, D_t is the log of the Federal Reserve Board (FRB) U.S. trade-weighted broad dollar index, and C_{it} is a vector of the following control variables: the log-change of the bilateral exchange rate between country i and the the U.S., the change in the 3-month LIBOR spread between country i and the U.S., and the change in the logarithm of the VIX. The sample period is weekly data from Jan 3, 2003 to Jan 3 2020. The Post-GFC period is Jan 4, 2008 to 3 Jan 2020. The Pre-GFC period is Jan 3 2003 to Dec 30, 2006. Columns 1–4 show estimates for the Post-GFC period with right-hand-side variables being introduced sequentially. Column 5 shows results for the Pre-GFC period. White heteroskedasticity consistent standard errors are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 6: Explaining Variation in the Cross-Currency Basis at the Country Level

	5-Year Basis		3-Month Basis	
Currency	Coefficient	R^2	Coefficient	R^2
AUD	-0.06**	0.25	-0.21**	0.26
	(0.025)		(0.119)	
CAD	-0.02	0.03	-0.05	0.02
	(0.011)		(0.038)	
CHF	-0.05***	0.09	-0.36*	0.09
	(0.015)		(0.198)	
DKK	-0.05*	0.09	-0.32*	0.14
	(0.030)		(0.179)	
EUR	-0.09***	0.26	-0.37**	0.16
	(0.016)		(0.167)	
GBP	-0.08***	0.19	-0.21*	0.14
	(0.015)		(0.129)	
JPY	-0.07***	0.14	-0.30**	0.14
	(0.017)		(0.140)	
NOK	-0.02***	0.05	-0.30**	0.33
	(0.006)		(0.162)	
NZD	-0.01	0.00	0.04	0.002
	(0.007)		(0.052)	
SEK	-0.04***	0.07	-0.26***	0.13
	(0.006)		(0.080)	

Note: This table presents estimates of equation (10), which is

$$\triangle z_t = \alpha_i + \beta \triangle y_t + \gamma \triangle D_t + \eta' C_t + \epsilon_t,$$

where z_{it} is the cross-currency basis for currency i with respect to the USD, α_i is a constant, and y_t is the average 5-year CDS spread for twelve U.S. and European banks. We only present estimates of β, for convenience. The sample is weekly data in the Post-GFC period: Jan 4 2008 to Jan 3 2020. White heteroskedasticity consistent standard errors are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. Controls are included but not reported in the table.

Table 7: Summary Statistics for REPO and IOER-Based Cross-Currency Bases

Currency	3-Month REPO	1-Week IOER	1-Month IOER
CHF	-38.6	-25	-29
	[30.94]	[61.2]	[38.35]
DKK	-50.8	-30	-35.5
	[43.65]	[53.15]	[40.27]
JPY	-40.6	-27.1	-33.99
	[33.07]	[61.27]	[40.45]

Note: This table presents CIP bases using 3-month REPO rates between Jan 4 2008 to Jan 3 2020, and short tenor (1-week and 1-month) IOER rates over the period Oct 10 2008 to Jan 3 2020, due to data availability. We do not include the euro as data in Bloomberg is only available for a shorter sample.

Table 8: Explaining Variation in the 3-Month REPO-Based Cross-Currency Basis

Measure of the Average CDS Spread			
RHS variable	U.S. Banks	European Banks	All the Banks
Δy	-0.4***	-0.16***	-0.47***
	(0.030)	(0.029)	(0.036)
ΔD	0.2	-0.87	-0.25
	(0.894)	(0.988)	(0.940)
Δ spot rate	0.12	0.43***	0.2**
	(0.08)	(0.118)	(0.080)
Δ LIBOR spread	44.3***	66.6***	53.8***
	(13.20)	(13.55)	(14.01)
Δ log of VIX	3.2***	-6.2***	4.5***
	(1.150)	(0.929)	(1.42)
Obs	1884	1884	1884
R^2	0.28	0.12	0.21

Note: This table presents estimates of equation (9), which is

$$\triangle z_{it} = \alpha_i + \beta \triangle y_t + \gamma \triangle D_t + \eta' C_{it} + \epsilon_{it},$$

where z_{it} is the 3-month repo-based cross-currency basis for currency i with respect to the USD, α_i is a currency fixed effect, y_t is the average 5-year CDS spread for either six U.S. or six European banks, D_t is the log of the Federal Reserve Board (FRB) U.S. trade-weighted broad dollar index, and C_{it} is a vector of the following control variables: the log-change of the bilateral exchange rate between country i and the the U.S., the change in the 3-month LIBOR spread between country i and the U.S., and the change in the logarithm of the VIX. The sample period is weekly data from Jan 4 2008 to Jan 3 2020. White heteroskedasticity consistent standard errors are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 9: Explaining Variation in the IOER-Based Cross-Currency Basis

	U.S. Banks		European Banks		All the Banks	
RHS variable	1-week	1-month	1-week	1-month	1-week	1-month
Δy	-0.47***	-0.31***	-0.12***	-0.03	-0.47***	-0.28***
	(0.05)	(0.014)	(0.021)	(0.024)	(0.055)	(0.023)
ΔD	5.5***	1.84**	4.66***	1.22	5.26***	1.63**
	(1.43)	(0.730)	(1.520)	(0.760)	(1.468)	(0.733)
Δ spot rate	0.59***	-0.61***	0.86***	-0.4***	0.65***	-0.56***
	(0.040)	(0.076)	(0.040)	(0.118)	(0.024)	(0.085)
Δ LIBOR spread	88.46***	85.6***	110.9***	100.9***	97.8***	92.4***
	(21.65))	(23.31)	(25.55)	(24.40)	(23.72)	(24.4)
Δ log of VIX	-0.86	7.2***	-10.7	-0.85	0.10	7.1***
	(4.59)	(2.470)	4.51	(2.570)	(4.43)	(2.72)
Obs	1758	1758	1758	1758	1758	1758
$\bar{R}^2$	0.02	0.10	0.01	0.07	0.02	0.09

Note: This table presents estimates of equation (9), which is

$$\triangle z_{it} = \alpha_i + \beta \triangle y_t + \gamma \triangle D_t + \eta' C_{it} + \epsilon_{it},$$

where z_{it} is either the 1-week or 1-month IOER and REPO-based cross-currency basis for currency i with respect to the USD, α_i is a currency fixed effect, y_t is the average 5 year CDS spread, D_t is the log of the Federal Reserve Board (FRB) U.S. trade-weighted broad dollar index, and C_{it} is a vector of the following control variables: the log-change of the bilateral exchange rate between country i and the the U.S., the change in the 3-month LIBOR spread between country i and the U.S., and the change in the logarithm of the VIX. Due to data availability this sample is from Oct 10 2008 to Jan 3 2020. White heteroskedasticity consistent standard errors are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 10: Bank Equity Prices

	Post-GFC Period		Pre-GFC Period
	(1)	(2)	(3)
ΔCDS_t	-0.07***	-0.04***	-0.10
	[0.012]	[0.008]	[0.090]
$\triangle I_t^m$		0.03***	0.08***
		[0.003]	[0.004]
R^2	0.09	0.22	0.15
Obs	7524	7524	2484

Note: This table presents estimates of equation (12), which is

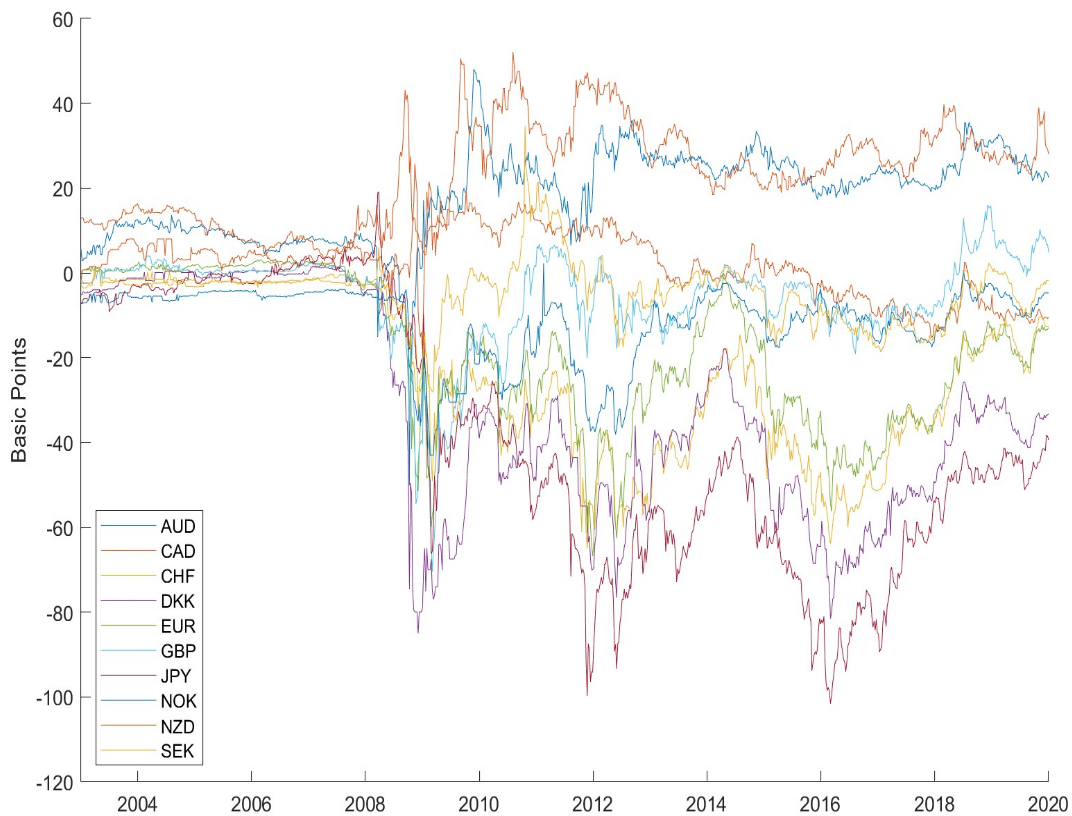
$$\triangle P_{it} = \alpha_i + \beta_1 \Delta CDS_t + \beta_2 \triangle I_t^m + \varepsilon_{it}, \tag{13}$$

where P_{it} is the stock price of bank i at time t, CDS_t is the average CDS spread for the dealers used in this study, and I_t^m is the S&P-500. The data are weekly. The Post-GFC period is Jan 4, 2008 to Jan 3, 2020. The dealers used are listed in Appendix Table (11).

Figure 1: 3-Month LIBOR-Based CIP Deviations

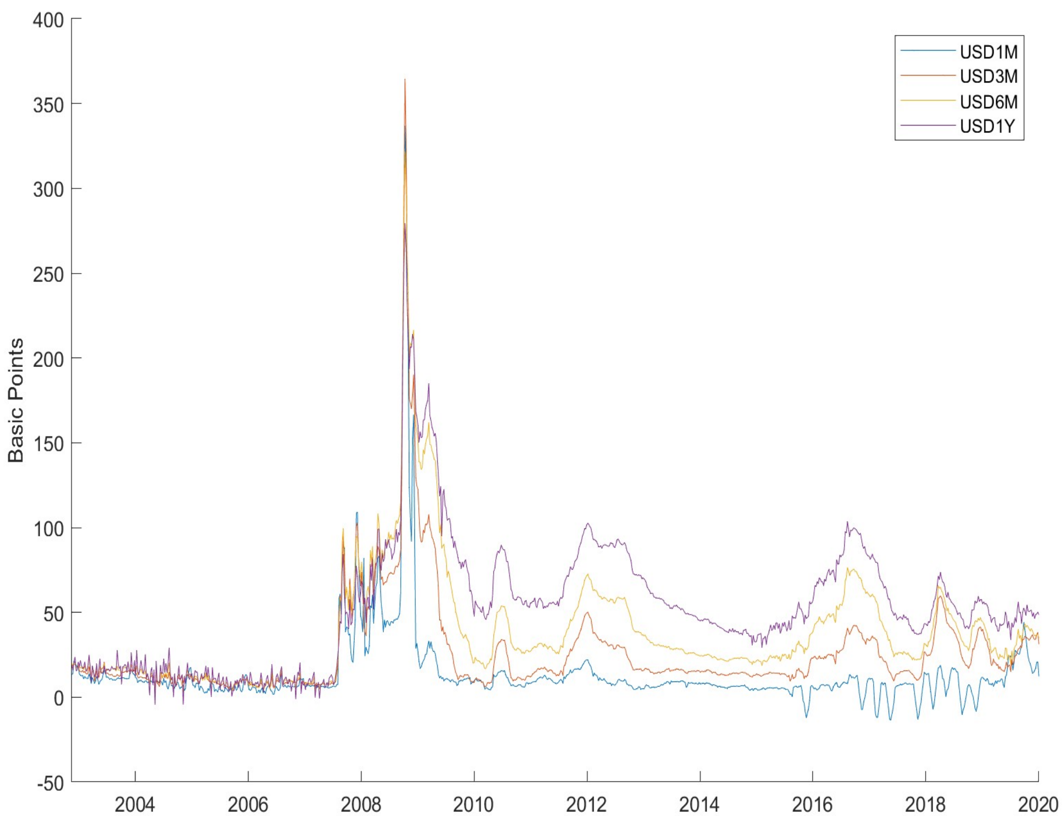
Note: This chart plots the 3-month cross-currency basis for the G10 currencies measured using LIBOR rates, and exchange rate data, sampled weekly, from Bloomberg. When the basis is positive (negative), the cost of borrowing dollars directly exceeds (is less than) the cost of borrowing dollars synthetically via the money market for the indicated currency.

Figure 2: 5-Year LIBOR-Based CIP Deviations



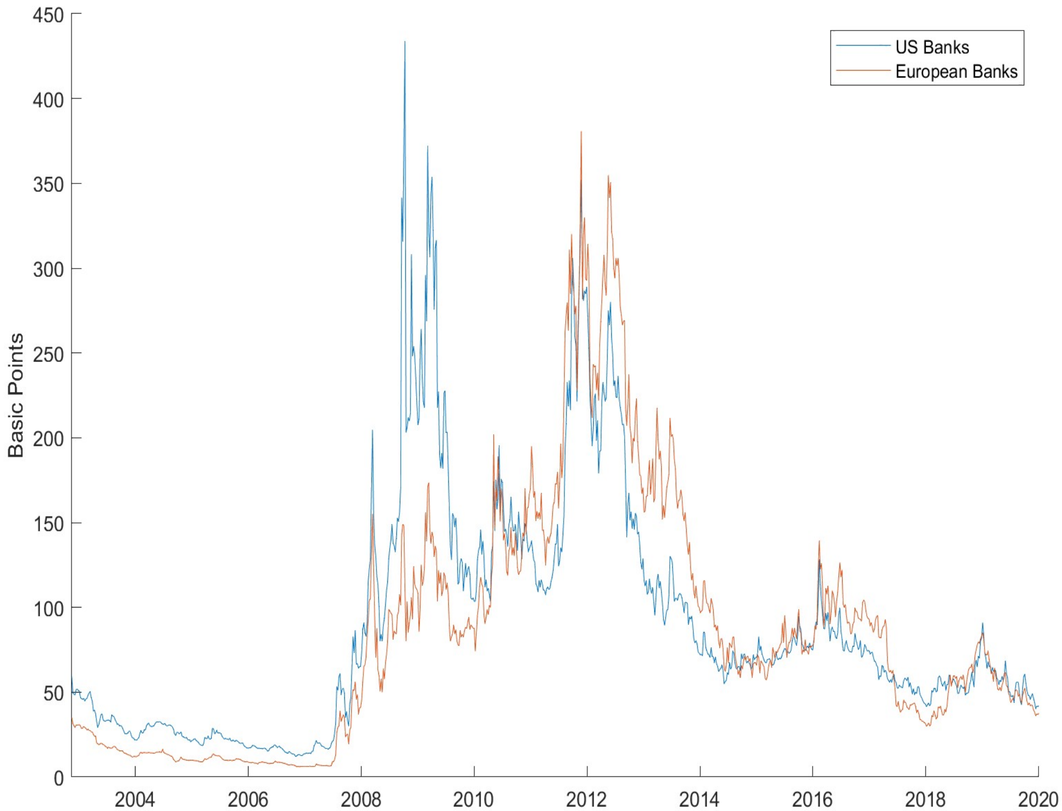
Note: This chart plots the 5-year cross-currency basis for the G10 currencies measured using LIBOR rates and exchange rate data, sampled weekly, from Bloomberg. When the basis is positive (negative), the cost of borrowing dollars directly exceeds (is less than) the cost of borrowing dollars synthetically via the money market for the indicated currency.

Figure 3: LIBOR-OIS Spreads



Note: This chart plots the one-month, three-month, six-month and one-year LIBOR-OIS spread, sampled weekly, from Bloomberg.

Figure 4: Average 5-Year CDS Spread for Major Banks



Note: This chart plots the average five-year CDS spread for six major U.S. and six major European dealer banks, sampled weekly, from Bloomberg.

Figure 5: Capital Ratio versus Average CDS

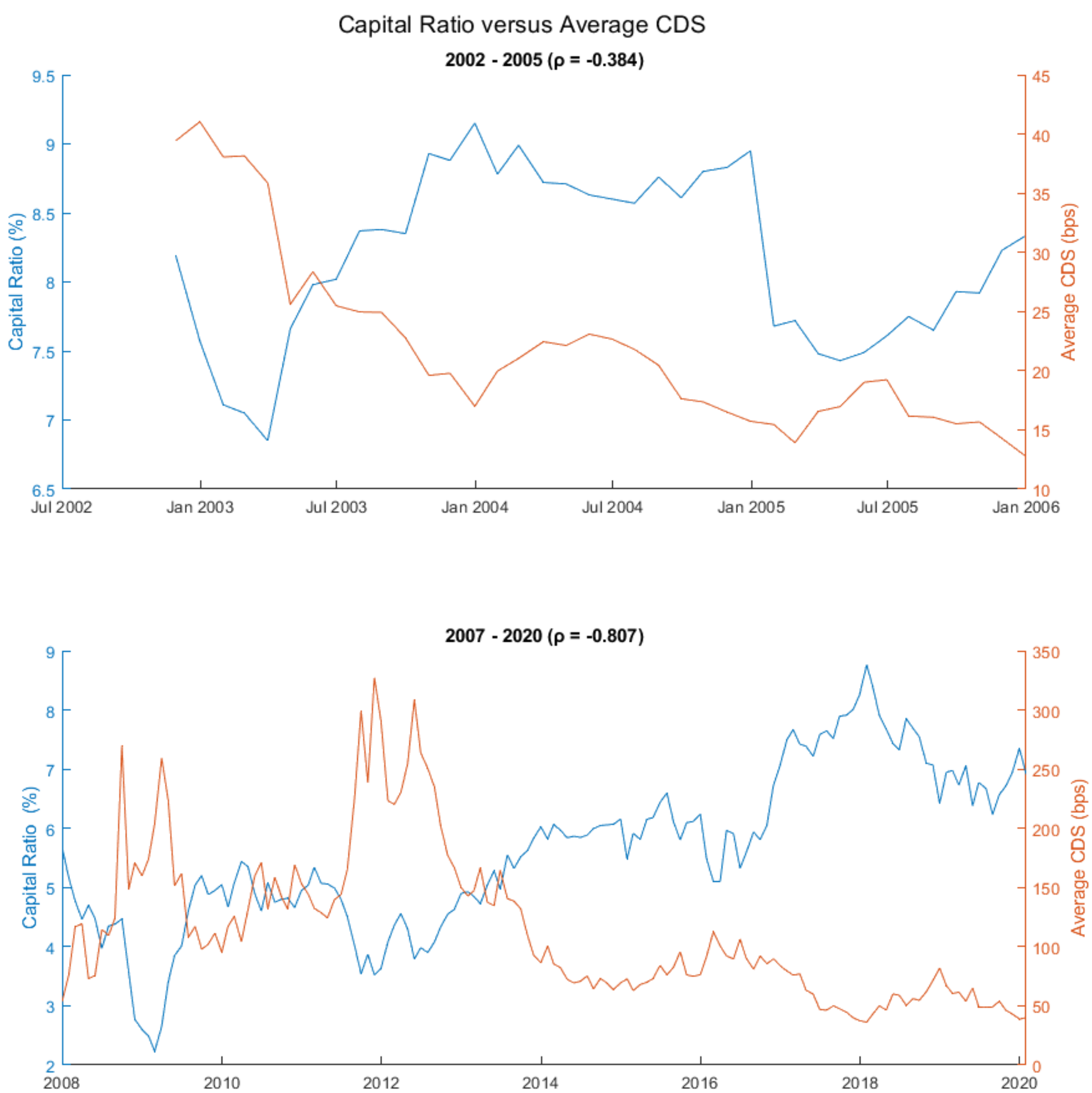
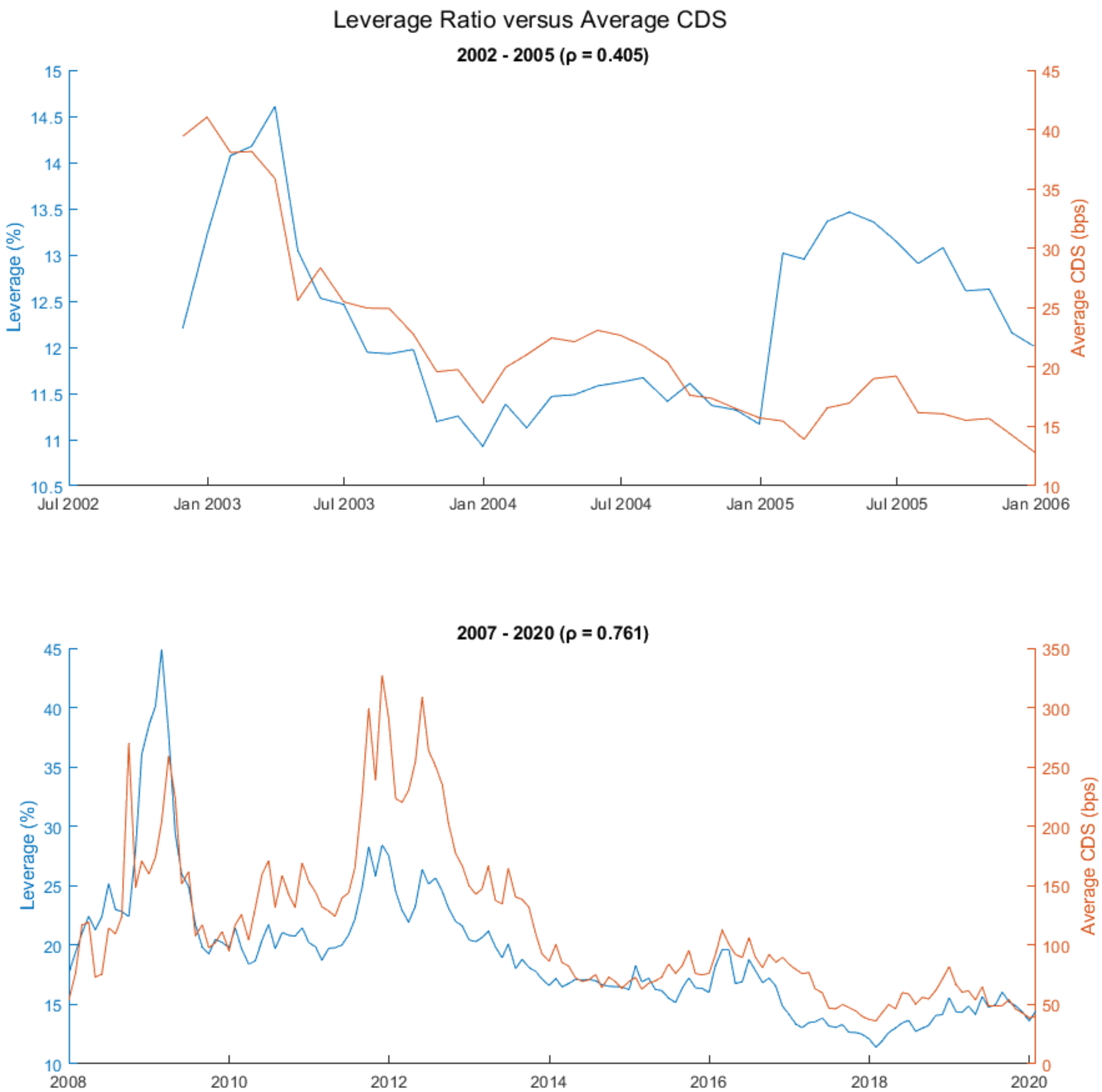


Figure 6: Leverage Ratio versus Average CDS



Appendix

Approximations in Section 3

To see that the approximation of equation (4) by equation (5) is accurate, consider the following. Equation (4) is equivalent to

$$1 = [q + (1-q)\kappa](1+r), \tag{14}$$

Applying the natural logarithm to both sides of this equation we have

$$0 = \ln[q + (1-q)\kappa] + \ln(1+r). \tag{15}$$

We can define a number y as:

$$y = (1-q)(1-\kappa). \tag{16}$$

Notice that y is a close to zero when the default probability, $1-q$, is small. We can rewrite equation (15) as

$$0 = \ln(1-y) + \ln(1+r) \tag{17}$$

Given that y is small, by the standard log approximation formula we therefore have

$$0 \approx -y + r \quad \text{or} \quad r \approx y = (1-q)(1-\kappa). \tag{18}$$

To see that the approximation in equation (7) is accurate, notice that equation (6) can be rewritten in terms of y as

$$\begin{aligned} \pi &= q\left[(1-y)(1+r^S) - (1+r)\right] \\ &= q\left(r^S - y - yr^S - r\right). \end{aligned} \tag{19}$$

Given that both y and r^Swill be small fractions it follows that

$$\pi \approx q\left(r^S - y - r\right). \tag{20}$$

Given that $q \approx 1$, the term inside brackets is small, and $y \approx r$ this means

$$\pi \approx r^S - r - y \approx (r^S - r) - r. \tag{21}$$

IOER Example

The risk free rate is again assumed to be 0. In this example the dealer bank borrows at the rate r^F where r^F is the IOER, a policy rate set by the Fed. For this reason we do not use equation (4) because the bank's borrowing rate is not determined by market forces that reflect its default probability. We continue to assume that the bank's probability of failure is q.

Now, imagine a CIP arbitrage trade in which the dealer bank borrows 1 USD at the rate r^F, and lends an equivalent amount of euros, swapped back to dollars, at the synthetic interest rate, $r^S > r^F$. We can assume, if we want to, that $r^F > r$ where r is determined by (4). Assume that the counterparty has a risk-neutral survival probability q, with the survival or failure of the dealer and counterparty being independent events. As in the case of the dealer, if the counterparty defaults the dealer is assumed to recover only the fraction κ of the loan amount.

In this example, if both the dealer and the counterparty survive, which happens with probability q^2, the payoff to shareholders has a present value of $r^S - r^F$. If only the dealer bank survives, which happens with probability $q(1-q)$, the present value of the payoff to shareholders is $\kappa(1+r^S) - (1+r^F)$. If the dealer bank fails the shareholders receive zero. Thus, the risk-neutral expected value of the trade to shareholders is

$$\begin{aligned} \tilde{\pi} &= q^2 \left[(1+r^S) - (1+r^F)\right] + (1-q)q\left[\kappa(1+r^S) - (1+r^F)\right]. \\ &= q\left\{\left[q + (1-q)\kappa\right](1+r^S) - (1+r^F)\right\} \end{aligned} \tag{22}$$

We can compare $\tilde{\pi}$ to the π in Section 3. Notice that

$$\tilde{\pi} - \pi = q(r - r^F)$$

so that, given equation (7),

$$\tilde{\pi} = (r^S - r) - r + q(r - r^F)$$

or

$$\tilde{\pi} = (r^S - r^F) + \underbrace{(1-q)(r^F - r) - r}_{\text{FVA}}.$$

The apparent gain from CIP arbitrage in this example is $r^S - r^F$ but the risk-neutral value to shareholders is smaller by the FVA. In the baseline example the FVA is $-r$. In this example it is slightly smaller in magnitude, but fairly negligibly so because $1 - q$ is the default probability (assumed to be small) and $r^F - r$ would be a smallish number in basis points. So even though the apparent gain would be smaller the FVA would be about the same size.

Table 11: List of Banks in this Study

Entity	Full Name
JPM US	JPMORGAN CHASE & CO
MS US	MORGAN STANLEY
WFC US	WELLS FARGO & CO
C US	CITIGROUP INC
BAC US	BANK OF AMERICA CORP
GS US	GOLDMAN SACHS GROUP INC
BNP FP	BNP PARIBAS
GLE FP	SOCIETE GENERALE SA
BARC LN	BARCLAYS PLC
NWG LN	NATWEST GROUP PLC
ACA FP	CREDIT AGRICOLE SA
SAN SM	BANCO SANTANDER SA

Table 12: Explaining Variation in the 5-Year Cross-Currency Basis: Using U.S. Banks' Credit Spread

	Post-GFC Sample				Pre-GFC Sample
RHS variable	[1]	[2]	[3]	[4]	[5]
Δy	-0.04***	-0.04***	-0.04***	-0.04***	-0.01
	(0.007)	(0.006)	(0.006)	(0.006)	(0.013)
ΔD		-0.36***	-0.36***	-0.34***	0.05
		(0.119)	(0.120)	(0.09)	(0.029)
Δ spot rate			-0.33***	-0.29***	-0.01**
			(0.100)	(0.028)	(0.006)
Δ yield spread				1.69***	-0.05
				(0.650)	(0.177)
Δ log of VIX				-0.84***	0.34***
				(0.250)	(0.08)
Obs	6270	6270	6270	6270	2080
R^2	0.07	0.08	0.08	0.09	0

Note: This table presents estimates of equation (9), which is

$$\triangle z_{it} = \alpha_i + \beta \triangle y_t + \gamma \triangle D_t + \eta' C_{it} + \epsilon_{it},$$

where z_{it} is the 5-year cross-currency basis for currency i with respect to the USD, α_i is a currency fixed effect, y_t is the average 5-year CDS spread for six U.S. banks, D_t is the log of the Federal Reserve Board (FRB) U.S. trade-weighted broad dollar index, and C_{it} is a vector of the following control variables: the change in the 10-year government bond spread between country i and the U.S., the change in the logarithm of the VIX, and the log-change of the bilateral exchange rate between country i and the the U.S. The sample period is weekly data from Jan 04 2008 to Jan 3 2020. Column 5 shows the results for the period prior to the GFC (Jan 3 2003 to Dec 30 2006). White heteroskedasticity consistent standard errors are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table 13: Explaining Variation in the 5-Year Cross-Currency Basis: Using European Banks' Credit Spread

	Post-GFC Sample				Pre-GFC Sample
RHS variable	[1]	[2]	[3]	[4]	[5]
Δy	-0.04***	-0.04***	-0.04***	-0.04***	-0.02
	(0.009)	(0.009)	(0.009)	(0.009)	(0.030)
ΔD		-0.46***	-0.45***	-0.43***	0.04
		(0.098)	(0.097)	(0.099)	(0.030)
Δ spot rate			-0.32***	-0.28***	-0.02***
			(0.015)	(0.032)	(0.006)
Δ yield spread				1.8***	-0.07
				(0.670)	(0.171)
Δ log of VIX				-0.75***	0.30***
				(0.214)	(0.090)
Obs	6270	6270	6270	6270	2080
R^2	0.04	0.06	0.06	0.07	0

Note: This table presents estimates of equation (9), which is

$$\triangle z_{it} = \alpha_i + \beta \triangle y_t + \gamma \triangle D_t + \eta' C_{it} + \epsilon_{it},$$

where z_{it} is the 5-year cross-currency basis for currency i with respect to the USD, α_i is a currency fixed effect, y_t is the average 5-year CDS spread for six European banks, D_t is the log of the Federal Reserve Board (FRB) U.S. trade-weighted broad dollar index, and C_{it} is a vector of the following control variables: the change in the 10-year government bond spread between country i and the U.S., the change in the logarithm of the VIX, and the log-change of the bilateral exchange rate between country i and the the U.S. The sample period is weekly data from Jan 4, 2008 to Jan 3 2020. Column 5 shows the results for the period prior to the GFC (Jan 3 2003 to Dec 30 2006). White heteroskedasticity consistent standard errors are in parentheses. ***, **, and * indicate statistical significance at the 1%, 5% and 10% levels, respectively.