Credit Migration and Covered Interest Rate Parity

Gordon Y. Liao

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Abstract

This paper examines the connection between covered interest rate parity deviation and discrepancy in the credit spread of bonds of similar risk but different currency denomination. These two pricing anomalies are highly aligned in both the time series and the cross section of currencies. The difference between these two pricing deviations represents the exchange rate hedged borrowing cost difference between currency regions and explains up to a third of the variation in the aggregate corporate debt issuance flow.

I show that arbitrage aimed at exploiting one type of security anomaly can give rise to another separate anomaly.


Keywords: Covered interest rate parity, limits of arbitrage, capital flows, credit market segmentation, debt issuance, dollar convenience yield, foreign exchange rate hedge

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Introduction

Deviations from covered interest rate parity (CIP) have been persistent after the financial crisis and have attracted the attention of a number of recent papers\(^1\). While the anomaly is significant in size given the liquidity and volume of the foreign exchange rate (FX) market, research linking this pricing anomaly to the quantity of arbitrage capital and the real impact on the financing of firms and households has been limited. In this paper, I examine the spillover of pricing anomalies between the FX funding market and the corporate credit market, as well as the impact on capital flow across currency regions. Using a data set covering $23 trillion of corporate bonds, I find that variation in the currency-hedged cost of borrowing across different currencies predicts firms’ decision on the currency denomination of their debt. FX-hedged capital flow in turn binds together the two deviations.

I relay my findings in three parts. First, I show large and persistent differences in the aggregate pricing of credit spreads for corporate bonds denominated in different currencies. This difference is not due to the quanto effect that arises from the correlation between exchange rate movement and default events, as evidenced by matched CDS contracts. Credit spreads should reflect the probability of default, loss-given-default, and risk premium. Previous studies\(^2\), however, have found that non-fundamental factors, such as local supply and demand shocks, are paramount determinants of credit spreads.

The difference in the aggregated credit spreads observed for similar bonds denominated in different currencies suggest a market segmentation along currency lines. Closely related to this paper, Maggiori, Neiman, and Schreger (2018) show a strong investor preference to hold debt in their own currencies regardless of the nationality of the issuer. I instead focus on the pricing implications and the firms that cater to this investor preference through foreign currency issuance. To my knowledge, this paper is the first to show this currency-denomination pricing anomaly for the aggregate corporate bond market.

As a concrete example, AT&T, the BBB-rated and U.S.-based telecommunication giant, had a credit spread of 203 basis points on its 15-year U.S. dollar-denominated bond in November 2014. At the same time, its euro-denominated bond of similar maturity had a credit spread of 129 basis points. The two bonds share the same rating, maturity, seniority, and jurisdiction. Credit risk of AT&T is therefore priced differently in USD and EUR. Generalizing from this example in the aggregate is difficult because few bonds are perfectly alike. Different terms of maturity, rating, liquidity, and firm-specific characteristics make comparisons challenging. I construct an aggregate measure of currency-specific pricing of

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\(^2\)Collin-Dufresne, Goldstein, and Martin, 2001; Huang and Huang, 2012.
credit risk that controls for other bond characteristics using a regression approach on a large panel of bond credit spreads. I refer to this measure as the residualized credit spread.

Second, I show that residualized credit spread differentials align in direction and size with deviations from covered interest rate parity such that the overall borrowing costs including FX-hedging costs are largely equilibrated across currencies. CIP is a textbook no-arbitrage condition asserting that the interest rate differential between two currencies in the cash market should equal the differential between the forward and spot exchange rates. A deviation from the CIP condition constitutes an additional cost (or benefit) of FX hedging beyond those implied by the cash funding rates. Although CIP held tightly prior to 2008, large deviations appeared in the aftermath of the financial crisis and have persisted through 2017. This anomaly is large given the size of the FX swap and forward market that has an average daily turnover of $3.1 trillion and outstanding notional of $58 trillion.

Figure 1 Credit spread differential and CIP deviation

This figure shows the residualized credit spread differential and 5-year CIP deviations for EURUSD. The residualized credit spread is estimated in the following cross-sectional regression at each month:

\[ S_{it} = \alpha_{ct} + \beta_{ft} + \gamma_{mt} + \delta_{rt} + \varepsilon_{it}, \]

where \( S_{it} \) is the credit spread at time \( t \) for bond \( i \) that is issued in currency \( c \), by firm \( f \), with maturity \( m \) and rating \( r \). The residualized credit spread of euro debt and dollar debt is calculated as the currency fixed effect, \( \alpha_{eur,t} - \alpha_{usd,t} \). The sample of bonds has an average maturity of five years. Vertical gray bars represent the 95% confidence interval with firm-level clustering. Details of the measure’s construction and additional controls are discussed in Section 1. CIP deviation measures the difference between FX-implied funding rate and the actual inter-bank funding rate in EUR. Details on CIP deviation are discussed in Section 2.

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\(^3\)Bank of International Settlement (2016, 2017)
Fig. 1 shows the time series of residualized credit spread differential and long-term CIP deviation between EUR and USD. Both of these deviations were close to zero prior to the Global Financial Crisis. Since 2008, however, these spreads have been large even in tranquil market conditions. The residualized credit spread difference between EUR- and USD-denominated bonds had reached over 70 basis points in 2016, which is equivalent to $25 billion, or 84% of net (12% of gross) annual issuance in the EUR corporate bond market. Periods when the residualized credit spread is lower in EUR than in USD (more negative dashed blue line) tend to coincide with larger CIP violation in the direction of dollar funding scarcity (more negative red solid line). The two pricing disconnects share similar magnitudes and are highly correlated (75%). This co-movement of pricing anomalies also appears in other developed country currencies (JPY, GBP, CHF, CAD, and AUD).

**Figure 2 Net deviation and issuance flow**

This figure shows the net deviation and bilateral debt issuance flow between the European Monetary Union (EMU) and the U.S. The net deviation is estimated as the currency fixed effects in the cross-sectional regression of $S_{t,adj}$, the bond-specific credit spread adjusted for maturity-matched CIP deviation, on covariates including currency, firm, maturity and rating fixed effects. Issuance flow is defined as the amount of USD debt issued by EMU firms minus the amount of EUR debt issued by U.S. firms scaled by the total amount of debt issuance at the quarterly frequency. Details of this variable’s construction are provided in Section 5.

Third, I show that capital flow responds to the remaining difference in FX-hedged borrowing cost among currencies. I refer to this difference between the residualized credit spread differential and CIP deviation as the *net deviation*. Fig. 2 shows that net deviation covaries...
with the aggregate debt issuance flow between the two currency regions for large global issuers. When the net deviation is negative— the overall FX-hedged borrowing cost is cheaper in EUR (negative red line), firms issue more in EUR (negative blue bars), and vice versa. Even though the marginal borrowing cost savings are typically small, large responses in capital flow suggest substantial inframarginal cost savings for cross-currency issuers. Empirically, I find that each standard deviation change in net deviation induces around 4% shift in bilateral issuance flow (as a fraction of total issuance) and net deviation explains up to 34% of the variation in bilateral issuance flow. In equilibrium, capital flows respond to the marginal cost savings and tie together the credit spread differential and CIP deviation.

Global investors can also provide cross-market arbitrage, however, I focus on issuers for three reasons. One, debt issuance data is readily available and more comprehensive compare to investor holding data. Two, investors have strong home-currency bias. As shown by Maggiori, Neiman, and Schreger 2018, investors have strong home-currency bias to such an extend that each country holds the bulk of all foreign debt securities denominated in their own currency. This investor preference incentivizes firms to take a more active role in facilitating capital flow across currency regions. Three, firms are natural cross-market arbitrageurs that can better overcome limits of arbitrage problems as shown by previous studies under other settings.\footnote{Previous work on firms as arbitrageurs include Baker and Wurgler (2000), Baker, Foley, and Wurgler (2009), Greenwood, Hanson, and Stein (2010), and Ma (2015).}

I develop a model of market segmentation to show that the reduction of either of these two deviations necessitates arbitrageurs to engage in distorting the other. When markets are segmented, the price of risk in one market may be disconnected from those in other markets. Specialization of risk taking contributes to market segmentation, as it has been studied in other contexts.\footnote{e.g. in MBS (Galai, Krishnamurthy, and Vigneron, 2007), options (Garleanu, Pedersen, and Poteshman, 2009), and bonds (Greenwood and Vayanos, 2014).} The two pricing anomalies studied in this paper reflect distinct market segmentations along two dimensions—the credit market is segmented by the denomination currencies, and the CIP violation is a disconnect between the spot and forward exchange rates. The arbitrageur is risk-averse and thus desires to isolate the arbitrage spread while avoiding other risks. However, each of the two deviations serves as a “short-sell” constraint to the other. To take advantage of the credit spread differential, the arbitrageur needs to hedge FX risk through trading forwards or swaps. To arbitrage the CIP deviation, she needs to borrow and lend in different currencies. Global debt issuers and investors are natural cross-market arbitrageurs as their activities straddle the credit and FX markets.

To understand the conceptual framework, consider again the AT&T example. The firm finds it cheaper to issue in EUR than in USD when considering the cost of debt payment
alone. However, for AT&T to take advantage of the lower credit spread in EUR, it would be exposed to substantial FX volatility. To hedge this volatility, AT&T needs to buy EUR in the forward market for its future debt repayment. In fact, AT&T did exactly this, it issued €800 million ($1 billion) in a 15-year EUR-denominated bond and entered into currency swap as a hedge. FX-hedged issuances among large, developed country firms have been pervasive. A textual analysis of 10K filings of S&P 500 firms indicates that around 40% of the firms have issued FX-hedged foreign debt in recent years (Section 4 presents this analysis).

What might be drivers of the two deviations in the first place? Local credit market shocks could emanate from quantitative easing (such as ECB corporate bond purchase), liability-driven investments (e.g. pension fund benchmark changes), and credit sentiments. I present a case study on the U.S. credit crunch around the time of Bear Stearns downfall. During this period, the dollar credit spread increased sharply relative to the euro credit spread for the same issuers, however, the FX market was not directly affected. I also study an episode of FX swap demand shock around 2011-2012. During this period, foreign banks relied on the FX swap market to cover their dollar funding shortages. These case studies support the model predictions on the spillover of anomalies and the role of currency-hedged capital flow.

The mechanism described in this paper complements that of intermediary-based asset pricing. Many papers have modeled cross-market arbitrageur as financially-constrained intermediaries. The marginal price setters in this study are instead debt issuers (and investors). The empirical implications stemming from this distinction are twofold. First, changes in the binding constraint of a common intermediary can determine the absolute level of deviations—that is how wide of a band within which deviations can fluctuate. However, intermediary capital alone cannot explain the matching size, direction, and covariance of the two deviations across time and the cross-section of currencies. The insufficient dealer arbitrage of CIP violation is rationalized in the context of Funding Valuation Adjustments by Andersen, Duffie and Song (2019). Second, the two spreads examined in this paper are sizable and comoves in calm market conditions when intermediary wealth constraints are un-

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6 A back-of-envelope calculation suggests that a 10% appreciation of USD would reduce AT&T's annual profit by one-third if the firm does not hedge its FX exposure on its outstanding foreign currency debt.

7 In its 10K statement, AT&T discloses the pervasiveness of its FX-hedged global bond issuance: “We have entered into multiple cross-currency swaps to hedge our exposure to variability in expected future cash flows that are attributable to foreign currency risk generated from the issuance of our Euro, British pound sterling, Canadian dollar and Swiss Franc denominated debt.”

8 Previous studies on credit sentiment and impact on asset prices include López-Salido, Zakrajšek and Stein (2017), Bordalo, Gennaioli, and Shleifer (2018), Greenwood, Hanson, and Jin (2016) Greenwood and Hanson (2013).

likely to the key driver. This finding is new relative to previous empirical studies that have shown widespread Law of One Price (LOOP) violations during stressed market conditions\(^\text{[10]}\).

Additional empirical analyses validate key model predictions. First, a counterintuitive implication of the model, which also appears in the data, is that the net deviation is small even when deviations in both CIP and credit are large individually. When the two deviations are meaningfully large (greater than 20 basis points), the absolute level of net deviation is only around one-fourth the size of the two individual deviations. Second, cross-currency issuance flow co-varies with the net deviation in predictable directions. For each one standard deviation change in the net deviation for EURUSD, firms respond by shifting around 5% of the aggregate debt issuance toward the cheaper issuance currency. Structure vector autoregressions (SVAR) and firm-level panel analysis also lend support to the model predictions on issuance flow and the spillover of deviations. Additionally, I show, through an event study approach, that cross-currency debt issuances have an observable price impact on CIP deviations around large issuance dates. Third, an exogenous increase in cross-market arbitrage capital represented by total bond issuance aligns the two deviations more closely. To test this prediction, I instrument total debt issuance with the amount of maturing debt. Maturing debt are often refinanced into new debt. An exogenous increase in borrowing needs provide firms with the capital with which to optimize the currency composition of issuance and integrate the markets.

**Related literature** Violations of the Law of One Price (LOOP) have been found in various corners of the financial market. The typical explanation involves limits of arbitrage arguments that follows from the seminar work of Shleifer and Vishny (1997). A number of important papers has contributed to the understanding of LOOP violation and arbitrage constraints: Kyle and Xiong (2001), Gromb and Vayanos (2002, 2017), Brunnermeier and Pedersen (2009), Gärleanu and Pedersen (2011), and He and Krishnamurthy (2013). This paper contributes to the study of arbitrage by showing, in a novel setting, that LOOP violations in one market can arise as an equilibrium outcome of arbitrageur actions intended to correct violations in another market.

This study relates to papers on international portfolio holdings, borrowings, and exchange rate. The findings of credit market segmentation and issuers reaching across currency boundaries to cater to investor demand echo the results of investor home-currency bias (Maggiori, Neiman, and Schreger, 2018; Burger, Warnock and Warnock, 2018). The influence of capital flows on CIP deviation resonates with theory on exchange rate determination and uncovered interest rate parity (Gabaix and Maggiori, 2015). Other works have examined local versus

\(^{10}\)Pasquariello (2014)
foreign currency borrowing by firms in different contexts (Bruno and Shin, 2014, 2017; Gozzi et al. 2015; Hale, Jones, and Spiegel, 2016). Bruno and Shin (2017) find carry trade motives for emerging market firms that issue in dollar without FX hedging. My result on corporate issuance flow being sensitive to net deviation at the aggregate level also expands upon the message by McBrady and Schill (2007), which finds an opportunistic motive for foreign currency borrowing by sovereign government and agency issuers.

CIP condition at the short- and long- maturities has been empirically validated in a number of early papers. A set of papers also examined short-term CIP violations during the financial crisis. The general conclusion from earlier work is that any CIP violations were short-lived before and during the financial crisis. My finding of FX-hedged corporate bond pricing differences parallels studies that examine sovereign bond pricing differences in currencies of different denominations. The result that the net deviation is relatively small in comparison to CIP deviation based on interbank funding rates accords with the findings of Rime, Schrimpf, and Syrstad (2017) that CIP holds well for most potential arbitrageurs when applying their marginal funding rates.

More closely related to my paper are Ivashina, Scharfstein, and Stein (2015), Du, Tepper, and Verdelhan (2018), and Sushko et al. (2016). Ivashina, Scharfstein, and Stein (2015) examine USD funding and lending behaviors of European banks during the Eurozone Sovereign Crisis and explore how the shrinkage of wholesale USD funding compelled banks to swap their EUR funding into USD, which in turn generated CIP violations and affected lending. Du, Tepper, and Verdelhan (2018) study persistent deviations from CIP in recent periods and propose an explanation relating to bank regulatory costs that lead to large quarter-end spikes in deviations. Sushko et al. (2016) examine the role of hedging demands and costly balance sheets in the determination of CIP violations. My contribution is to explain the joint determination of both long-term CIP violations and price discrepancies in corporate bonds of different denomination currencies. I show that the two deviations need to be considered together in formulating an explanation for the equilibrium prices and capital flows.

This paper also contributes to the understanding of the U.S. Treasury convenience yield.

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4. Bräuning and Ivashina (2016) further explore the role of monetary policy in affecting funding sources of global banks and the use of FX hedges.
examined in recent studies (Du, Im and Schreger, 2017; Jiang, Krishnamurthy and Lustig, 2018, 2019; Avdjiev et al., 2018). Using bonds from the same issuer but in multiple currencies, my analysis disentangles the currency effect from the entity effect in convenience yield. I show that a large part of the convenience yield can be attributed to the specialness of the U.S. dollar rather than that of U.S. Treasury. The convenience yield is large for high-grade, short-maturity corporate debt and the time variation is similar to those calculated from Treasuries. Additionally, I provide evidence on the active capturing of the convenience yield by firms.

The paper proceeds as follows. Section 1 discusses the measurements of residualized credit spread. Section 2 presents the stylized fact that residualized credit spread differential and CIP deviation are highly aligned. Section 3 provides a model to explain the co-determination of these two violations. This is followed by discussion of firms as arbitrageurs in Section 4. Additional model predictions are tested empirically in Section 5. Section 6 discusses two case studies that capture shocks to the credit market and FX funding market respectively.

1 Residualized credit spreads

In this section, I develop a measure of the aggregated credit spread difference for bonds denominated in different currencies. The ideal experiment is to find pairs of identical bonds (same issuer, maturity, etc) that differ only in the currency denomination. Since few bonds are perfectly alike, this approach would result in a small sample that might not be representative of the aggregate bond market. To study the aggregate difference in credit spread, I use a regression approach to estimate the currency effect while controlling for other bond characteristics.

1.1 Data

I obtain yields on individual bonds from Bloomberg and bond attributes from the Financial Securities Data Company (SDC) Platinum Global New Issues data set and Moody’s Default & Recovery Database. The selection of bonds is as exhaustive as possible. The sample

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Du, Im and Schreger (2017) calculate a convenience yield associated with holding U.S. Treasury over other developed-country government bonds when swapped into dollar. Jiang, Krishnamurthy and Lustig (2018) develop a model of safe asset demand that generates co-movement between the convenience yield and the dollar exchange rate. Avdjiev et al. (2018) show that the dollar is a key barometer of risk-taking capacity that underpins the relationship between deviation from CIP and cross-border bank lending in the dollar. Jiang, Krishnamurthy and Lustig (2019) rationalize the outside impact of dollar on the global financial cycle in the context of dollar safety demand.
data contains more than 35,000 corporate bonds in seven major funding currencies (USD, EUR, GBP, JPY, AUD, CHF, and CAD) from 2004 to 2016. The selection includes all fixed-coupon, non-callable, bullet corporate bonds with outstanding amounts of at least $50 million and original maturities of at least one year. The total notional of the data set is $23 trillion and the outstanding notional as of June 2016 is $12 trillion. These bonds were issued by more than 3,800 entities, including supranationals (such as the World Bank) and sovereign agencies (such as state-owned banks) that are generally considered a part of the corporate bond market. I use the yield spread against the LIBOR swap curve as a measure of credit spread. An alternate measure using the yield spread against the overnight index swap curve (e.g., swaps based on EONIA and fed fund effective rates) generates similar residualized credit spread differential (since LIBOR-OIS spreads in different currencies are mostly netted out). Details of the data sample and a descriptive summary of the bond data is presented in the Internet Appendix.

1.2 Matrix pricing of corporate credit

To assess the impact of denomination currency on the pricing of credit risk, I estimate the following cross-sectional regression separately at each date:

$$S_{it} = \alpha_{ct} + \beta_{ft} + \gamma_{mt} + \delta_{rt} + \varepsilon_{it}$$

where $S_{it}$ is the credit spread for bond $i$ traded in the secondary market at time $t$. $\alpha_{ct}$, $\beta_{ft}$, $\gamma_{mt}$, and $\delta_{rt}$ are fixed effect estimates for currency $c$, firm $f$, maturity bucket $m$ and rating bucket $r$ respectively at date $t$. The firm fixed effect is particularly important because it controls for other bond characteristics that are present at the firm level. The data sample is limited to securities with remaining maturity less than one year or ten percent of original maturity are excluded from the sample as liquidity tends to be poor and pricing observations are often missing. Excluding debt less than one year also effectively rules out short-term funding instruments such as commercial paper.

The equivalent panel regression approach estimates the following

$$S_{it} = \gamma + \sum_{c \neq USD} \alpha_c D_{ci} + \sum_t \tau_t D_{ti} + \sum_c \sum_t \delta_{ct} (D_{ci} D_{ti}) + X_{it} \beta + \varepsilon_{it}$$

where $D_{ci}$ and $D_{ti}$ are dummies for currency $c$ and time $t$ respectively, $X_{it}$ is a list of controls including firm, rating, maturity fixed effects and the associated interaction terms with date. The residualized credit spread difference can be obtained by $\kappa_{ct} = E[S_{it}|c, t, X_{it}] - E[S_{it}|c = USD, t, X_{it}] = \alpha_c + \tau_t + \delta_{ct}$. The large number of interactions, especially due to firm-time fixed effects, introduces computational challenges. The standard errors are improved in the panel regression.

The maturity of the bond at each pricing date $t$ is categorized into four buckets (1 to 3 years, 3 to 7 years, 7 to 10 years and beyond 10 years). Alternative specification that includes maturity as a linear control is also tested and produce similar results.
limited to only bonds belonging to multi-currency issuers. The currency fixed effect $\alpha_{ct}$ thus measures the residualized credit spread for bonds denominated in currency $c$. This method of attribution is analogous to the standard industry practice of matrix pricing in which a bond with unknown prices is assessed against other bonds with similar maturity and rating.

The residualized credit spread differential between currency $c$ and USD is denoted as $\kappa_{ct}$ and estimated as $\kappa_{ct} = \alpha_{ct} - \alpha_{USDt}$. Fig. 3 presents time series of $\kappa_{ct}$ estimated at the end of each month for EUR, GBP, JPY, AUD, CAD, and CHF relative to USD. The currency fixed effect coefficients are estimated with relative precision given the large sample size (median number of observations each month: 5504). The median firm-clustered standard error on the currency fixed effects is 3.6 basis points (mean: 4.8 basis points). The mean and median R-squared are both 82%. This suggests that the regression specification captures most of the variation in bond pricing.

**Figure 3 Residualized foreign currency credit spreads relative to dollar credit spread**

![Residualized foreign currency credit spreads relative to dollar credit spread](image)

This figure presents the residualized credit spreads $\kappa_{c,t}$ relative to the dollar credit spread for $\kappa_{c,t} = \{AUD, CAD, CHF, EUR, GBP, JPY\}$.

The credit spread differentials were relatively small from 2004 to 2007 but increased significantly during the Global Financial Crisis. Foreign credit spreads tightened considerably relative to the dollar credit spread during the crisis period. In particular, EUR and JPY credit spread differentials reached deviations beyond negative 100 basis points during the

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20 In constructing currency fixed effect estimates, the dummy variable associated with the dollar is omitted. Therefore, the coefficient estimates on other currency dummies are directly interpreted as estimates of the differential.

21 Confidence intervals constructed with firm-clustered standard errors are presented in Fig. 7
peak of the crisis. The deviations briefly reversed after the crisis. However, since 2010, the credit spread differentials have widened again. In the cross section, the spread differentials for each market have been persistent in the sign and relative magnitude. JPY credit (purple line) has been the cheapest to borrow (negative spread differential) relative to USD credit, and AUD credit (red line) has been the most expensive to borrow (positive differential) relative to the USD credit market. Against the backdrop of more aggressive ECB QE, the EUR credit spread differential (black line) trended more negatively starting in 2014 and had reached negative 70 basis points in 2016.

1.3 Comparison with benchmark credit spreads

The residualization of credit spreads using the above methodology produces time series that are substantially different from unresidualized credit spread benchmarks. In Fig. 4, I compare the residualized EUR-USD credit spread differential against two unresidualized benchmark indices — the Bank of America Merrill Lynch Corporate Single A index and the Barclays Corporate Single A index. The residualized and unresidualized spreads are quantitatively and qualitatively different. In contrast to the residualized spread that was negative (indicating a tighter EUR credit spread than the USD credit spread), the unresidualized versions of the spread were positive and substantial for a large portion of the sample period. This difference reflects composition discrepancies of the benchmark bond portfolios in different currency denominations. The regression methodology addresses the composition effect by controlling for firm and other bond characteristics using individual bond prices.
This figure compares the residualized credit spread differential with unresidualized credit spread differentials from the Bank of America Merrill Lynch Single A Corporate index (BAML) and Barclays Single A Corporate index for EUR-USD. The unresidualized credit spread differential is the difference between the USD-denominated single-A option adjusted spread (OAS) and the EUR-denominated single-A OAS benchmarks published by BAML and Barclays.

1.4 Additional controls

I conduct a number of robustness checks in the estimation of the residualized credit spread differential. In addition to the bond-level and firm covariates in Eq. 1, I augment the regression specification with additional controls—amount outstanding, bond age relative to initial maturity, seniority, and governance law. The first two controls serve as liquidity proxies. Larger bond issuance size and newly issued bonds are known to be more liquid. On-the-run bonds, or newly issued bonds, have a premium when compared to off-the-run bonds of similar maturities (Krishnamurthy, 2002). To capture this effect, the control for bond age is defined as the ratio of remaining maturity to initial maturity. I control for the governance law of bonds. Early work by Kim and Stulz (1988) find positive abnormal return associated with Eurobond issues. The Eurobond market refers to the offshore market that has less regulatory oversight and offer some level of anonymity of the bond bearer. It has no relation, however, to the currency denomination of the bond. An additional control for bond seniority (e.g., senior secured, unsecured, subordinate, etc) is obtained from the Moody’s Default & Recovery Database and added to the expanded regression. These controls make little difference on the residualized credit spread differentials (see Internet Appendix).

Other unobserved bond attributes should not affect the aggregate residualized credit
spread differential as they are likely idiosyncratic in nature. The residualized credit spread differentials were small prior to the financial crisis. It is unlikely that bond-specific unobservables only begin to vary systematically across currencies after the crisis.

Another potential concern is that the aggregate credit rating varies significantly across different currency-segmented bond markets. That is, if all EUR-denominated bonds have a rating of triple-A while all USD-denominated bonds have a rating of single-A, then naturally there would be a lower credit spread for EUR-denominated bonds. Under this hypothetical scenario, the residualized credit spread differential would pick up the difference between triple-A bonds and single-A bonds rather than a difference due to currency denomination. I address this concern in two ways. First, I limit the data sample on each date to only bonds that are issued by entities that have debt outstanding in another currency. This filtering reduces the concern above since bonds issued by the same firm generally have similar credit ratings. Second, I perform a further robustness check by splitting the sample for high-grade and low-grade bonds (see Internet Appendix). The residualized credit spread differential persists in the sub-samples.

1.5 Independence of bond default and currency

The residualized credit spread differential for similar bonds trading in different currencies can reflect a firm’s propensity to default selectively on debt denominated in one currency but not in the other. Even without selective default, the correlation between the intensity of default and exchange rate can lead to the quanto effect (Lando and Nielsen, 2016). Previous studies on sovereign bonds present mixed results on the effect of quanto risk. Buraschi, Sener and Menguturk (2015) conclude that the quanto effect is minimum for a set of emerging market countries in their sample from 2005 to 2010. Du and Schreger (2016) show that the quanto adjustment can explain the large persistent level differences between local currency and foreign currency credit spreads of emerging market sovereign bonds. Augustin, Chernov, and Song (2018) find that the quanto spreads of Eurozone sovereigns were substantial during the 2011-12 European sovereign crisis due to the risk of simultaneous EUR depreciation and bond default.

Using the same approach, I find that the risk of simultaneous corporate default and currency depreciation is muted for large corporate issuers. To calculate the corporate quanto adjustment, I match CDS contracts for the same firm and contractual terms (document clause and tier) but different denomination currencies. CDS prices on global debt issuers are obtained from Markit, a pricing service provider that aggregates contributed quotes from market makers. The sample size of issuers with quotations of matched CDS contracts in
multiple currencies ranges from 201 to 271 for EUR and USD and 76 to 224 for JPY and USD. Fig. 5 presents the distribution and time variation of quanto adjustment implied by the CDS contracts for EUR and JPY relative to USD. Most issuers have quanto adjustments of less than 5 basis points at the extreme. The 10th to 90th percentile of the quanto adjustments for EUR-USD is zero except for a brief period during the Eurozone crisis. The spreads for JPY-USD is more dispersed. This is possibly due to smaller sample of firms with multi-currency CDS. The 10th to 90th percentile of the issuers have quanto spread less than 5 basis points and the median is close to zero during most of the sample period.

**Figure 5 Quanto adjustment from matched CDS contracts**

![Graph showing quanto adjustment from matched CDS contracts](image)

This figure shows the observed distribution of five-year quanto spreads for global debt issuing firms that have dollar CDS contracts with matching contracts denominated in EUR (left) and JPY (right). The quanto adjustment is calculated as the difference between the non-dollar and the dollar CDS spread for contracts with matching firm, debt tier, and CDS doc clause.

Additional reasons further alleviate the concern of correlated default and currency movement. First, corporate bonds with different currency denominations but the same credit rating most often have pari-passu clauses that dictate the same treatment to creditors. Second, the observed cross-sectional and time variations in residualized credit spread differentials do not match the intuition of quanto effect. For instance, the JPY-USD residualized credit spread differential was more negative during the Eurozone crisis (and in the entire sample period) than that of the EUR-USD spread despite the JPY being a safe-haven currency that typically appreciates in crisis. Furthermore, both JPY-USD and EUR-USD residualized credit spreads were larger in 2016 than during the Eurozone crisis. Third, the residualized credit spread differentials anomaly was small before 2008 but have been persistently large.
since then, whereas quanto risk would have been priced prior to 2008 if it were the main contributor to the credit spread difference.

2 Alignment of the residualized credit spread differential and CIP violation

In this section, I define measurement of CIP deviation, present evidence on the alignment of the two pricing distortions and calculate currency-hedged credit spread differential.

2.1 Measurement of CIP deviation

CIP condition is defined by

\[ F_{t,T} = S_t \frac{(1 + r_{t,T})^T}{(1 + r_{t,T}^*)^T} \]  (2)

where \( S_t \) is the spot exchange rate at time \( t \) expressed in units of domestic currency per foreign currency, \( F_{t,T} \) is the forward exchange rate with maturity \( T \), and \( r_{t,T} \) and \( r_{t,T}^* \) denote the \( T \)-period risk-free zero-coupon cash market rates in the domestic currency and the foreign currency respectively. A violation of CIP occurs when the above equation fails to hold. For exposition, assume that \( T = 1 \). Dropping subscripts, we can rewrite Eq. 2 as \( 0 = \frac{S}{F} (1 + r) - (1 + r^*) \). In other words, CIP states that the FX-implied foreign funding rate is equal to the actual foreign funding rate. A violation of CIP can be expressed as a basis \( b \):

\[ b = S \frac{(1 + r)}{F} - (1 + r^*) \]  (3)

I measure \( b \) empirically using LIBOR-based cross-currency basis swap, consistent with other papers\(^ {22} \) studying CIP violation. A cross-currency basis swap is a bilateral market instrument that allows the market participant to simultaneously borrow in one currency and lend in another currency at the respective floating interest rates. The counterparty of the swap transaction agrees to take on the reverse position. The currency basis is a market-determined adjustment to the reference floating funding rates. It is analogous to the market pricing of \( b \) in Eq. 3. The funding rate considered in Eq. 3 and typically used in FX swaps is the inter-bank borrowing rates (LIBOR). An alternative definition using overnight index swap (OIS) rates with reference to actual transactions short rates, such as Fed Fund Effective Rate and the EONIA rate, produces bases that are largely similar. See the Internet Appendix

for comparison. Calculating CIP deviations using FX forward and spot rates also produces similar results. Since LIBOR-based cross-currency basis swap is the most liquid FX-hedging instrument for maturities greater than a year and has the most comprehensive data across maturities and currencies, I focus on this measure in the main analysis. Details of the cross-currency basis swap, its relation with forwards and CIP violation at different maturities are discussed in the Internet Appendix\textsuperscript{23}.

The sign of $b$ provides intuition on the cost of liquidity demand and the direction of possible FX-hedging demand imbalance. Continuing with the earlier example, AT&T issues in EUR and swaps the bond proceed to dollar. This FX swap transaction from EUR to USD can be equivalently stated in two other ways: (1) simultaneously borrow USD and lend EUR, or (2) simultaneously sell EUR for USD in the spot market and buy EUR against USD in the forward market. Holding the spot exchange rate $S$ and funding rates $r$ and $r^*$ fixed in Eq. 3, a rise in $F$ necessitates a decrease in $b$. Therefore, when $b$ is negative, it is costly to swap the foreign currency to dollar, and vice versa.

Fig. 6 shows the deviations from CIP at the five-year horizon for AUD, CAD, CHF, EUR, GBP, and JPY relative to the USD. CIP condition had held tightly prior to 2008. However, large deviations from the CIP relation appeared in the aftermath of the financial crisis and persist through 2016. Negative CIP basis $b$ signals the relative expensiveness to swap to USD from non-USD currency (to buy the foreign currency against selling USD in the forward market). This can be a reflection of hedging demand by firms and investors. Positive $b$ in AUD and CAD during most of the sample period reflects expensiveness to swap to these currencies from USD. Du, Tepper, and Verdelhan (2018) provide a detailed exposition of post-crisis CIP violation and document a strong quarter-end effect in short-term CIP deviation that indicates regulatory window dressing. Here, I examine CIP deviations at longer maturities that matches the bond maturities.

\textsuperscript{23}In the Internet Appendix, I show that $T$-horizon CIP deviation $b_T$ is related to cross-currency basis swap rate $B_T$ by the following approximation:

$$b^{(T)} \approx B_T \left[ \sum_{t=1}^{T} \frac{1 + Z_t^*}{t} \right] \frac{1 + Z_T^*}{T}$$

where $Z_t^*$ denotes the foreign zero-coupon rate with maturity $t$. 

16
This figure presents covered interest rate parity deviations, $b_{c,t} \equiv r_{c,t}^{FX-implied} - r_{c,t}^{actual}$, at the 5-year maturity for $c = \{AUD, CAD, CHF, EUR, GBP, JPY\}$ against the USD.

### 2.2 Alignment

CIP violations and the residualized credit spread differentials are highly aligned in the time series and the cross section. Fig. 7 graphs the time series of credit spread differential and CIP deviations at the five-year horizon (matching the average bond maturity) for six major funding currencies. The time series of the two violations match closely in magnitude and direction for each currency, especially outside of the crisis period. The correlation in the cross section is also high. Pooling the observations across time and currency, the two violations have a correlation of 81%.

Fig. 8 shows a scatter plot with credit spread differential on the horizontal axis and deviation from CIP on the vertical axis. This figure highlights both the cross-sectional and time-series correlation between the two violations. The different signs across currencies suggest that dollar liquidity shortage cannot be the sole explanation for CIP deviations. CIP deviations in EUR and JPY have been negative, indicating dollar liquidity shortage, but the positive deviations in other currencies (e.g., AUD, CAD, and GBP at times) would indicate a dollar liquidity surplus. The high correlation and persistence in the two pricing discrepancies are striking. Japan (purple) has negative deviations in both CIP and credit, suggesting that the JPY credit spread is tighter than the USD credit spread for comparable bonds at the same time as it is costly to swap JPY to USD. Australia (red), on the other hand, has deviations that are both positive, indicating that its credit spread is wider than the U.S. equivalent at the same time as it is costly to swap USD into AUD.
Figure 7 Credit spread differential and CIP violation relative to the USD

This figure presents the residualized credit spread differentials, \( \kappa_{c,t} \), and CIP deviations \( b_{c,t} \) relative to the USD for six major funding currencies \( c = \{\text{EUR, GBP, JPY, AUD, CHF, CAD}\} \). The CIP deviations are in solid red, with negative direction indicating expensiveness to swap to USD. Credit spread differentials (foreign currency minus USD) are in dashed blue. Vertical bars (gray) represent the 95\% confidence interval for the estimated credit spread differentials constructed using robust standard errors clustered at the firm level.

Figure 8 Credit spread differential and CIP violation

This figure presents the residualized credit spread differential \( \kappa_{c,t} \) and CIP violations \( b_{c,t} \) for \( c = \{\text{EUR, GBP, JPY, AUD, CHF, CAD}\} \) relative to USD.
Descriptive regressions also confirm both the cross-sectional and the time-serial correlation between credit spread differential and CIP deviations. Table I presents the relationship between the two pricing anomalies for the six currencies in panel and individual regressions. Most coefficients range from 0.7 to close to 1 and are highly significant. Columns 2 and 3 present regressions controlling for time and currency fixed effects. These regressions cannot be interpreted as causal, nonetheless they demonstrate the close alignment of the two anomalies.

The high alignment between the two anomalies does not arise mechanically from changes in risk-free rate. Naively taking partial derivatives on credit spread differential \( \kappa \) and CIP basis \( b \) with respect to the foreign funding rate \( r^* \) would yield \( \frac{\partial \kappa}{\partial r^*} < 0 \) and \( \frac{\partial b}{\partial r^*} < 0 \). This is however not true in the data. Event study using intraday prices around ECB policy announcements shown by Du, Tepper, and Verdelhan (2018) suggests that \( b_{EUR} \) increases when there is a positive shock to the EUR interest rate. Further discussion ruling out mechanical effects can be found in the Internet Appendix.

2.3 Imperfect alignment and net deviation

**Net deviation in issuance costs** I define net deviation, \( \Psi_c \), as the difference between the residualized credit spread differential and CIP violation for a given currency \( c \) relative to the USD, i.e. \( \Psi_c \equiv \kappa_c - b_c \). Since the maturity of each individual bond is different, I first adjust the swap yields at each maturity by the corresponding currency basis. I then linearly interpolate the CIP-adjusted swap curve to each individual bond’s maturity in calculating the bond’s FX-hedged credit spreads, \( S_{adj}^{it} \). Lastly, I estimate cross-sectional regression similar to Eq. 1 but with the bond-level FX-hedged credit spreads as the dependent variable,

\[
S_{adj}^{it} = \alpha_{ct} + \beta_{ft} + \gamma_{mt} + \delta_{rt} + \epsilon_{it}
\]

I take the currency fixed effects as estimates of the net deviation. Since the average maturity of the bond portfolio is around five years, the regression method produces estimates of \( \Psi \) similar to a measure that directly subtracts the five-year CIP deviation from the residualized credit spread differential.

The two deviations in credit and FX are misaligned when the size of net deviation is large or when their correlation is low. Fig. 9 shows the net deviation time series for each of the six currency pairs (relative to USD). Apart from the financial crisis period, the net deviation is much smaller in magnitude relative to either CIP deviation or credit spread differential alone. This indicates that the two violations in credit and CIP are generally well aligned in magnitude and the currency-hedged cost of borrowing are largely equalized across
Table 1 Descriptive regression of credit spread differential on CIP deviations

This table presents regressions of the credit spread differential on CIP deviations at the 5-year horizon for six major currencies against the U.S dollar. The sample period is from January 2004 to July 2016 with monthly observation. Column 1 presents the pooled sample regression, columns 2 and 3 present panel regressions with time and currency fixed effects, and columns 4 to 9 present regressions for each of the six currencies. In columns 1 to 3, $t$-statistics in brackets are based on Driscoll and Kraay (1998) standard errors with a maximum lag of 12 months. In columns 4 to 9, $t$-statistics in brackets are based on Newey-West standard errors with lag selection following Newey-West (1994).

<table>
<thead>
<tr>
<th></th>
<th>(1) Pooled</th>
<th>(2) Time FE</th>
<th>(3) ccy FE</th>
<th>(4) EUR</th>
<th>(5) GBP</th>
<th>(6) JPY</th>
<th>(7) AUD</th>
<th>(8) CHF</th>
<th>(9) CAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIP basis</td>
<td>0.737</td>
<td>0.683</td>
<td>0.704</td>
<td>0.799</td>
<td>0.821</td>
<td>0.688</td>
<td>0.292</td>
<td>0.705</td>
<td>0.918</td>
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<td></td>
<td>[18.62]</td>
<td>[31.72]</td>
<td>[11.32]</td>
<td>[5.22]</td>
<td>[4.34]</td>
<td>[13.02]</td>
<td>[2.78]</td>
<td>[7.87]</td>
<td>[3.73]</td>
</tr>
<tr>
<td>_cons</td>
<td>-7.36</td>
<td>-5.94</td>
<td>0.888</td>
<td>-9.65</td>
<td>-2.4</td>
<td>-14.3</td>
<td>-7.1</td>
<td></td>
<td></td>
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<td></td>
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<td>[-0.97]</td>
<td>[-3.79]</td>
<td>[-3.56]</td>
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</tr>
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<td>rsq</td>
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<td>0.56</td>
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<td>0.53</td>
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<td>906</td>
<td>906</td>
<td>151</td>
<td>151</td>
<td>151</td>
<td>151</td>
<td>151</td>
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</tr>
</tbody>
</table>
currencies. Credit spread differential had higher spikes during the peak of the crisis than CIP deviation for most currencies. This is in part because CIP deviations were eventually capped when the Fed established swap lines with other central banks for the lending USD funding to foreign institutions (Goldberg, Kennedy, and Miu, 2011; McGuire and von Peter, 2012; Reis and Bahaj, 2018). On the other hand, credit market distortions were exacerbated during the financial crisis by the lack of liquidity in the fixed income market.

Figure 9 Net deviation

![Graphs showing net deviation for various currencies](image)

This figure presents the net deviation $\Psi_{c,t}$ for EUR, GBP, JPY, AUD, CHF, and CAD relative to the USD. Vertical bars (gray) represent the 95% confidence interval with firm-level clustering.

### 2.4 Heterogeneity in the sub-samples and the dollar convenience yield

The net deviation series presented above reflect the overall FX-hedged credit spread difference for the entire sample. The data also allow for dis-aggregation that reveals which segment of the bond market provides the most incentive for potential arbitrage. I limit this sub-sample exercise to the EUR-USD net deviation since the two currencies have the largest sample size. Fig. 9 shows the comparison of net deviations for high grade and low grade bonds. Panel A shows that high grade bonds typically trade with lower credit spread in dollar relative to EUR (positive net deviation, red line) while low grade bonds typically trade more cheaply in dollar when adjusted for the cost of FX hedging (negative net deviation, blue line). Panel B shows that shorter maturity bonds generally have a tighter dollar credit spread than longer
maturity bonds when adjusted for FX hedging cost.

**Figure 10 Net deviation: heterogeneity across ratings and maturities**

Panel A: Comparison between high grade and low grade bonds

Panel B: Comparison between long and short maturity bonds

**Dollar convenience yield** The net deviation relative to USD can be interpreted as a measure of dollar safe asset premium in the corporate credit market. The convenience yield of holding U.S. treasury over other developed-country government bonds with currency swaps has been documented and studied by other works (Du, Im and Schreger, 2017, and Jiang, Krishnamurthy, and Lustig, 2018). In contrast with developed market sovereigns that typically only issue in their respective home currency, firms studied in this paper issue in multiple currencies. The advantage of estimating convenience yield using multi-currency issuers is that entity-specific effects are removed; thus the derived convenience yield is entirely attributed to the currency denomination.

My result suggests that a substantial portion of the U.S. Treasury convenience yield is due
to its dollar denomination and that the highest convenience is derived from short-maturity, highly rated bonds. Fig. 11 presents a comparison of convenience yield in Treasury and safe corporate bonds. The Treasury convenience yield (or Treasury basis) is from Jiang, Krishnamurthy, and Lustig (2018) and is averaged across a sample of developed market sovereign bonds with one year constant maturity. Du, Im and Schreger (2017) calculate equivalent convenience yields for a large number of countries at different maturities. The corporate basis is the estimated net deviation from Eq. 4 using a sample of high-grade, short-maturity bonds. The two types of convenience yields are highly correlated and positive throughout most of the sample period, indicating a premium for dollar safe assets. The Treasury basis is on average higher than corporate basis, indicating relatively more safety premium or convenience. The 1-3Y corporate basis with highest credit ratings is on average the next highest and aligns well with the Treasury basis. The 1-7Y corporate basis estimated from a larger range of maturity and credit ratings shows lower premium on average. This result is in line with the finding from Du, Im, and Schreger (2017) that the term structure of convenience yield has been downward sloping in recent years.

Figure 11 Convenience yield in Treasury and corporate bonds

The Treasury basis is the spread between 1-year U.S. Treasury bonds and foreign government bond yields, swapped into dollars. The 1-3Y corporate basis is the average net deviation of bonds with credit ratings from AA- to AAA and maturities of 1 to 3 years. The 1-7Y corporate basis is an average for bonds with credit ratings from BBB- to AAA and maturities from 1 to 7 years. Foreign in both cases is a sample of developed economies.

3 A model of aligned deviations in credit and FX markets

In this section, I present a model that explains the high degree of alignment between the two anomalies. We take market segmentation as given in a setup similar to Gromb and Vayanos
There are two risky assets – a bond denominated in EUR and a bond denominated in USD. The markets for these two assets are segmented in that EMU investors can only invest in EUR-denominated risky bond and a riskless asset, and U.S. investors can only invest in USD-denominated bond and a riskless asset. However, some agents (cross-market arbitrageurs) can trade in both markets. The cross-market arbitrageur is an issuer that sells debt, although it can broadly be interpreted as a global investor that both buys and sells debt. The issuer avoids currency mismatch by trading FX forward to hedge currency exposure. Therefore, the issuer is also exposed to CIP violation.

I use the model to illustrate the transmission of shocks across markets, the alignment of the two deviations, and the response and impact of issuance capital flow. The model also delivers testable predictions that are examined in Section 5. An extended model in the Internet Appendix relaxes many of the simplifying assumptions presented in the main text.

### 3.1 Cross-market issuer

In this static model, a representative price-taking firm needs to raise a fixed debt amount \( D \) for dollar-based investments. The firm observes its dollar bond yield \( Y_S \), a credit spread differential between its EUR- and USD- denominated bonds \( \kappa \) and a CIP deviation (FX basis) \( b \). The FX basis constitutes hedging costs beyond the risk-free rate differential. The firm fully hedges FX exposure and eliminate currency mismatches between the asset and liability side of its balance sheet\(^{24}\). Exchange rate is normalized to one as it does not enter into the decision. The firm chooses dollar debt issuance share \( \mu \) to minimize borrowing cost, \( \min_\mu [Y_S - (\kappa - b) \mu] D \). The solution to the issuer's currency choice is binary:

\[
\mu = \begin{cases} 
1 & \text{if } \kappa - b > 0 \\
0 & \text{otherwise}
\end{cases}
\]

If the net deviation is positive, \( \kappa - b > 0 \), then the firm shifts its issuance entirely to USD. Otherwise, it issues in EUR. Issuance capital flow responds to the net deviation between credit and CIP violations.

We can introduce capital structure friction, natural asset hedges, and partial FX-hedging to produce interior solution and carry trade motives. The main result and intuition carries through with these extensions. An extended model is provided in the Internet Appendix.

\(^{24}\)We can relax the simplification that the firm only has dollar asset and must fully hedge FX risk. The Internet Appendix shows an extension in which the firm has a desired dollar funding ratio \( m \), that is \((1 - m)\) fraction of its asset is in EUR and serve as a natural hedge. The firm decides on the deviation from its optimal debt currency mix \((\mu - m)\) and a FX hedging ratio \( h \).
3.2 Credit markets

To understand how deviation in one market spills over to the other market, we endogenize $\kappa$ and $b$. We start with endogenizing $\kappa$.

There are two risky bonds (EUR and USD bonds) each in zero net supply. The bonds represent two credit markets. The investor base is segmented. U.S. active investors specialize in the investment of USD-denominated corporate bonds, and European active investors only invest in EUR-denominated bonds. The firm supplies debt in both USD and EUR.

**Local active investors** Investors have funding cost equal to the domestic short rate, $r_i$, and purchase bonds with a promised net yield of $Y_i$, where $i = \text{€}$ for EUR or $\$ for USD. The two bonds have identical default probability $\pi$ and loss-given-default $L$. The payoff of bonds has a variance of $V$, which is treated as an exogenous constant in the model for tractability\(^{25}\). The investors have a mean-variance preference with identical risk tolerance $\tau$ and choose investment amount $X_i$ to solve: $\max_{X_i} \left[ X_i \left( (1 - \pi) Y_i - \pi L - r_i \right) - \frac{1}{2\tau} X_i^2 V \right]$. This has the solution $X_i = \frac{1}{\tau} \left( (1 - \pi) Y_i - \pi L - r_i \right)$.

**Exogenous demand** In addition to active local investors, there are exogenous bond demand $\varepsilon_i$. The source of demand $\varepsilon_i$ shocks can originate from quantitative easing (such as ECB corporate bond purchase program), changes to preferred-habitat investors (e.g. liability-driven investments, pension fund benchmark changes), and credit market sentiments. Section 6 presents a case study of a credit shock during early 2008 around the time of the downfall of Bear Stearns. The Internet Appendix provides in-depth discussion of potential credit market shocks.

**Market-clearing** Combining the investor demand with firm debt issuance supply, the market-clearing conditions for the two credit markets are $X_\text{\$} + \varepsilon_\text{\$} = \mu D$ and $X_\text{\$} + \varepsilon_\text{\$} = (1 - \mu) D$.

We can rewrite the difference between the two promised yields as a credit spread difference and interest rate difference, $Y_\text{\$} - Y_\text{\text{€}} \equiv \kappa + (r_\text{\$} - r_\text{\text{€}})$. Solving for the credit spread differential using the market clearing conditions, we obtain: $\kappa = \left( \frac{1}{1 - \tau} \right) \frac{V}{\tau} \left( (1 - 2\mu) D - \varepsilon_\kappa \right) + \left( \frac{\varepsilon_\kappa}{1 - \tau} \right) (r_\text{\$} - r_\text{\text{€}})$, where $\varepsilon_\kappa \equiv \varepsilon_\text{\text{€}} - \varepsilon_\text{\$}$ is defined as the relative excess EUR credit demand. The coefficient on the second term, $\frac{\varepsilon_\kappa}{1 - \tau}$, is negligible given realistic default probabilities for large firms in developed countries\(^{26}\). With a focus of studying meaningful drivers in the variations of $\kappa$, we apply first-order Taylor approximation for $\pi$ around 0 and express

\(^{25}\)A Bernoulli default distribution with probability $\pi$, loss-given-default $L$, and promised yield $Y$ implies that $V = \pi (1 - \pi) (Y + L)^2$. The solution to the investors’ problem would contain a quadratic root. To keep the model tractable, $V$ is assumed to be an exogenous constant and the same for both bonds.

\(^{26}\)The annual default rate averages less than 0.1% for investment grade bonds and 4.1% for high yield bonds in the U.S. from 1981 to 2016 (S&P Global).
credit spread differential as:

\[
\kappa = \frac{V}{\tau} \left( \frac{(1 - 2\mu) D}{\text{relative debt issuance}} - \frac{\varepsilon_\kappa}{\text{exog. EUR credit demand}} \right)
\]

(6)

The intuition is that \( \kappa \) is equal to the quantity of risk – the net supply and demand imbalances between the two markets – multiplied by the price of risk – the elasticity of bond demand. The cross-currency issuer can influence the relative credit spread through its choice of \( \mu \), though its influence is limited by the size of the total debt issuance \( D \).

### 3.3 Currency swap market

Next, I endogenize CIP basis \( b \) and describe the dynamics of the currency swap market. The intuition is similar to that of credit market above, but instead of investor risk preference that determines the slope of demand curve, the FX trader’s collateral and capital constraints limit arbitrage in CIP deviation. There are two main players in this market: currency swap trader and issuer.

**Currency swap trader** The currency swap trader chooses the amount of capital to devote to either CIP deviations \( b \), or an alternate investment opportunity with profit of \( f(I) \), where \( I \) is the amount of investment.

The trader must set aside a haircut \( H \) when it enters the swap transaction to arbitrage CIP violation. Following Garleanu and Pedersen (2011), the haircut amount is assumed to be proportional to the size \( s \) of the swap position, \( H = \gamma |s| \). Therefore, the capital devoted to alternative investment is \( I = W - \gamma |s| \). The swap trader has total wealth \( W \) and solves \( \max_s bs + f(W - \gamma |s|) \). The solution, \( b = \text{sign}[s] \gamma f'(W - \gamma |s|) \), provides the intuition that the expected gain from conducting a unit of additional CIP arbitrage is equal to the marginal profitability of the alternative investment. A simple case is when the alternative investment activity is quadratic, \( f(I) = \phi_0 I - \frac{1}{2} \phi I^2 \). In this case, \( b = \text{sign}[s] \gamma (\phi_0 - \phi W + \gamma \phi |s|) \).

I make an additional simplifying assumption that CIP deviation \( b \) disappears when there is no net demand for swaps, but as soon as there is net demand for swaps, \( b \) becomes nonzero. This assumption is equivalent to stating \( \frac{\phi_0}{\phi} = W \), which means that the arbitrageur has just enough wealth \( W \) to take advantage of all positive-NPV investment opportunities in the alternative project \( f(I) \). Simplifying with this assumption and omitting the constant intercept term in the equation for \( b \), and we obtain that CIP deviation is proportional to the trader’s position, \( b = \phi \gamma^2 s \). I further normalize \( \phi \) equals to one for simplicity. This model of
swap trader is analogous to that of Ivashina, Scharfstein, and Stein (2015) which models the outside alternative activity of the trader with a log functional form instead of the quadratic form.

**Exogenous demand** The representative firm from earlier uses the FX market to convert its EUR issuance proceed, \( D(1 - \mu) \), to USD. In addition, there are exogenous shocks to CIP basis \( \varepsilon_b \) that represent other non-debt-related uses of FX swaps. The sources of \( \varepsilon_b \) shocks include banks’ dollar funding through FX market, regulatory-driven hedging demand, structured note hedging, among others. Section 5 presents a case study of \( \varepsilon_b \) shock during the European Sovereign Crisis in 2011-2012. The Internet Appendix provides further discussions on sources of \( \varepsilon_b \) shocks.

**Market clearing** The market-clearing condition of the FX swap market implies that the equilibrium level of CIP deviation satisfies

\[
\begin{align*}
\text{CIP basis} b & = -\gamma^2 (D(1 - \mu) + \varepsilon_b) \\
& \text{haircut on collateral} \quad \text{net hedging demand to swap EUR into USD}
\end{align*}
\]

CIP deviation \( b \) is proportional to net hedging demand (quantity of risk) multiplied by the collateral haircut (price of risk). The negative sign comes from swap trader taking the opposite position of the hedging demand imbalance. Higher haircut \( \gamma \) amplifies the impact of hedging demand, but without net hedging demand, \( b \) does not deviate from zero.

Exogenous hedging demand \( \varepsilon_b \) can differ in sign from \( D(1 - \mu) \). If \( \varepsilon_b < 0 \) and \(|\varepsilon_b| > |D(1 - \mu)|\), then the issuer provides (rather than demand) liquidity in the FX swap market and incurs an additional benefit (instead of cost) through hedging.

### 3.4 Predictions

The market clearing conditions in credit market (Eq. 6) and FX (Eq. 7) combined with issuer currency choice (Eq. 5) result in the following propositions.

**Proposition 1. (Spillover of deviations)** If \( \varepsilon_\kappa \uparrow \), then \( \kappa \downarrow \Rightarrow \mu \downarrow \Rightarrow b \downarrow \). If \( \varepsilon_b \uparrow \), then \( b \downarrow \Rightarrow \mu \uparrow \Rightarrow \kappa \downarrow \). Shocks to one market are transmitted to the other through capital flows. Credit spread differential \( \kappa \) and CIP deviations \( b \) respond in the same direction to either credit demand shocks \( \varepsilon_\kappa \) or FX swap demand shocks \( \varepsilon_b \).

---

\(^{27}\text{These transitions occur discretely at the boundary when } \kappa - b \text{ changes sign, a small amount of friction to the firm’s capital structure would generate an interior solution as shown in the Internet Appendix.}\)
Proposition 1 has a clear prediction for the signs of $\kappa$ and $b$, but the sign of $\mu$ is ambiguous without precisely distinguishing whether the shock originates from $\varepsilon_\kappa$ or $\varepsilon_b$. However, the relation between $\mu$ and the net deviation $\kappa - b$ is unambiguous, leading to the following prediction.

**Proposition 2.** *(Issuance flow and net deviation)* $(\kappa - b) \uparrow \implies \mu \uparrow$ More expensive net cost of issuance in EUR induces more issuance in USD and less issuance in EUR.

Another related prediction that follows from the above is that more cross-market arbitrage capital reduces the net deviations and the two deviations are perfectly aligned in the limit.

**Proposition 3.** *(Arbitrage capital and aligned deviations)* $D \uparrow \Rightarrow |\kappa - b| \downarrow$ and $\lim_{D \to \infty} \kappa - b = 0$. An increase in the total amount of debt issuance decreases the absolute value of the net deviation. As the total amount of debt increases toward infinity, the two deviations become identical.

**Proposition 4.** *(Limits to arbitrage spillover)* Comparative statics with respect to variables indicating prices of risk are as follows:

<table>
<thead>
<tr>
<th>FX haircut $\gamma \uparrow$</th>
<th>Credit investor risk tol. $\tau \uparrow$</th>
<th>bond risk $V \uparrow$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$</td>
<td>\kappa</td>
<td>\uparrow \downarrow \uparrow$</td>
</tr>
</tbody>
</table>

Proposition 4 suggests that limits of arbitrage are carried over from one market to the other. For instance, while the haircut on FX swap trades $\gamma$ directly affects CIP basis $b$, $\gamma$ also indirectly affects the credit spread differential $\kappa$ through the action of the cross-market arbitrageur. Similarly, the risk tolerance of bond investors $\tau$ and bond risk $V$ also affect CIP deviation. Thus, limits of arbitrage from one market can spill over to a completely different market.

### 3.5 Distinction from intermediary-based asset pricing

The model developed above is also useful for assessing alternative explanations of the alignment between the two anomalies. One alternative hypothesis is based on intermediary-based asset pricing. Under this alternative, a financial intermediary with financing constraint trades in both the FX market and credit market. Deviations might be correlated when there are fluctuations in the binding constraints for the common intermediary. A way of incorporating this alternative in the framework above is to define a common intermediary constraint $\lambda$ that
captures the constraints faced by the FX trader and active credit investors, i.e. \( \lambda \equiv \gamma^2 = c\gamma \), where \( c \) is a constant. In the presence of a shock to \( \lambda \), both \( \kappa \) and \( b \) would be affected.

There are three reasons to falsify this alternative hypothesis in explaining the alignment of credit spread differential, CIP deviation and issuance flow. First, absent of net demand imbalances in each market, changes in \( \lambda \) would not cause deviations to occur; it would only amplify the effect of demand imbalances. Second, while the absolute value of deviations would be correlated through intermediary capital (i.e., \( \frac{\partial |b|}{\partial \lambda} \propto \frac{\partial |\kappa|}{\partial \lambda} \)), changes in \( \lambda \) would not explain the direction and magnitude of the deviations in \( b \) and \( \kappa \) across time and the cross section of currencies. Lastly, changes in \( \lambda \) does not speak to co-movement of the net deviations \( \kappa - b \) with capital flow \( \mu \). Therefore, the mechanism involving demand imbalances that impact multiple markets is distinct from one that focuses on fluctuations in \( \lambda \).

4 Firms as natural cross-market arbitrageurs

The cross-market arbitrageurs in the model can be broadly interpreted as global investors as well as firms. I focus the capital flow analysis on firms for a few reasons.

To consider issuance flow as arbitrage capital, it must be the case that investors are not supplying sufficient arbitrage capital. Why might investors be constrained in performing the arbitrage? While many institutional investors such as pension funds, life insurance companies, and endowments have diversified exposure to bonds in different currencies, they often have clear mandates on their benchmarks and currency exposure. The rigidity of their mandates allows for little discretion in their portfolio allocation choice. They are also often limited in their usage of derivatives due to the lack of expertise and regulatory restrictions. Mutual funds and hedge funds in fixed income also typically follow benchmarks. Unrestricted global funds are limited in size. For instance, global bond mutual funds hold only a total of €55 billion of EUR corporate bonds\(^{28}\). For these reasons, investors have heavy bias in investing in their own currencies as shown by Matteo, Neiman, and Schreger (2018).

The limited number of hedge funds that do engage in the active trading of global credit markets face balance sheet constraints and high transaction costs in round-trip arbitrage. This is because a long-short strategy requires conducting repo borrowing in one market and reverse-repo lending in the other market to fund the bond positions while also engaging in FX hedging. Limits to arbitrage associated with investor redemption and a short investment horizon as highlighted in Shleifer and Vishny (1997) pose a challenge to specialized funds that perform arbitrage. Dealers are also unable to fully arbitrage CIP violation as a result of balance sheet frictions such as Funding Valuation Adjustments as suggested by Andersen,

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\(^{28}\)EPFR data
Duffie and Song (2019). In short, dedicated investors simply do not have enough capital or financing to digest large demand shocks.

Firms are natural arbitrageurs to exploit capital-intensive, slow-convergence arbitrage opportunities. They can bear noise-trader risk, withstand large mark-to-market losses, and endure long investment horizons. Previous papers have examined the role of corporate arbitrageurs in other contexts (Baker and Wurgler [2000], Greenwood, Hanson, and Stein [2010], and Ma [2015]). Because firms have stable cash flows and do not face redemption, a one-time issuance and hedging choice is equivalent to holding an arbitrage trade to maturity. The standard deviation of monthly issuance flow between the Eurozone and the U.S. is more than $6 billion in the data sample. This is equivalent to the creation and destruction of a sizable hedge fund fully dedicated to exploiting the two pricing anomalies at the monthly frequency.

An additional reason to focus the empirical analysis of capital flow on debt issuance is because of the availability and relative comprehensiveness of the data. Debt offerings are typically recorded in public filings and broadly advertised to investors even if the offering is private. Issuance also mirror institutional investor demand in the size and frequency of offerings. In contrast, comprehensive global investor holding data, especially those from institutional investors, are limited for research.

**Evidence from textual analysis of SEC filings** I find evidence of firms engaged in FX-hedged debt issuance through a textual analysis of SEC filings by S&P 500 firms. Fig. [12] graphs the fraction of 10K filings with mentions of words relating to (1) “debt”, (2) “exchange rate”, (3) “hedging”, and (4) “derivatives” in the same sentence. The restriction of having all four groups of words appear in a single sentence likely under-estimates the actual disclosure of currency-hedged issuance since the disclosure could be relayed in multiple sentences. While this proxy might be imperfect, it nonetheless indicates that a substantial fraction of S&P 500 firms has engaged in currency-hedged issuance in recent years. The sharp rise in this proxy from 2007 to 2010 corresponds to the period when deviations in the credit and CIP markets first begin to emerge. This analysis attests to the pervasiveness of firms acting as cross-market arbitrageurs between the credit market and CIP market in recent years.
Figure 12 Textual analysis of FX-hedged foreign debt issuance for S&P 500 firms

Examples of SEC filings with mentions of currency-hedged debt issuance

Fraction of 10K filings with mentions of currency-hedged debt issuance
5 Additional tests of model predictions on capital flow

In this section, I provide further validation of the theoretical framework using data on bond issuance. I first describe the measurement of issuance flow and patterns in the misalignment. Then I present evidence supporting the model predictions using structural VAR analysis, price impact event study around large issuance dates, forecast of capital flow, firm-level analysis and an instrumental variable approach with debt rollovers.

5.1 Definition of issuance flow $\mu$

To test the model predictions on cross-currency capital flow, I analyze the amount of corporate debt issued by public firms in the seven free-floating funding currencies. Debt issuance amount and other bond characteristics are obtained from the Thomson One SDC Platinum data set. I focus on bilateral issuance flows with the U.S. since the U.S. corporate bond market is the largest, with more than one-third of the global corporate debt issuance in the data sample. I define the monthly bilateral issuance flow between two currency regions as the amount of debt issuance by foreign firms in USD minus the amount of debt issuance by U.S. firms in the corresponding foreign currency expressed as a percentage of total issuance. For example, the bilateral issuance flow between the European Monetary Union (EMU) and the U.S. is expressed as

$$issPct^{EMU\rightarrow US} = \frac{EMU\text{ firm issuance in USD} - U.S.\text{ firm issuance in EUR}}{total\text{ issuance in USD & EUR}}.$$ 

This variable definition aims to capture the issuers’ active behavioral of reaching across currency boundaries to cater to investor demand. An alternative measure is the ratio of all debt issuance in a currency to total issuance. However, this alternative measure is confounded by changes in overall investment opportunity and debt issuance needs in local currency regions and is less representative of the issuers’ active currency denomination choice.

5.2 Prediction 1: spillover of deviations

I test the spillover of deviations through the channel of debt issuance by analyzing the impulse responses of credit spread differential $\kappa$, CIP violation $b$, and issuance flow $\mu$ to $\varepsilon_\kappa$ and $\varepsilon_b$ shocks. Additionally, I show that large issuances have a price impact on the FX basis.

**SVAR analysis** Structure vector auto-regression (SVAR) analysis is informative in this context since the simultaneity of $\varepsilon_\kappa$ and $\varepsilon_b$ shocks and slow issuance responses pose particular challenge to identification. As discussed in Section 3, there are many potential sources of
$\varepsilon_\kappa$ and $\varepsilon_b$ shocks. These shocks can occur concurrently, and they can be protracted and anticipated (e.g., gradual regulatory changes). Moreover, arbitrage capitals provided by non-specialized agents are often slow to react to market distortions due to inattention and institutional impediments to immediate trade (Duffie, 2010; Mitchell, Pedersen and Pulvino, 2007). In this setting, cross-currency issuance responds to shocks gradually only when firms have issuance needs.

Fig. 13 presents the orthogonalized impulse response functions with shocks to the credit and CIP deviations. I apply Cholesky Decomposition using a strict ordering of variables assuming that issuance responds with a lag to both $\kappa$ and $b$, and $b$ respond with a lag to $\kappa$. That is, I estimate the following:

$$
\begin{pmatrix}
1 & 0 & 0 \\
a_{\kappa\mu} & 1 & 0 \\
a_{b\mu} & a_{bc} & 1
\end{pmatrix}
\begin{bmatrix}
\mu_t \\
\kappa_t \\
b_t
\end{bmatrix}
= B
\begin{bmatrix}
\mu_{t-1} \\
\kappa_{t-1} \\
b_{t-1}
\end{bmatrix}
+ \begin{bmatrix}
\varepsilon_{\mu,t} \\
\varepsilon_{\kappa,t} \\
\varepsilon_{b,t}
\end{bmatrix}.
$$

Since it is ambiguous whether CIP deviations arise before distortions in credit spread, I also consider an alternate ordering in which $\kappa$ responds with a lag to $b$. This alternate specification yields similar result and is presented along with a partial identification approach\textsuperscript{29} in the Internet Appendix. I conduct this analysis for both on EURUSD and on all six currency pairs against USD in a panel VAR. The resulting impulse response functions are similar.

Proposition 1 states that an exogenous increase in foreign currency credit demand tightens the credit spread differential $\kappa$ (relative to USD), increases foreign currency issuance and reduces USD debt issuance $\mu$, and widens currency basis $b$ to be more negative (more expensive to swap foreign issuance proceeds to USD). The first row of Fig. 13 confirms this model prediction. Upon a shock that decreases $\kappa$ (top left), both $\mu$ (top middle) and $b$ (top right) are reduced. Credit spread differential then gradually normalizes over the next few months after the initial shock, as do $\mu$ and $b$.

The persistence of response in issuance flow $\mu$ to $\varepsilon_\kappa$ and $\varepsilon_b$ shocks suggests that corporate financing decisions are slow-moving. The price under-reaction in the market not receiving direct shock (the reactions of $\kappa$ to $\varepsilon_b$ and $b$ to $\varepsilon_\kappa$) also conforms with model prediction of asset dynamics in slow-moving, partially segmented markets (Greenwood, Hanson, and Liao, 2018).

The bottom row presents the impulse responses with an exogenous shock in $\varepsilon_b$ that signals an increase in the cost of swapping to USD from other currencies (more negative $b$). As predicted by Proposition 1, we observe the exact opposite dynamics in the second row.

\textsuperscript{29}The partial identification approach restricts $\mu$ to respond with a lag to $\kappa$ and $b$ but allows $\kappa$ and $b$ to have contemporaneous effects on each other.
Figure 13 Impulse responses of deviations and issuance flow

Foreign currency credit demand shock: $\varepsilon_c \uparrow \Rightarrow \kappa \downarrow \quad \text{Foreign credit tightens}
\mu \downarrow \quad \text{reduced issuance in USD}
\mu \downarrow \quad \text{FX basis widens}

Dollar liquidity shock: $\varepsilon_b \uparrow \Rightarrow \mu \uparrow \quad \text{FX basis widens}
\kappa \downarrow \quad \text{tighter foreign credit spread}

This figure plots the orthogonalized impulse responses to $\varepsilon_c$ and $\varepsilon_b$ shocks for structure panel vector auto-regression. The choice of lag 1 is selected by Bayesian Information Criteria. 95% confidence intervals are shown in gray.
FX swap to USD initially becomes costly, $b$ is more negative (bottom left). Issuance flow initially shifts toward USD (bottom middle), then the issuance flow gradually normalizes over the next nine months. Foreign currency credit spread relative to USD credit spread also decreases gradually before plateauing around six months after the shock (bottom right).

**Issuance impact on FX bases** I find evidence of price impact on CIP basis during large issuance flows, a phenomenon consistent with the channel for deviation alignment. Large cross-currency debt issuances are a recurrent source of FX-hedging demand and a laboratory for studying price impact. Debt issuance is announced ahead of the actual issuance date and anticipated by market participants. Anecdotal accounts of FX traders front running large cross-currency issuance and issuers’ placement agents pre-hedging in advance of the actual debt offering date would suggest possible FX swap price movements prior issuance date. I conduct an event study that examines changes in CIP deviation (FX basis) around days with large cross-currency issuance. The event dates are defined for each currency pair as dates for which there are large total issuance (greater than $250mm) of dollar-denominated bonds by foreign firms (often referred to as Yankee bonds) and dates on which there are large foreign-currency bonds issued by U.S. firms (Reverse Yankee bonds). For instance, if the sum of USD-denominated bond issued by Australian firms is greater than $500mm on a particular date, this date is categorized as a large Yankee bond issuance date for AUDUSD. Defining event dates using other issuance size cutoffs of significant size, i.e. $250 million, $1 billion, generates similar results. With an issuance size cutoff of $500 million, 7.8% of the trading days qualify as large Yankee issuance events and 2.5% of the sample qualifies as large reverse Yankee issuance events averaged across the six currencies.

Fig. [14] presents the event study result. On the days before large dollar bond issuance by foreign firms, the price of swapping bond proceed from USD to the foreign currency gradually increases until the event date (red line). The reverse price action can be observed for large issuance by U.S. firms in the foreign currency (blue line).

Similar to the price impact on FX bases, new debt supply also have impact on the credit spread at the individual firm and the aggregate level. For instance, Newman and Rierson (2004) show that an issuance of 15.5 billion Euros by Deutsche Telekom had noticeable

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30 Dollar debt issuance by foreign firms can occur both in the U.S. bond market (Yankee bonds) or in the international Eurobond market. I emphasize on the currency denomination and therefore include bonds of both types.

31 Alternatively, defining large cross-currency issuance event days by quantile for each of the currencies separately also produce similar results. For instance, I define event dates as the top 1% of days with large dollar bond issuance by firms originating in the E.M.U. (the corresponding absolute cutoff size is $8 billion). I also perform additional robustness checks by removing the impact of large outliers, defining event dates as ones that has cross-currency issuance of size between $500 mm and $3 billion.
Figure 14 Impact of large cross-currency issuance on FX basis

This figure graphs changes in five-year CIP deviation around dates with large cross-currency issuance for EUR, GBP, AUD, JPY, CHF, and CAD relative to USD. Yankee bond issuance refers to dollar denominated bond issuance by non-U.S. firms and reverse Yankee issuance refers to non-dollar denominated bond issuance by U.S. firms. The dashed lines represent the 95% confidence interval from bootstrapping with 1,000 draws.
pricing impact on the entire European telecom debt sector. Given that the residualized credit spread differential is estimated with a standard error, the same event study approach on the residualized credit spreads cannot be as easily applied.

5.3 Prediction 2: Issuance flow and net deviation

Another prediction from the model is that capital flow fluctuates with the net deviation in predictable directions. As firms observe different cost of borrowing inclusive of FX hedging cost, they shift issuance from one currency to another.

I conduct SVAR analysis on the issuance flow and the net deviation allowing issuance to respond with a lag to shocks to the net deviation and estimate the following

\[
\begin{bmatrix}
1 & 0 & \mu_t \\
\alpha_{\kappa-b,\mu} & 1 & \kappa_t - b_t \\
\end{bmatrix}
= B
\begin{bmatrix}
\mu_{t-1} \\
\kappa_{t-1} - b_{t-1} \\
\end{bmatrix}
+ \begin{bmatrix}
\varepsilon_{\mu,t} \\
\varepsilon_{\kappa-b,t} \\
\end{bmatrix},
\]

where \( \mu_t \) is the bilateral issuance flow, \( \kappa_t \) is the credit spread differential, and \( b_t \) is the CIP deviation.

Fig. 15 presents the orthogonalized impulse response function of issuance flow upon a shock to the net deviation. The impulse response shows that issuance flow continues to be significant up to 10 months after a shock to the net deviation.

Figure 15 Impulse response of issuance flows to shock to net deviation

This figure shows the orthogonalized impulse response of monthly issuance flows to shock to the net deviation. The choice of one-period lag is selected by Bayesian Information Criteria. Confidence intervals at the 95% level are shown in gray.

The co-movement of issuance flow and net deviation can also be examined through forecasting regressions. Table 2 presents regression results showing the relation between net
deviation (effective credit spread differential) and issuance flow. To account for the gradualness in issuance response, I examine the relation between net deviation at month \( t \) and issuance flow averaged over the following six months.

The coefficient on net deviation for EMU-U.S. bilateral issuance flow in the first column is economically and statistically significant. The coefficient of 0.285 means that for each basis point increase in the net deviation (indicating more attractive borrowing costs in USD), firms tilt their borrowing toward USD-denominated debt by 0.285 percent of their total issuance. This is large and corresponds to an increase of 4% in dollar borrowing for each standard deviation increase in the net deviation. The R-squared in this univariate regression (column 1) is 0.34, indicating that the net deviation explains a sizable portion of issuance flow variation. The coefficients for GBP, JPY and CHF (column 2, 3, and 5) are also positive and suggest a response of issuance flow to net deviation, corroborating model prediction. The smaller size of the coefficients for these three currencies indicates weaker bilateral flow response and reflects smaller bond market (as the issuance flow is scaled by the total size of issuance in USD and the alternate currency). The coefficients for AUD and CAD (column 4 and 6) show muted issuance response to net deviation; this discussion is deferred to later in this section.

Columns 7 to 12 present the issuance response regression with a control for interest rate differential. The interest rate differential measures FX-unhedged (dis)advantage of issuing in one currency versus another. One interpretation of this variable is that it proxies for carry trade motives. The interest rate differential coefficient is small and insignificant for EUR, GBP, and CHF (columns 7, 8, 11). This result suggests that issuance flow is responsive to FX-hedged borrowing cost difference rather than FX-unhedged carry incentives for these currencies. For JPY (column 9), both hedged cost difference and unhedged cost difference is significant; the hedged cost difference have a larger coefficient size but the coefficient for unhedged cost difference is more significant.

Columns 13 to 18 show the issuance response to CIP deviation and credit spread differential separately. The directions of the response match model predictions. The negative coefficients on CIP deviation indicate that firms issue more in USD when the FX basis is wide (more negative), more costly to swap from the other currency to the U.S. dollar. The positive coefficients on credit differential indicate that when credit spread is wide in the other currency relative to the dollar, firms issue more in the dollar. The model also predicts that issuance flow should respond to both \( \kappa \) and \( b \) to the same degree. The size of the coefficients for the two deviations is on the same orders of magnitude for EUR, GBP and CHF. Hence, the relatively smaller coefficient size for credit spread differentials might be because the measure itself is estimated with uncertainty around the point estimate.
In contrast to statistically significant net deviation coefficient for EUR, GBP, JPY, and CHF, issuance flow response to the net deviation is close to zero for AUD and CAD (column 4 and 6). One possible interpretation is that issuance flow is an important source of arbitrage capital in some currency pairs, but it is not a dominant force of arbitrage capital for other currency pairs. On the contrary, the table shows that coefficients on interest rate differential (in column 10 and column 12) is highly significant for AUD and CAD. As local interest rate differential proxies unhedged carry trade returns, these coefficients indicate that issuers might be issuing unhedged for carry trade motives, a phenomenon that Bruno and Shin (2017) documented for corporate issuers in emerging markets. Related to this hypothesis, CIP deviations in AUD and CAD relative to USD are less correlated with their credit spread differentials as presented earlier in Fig. 7 and Table 1.

Table 3 presents the response of issuance flow sensitivity pre- and post- financial crisis. The dependent variable is the aggregated issuance flow between the U.S. and the combined four currency regions (EMU, U.K., Japan, and Switzerland) that exhibit sensitivity of issuance to deviations. The per-crisis sample displays insignificant issuance response to deviations (column 2 and 5); this is in contrast with strong issuance flow response to deviations after the crisis (column 3 and 6). The result suggests that debt issuing firms started to arbitrage the deviations at the aggregate level only after the crisis. This is possibly because the deviations were smaller in pre-crisis period and that traditional institutions such as banks played a larger role in arbitrage activities.

**Firm-level analysis** The aggregate results showing the response of capital flow to the pricing anomalies can also be tested using a panel of firm-specific credit spread differentials. I explore the decision of firms’ currency debt choice with a linear probability model. The firm-level study relies on variations within firm and cross-sectionally within time period, it therefore serves as validation of the aggregate result. To construct firm-specific credit spread differentials, I estimate the cross-sectional regression at each date $t$, $S_{it} = \alpha_{ct} + \delta_{ft} + \alpha_{ct} \cdot \delta_{ft} + \varepsilon_{it}$, where $S_{it}$ is the credit spread for bond $i$ issued in currency $c$, by firm $f$. $\alpha_{ct}$ and $\delta_{ft}$ are currency and firm fixed effects. The firm-specific residualized credit spread differential, $\kappa_{fct}$, is estimated as $\kappa_{fct} \equiv \hat{\alpha}_{ct} + \hat{\delta}_{ft} + \hat{\alpha}_{ct} \cdot \hat{\delta}_{ft}$. I also construct firm-specific net deviation $\Psi_{fct}$ using the same approach except with credit spread adjusted for FX basis $S_{it}^{adj}$ as the dependent variable. Table 4 presents the result of the firm-level currency choice analysis. Column 1 shows that a firm’s debt currency choice is sensitive to both its own credit spread and the commonly observed FX swap basis. Each standard deviation increase in the firm-specific credit spread differential $\kappa_{fct}$ is associated with 1.6% decrease in the probability of issuing that that currency. Each standard deviation increase in $b$ (a reduction in the cost of
### Table 2 Issuance flow response

This table presents forecasting regressions of future issuance flow. The dependent variables measure the bilateral issuance flow between a foreign currency region and the U.S. It is defined as the amount of debt issuance by foreign firms in dollar minus the amount of debt issuance by U.S. firms in the foreign currency scaled as a percentage of total issuance. This measure is calculated as an average over the following six months. The sample period is from January 2004 to July 2016 with monthly observation. \( t \)-statistics in brackets are based on Newey-West (1987) standard errors with lag selection following Newey-West (1994).

\[
issPct_{\text{net}, \text{avg.}}^{\text{Foreign} \rightarrow \text{US}} = a + b \cdot \text{netdev}_t + c'X_t + \varepsilon_{t+1}
\]

<table>
<thead>
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<th>net dev.</th>
<th>0.285</th>
<th>0.164</th>
<th>0.0462</th>
<th>-0.011</th>
<th>0.115</th>
<th>0.0241</th>
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<td></td>
<td>[4.70]</td>
<td>[2.48]</td>
<td>[1.79]</td>
<td>[-0.10]</td>
<td>[3.44]</td>
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<td>-0.0165</td>
<td>0.0256</td>
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<td>0.00675</td>
<td>0.0093</td>
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<td>[1.14]</td>
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<td>-0.154</td>
<td>0.0804</td>
<td>-0.151</td>
<td>-0.243</td>
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<td>[-4.72]</td>
<td>[-6.94]</td>
<td>[0.92]</td>
<td>[-3.90]</td>
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<td>0.12</td>
<td>0.0194</td>
<td>0.0215</td>
<td>0.0057</td>
<td>-0.00511</td>
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<tr>
<td></td>
<td>[4.92]</td>
<td>[1.97]</td>
<td>[1.15]</td>
<td>[0.16]</td>
<td>[2.12]</td>
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<td>_cons</td>
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<td>8.72</td>
<td>0.558</td>
<td>7.88</td>
<td>-0.704</td>
<td>7.6</td>
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<td>151</td>
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</table>

Bilateral net issuance flow to dollar credit market by currency region origin
Table 3 Pre- and post-crisis issuance flow sensitivity

This table presents forecasting regressions of future issuance flow using net deviation, CIP basis $b$, and credit differential $\kappa$. $t$-statistics in brackets are based on Newey-West (1987) standard errors with lag selection following Newey-West (1994).

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
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<th>6</th>
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<td></td>
<td>full sample</td>
<td>Pre-2009</td>
<td>Post-2009</td>
<td>full sample</td>
<td>Pre-2009</td>
<td>Post-2009</td>
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<td>0.132</td>
<td>-0.224</td>
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<td>CIP dev.</td>
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<td></td>
<td>0.112</td>
<td>0.0182</td>
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<td>91</td>
<td>151</td>
<td>60</td>
<td>91</td>
</tr>
<tr>
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<td>0.00</td>
<td>0.31</td>
<td>0.54</td>
<td>0.01</td>
<td>0.34</td>
</tr>
</tbody>
</table>

swapping from non-dollar currency to USD) is associated with 7.2% increase in the probably of issuing in the currency. Column 2 shows that the impact of firm-specific net deviation is equally large. A one standard deviation increase in net deviation (more expensive FX-hedged non-USD issuance) reduces foreign issuance by 3.6%.

5.4 Prediction 3: Arbitrage capital and deviation alignment

Prediction 3 states that an exogenous increase in debt issuance amount $D$ allows firms to deploy more arbitrage capital and reduces the net deviation. As $D$ increases toward infinity, we would expect the net deviation to converge toward zero. In this section, I analyze whether changes in the amount of arbitrage capital affect the net deviation by an instrumental variable approach that uses the amount of maturing debt to instrument for the need to roll over and refinance through new debt issuance. Specifically, I run a regression of the following form:

$$\Delta|\kappa - b|_{t,c} = \alpha + \beta_1 D_{t,c} + \varepsilon_t,$$

where $\Delta|\kappa - b|_{t,c}$ is the monthly change in the absolute value of net deviation and $D_{t,c}$ is the total amount of debt issued in both currency $c$ and USD in month $t$. Note that $D_{t,c}$ is the amount of debt issued at time $t$, not the level of outstanding debt.

Conceptually, the analysis relies on the assumption that firms are being opportunistic on the relative allocation of issuance in different currencies rather than engaged in market
### Table 4 Firm-level issuance choice and violations in credit and CIP

This table presents regressions of firm-level debt denomination choice on credit spread differential and CIP deviation. I estimate the probability that a firm issues debt in currency $c$ conditional on the firm issuing debt in that quarter. I estimate the following specifications in column 1:

$$I_{ftc} = \beta_0 + \beta_1 \kappa_{ftc} + \beta_2 b_{ct} + X_{it}' \beta + \varepsilon_{ftc},$$

$I_{ftc}$ is an indicator variable that equals 1 if firm $f$ issues in currency $c$ in quarter $t$. $\kappa_{ftc}$ is the firm-specific residualized credit spread differential defined in the text. In column 2, I estimate the regression with net deviation as the independent variable,

$$I_{ftc} = \beta_0 + \beta_1 \Psi_{ftc} + X_{it}' \beta + \varepsilon_{ftc},$$

where net deviation $\Psi_{ftc}$ is estimated similarly to $\kappa_{ftc}$. $t$-statistics in brackets are based on robust standard errors clustered by firm and time.

<table>
<thead>
<tr>
<th></th>
<th>probability of issuing in ccy $c$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
</tr>
<tr>
<td></td>
<td>(2)</td>
</tr>
<tr>
<td>credit diff $\kappa_{ftc}$</td>
<td>-0.0727 [-5.41]</td>
</tr>
<tr>
<td>cip $b$</td>
<td>0.135 [3.19]</td>
</tr>
<tr>
<td>net dev. ($\Psi$)</td>
<td>-0.074 [-5.53]</td>
</tr>
<tr>
<td>firm FE</td>
<td>x</td>
</tr>
<tr>
<td>time FE</td>
<td>x</td>
</tr>
<tr>
<td>rsq</td>
<td>0.18</td>
</tr>
<tr>
<td>n</td>
<td>28726</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>probability of issuing in ccy $c$</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>firm FE</td>
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</tr>
<tr>
<td>time FE</td>
<td>x</td>
</tr>
<tr>
<td>rsq</td>
<td>0.18</td>
</tr>
<tr>
<td>n</td>
<td>28726</td>
</tr>
</tbody>
</table>
timing and changing the total issuance amount. Even though the market timing motive is important and documented in a number of studies, it does not preclude the choice analyzed here that focuses on the relative currency denomination conditional on firms having decided the total amount of debt to issue.

To address the potential concerns with the endogenous debt issuance decision, I instrument the debt issuance amount with the maturing debt amount, $M_{t,c}$. Firms frequently issue new debt to rollover maturing debt. When deciding to rollover old debt, firms can choose a denomination currency different from that of the maturing debt. In effect, the amount of debt that needs to be rolled over represent arbitrage capital that issuers can deploy to take advantage of profitable deviations.

Table 5 presents the result of this analysis. Column 1 shows the OLS regression estimates and column 4 shows the IV result. The coefficients on debt issuance amount is significant and economically meaningful. For each standard deviation ($25 billion) increase in total issuance amount in USD and EUR debt, the net deviation is reduced by around two basis points. This price elasticity is likely an underestimate due to anticipatory effect of debt issuance and front-running by other market participants. Debt issuance and rollovers are pre-announced (through roadshows, dealers and regulatory filings) and anticipated by investors and hedge funds ahead of the time. The full unanticipated effects are likely larger.

5.5 Prediction 4: Spillover of limits to arbitrage

Lastly, I discuss suggestive evidence of limits to arbitrage spillover. The model shows that frictions that are constraining in one market can also be constraining for the other market. These limits to arbitrage frictions can be either quantifiable costs, such as transaction costs, or difficult-to-observe frictions, such as agency frictions. In the model, these constraints are represented by FX swap collateral haircut $\gamma$ in Eq. 7 and the ratio of bond risk to risk tolerance $\frac{V}{\gamma}$ in Eq. 6. The FX haircut is a direct cost while the latter might proxy for indirect agency frictions associated with holding an arbitrage position that could become more dislocated before converging.

The empirical measures of these two types of limits to arbitrage are difficult to assess. FX collateral haircut for a derivative transaction is specific to the trade and depends on the currency, maturity, and counterparty. The indirect costs of holding arbitrage positions to maturity are also challenging to quantify. As a suggestive test, I analyze the impact of broker-dealer leverage, proxying for $\gamma$, and the VIX index, proxying for $\frac{V}{\gamma}$, on the absolute level of credit spread differential and CIP deviation. The results, presented in table 6, are suggestive of Prediction 4 in the model. Column 1 and 3 shows that a positive innovation to
Table 5 Debt issuance amount and deviation alignment

This table presents regressions of the monthly change in the absolute value of net deviation on total debt issuance amount in the same month. The regression is specified as follows:

$$\Delta|\kappa - b|_{c,t} = \alpha_c + \beta_1 D_{c,t} + \varepsilon_t,$$

where $D_{c,t}$ is the total combined amount of debt issued in currency $c$ and USD expressed in $\text{billion}$s, where $c = \text{AUD, CAD, CHF, EUR, GBP, or JPY}$. The amount of debt issued is instrumented by the amount of maturing debt, $M_{c,t}$. Column 1 shows the OLS result with debt issued. Column 2 shows the reduced-form regression with maturing debt. Column 3 shows the first stage regression of issued debt on maturing debt. Column 4 shows the IV regression. $t$-statistics in brackets are based on robust standard errors clustered by time.

|                  | OLS $D_{c,t}$ | Reduced form $\Delta|\kappa_{c,t} - b_{c,t}|$ | 1st stage $\Delta|\kappa_{c,t-1} - b_{c,t-1}|$ | IV |
|------------------|---------------|---------------------------------------------|-----------------------------------------------|----|
|                  |               | $\beta_1$                                  |                                               |    |
|                  |               |                                              |                                               |    |
|                  | -0.080        | -0.0939                                     |                                              |    |
|                  | [-3.98]       | [-2.05]                                     |                                              |    |
| $M_{c,t}$        | -0.0500       | 0.525                                       |                                              |    |
|                  | [-2.42]       | [4.94]                                      |                                              |    |
|                  | -0.089        | -0.073                                       | -0.0929                                       |    |
|                  | [-1.44]       | [-1.16]                                     | [1.29]                                        |    |
| ccy fe           | x             | x                                           | x                                             | x  |
| rsq              | 0.05          | 0.01                                        | 0.63                                          | 0.05|
| n                | 1180          | 1180                                        | 1198                                          | 1180|

44
broker-dealer leverage factor is associated with reductions in the absolute level of CIP basis and credit spread differential. Column 2 and 4 shows that a positive increase in the VIX index is associated with increases in the absolute level of the two deviations. I treat these results as suggestive evidence only since these variables are proxies to the model parameters.

Table 6 Broker-dealer leverage and risk tolerance

This table presents the regression of the absolute level of deviations on broker-dealer leverage and the VIX index. Broker-dealer leverage factor is constructed following Adrian, Etula and Muir (2014) using the Flow of Funds data.

<table>
<thead>
<tr>
<th></th>
<th>CIP basis</th>
<th>credit diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>levfac</td>
<td>-1.755</td>
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</tr>
<tr>
<td></td>
<td>[-2.26]</td>
<td>[-3.40]</td>
</tr>
<tr>
<td>vix</td>
<td>0.499</td>
<td>0.932</td>
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<tr>
<td></td>
<td>[3.25]</td>
<td>[4.15]</td>
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<tr>
<td>_cons</td>
<td>18.37</td>
<td>9.589</td>
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<tr>
<td></td>
<td>[8.09]</td>
<td>[2.40]</td>
</tr>
<tr>
<td></td>
<td>17.83</td>
<td>0.947</td>
</tr>
<tr>
<td></td>
<td>[8.70]</td>
<td>[0.21]</td>
</tr>
<tr>
<td>N</td>
<td>288</td>
<td>906</td>
</tr>
</tbody>
</table>

6 Case Studies

This section discusses two case studies that are illustrative of credit shock $\varepsilon_\kappa$ and FX funding shock $\varepsilon_b$. These cases highlight the model’s predictions as well as its shortcomings. I construct daily residualized credit spread differential using the cross-sectional regression approach similar to before. The use of daily pricing data rather than month-end data introduces larger standard errors in the estimates. The 95% confidence interval is generally tight in the range of 10 basis points, but can be over 50 basis points during the peak of the crisis.

6.1 U.S. credit crunch and Bear Stearns downfall

U.S. credit crunch in early 2008 marked by the downfall of Bear Stearns is a plausible example of $\varepsilon_\kappa$ shock that was not associated with $\varepsilon_b$ shock. I focus on this episode for two reasons. First, the collapse of Bear Stearns did not result in pervasive halting of trading and liquidity provision in the fixed income and derivatives markets as there were with Lehman’s collapse. In the language of the model presented earlier, Lehman’s collapse resulted in simultaneous $\varepsilon_\kappa$ and $\varepsilon_b$ shocks as counterparties frantically searched to replace their unmatched book
exposure across asset classes immediately following Lehman’s bankruptcy. In contrast, Bear Stearns’ downfall is more representative of a $\varepsilon_\kappa$ shock without a $\varepsilon_b$ shock. Second, the collapse of Bear Stearns was a more unexpected credit event rather than a liquidity shock compared to the collapse of Lehman Brothers. Bear Stearns’ stock price was as high as $68$ a share on March 11, 2008, the week prior to it agreed to be bought out by JP Morgan at the price of $2$ a share on March 17, 2008.\footnote{A revised deal of $10$ a share was struck on March 24, 2008 as a class action was filed on behalf of shareholders challenging the original terms of the acquisition.} In comparison, Lehman’s collapse followed a prolonged deterioration in its stock price from around $20$ per share in the beginning of 2008 to $10$ a share on September 12, 2008, the Friday before its filing of bankruptcy.

Fig. \ref{fig:16} shows the two deviations and the monthly net issuance flow around the time of Bear Stearns’ collapse and the onset of the Financial Crisis. The two vertical lines indicate the collapse of Bear Stearns and Lehman Brothers respectively. Panel A shows that the residualized dollar credit spread widened (relative to euro spread) in March 2008. This deterioration in dollar credit market might reflect a shift in sentiment rather than fundamentals as the calculated credit spread is residualized and controls for firm fixed effect and other observables. The dollar credit crunch eased somewhat over the next few months, but dollar credit remained underpriced relative to euro credit over the summer. In contrast, CIP deviation did not show much response initially upon Bear Stearns’ collapse but drifted downwards more gradually over the summer. Panel B shows that large net issuance flow from U.S. to Europe ensued in March and continued for several months until July. This suggests that more U.S. firms decided to issue in Europe, as the credit condition in the U.S. was unfavorable. Their debt-related hedging might have contributed to the more gradual downward drift of CIP violations, making swapping proceeds from EUR to USD more expensive. The direction of issuance flow and subsequent reactions in CIP deviations were in line with model predictions.

\subsection{European Sovereign Crisis, 2011-2012}

The European Sovereign Crisis was plausibly associated with larger $\varepsilon_b$ shock than $\varepsilon_\kappa$ shock. Concerns over European sovereign debt started to surface in 2009 and intensified in the early part of 2011. In May 2011, large outflows in money market funds that are exposed to European banks led to a shrinkage of short-term dollar currency funding for these banks. The total money-fund holdings of European bank paper declined by 37\%, from $453$ billion to $287$ billion, between May and August of 2011, according to Chernenko and Sunderam (2014). The shrinkage of the dollar money market funding meant that Eurozone banks with dollar lending needed to rely on the FX swap market to fund their dollar asset, and this
created direct pressure that led to CIP deviation (Ivashina, Scharfstein, and Stein 2015).

Fig. 17 shows the two deviations and the monthly net issuance flow during this period. Panel A shows that the 5-year CIP deviation widened from around -15 bps in early May to -70 bps by January 2012 indicating it was costly to borrow dollar/lending euro through the FX funding market. As the European banks were in need of replacing its short-term wholesales funding, the widening in CIP for shorter maturities was much larger and led the widening across the maturity curve. Panel B shows that the 3-month CIP widened to as much as -125 basis points around this time.

Panel C shows that net issuance flow that were previously tilted toward European firms issuing in the U.S. declined dramatically from over $12 billion in April 2011 to close to zero over the reminder of the year. The net issuance flow, however, did not reverse direction. There were few U.S. firms attempting to issue in EUR to take advantage of the net deviation. This perhaps indicates a reluctance to issue in EUR given uncertainties regarding the future of the currency. Global credit investors likely also shared the firms’ concerns when deciding on investment opportunity. As a result of the slowness and reluctance in capital deployment, the residualized credit spread only gradually declined over this period.
Figure 16 Case study: U.S. credit crunch in 2008

This figure shows the residualized credit spread differential and CIP deviation (Panel A) and issuance flow (Panel B) from November 2007 to November 2008 for EURUSD. The two vertical lines indicate the downfall of Bear Stearns and Lehman Brothers respectively. Vertical gray bars represent the 95% confidence interval with firm-level clustering.

Panel A: Residualized credit spread differential and CIP deviations

Panel B: Net issuance flow (EMU to U.S.) in $billions
Figure 17 Case study: European Sovereign Crisis in 2011-2012

This figure presents the residualized credit spread differential and CIP deviations (Panel A), short-term and long-term CIP deviations (Panel B), and issuance flow (Panel C) around the time of the European Sovereign Crisis in 2011-2012. The first vertical line marks May 2011, when the U.S. wholesales funding market rapidly deteriorated. The second vertical line marks June 2012, when Greece elected the pro-austerity New Democracy Party. Vertical gray bars represent the 95% confidence interval with firm-level clustering.

Panel A: Credit spread differential and CIP deviations

Panel B: Short-term and long-term CIP deviation

Panel C: Net issuance flow (EMU to U.S.) in $billions
7 Conclusion

This paper examines the connection between CIP deviation and discrepancy in the credit spread for bonds of different denominated currencies. I document that these two pricing anomalies are substantial and persistent since the financial crisis and that the two anomalies are highly aligned in magnitude and direction in both the time series and the cross section of currencies. The difference between the two pricing deviations represents a difference in the net FX-hedged borrowing cost that explains up to a third of the variation in cross-currency debt issuance flow. I develop a model of market segmentation along two dimensions – in the credit market along currency denomination and in the FX market between spot and forward exchange rates. This framework shows that arbitrage aimed at exploiting one type of security anomaly can give rise to another separate anomaly. Arbitrage processes are imperfect in either market, but capital flow, such as debt issuance and investment, ensures that the two anomalies are intimately connected.
References


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