

Credit Migration and Covered Interest Rate Parity

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Abstract

I establish the joint determination of two economically large and persistent market anomalies in the foreign exchange rate market and the corporate credit market. I document large aggregate differences among local currency credit spreads of corporate bonds issued by the same issuer but denominated in different currencies. This price discrepancy in credit risk across currencies is closely related to deviation from covered interest rate parity in both the time-series and the cross-section of currencies. Through a model of market segmentation, I show that the two types of pricing distortions are determined jointly such that the overall currency-hedged cost of debt across different currencies are equilibrated. Large credit demand shocks, such as those stemming from quantitative easing, are transmitted across currency boundaries through currency-hedged capital flows. Using a dataset of 35,000 corporate bond prices and issuances, I find that variation in the currency-hedged cost of debt across different currencies predicts firms' issuance: firms issue the most in those currencies in which borrowing is cheaper (including the cost of currency hedging). Furthermore, exogenous increases in issuance, as instrumented by the roll-over of maturing debt, align the two types of deviations closer. Limits of arbitrage can spill over from one market to another.

Keywords: Covered interest rate parity, limits to arbitrage, debt issuance, international capital flow, credit market, QE spillover

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Introduction

The finance literature is full of examples in which security markets violate the Law of One Price (LOOP), a cornerstone of finance theory stating that assets with identical payoffs should have identical prices. For instance, closed-end funds, twin shares, and stub pricing are well-documented examples of price discrepancies in securities with similar cashflows¹ (see Lamont and Thaler 2003 for survey). Apart from widespread contagions that occur during periods of financial stress, these violations are often studied in isolation and attributed to behavioral and institutional frictions in a particular market. I show, 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.

I relay my findings in three parts. First, I document large and persistent differences in the aggregate pricing of credit risk for corporate bonds denominated in different currencies. Textbook asset pricing theory predicts that identical claims issued by the same firm but traded in different markets are priced similarly due to arbitrage. I show that persistent discrepancies exist for the entire euro corporate bond market versus the dollar bond market (as well as between other currencies). For example, in November 2014, 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, while its euro-denominated bonds of similar maturity had a credit spread of 129 basis points. Credit risk of AT&T is therefore priced differently in the U.S. and European bond markets.

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 create challenge in the comparison. AT&T, for example, issues more long-term bonds in euro than in dollar. I construct an aggregate measure of currency-specific pricing of credit risk that controls for other bond characteristics by applying cross-sectional regressions on a large panel of bond credit spreads. I refer this measure to as residualized credit spread throughout this paper.

The differences in residualized credit spreads of debt denominated in various currencies have dramatically widened since the Global Financial Crisis. From 2004 to 2007, the residualized credit spreads of Australian dollar (AUD), Canadian dollar (CAD), Swiss francs (CHF), Euro (EUR), British Pound Sterling (GBP), and Japanese Yen (JPY) relative to USD maintained a narrow

¹To be clear, these are LOOP violations in the classical, frictionless sense, if one were to actually construct an arbitrage strategy, the cashflows might very well be different.

range of 10 bps. Since 2008, however, these spreads have diverged significantly and have been large even in tranquil periods. For instance, the difference between the residualized credit spread of euro- and dollar- denominated bonds had reached over 70 basis points in 2016. The price discrepancies are substantial in terms of dollar value given the sheer size of the aggregate bond markets (e.g. EUR corporate bond market has \$3 trillion of long-term outstanding debt, USD corporate bond market has \$10 trillion of outstanding debt²). A 70 basis points price discrepancy amounts to \$25 billion or represent 84% of net (12% of gross) annual issuance in the euro corporate bond market.

What might be causing this divergence? The differential pricing of credit risk for bonds denominated in different currencies implies segmentation of market participants. Recent work by Matteo, Neiman, and Schreger (2018) has documented a strong investor preference to hold debt in their own currencies regardless of the nationality of the issuer. This home-currency bias makes investors less willing to exploit price differences for similar bonds denominated in different currencies and thus creates a segmentation of corporate debt market along currency lines. In the presence of large supply or demand shocks, market segmentation results in differentiated pricing of risk.

Second, I relate differences in residualized credit spreads to deviations from Covered Interest Rate Parity condition, another LOOP violation that has recently attracted attention from a variety of other papers (Sushko, et al. [2016], Du, Tepper, and Verdelhan [2016], Iida, Kimura, and Sudo [2016]). Covered Interest Rate Parity (CIP) condition is a textbook no-arbitrage relation asserting that the forward currency exchange rate must be equal to the spot exchange rate after adjusting for the funding rate differential between two currencies. The CIP condition held tightly prior to 2008. However, large deviations from the CIP relation appeared in the aftermath of the financial crisis and have persisted through 2016. For a detailed documentation and exposition of CIP violations, see Du, Tepper, and Verdelhan (2016).

Figure 1 shows the time series of price discrepancies in credit risk and deviations from CIP for EUR/USD. Periods when the price of credit risk is lower in euro than in dollar (more negative dashed blue line) tend to coincide larger CIP violation in the direction of dollar scarcity (more negative CIP deviation as indicated by the red solid line). The two series share similar magnitude of deviation and are highly correlated (77%). The close alignment of the two LOOP violations is not mechanically driven by interest rate fluctuation, as explained in Section 2. This co-movement of

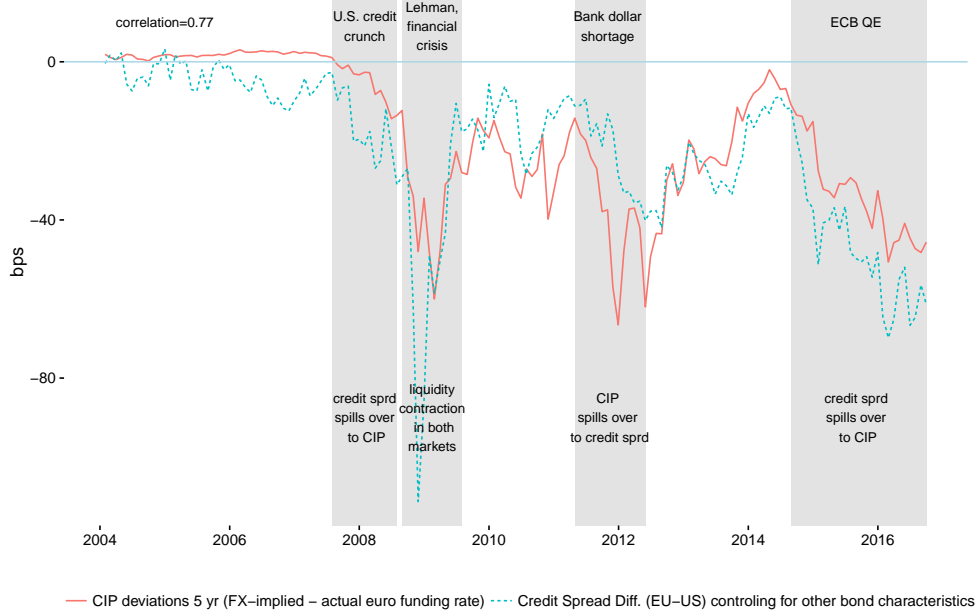
²ECB; Federal Reserve Flow of Funds L.213

Figure 1 Credit risk price discrepancies and CIP deviations for EURUSD

This figure shows the residualized credit spread differential (dotted blue) and violations of CIP at the 5-year horizon (solid red) for EURUSD. To construct the residualized credit spread, I estimate the following cross-sectional regression at each date t

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

where S_{it} is the yield spread over the swap curve for bond i that is issued in currency c , by firm f , with maturity m and rating r . The residualized credit spread of euro relative to dollar at time t is defined as $\hat{\alpha}_{eur,t} - \hat{\alpha}_{usd,t}$. Details of the measure's construction and additional controls are discussed in Section 1.2.



LOOP violations also holds true in other currencies. In a pooled sample of AUD, CAD, CHF, EUR, GBP, and JPY relative to USD, the correlation between CIP violation and credit price discrepancies is 81%.

Third, I provide an explanation for the joint determination of credit risk pricing discrepancies in different currencies and CIP violations based on a model of market segmentation and limited arbitrage. When markets are segmented, prices of risk in one market may be disconnected from those in other markets. The two pricing disconnects reflect two distinct market segmentations – the credit market is segmented by denomination currencies and the CIP violation is a disconnect between spot and forward exchange rates in the FX markets. I show through a model that the reduction of either of these two deviations necessitates arbitrageurs to engage in distorting the other.

The mechanism described in this paper is distinct from that of intermediary-based asset pricing³.

³See Gârleanu and Pedersen 2011, He Krishnamurthy 2012, among others.

Previous empirical studies on dislocations have found widespread LOOP violations to occur during stressed market conditions (Pasquariello 2014). Changes in the binding constraint of a common intermediary can influence the *absolute level* of deviations. However, intermediary capital cannot explain the *directionalities* and shared *magnitudes* of the two deviations, especially in calm market conditions.

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 amount of FX volatility. 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. To hedge for this volatility, AT&T would need to buy EUR in the forward market for the future repayment of its debt – in fact, AT&T did exactly this: it issued €800 million (\$1 billion) in a 15-year euro-denominated bond and entered currency derivatives as a hedge. In its 10K statement, AT&T describes 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.”

It is therefore natural to think of AT&T as a corporate arbitrageur that not only links together the two credit markets but also connects the FX forward and spot markets through its currency hedges.

The cross-market arbitrageurs linking the two LOOP violations can be either debt-issuing firms or global debt investors that have sensitivity to FX exposure. This paper focuses on firms for several reasons. Firms are natural cross-market arbitrageurs that can better withstand noise trader shocks and more easily overcome limits of arbitrage problems raised by Shleifer and Vishny (1997). This point had been argued by previous papers including Baker and Wurgler (2000), Baker, Foley, and Wurgler [2009], Greenwood, Hanson, and Stein (2010), and Ma (2015). The standard deviation of monthly issuance flow between the Eurozone and the U.S. is more than \$6 billion. This is equivalent to the creation of a sizable hedge fund fully dedicated to exploiting the two LOOP violations every month. The empirical analysis in this paper focuses on firms as debt issuance data is readily available

and comprehensive.

There are four actors in my model: a FX arbitrageur, two specialized credit investors, and a representative debt-issuing firm. The two specialized credit investors each invest in corporate bonds in their respective home currencies, the euro and the dollar, and they each have a downward sloping demand curves in the credit markets. The FX arbitrageur connects the spot and forward exchange rate markets and has a downward sloping demand curve because of limited balance sheet capacity to perform the arbitrage.

The firm connects the credit and FX markets by engaging in FX-hedged debt issuance. Its objective is to minimize its overall financing cost by choosing the optimal share of debt to issue in each currency. When the foreign credit spread is low, the firm allocates a greater share of debt to be issued abroad. Issuing in the foreign currency, however, generates FX exposure, which the firm hedges using currency forwards. To integrate the two downward-sloping demand curves in the bond markets, the firm must walk down the demand curve in the FX forward market. Conversely, when CIP violations are large, the firm chooses to integrate the forward and spot FX exchange rates instead while walking down the demand curves of the credit markets. The two violations of LOOP are aligned such that the firm's first order condition is satisfied.

Two types of exogenous demand shocks affect the system. First, there are credit demand shocks (perhaps originating from central bank purchases outside of the model) that raise the relative price of credit for bonds in one currency versus the other. Second, there are CIP shocks originating from other end-users of FX forwards that decouple the forward exchange rates from the spot exchange rate. The shocks are transmitted between the FX and credit markets by firms engaged in currency-hedged foreign debt issuance. Credit demand shocks cause discrepancies in the price of credit risk as well as deviations from CIP. Similarly, CIP shocks also spill over to affect the relative price of credit.

The model generates four key predictions. First, LOOP violation in one market (FX or credit) spills over to the other market. Arbitrage processes are imperfect in both markets, but capital flow ensures that the two LOOP deviations are aligned. Second, the amount of cross-currency issuance, which represents arbitrage position, co-varies with the profitability of the arbitrage. The profit margin is indicated by the difference between credit spread differential and CIP deviation. Third, an exogenous increase in cross-market arbitrage capital, represented by total bond issuance amount,

aligns the two deviations more closely. Lastly, limits of arbitrage in one market spill over to and become a constraining factor in the other market.

Empirical analyses lend support to the model predictions. A counterintuitive implication of the model, which also appears in the data, is that the net deviation from LOOP is small even when both deviations in CIP and credit are large individually. When the two deviations are meaningfully large (greater than 20 basis points), the level of net deviation is only around a quarter of the size of the two individual deviations. Evidence from currency-hedged debt issuance also accords with channel discussed. A textual analysis of 10K filings by S&P 500 firms indicates that around 40% of firms have issued currency-hedged foreign debt in recent years. Furthermore, issuance flow at the monthly and quarterly horizon fluctuates with the net deviation. For each one standard deviation increase in the difference between residualized credit spread differential and CIP violation for EURUSD, firms respond by shifting around 5% of the aggregate debt issuance towards the cheaper issuance currency (0.75 standard deviation of issuance flow). Similar findings are found through Vector Autoregression (VAR) that show issuance flow responding to shocks in credit and FX markets in the direction predicted by the model. The VAR analyses are also consistent with theories on slow moving capital (Duffie [2010], Greenwood, Hanson, and Liao [2015]). Further robustness checks using firm-level panel regressions confirm the same result as in the aggregate data. In addition, an increase in the overall debt issuance, as instrumented by maturing debt that needs to be rolled over, contributes to the alignment of the two LOOP violations.

My paper takes the idea of limits of arbitrage a step further. Noise trader risks and agency problems pose limits to the amount of arbitrage activities (De Long et al. [1990], Shleifer and Vishny [1997]) in a single market. I provide a conceptual framework and document a clear-cut example in which arbitrage constraints and violations of LOOP spill over from one market to a completely different market. The magnitude and direction of the two LOOP violations are determined jointly in equilibrium.

My paper also contributes to the literature on the determination of foreign exchange rate dynamics. Gabaix and Maggiori (2015) provide a theory of the determination of exchange rates based on capital flows in imperfect financial markets. The study of exchange rate determination typically focuses on *uncovered* interest rate parity. In contrast, I model and provide empirical evidence for

the determination of *covered* interest rate parity violations. The two concepts are intimately related. As deviation from CIP becomes large, firms and investors eventually forgo hedging (since CIP deviation is a hedging cost), the unhedged capital flow thus leads to UIP violation.

This paper also relates to previous work showing that corporations behave like arbitrageurs in their financing activities (Baker and Wurgler [2000] and Baker, Foley, and Wurgler [2009], Greenwood, Hanson, and Stein [2010], and Ma [2015]). Of particular relevance, McBrady and Schill (2007) find an opportunistic motive for foreign currency denominated borrowing by sovereigns, supranationals and agencies issuers. Greenwood, Hanson, and Liao (2015) explore asset price dynamics when large supply shocks are transmitted across markets by slow-moving market generalists such as firms. My paper contributes to the literature on firms as arbitrageurs in two ways. First, this paper shows that firm are advantageous at exploiting LOOP violations in addition to previously documented arbitrage of inexact valuation differences, e.g. between debt and equity and market timing of issuance. The arbitrage strategies in LOOP violations typically require specialized knowledge and capital, and were previously dominated by sophisticated hedge funds. Firms' increasing involvement in specialized arbitrage demonstrates the difficulty of deploying traditional arbitrage capital in the post-crisis financial and regulatory environment. Second, firms are arbitraging multiple markets at the same time – e.g. credit and FX, and they play a role in transforming LOOP violation of one form into that of another form.

A small set of literature has examined short-term CIP violations during the financial crisis (Baba, Packer, and Nagano [2008], Coffey, Hrungr, and Sarkar [2009] Griffoli and Ranaldo [2011], and Levich [2012]). Fletcher and Taylor (1996) document long-term CIP violations of the early 1990s and conclude that these violations have diminished or disappeared over time. While these papers discuss limits to arbitrage that prevent the elimination of CIP violations, their examinations of the root cause of deviation in both crisis and non-crisis periods are limited. Other papers have examined sovereign bond pricing differences in different denomination currencies. Buraschi, Sener and Menguturk (2015) explores the relative pricing of EM sovereign bonds issued in dollars and euros during the 2007-2008 financial crisis and shows that the magnitude of mispricing depends on the degree of fragility in the wholesales funding markets. Corradin and Rodriguez-Moreno (2016) compares a matched sample of sovereign bonds issued in both EUR and USD and studies the effect of ECB collateral and liquidity factors on the pricing variations.

More closely related to my paper are Ivashina, Scharfstein, and Stein (2015), Du, Tepper, and Verdelhan (2016), and Sushko et al. (2016). Ivashina, Scharfstein, and Stein (2015) examine the dollar funding and lending behaviors of European banks during the Eurozone Sovereign Crisis in 2011-2012 and explore how shrinkage of wholesales dollar funding compelled the banks to swap their euro funding into dollar, which in turn generated CIP violations and affected lending. Bräuning and Ivashina (2016) further explore the role of monetary policy in affecting global bank's funding sources and the use of FX hedges. Du, Tepper, and Verdelhan (2016) extensively document persistent deviations from CIP in recent periods and propose explanations based on costly financial intermediation and global imbalances. Sushko et al. (2016) examine the role of hedging demands and costly balance sheet in the determination of CIP violations. Relative to these papers, my contribution is to document and explain the joint determination of both CIP violation and price discrepancies in corporate bonds of different denomination currencies. I show that the two LOOP violations need to be considered together in formulating an explanation of the equilibrium prices and capital flows.

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 in Section 4. Additional model predictions are tested empirically in Section 5.

1 Measuring residualized credit spread

In this section, I develop a procedure to measure the price of credit risk in different currencies. The ideal experiment is to find pairs of otherwise identical bonds (same issuer, maturity, etc) in different currencies. This is challenging because no two bonds are perfectly alike. My proposed methodology relies on cross-sectional regression to control for differences in rating, maturity, and firm characteristics. From here on in the paper, I refer to the differential in the residualized credit spread of bonds denominated in different currencies simply as *credit spread differential*.

1.1 Data

I utilize a comprehensive sample of individual bond yields from Bloomberg and bond attributes from Financial Securities Data Company (SDC) Platinum Global New Issues data set. The selection of bonds is as exhaustive as possible. I obtain yields of more than 35,000 corporate bonds in seven major funding currencies (USD, EUR, GBP, JPY, AUD, CHF, CAD) from 2004 to 2016. The selection includes all fixed-coupon, bullet corporate bonds with outstanding amount of at least \$50 million and original maturity of at least one year available on Bloomberg and in the SDC dataset. These bonds were issued by more than 4,600 entities. The issuing entities also include a number of large supranational (such as the World Bank) and sovereign agencies (such as state-owned banks) that are generally considered a part of the corporate bond market. The total notional of outstanding bonds in the database as of June 2016 is around \$10 trillion, representing the majority of bonds outstanding in the market. I use the yield spread against the swap curve as a measurement of credit spread. Alternate measure using yield spread against over-night index swap curve (e.g. swaps based on Eonia and Fed Fund Effective rates instead of Libor) generates similar residualized credit spread differential. Pricing data on swaps are obtained from Bloomberg. Additional bond attributes used for robustness checks are obtained from Moody's Default & Recovery Database. A summary of the bond data is provided in Table 1.

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 at each date t

$$S_{it} = \alpha_{ct} + \beta_{ft} + \gamma_{mt} + \delta_{rt} + \varepsilon_{it} \quad (1)$$

where S_{it} is the yield spread over the swap curve for bond i traded in the secondary market at time t . α_{ct} , β_{ft} , γ_{mt} , and δ_{rt} are fixed effect estimates for currency c , firm f , maturity bucket⁴ m and rating bucket r respectively at date t . The firm fixed effect is important here since it controls for other characteristics of bonds that are common at the firm level, e.g. industry effect. Furthermore,

⁴The maturity of the bond at each pricing date t is categorized into four buckets (under 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.

the data sample is limited to only bonds belonging to multi-currency issuers. As with the AT&T example in the introduction, the idea here is to match bonds of similar characteristics issued by the same firm with the only difference being the currency in which they are denominated. α_{ct} thus measures the *residualized* credit spread controlling for all other observables. 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 estimate, $\hat{\alpha}_{ct} - \hat{\alpha}_{USDt}$, measures the deviation in the pricing of credit risk in currency c relative to the pricing of credit risk in dollar. The large number of observations for each date t ensures a reasonably tight confidence interval⁵.

Figure 2 presents time series of the point estimates of $\alpha_{ct} - \alpha_{USDt}$ at each date for currencies EUR, GBP, JPY and AUD. All four credit spread differentials were relatively small from 2004 to 2007. The spreads blew out during the Global Financial Crisis. Yen, sterling, and euro credit all tightened considerably relative to U.S. dollar. In particular, euro and yen credit spread differentials reached deviations beyond -100 basis points during the 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 directionally. JPY credit (purple long dashed line) has been the most over-priced (negative spread) relative to dollar credit, and AUD credit (solid red) has been under-priced (positive spread) relative to the dollar credit market. EUR credit spread differential (green dots) became more negative since 2014, and reached -70 basis points in 2016.

The size of the deviations is substantial and economically large in dollar terms. As of June 2016, the total amount of outstanding long-term corporate debt in EUR is €3.2 trillion⁶. The residualized credit spread differential between EUR and USD in June 2016 is -70 basis points. A back-of-the-envelope calculation suggests that the discrepancy in the pricing of default risk represents a dollar value difference of around \$25 billion if all EUR corporate bonds were priced in USD instead. This amount is economically large, representing 84% of the net issuance amount (12% of gross issuance) in EUR by the corporate sector in 2015⁷.

⁵Confidence interval is provided in Figure 5

⁶ECB defines long-term debt as debt with original maturity at issuance of greater than one year.

⁷Total net issuance of long-term debt by corporate sector in 2015 is €26.6 billion and gross issuance is €192.2 billion according to ECB statistics.

1.3 Comparison with benchmark credit spreads

The residualization of credit spreads using the above methodology produces time series that is substantially different from un-residualized aggregate credit spreads. I compare the residualized credit spread differential in EURUSD against two un-residualized benchmark indices – the Bank of America Merrill Lynch Corporate Single A index and Barclays Corporate Single A index in Figure 3. The residualized and un-residualized spreads are quantitatively and qualitatively different. While the residualized spreads were always negative (indicating tighter euro credit spread than dollar), the unresidualized versions of the spread were positive for a substantial part of the sample and had larger magnitudes. This large difference between the residualized and un-residualized versions is due to compositional differences of the aggregate indices for EUR and USD benchmark bond portfolios provided by Bank of America and Barclays. The regression methodology addresses the compositional difference by controlling for firm and other bond characteristics using individual bond prices.

1.4 Robustness in the measurement of the credit spread differential

In this section, I conduct a number of robustness checks in the estimation of the residualized credit spread differential.

1.4.1 Additional Controls

I augment the regression specification of Equation 1 with three additional controls – amount outstanding, age, and seniority. 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 age of the bond is defined as the ratio of remaining maturity to initial maturity 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 estimates of the credit spread differentials⁸.

⁸see Internet Appendix

While there might be other idiosyncratic bond attributes not captured in the augmented specification, these additional attributes should not affect the *aggregate* residualized credit spread differential. As can be seen in Figure 2, 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. Therefore, additional unobserved bond features are treated as idiosyncratic noise in the estimation.

1.4.2 Heterogeneity for different credit ratings

Another potential concern is that the aggregate credit rating varies significantly across different currency-segmented bond markets. That is, if all euro-denominated bonds have rating of AAA while all dollar-denominated bonds have rating of single-A, then naturally there would be a tighter credit spread for euro-denominated bonds. Under this hypothetical scenario, the residualized credit spread differential would pick up the difference between AAA bonds and single-A bonds rather than a differential due to the denominating currency.

I address this concern in two ways. First, I limit the sample on each date to only bonds that are issued by entities that have debt outstanding in another currency. In this case, controlling for firm fixed-effects alleviate the concern raised above, as 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 bonds⁹. When the sample is restricted to low-grade bonds only, the credit spread differentials are larger in magnitude than those of high-grade bonds. This is intuitive since low-grade bonds have higher credit spreads to begin with, the credit spread differential are also amplified.

1.4.3 Independence of bond default and currency

Residualized credit spread differential for similar bonds trading in different currencies can reflect firm's propensity to default selectively on debt denominated in one currency but not in the other. Even with simultaneous default, the correlation between the intensity of default and exchange rate can lead to quanto effect (Lando and Nielsen 2017). Buraschi et al. (2015) shows that independence of exchange rate and default decision is necessary for foreign currency credit spreads not to be

⁹see Internet Appendix

contaminated by default decisions.

Three observations alleviate this concern. First, corporate debt with different currency denominations but sharing the same credit rating most often have pari-passu clauses that dictate the same treatment to creditors. Second, the quanto effect plays much less of a role in corporate bonds as it does in sovereign bonds. Quanto spreads of European sovereigns were substantial during the Eurozone crisis in 2011-2012 due to the risk of sudden euro depreciation that occurs at the same time as bond default. In the corporate debt market, the argument for AT&T defaulting on its euro-denominated debt and simultaneous depreciation of the euro is more difficult to establish. Furthermore, there are no substantial difference between residualized credit spreads of U.S. firms and non-U.S. firms. The time variations in residualized credit spread differential also do not covary with FX return consistently. Third, the cross-sectional and time variations in residualized credit spread differentials cannot be explained by quanto effect. For instance, the yen-dollar residualized credit spread differential was more negative during the eurozone crisis (and in the entire sample period) than that of euro-dollar despite the yen being a much more stable currency during the time. In time series, the residualized credit spread differentials first emerged during 2008 but have not disappeared since. In contrast, quanto effect in developed currencies have mainly been a phenomenon on European sovereigns during the Eurozone crisis.

2 Alignment of credit differential and CIP violation

In this section, I define and discuss the measurement of deviation from Covered Interest Rate Parity condition and show the similarities in the time series of CIP deviations and credit spread differentials. Taking the currency pair EUR/USD as an example, the classic text book definition of CIP condition is

$$F_T = S \frac{(1 + r_{D,T})^T}{(1 + r_{E,T})^T} \quad (2)$$

where S is the spot exchange rates expressed in dollars per euro, F_T is the forward exchange rate with maturity T also expressed in dollars per euro, $r_{D,T}$ and $r_{E,T}$ denote the T -period risk-free zero-coupon funding rates in dollar and euro respectively. A violation of CIP occurs when the above

equation fails to hold. For expositional purpose, assume that $T = 1$. We can rewrite equation 2 as

$$0 = \underbrace{\frac{S}{F}(1 + r_D)}_{\text{FX-implied}} - \underbrace{(1 + r_E)}_{\text{actual}} .$$

euro funding rate euro funding rate

In other words, CIP condition states that the FX-implied foreign funding rate is equal to the actual foreign funding rate. A violation of CIP condition can be expressed as a basis b

$$b = \underbrace{\frac{S}{F}(1 + r_D)}_{\text{FX-implied}} - \underbrace{(1 + r_E)}_{\text{actual}} . \quad (3)$$

euro funding rate euro funding rate

I measure b empirically using the level of cross-currency basis swap, consistent with other concurrent papers¹⁰ studying CIP deviations. A cross-currency basis swap is a 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 counter party of the swap transaction agrees to take on the reverse position. A currency basis is a market-determined adjustment to the reference floating funding rates. It is analogous to the market pricing of b in Equation 3 above. The empirically-relevant funding rates, represented by r_D and r_E in Equation 3, are Libor-based swap rates. An alternative definition using Overnight Index Swap (OIS) rates based on actual transactions such as Fed Fund Effective rate or Eonia rate generates similar results as presented in the Internet Appendix. Calculating CIP deviations using FX forward and spot rates also yield similar results. The details of cross-currency basis swap, relation with CIP violation and maturity of CIP deviations are discussed in the Internet Appendix¹¹.

To provide intuition for b , I continue with the earlier example. Suppose AT&T issues in EUR

¹⁰Sushko, et al. [2016], Du, Tepper, and Verdelhan [2016], Iida, Kimura, and Sudo [2016]

¹¹In the appendix, I show that T -horizon CIP deviation b_T is related to cross-currency basis swap rate B_T by the following approximation:

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

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

as the euro credit spread is 74 basis points tighter than the dollar credit spread. If there were no CIP deviation, i.e. $b = 0$, AT&T is able to keep the entire 74 basis points by issuing in EUR and swapping EUR into USD. The hedging cost (or benefit) would just be the interest rate differential. If there were a CIP basis $b \neq 0$, the hedging cost would adjust accordingly.

The sign of b is also intuitive. In my example, AT&T issues in EUR and wants to swap EUR to USD. This FX swap transaction can be equivalently stated in two other ways. A FX swap of EUR to USD is equivalent to 1) simultaneously borrowing dollar to lend in euro, and 2) sell euro in the spot market and buy euro in the forward market. Holding the spot exchange rate S and interest rates r_D and r_E fixed in equation 3, an increase in F necessitates a decrease in b . Therefore when b is negative, it is costly to swap from euro to dollar (expensive to buy euro in the forward market), and when b is positive, it is expensive to swap from dollar to euro.

Figure 4 shows the deviations from CIP at the 5-year horizon for AUD, EUR, GBP, and JPY relative to USD. This condition had been upheld tightly prior to 2008. However, large deviations from the CIP relation appeared in the aftermath of the financial crisis and persist through 2016.

My key finding is that CIP violation and credit spread differential are highly correlated. Figure 5 graphs the time series of credit spread differential and CIP deviations at the 5-year horizon 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%.

Figure 6 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 dispel dollar liquidity shortage as the sole explanation for CIP deviations. CIP deviations in EUR and JPY indicate dollar liquidity shortage but deviations concurrently indicate dollar liquidity surplus in other currencies (e.g. AUD, CAD, and GBP for a period). Japan has negative deviations in both CIP and credit, meaning that yen credit spread is tighter than dollar credit spread for comparable bonds and it is costly to swap yen to dollar. Australia, on the other hand, has both positive deviations, meaning that both its credit spread is wider and it is costly to swap from USD to AUD.

Descriptive regressions also confirm both cross-sectional and time-serial correlation between

credit spread differential and CIP deviations. Table 2 presents the relationship between the two LOOP violations for the six currencies in panel and individual regressions. Most coefficients range from 0.7 to close to 1 and are highly significant. Column 2 and 3 present regressions controlling for time and currency fixed effects. While these regressions cannot be interpreted as causal, nonetheless they demonstrate the close alignment of the two LOOP violations. Empirical identification of the impact of one LOOP violation on another is achieved through additional empirical tests of model predictions in subsequent sections.

3 A model of aligned deviations in credit and currency markets

In this section, I present a model of segmented markets that provide an explanation for the high degree of alignment between the two LOOP violations. In this model, I assume that there are two credit markets, one denominated in euro and another denominated in dollar. These two credit markets are segmented from one another except through capital flow provided by a representative debt-issuing firm. The issuer has funding needs in dollar but issues in both currencies and engages in currency hedging. While the cross-market arbitrageur is modeled as a firm selling debt, it can also be alternatively interpreted as global investors that both purchase and sell across markets. I use the model to illustrate the transmission of shocks across markets, the alignment of LOOP violations, and the response of issuance capital flow. In addition, the model delivers testable predictions that are examined in Section 5. An extended model in the Internet Appendix relaxes many of the assumptions made here.

3.1 Firm decision

In this static model, a representative price-taking firm chooses the currency of debt denomination given a fixed debt amount D that needs to be raised. It faces two prices. First, the firm observes a credit spread differential between euro-denominated bonds and dollar-denominated bonds denoted as c . From the earlier example, c is -74 basis points, meaning that AT&T's euro bond credit spread is 74 basis points tighter than the dollar bond spread. If CIP holds, AT&T would save 74 basis points by issuing in EUR and swapping the issuance to USD with currency hedge, as the CIP condition implies that the currency hedging cost is entirely accounted for by the interest rate

differential. However, when CIP fails, the firm observes a CIP basis, denoted b , which constitutes as additional hedging cost. As defined earlier in Section 2, a negative b means that it is expensive to swap EUR to USD. Suppose $b = -50$, this means that AT&T must pay 50 basis points to swap its euro bond issuance proceeds to dollar. Effectively, AT&T observes a net issuance cost saving of $c - b = 25$ basis points by issuing in EUR instead of USD. Given this cost saving and absent any firm capital structure frictions, AT&T would choose to conduct its entire debt capital raising in EUR instead of USD. That is, the firm chooses dollar issuance share μ to minimize cost

$$\min_{\mu} \left(\underbrace{-c}_{\text{credit spread diff.}} + \underbrace{b}_{\text{CIP/hedging cost}} \right) \mu D.$$

Two predictions emerge immediately from this simple setup. First, issuance capital flow responds to the net deviation of credit and CIP violations. That is, if the net deviation is negative, $c - b < 0$, then the firm chooses $\mu = 0$, otherwise it chooses $\mu = 1$. Second, the two deviations are perfectly aligned when the capital available for cross-market arbitrage is large. That is, if the total amount of debt D is large, then $c - b$ is driven to zero in general equilibrium.

In this setup, I assume for simplicity that UIP holds, firms always currency-hedge when issuing abroad, and that there are no capital structure frictions to prevent firms from issuing all of its debt in one currency versus another. These assumptions can all be relaxed without changing the main results. I provide an extended model in the appendix that provides an interior solution to μ and yield similar predictions. For expositional purpose, I continue with the simple version of the firm's decision.

3.2 Credit markets

While the above setup generates simple intuitions for the alignment and elimination of the two types of LOOP violations, understanding how deviation in one market spills over to the other requires endogenizing the two violations. We start with endogenizing c .

There are two credit markets (EUR and USD bond markets), and three main credit market players: active local investors in Europe, active local investor in the U.S. and the representative firm from earlier that has access to both debt markets.

Local investors U.S. active investors specialize in the investment of corporate bonds denominated in dollars, and European investors only invests in EUR denominated bonds. Investors borrow at the domestic short rate, r_i , and purchase bonds with a promised net yield of Y_i , where $i = EUR$ or USD . The two bonds have identical default probability π , loss-given-default L . The payoff of bonds has a variance of V , which is treated as an exogenous constant in the model for tractability¹². U.S. and European investors have a mean-variance preference with identical risk tolerance τ and choose investment amount X_i to solve the following

$$\max_{X_i} \left[X_i ((1 - \pi) Y_i - \pi L - r_i) - \frac{1}{2\tau} X_i^2 V \right] \quad (4)$$

which has the solution $X_i = \frac{\tau}{V} ((1 - \pi) Y_i - \pi L - r_i)$ for $i = EUR$ or USD .

Market clearing conditions In addition to active local investors, there are exogenous relative bond demand ε_c . The sources of exogenous ε_c shocks are discussed in Section 4 and can represent those that originate from QE or preferred-habitat investors. Combining the demand with firm debt issuance supply defined earlier, the market clearing conditions for the dollar and euro credit markets are

$$X_U = \mu D \quad (5)$$

$$X_E + \varepsilon_c = (1 - \mu) D. \quad (6)$$

We can rewrite the difference between the two promised yields as a credit spread difference and interest rate difference, $Y_E - Y_U \equiv c + (r_E - r_U)$. Combining the investor demands with the market clearing conditions and applying first-order Taylor approximation for π around 0, we can express credit spread differential as:

¹²A Bernoulli default distribution with probability π , 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 EUR- and USD- denominated bonds.

$$\begin{array}{ccc}
\underbrace{c}_{\text{credit spread}} & = & \underbrace{\frac{V}{\tau}}_{\text{elasticity of}} \underbrace{\left(\underbrace{(1-2\mu)D}_{\text{relative debt issuance}} - \underbrace{\varepsilon_c}_{\text{exog. eur bond demand}} \right)}_{\text{net bond supply}} \\
\underbrace{\text{differential}}_{\text{(eu-us)}} & & \underbrace{\text{eur relative to usd}}
\end{array} \quad (7)$$

The intuition is that c is determined by the net supply and demand imbalances between the two markets multiplied by the elasticity of bond demand. The cross-currency issuer can influence the relative credit spread through its choice of μ , albeit the impact 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 LOOP violation, but instead of risk preference that determines the slope of demand curve, arbitrage in CIP is limited by intermediary collateral and capital constraints. There are two main players in this market: currency swap traders and issuers.

Currency swap traders Currency swap traders choose amount of capital to devote to either CIP deviations b , or alternate investment opportunity with profit of $f(I)$, where I is the amount of investment.

The arbitrageur must set aside a haircut H when it enters the swap transaction to arbitrage CIP violation. Following Garleanu and Pedersen (2011), the amount of haircut is assumed to be proportional to the size s of the swap position, $H = \gamma|s|$. Therefore, the capital devoted towards alternative investment is $I = W - \gamma|s|$. Swap traders has total wealth W and solve the following

$$\max_s bs + f(W - \gamma|s|)$$

which generates the intuitive result that the expected gain from conducting a unit of additional CIP arbitrage is equal to marginal profitability of the alternative investment, $b = \text{sign}[s]\gamma f'(W - \gamma|s|)$. 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 non-zero. This assumption is equivalent to stating $\frac{\phi_0}{\phi} = W$, which means that 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 remove the constant intercept term in the equation for b , and we obtain that CIP deviation is proportional to swap trader position, $b = \phi\gamma^2 s$. I further normalize $\phi = 1$. This model of swap traders 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.

Equilibrium The representative firm from earlier uses FX market to convert the amount of its euro debt issuance, $D(1 - \mu)$, into dollar. In addition, there are exogenous shocks to CIP basis ε_b that represent other non-issuance-related use of FX-swaps. The sources of shocks are discussed in Section 4.

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

$$\underbrace{b}_{\text{CIP basis}} = - \underbrace{\gamma^2}_{\text{haircut on collateral}} \underbrace{(D(1 - \mu) + \varepsilon_b)}_{\text{net hedging demand (swap euro to dollar)}} \quad (8)$$

The negative sign arise since the swap trader takes the opposite position of the hedging demand. CIP deviation b is proportional to net hedging demand multiplied by the elasticity of supply, which is determined by the collateral margin. Higher haircut γ amplifies the impact of hedging demand, but without net hedging demand, b does not deviate from zero.

Debt issuer hedging demand $D(1 - \mu)$ does not have to have the same sign as other exogenous hedging demand ε_b . If ε_b has the opposite sign as and larger in magnitude than the issuer demand, the issuer would incur an additional benefit (instead of cost) through hedging. In this case, the firm would contribute to the elimination of CIP deviation and act as a supplier of liquidity in the

currency forward market.

An extension of the model with natural hedges (using the firm's real asset and cashflows in the foreign currency) and partial hedging is analyzed in the appendix, but it does not alter the main predictions in the model.

3.4 Summary of equilibrium conditions and predictions

The three equilibrium conditions are summarized below:

1. Credit spread differential (EU-US):

$$\underbrace{c}_{\text{credit deviation}} = \underbrace{\frac{V}{\tau}}_{\text{elasticity of bond demand}} \underbrace{((1 - 2\mu)D - \varepsilon_c)}_{\text{net bond supply in EUR rel. to USD}}$$

2. CIP basis (negative means more costly to swap into USD):

$$\underbrace{b}_{\text{CIP basis}} = - \underbrace{\gamma^2}_{\text{elasticity of fx swap supply}} \underbrace{(D(1 - \mu) + \varepsilon_b)}_{\text{net hedging demand to swap euro to dollar}}$$

3. Firm choice of dollar issuance ratio:

$$\mu = \begin{cases} 1 & \text{if } c - b > 0 \text{ cheaper to issue in dollar} \\ 0 & \text{if } c - b < 0 \text{ cheaper to issue in euro and swap to dollar} \end{cases}$$

With these equilibrium conditions, we can analyze the transmission of ε_c and ε_b shocks from one market to the other stated as the following propositions.

Proposition 1. (*Spillover of deviations*) If $\varepsilon_c \uparrow$, then $c \downarrow \Rightarrow \mu \downarrow \Rightarrow b \downarrow$. If $\varepsilon_b \uparrow$, then $b \downarrow \Rightarrow \mu \uparrow \Rightarrow c \downarrow$. Shocks to one market are transmitted to the other through capital flows. Credit spread differential c and CIP deviations b respond in the same direction to either credit demand shocks ε_c or FX swap demand shocks ε_b ¹³.

While Proposition 1 has a clear prediction for the signs of c and b , the sign of μ is ambiguous without precisely distinguishing whether the shock originates from ε_c or ε_b . However, the correlation

¹³While these transitions occur discretely at the boundary when $c - b$ flips sign, a small amount of friction to the firm's capital structure would generate a continuous spillover of deviations as shown in the appendix.

between μ and the net deviation $c - b$ is unambiguous and testable, which leads to the following prediction.

Proposition 2. (*Issuance flow and net deviation*) $(c - b) \downarrow \implies \mu \downarrow$ Cheaper net cost of issuance in euro induces more issuance flow in euro and less issuance in dollar.

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*) $\frac{\partial |c-b|}{\partial D} < 0$ and $\lim_{D \rightarrow \infty} c - b = 0$. An increase in the total amount of debt issuance decreases the absolute value of the net deviation. As the total amount of debt increases towards infinity, the two deviations become identical.

Proposition 4. (*Limits to arbitrage spillover*) Additional comparative statics of the model are summarized in the following table:

	FX haircut $\gamma \uparrow$	Credit investor risk tol. $\tau \uparrow$	bond risk $V \uparrow$
$ c $	\uparrow	\downarrow	\uparrow
$ b $	\uparrow	\downarrow	\uparrow

Proposition 4 suggests that limits of arbitrage are carried over from one market to the other. For instance, while the amount of haircut on FX swap trades, γ , directly affects CIP basis b , γ also affects the credit spread differential c indirectly through the cross-market arbitraging firm. Similarly, the risk tolerance of localized bond investors that do not engage in FX swaps also affects the level of CIP deviation through capital flow. Thus, limits of arbitrage can spill over to a completely different market.

On the surface, the prediction of aligned deviation might appear to be similar to implications of intermediary-based asset pricing models that have a single intermediary trading in multiple markets. To distinguish my explanation from those of intermediary-based asset pricing, I discuss the falsifiable alternative below.

3.5 Falsifiable alternative: intermediary-based asset pricing

The model developed above is also useful for assessing alternative explanations of the alignment between the two LOOP violations. One alternative hypothesis relies on intermediary-based asset pricing: deviations might be correlated when there are fluctuations in the binding constraints for a common intermediary that operates in both markets. That is, arbitrageurs face the same constraint to arbitrage in credit and CIP, and a shock is delivered to this constraint. An equivalent way of stating this hypothesis in the framework of my model is to set $\gamma^2 = \frac{V}{\tau} \equiv \lambda$ and suppose there is a shock to λ .

There are two reasons for why this alternative hypothesis would not explain the alignment of the credit and CIP violations. First, absent of net demand imbalances in each market, changes in λ 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. $\frac{\partial |b|}{\partial \lambda} \propto \frac{\partial |c|}{\partial \lambda}$, changes in λ would not explain the high alignment in the *direction* and *magnitude* of the deviations in b and c . Fluctuations in the common constraint λ are therefore distinct from a spillover of deviation and frictions from one market to the other. Furthermore, one would not expect to observe changes in capital flow as represented by μ under this alternative explanation.

4 Discussions

In this section, I discuss the sources of shocks, limits to arbitrage in each market and why firms are natural cross-market arbitrageurs. The schematics in Figure 7 summarizes the discussion.

4.1 Source of ε_c and ε_b shocks

4.1.1 ε_c shocks

- **Central bank QE** Large asset purchasing programs by central banks have contributed to the displacement of traditional government debt investors in search of high-yielding assets such as corporate bonds. The differential timing and sizes of ECB and Fed quantitative easing programs likely changed the relative demand for credits in Europe and the U.S., resulting in changes in ε_c .

- **Passive investor portfolio changes** Shifts in passive institutional investor’s benchmarks and portfolios can bring large changes to the demand for assets. For instance, Japan’s Government Pension Investment Fund, which holds US\$1.2 trillion in asset and serves as the most frequently used portfolio benchmark for other Japanese-based asset managers, decided in October 2014 to reduce its domestic bond holding from 60% to 35% and increase its allocations to stocks and foreign assets. This large, one-time portfolio shift differs from that of active credit specialists who decide on bond investments based on credit risks at higher frequencies.
- **Regulatory-driven demand shocks** Portfolio shifts can also be driven by regulatory reforms. One such regulatory change occurred in the United Kingdom, where the 2005 Pension Reform Act forced pension funds to mark their liabilities to market by discounting them at the yield on long-term bonds. This reform significantly increased the demand for long-term securities (Greenwood and Vayanos 2010).
- **Credit-market sentiments** Many papers have analyzed the role of credit sentiment on asset prices and the real economy (López-Salido, Zakrajšek and Stein [2015], Bordalo, Gennaioli, and Shleifer [2016], Greenwood, Hanson, and Jin [2016], Greenwood and Hanson [2014]). A shock to the relative credit demand between bond markets can arise if credit sentiments differentially impact different markets. One such episode occurred around the time of the Bear Stearns collapse, when the *residualized* dollar credit spread widened relative to the euro credit spread as fears of US credit market meltdown heightened. Further analysis on this case study is presented in the Internet Appendix.

4.1.2 ε_b shocks

- **Dollar liquidity shortage** Since the crisis, non-U.S. banks, in need of short-term dollar funding for their U.S. operations, have become active borrowers of dollar through FX swaps¹⁴. A particularly striking episode of demand shock for FX swaps into dollar is during the Eurozone Sovereign Crisis in 2011-2012. Dollar money-market funds stopped lending to European banks

¹⁴Banks do not all have dollar liquidity shortage (i.e. ε_b could also be negative). For instance, in Australia, banks need to fund abroad their long term needs as the base of investors lending long-term is small. They borrow in USD or EUR and swap it back in AUD. CIP deviations in AUD indicates that it is more expensive to swap into AUD instead of the other way around (due to the negative ε_b shock). This demand is partially captured in the data on corporate debt issuance since the Australian banks fund both through long-term debt market and short-term money market.

in of fear of fallouts from the sovereign crisis. This episode is detailed in Ivashina, Scharfstein, and Stein (2015) and analyzed as a case study in the Internet Appendix. Acute ε_b shocks typically affect short-term CIP more than the long-term.

- **Money market reform** in the U.S. that took effect in October 2016 has reduced the availability of wholesales dollar funding to foreign banks and increased their reliance on funding via currency swaps (Pozsar and Smith 2016).
- **Structured note issuers** also utilize currency swaps in the hedging of ultra long-dated structured products whose payoff depends on exchange rate at a future date. The hedging of Power Reverse Dual Currency Notes by issuers had been an important driver of currency basis in AUD, JPY and other Asian currencies.
- **Regulatory-driven hedging demands** New regulatory requirements for the hedging of previously under-hedged exposures also have been a factor driving the CIP basis. Solvency II Directives on E.U. and U.K. insurance companies demanded greater usage of longer-dated cross-currency basis swaps to reduce foreign currency exposure of insurance firm asset holdings¹⁵. The Solvency II rules started with initial discussions in 2009 and finally took effect in 2016.
- **Central bank policies** European banks with excess euro liquidity have been able to take advantage of the higher Interest on Excess Reserve (IOER) rate offered by the Fed through conversion via FX swaps. As of September 2016, foreign bank offices in the U.S. have \$377 billion currency-swapped deposit at the Fed ¹⁶.

The policies at other central banks also had impacts on CIP violations. For example, the termination of ECB’s sterilization programs reduced the amount of High Quality Liquid Asset for European banks and were a contributing factor to the widening of the CIP violation in 2014¹⁷.

¹⁵Previously, insurance firms partially hedged using rolling short-dated FX forwards

¹⁶Foreign banks have a total excess reserve at the Fed totaling \$766 billion as of September 2016, of which \$429 billion are funded through Fed Fund and Repo agreements as a part of the IOER-Fed Fund arbitrage. (Flow of Funds Table L.112)

¹⁷ECB’s Security Market Program that started in 2010 and the Outright Monetary Transaction program that started in 2012 both were initially sterilized purchasing programs. Sterilization encouraged the use of ECB excess reserved and provided a way for banks to obtain HQLA (High Quality Liquid Asset) needed to fulfill LCR (Liquidity

- **Hedging demand from investors** I do not consider this as an ε_b shock since the issuers in my model can be broadly interpreted as both sellers and buyers of bonds. Another reason why investors are not a major contributor to long-term CIP violations is that they often hedge FX risk using rolling short-dated forwards¹⁸.

4.2 Why CIP deviations cannot be eliminated alone?

Why do the two deviations persist? One way of explaining the co-existence of the two LOOP violations is that each of them serves as “short-sell” constraint to the other. This joint determination of the two LOOP violations is analogous to heavily-shorter stocks being overvalued while they have high cost to borrow (Negal [2005], D’Avoli [2002]).

Unlike the textbook notion of costless arbitrage, eliminating CIP violations in practice is very balance sheet intensive. Even an arbitrage strategy that aims to capture CIP deviations at the 1-day horizon in EURUSD requires large cash outlay in one currency versus investment in another. The arbitrageur would need to 1) fund large amount of dollar in cash and 2) invest large amount of euro that is received from the swap. If one were able to do (1) and (2) without cost at Libor (or the Overnight Index Swap rate), then CIP deviations would easily be eliminated. Below I discuss and rule out possible arbitrageurs:

- **Banks** Traditionally, depository institutions’ Asset Liability Management desks were the marginal arbitrageurs of CIP deviations by flexibly lending out their balance sheets as needed. However, few institutions can do so today in the post-crisis environment with tightened balance-sheet constraints. On the contrary, as discussed earlier, banks had become a net contributor to CIP violation as they themselves rely on FX swaps to fund in different currencies.
- **Hedge funds** are often mistakenly viewed as a source of arbitrage capital for eliminating CIP violation. Hedge funds only integrate the *term structure* of the currency forwards but

Coverage Ratio) requirements. The end of ECB sterilization in 2014 meant that European banks needed to look for other HQLA to replace around \$200 billion of ECB excess reserve. Therefore, these banks had to either invest in Euro assets or swap into other currencies and park their cash at the Fed or other central banks.

¹⁸Most benchmark indices calculate total returns on foreign sovereign and corporate bonds either as unhedged returns or hedged returns using 1-month rolling FX forwards. Bank of America Merrill Lynch, Barclays, and Citi each state in their index methodology that 1 month rolling forwards are used in the calculation of total returns for currency hedged indices. Longer horizon FX hedges are sometimes used but generate tracking errors from benchmark for investors. Of course, the long- and short- dated CIP basis are integrated to a certain extent as discussed below.

provide little mitigation of the *outright level* of deviation from CIP. This is because outright arbitrage of CIP is a capital-intensive transaction that requires the physical delivery of cash. It is difficult for hedge funds to obtain funding and invest at Libor or OIS rates¹⁹. The key point is that low-risk, balance sheet intensive activities are costly to conduct. Instead, hedge funds transmit shocks across the maturity curve of CIP deviations by entering forward starting cross-currency basis swaps that do not have physical exchanges of notional and unwind the trades before the actual delivery of cash. This form of term structure integration can be modeled similarly as Vayanos and Vila (2009) and Greenwood and Vayanos (2014).

- **Debt issuers and investors** The ability to borrow and to invest large amount of cash in a deep market is a defining characteristic of the debt capital markets. Therefore, It is natural to expect issuers and investors to play a large role in eliminating CIP violation. This is precisely why CIP violation is linked to corporate credit spread differential (and sovereign spread differentials to some extent²⁰).

More stringent regulatory requirements have also raised the cost of arbitraging CIP deviations. In other words, γ has increased. Since the Financial Crisis, the margin on basis swap trades increased endogenously a la Geanakoplos (2010) and further exacerbated the violations. Specifically, Supplementary Leverage Ratio has increased the cost of holding low-risk positions. Mandatory margining by different local regulator and other Basel III rules has also increased the cost of trading FX swaps. An alphabet soup of different funding costs has also emerged²¹ in response to post-financial-crisis regulatory and market environment. Related to this, Levich (2012) finds that trading in over-the-counter currency forward has declined in favor of currency futures. In short, there are hefty costs to low-risk, low-return projects.

¹⁹Alternatively, using equity capital from investors to arbitrage CIP earns unattractive returns

²⁰While the government bond market is more liquid, developed market sovereigns seldomly issue in foreign currencies with the same covenants as their domestic bonds. Sovereigns can also choose to default on foreign bonds without defaulting on domestic bonds. Investors would face different sovereign risk if they were to bundle together the arbitrage of CIP violation with government debt investments. On the other hand, bonds issued by corporates and supranationals in multiple currencies have the same underlying credit risks across denominating currencies, therefore, corporate debt is a natural choice for facilitating CIP arbitrage.

²¹These funding costs include CVA (Credit Valuation Adjustments) that accounts for counter-party default risk, KVA (Capital Valuation Adjustment) imposed by banks on clients to account for the lifetime capital consumption of individual trades, MVA (Margin Valuation Adjustment) that adjusts for interest earned on the initial margin to reflect interest on investments of similar risk elsewhere, and FVA (Funding Valuation Adjustment) that adjusts for differential funding rates associated with derivative collateral posting. Collectively these are known as XVAs.

4.3 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 my analysis on firms for two reasons. First, bond issuance data is readily available and comprehensive. This data allows the testing of model predictions on capital flow, shock transmissions, and deviation elimination. Second, firms are natural cross-market arbitrageurs that can better withstand noise trader shocks and more easily overcome limits of arbitrage problems raised by Shleifer and Vishny (1997). This point had been argued by previous papers including Baker and Wurgler (2000), Greenwood, Hanson, and Stein (2010), and Ma (2015).

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 retail bond fund holds only a total of €55 billion of EUR corporate bonds²². The small number of hedge funds that do engage in the active trading of foreign credit markets face balance-sheet constraints as discussed earlier and high transaction costs in long-short strategy. This is because a long-short strategy requires conducting repo in one market and reverse-repo in the other market to fund the bond positions while also engages in FX hedging. Limits to arbitrage associated with investor redemption and short investment horizon as highlighted in Shleifer and Vishny (1997) pose a challenge to all specialized funds that perform arbitrage. In short, dedicated investors simply do not have enough capital or risk tolerance 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. Because firms have stable cash flows and do not face redemptions, making a onetime issuance and hedging decision is equivalent to holding the arbitrage trades to maturity.

²²EPFR data

The standard deviation of monthly issuance flow between the Eurozone and the U.S. is more than \$6 billion. This is equivalent to the creation of a sizable hedge fund fully dedicated to exploiting the two LOOP violations every month.

4.3.1 Evidence from textual analysis of SEC filings

I conduct a textual analysis of SEC filings by S&P 500 firms that is indicative of the pervasive use of currency-hedged debt issuance. Figure 8 shows the result of this analysis. I graph 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 to 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 had 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 widen. This analysis of SEC filings shows the pervasiveness of firms acting as cross-market arbitrageurs between the credit market and CIP market in recent periods²³.

5 Empirical test of model predictions

In this section, I take the model to the data. I first describe the issuance data, the measurement of net deviations, and patterns in the misalignment. Then I present supporting evidence for the model predictions.

5.1 Data and definition

5.1.1 Issuance flow μ

To test the model predictions on cross-currency capital flow, I analyze the amount of corporate debt issued by public firm in the seven free-floating funding currencies. Debt issuance amount and other bond characteristics are obtained from Thompson One SDC Platinum data set. I define the

²³Figure 8 also shows that a smaller fraction of firms have indicated currency-hedged issuance as early as 2004 even though both the CIP violation and the aggregate credit spread differentials were small prior to 2007. This is possibly explained by issuer-specific idiosyncratic credit spread differentials that did not appear in the aggregate.

monthly bilateral issuance flow between two currency regions as the amount of debt issuance by foreign firms in dollar minus the amount of debt issuance by U.S. firms in that currency expressed as a percentage of total issuance. For instance, the issuance flow between Europe and the U.S. is expressed as

$$issPct^{EU \rightarrow US} = \frac{\text{EU firm issuance in dollar} - \text{US firm issuance in euro}}{\text{total issuance in dollar \& euro}}.$$

This measure of issuance flow proxies for μ in my static model²⁴.

5.1.2 Net deviation ($c - b$)

I define *net deviation* as the difference between the residualized credit spread differential and CIP violation. Since the maturity of FX forward used to hedge each individual bond is different, I first adjust the swap yield curve by the corresponding CIP deviation maturity curve. I then linearly interpolate to each individual bond's maturity in calculating the bond's effective credit spreads. Lastly, I conduct cross-sectional regression as specified in Equation 1 using the bond-level effective credit spreads as the dependent variable. I take the currency fixed effects as estimates of the net deviation that corrects for maturity mismatches between FX forwards and bonds. This procedure produces estimates of $c - b$ that is similar to a measure that directly subtracts the 5-year CIP deviation from the credit spread differential.

Misalignment of LOOP violations The two violations are misaligned when the size of net deviation is large or when their correlation is low. Figure 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. The misalignment, however, is larger during the financial crisis. This is consistent with the model predictions that larger demand shocks in the FX and credit market, more risk aversion, and less debt issuance lead to larger misalignment between c and b . Credit spread differential had higher

²⁴An alternative measure is the ratio of all debt issuance in euros to total issuance in euros and dollars. This measure is confounded by fluctuations in overall debt issuance in different regions and less reflective of the currency choice of the debt issuers.

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 U.S. Federal Reserve established swap lines with other central banks for the lending of dollar funding to foreign institutions. On the other hand, credit market distortions were exacerbated during the financial crisis by the lack of liquidity in the fixed income market.

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 c , CIP violation b , and issuance flow μ to ε_c and ε_b shocks. In addition, I provide interpretation of the time series magnitudes and lead-lags relationships.

5.2.1 VAR analysis

VAR analysis is useful in this context since the shocks to credit and CIP can occur simultaneously and transmission could be slow. As discussed in Section 4, there are many source of ε_c and ε_b shocks. These shocks can occur concurrently and might be anticipated, e.g. gradual regulatory changes. Furthermore, 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). In this context, cross-currency issuance transmits the shocks gradually.

Figure 10 presents the orthogonalized impulse response functions with shocks to credit and CIP. The impulse response in this figure applies Cholesky Decomposition using a strict ordering of variables. I assume that issuance respond with a lag to both c and b , and b respond with a lag to c . That is, I estimate the following,

$$\begin{bmatrix} 1 & 0 & 0 \\ a_{c\mu} & 1 & 0 \\ a_{b\mu} & a_{bc} & 1 \end{bmatrix} \begin{bmatrix} \mu_t \\ c_t \\ b_t \end{bmatrix} = B \begin{bmatrix} \mu_{t-1} \\ c_{t-1} \\ b_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{\mu,t} \\ \varepsilon_{c,t} \\ \varepsilon_{b,t} \end{bmatrix}.$$

Proposition 1 states that an exogenous increase in the euro credit spread c (less demand of euro credit, $\varepsilon_c \downarrow$) raises dollar debt issuance μ and currency basis b (less FX swapping cost from euro to dollar) as firms avoid the higher credit spread in EUR and issue more in USD. The first row

of Figure 10 confirms this model prediction. Upon a shock that increases c (top left), both b (top middle) and μ (top right) are raised. Credit spread differential then gradually declines after the initial shock as do μ and b .

The slow responses of issuance flow μ and CIP deviation b to an ε_c shock are reflective of the slow-moving nature of corporate financing decisions. The price under-reaction in the market not directly receiving the shock also matches the prediction of cross-market price dynamics with slow moving capital (Greenwood, Hanson, and Liao 2016).

The bottom row presents the impulse responses with an exogenous increase in b that signals an increase in the cost of swapping dollar to euro. We observe the exact opposite dynamics in the second row as predicted by Proposition 1. Cost of swapping into euro initially is raised then gradually declines over time (bottom middle). The slow moving capital effect is also discernible. Issuance flow initially shifts towards euro (bottom right) to take advantage of the lower cost of swapping into dollar, then the issuance gradually normalizes over the next nine months. Credit deviations also increase gradually before plateauing around 6 months after the shock (bottom left).

Since it is ambiguous whether LOOP violation in CIP arises before violation in credit risk pricing, I also consider an alternate ordering in which issuance responds with a lag to both c and b , and c responds with a lag to b . This alternate specification yields similar results as Figure 10 and is presented along with a partial identification approach²⁵ in the Internet Appendix. Furthermore, I conduct the same analysis on all six currency pairs against the dollar in a panel VAR. The resulting impulse response function is similar to that of EURUSD and is presented in Figure 11.

5.2.2 Time series

Beyond VAR analysis, the time series of the two LOOP violations are also informative in establishing the direction of spillover. The changing lead-lag relationship and relative magnitudes of the two deviations in different periods provide intuitions on whether shocks might have originated from credit demand or FX forward demand. As seen in Figure 1, CIP deviation appears to have led the credit spread differential both in time and magnitude during the 2011-2012 Eurozone Sovereign Crisis that

²⁵The partial identification approach restricts μ to respond with a lag to c and b but allow the c and b to have contemporaneous effects on each other.

deteriorated foreign bank’s wholesales dollar funding conditions²⁶. In more recent periods, credit spread differential has overtaken CIP deviation in magnitude and time lead, which is potentially a reflection of credit demand shocks originating from ECB asset purchases.

The term structure of CIP deviations also supports the above narrative. Short-term CIP condition became more distorted than long-term CIP during 2011-2012 reflecting a ε_b shock originating from the banking sector²⁷. However, in recent periods, short-term and long-term CIP are similar in magnitude, potentially indicating that the CIP shocks from the bank’s need of short-term dollar funding no longer dominate and ε_c shock is more important.

5.3 Prediction 2: Issuance flow and net deviation

Another key prediction from the model is that capital flow fluctuates with net deviation. In the case of corporate arbitrageurs, capital flow is represented by cross-currency issuance.

I focus on bilateral issuance flows with the U.S. since the U.S. corporate bond market is the largest, with over a third of the global corporate debt issuance in the data sample. Figure 12 compares the quarterly time series of the issuance flow and net deviation for EURUSD. Consistent with the model prediction on the co-movement between μ and $c - b$, issuance flows from Europe to the U.S. when the effective residualized credit spread of euro-denominated debt is high relative to dollar-denominated debt, and vice versa.

The sign reversals of the issuance flow and net deviation mark distinct time periods. Prior to the credit crunch in 2007, the net deviation was relatively small and net issuance flow oscillated between the two markets with a tilt towards issuance flowing into Europe. The onset of the U.S.-led credit crunch in 2007 coincided with a reduction of residualized euro-credit spread relative to dollar credit spread. This is surprising since the residualization suggests that similar bonds issued by the *same* firm are differentially affected by the credit crunch depending on the denomination currency. The change in net deviation is coupled with several quarters of strong issuance flow from the U.S. to Europe. As the U.S. Federal Reserve begins its quantitative easing (QE) program in late 2008 and early 2009, both the signs for issuance flow and net deviation turned positive. Even though the asset purchase was in treasury and MBS, QE also indirectly affected the corporate bond market

²⁶Chernenko and Sunderam (2014) document that the total money-fund holdings of Eurozone bank paper declined by 37%, from \$453 billion to \$287 billion, between May and August of 2011.

²⁷see Appendix Figure ??

but with lag (Mamaysky 2014, Greenwood, Hanson, and Liao 2015). Foreign issuance in dollar was popular during this period of Fed QE. In the more recent period since 2014, both time series have reversed sign once again towards the negative. The tapering of Fed QE and the ramp up of ECB asset-purchasing program coincided with lower euro-relative-to-dollar credit spread. The issuance of non-dollar denominated debt by U.S. firms have increased and driven the net issuance flow towards Europe.

The co-movement of issuance flow and net deviation can also be examined through regressions. Table 3 presents regression results showing the relation between net deviation (effective credit spread differential) and issuance flow. As seen earlier in the VAR analysis, issuance flow continues for several months after a shock to the credit and CIP violations. Because of the gradualness in response, I examine the relation between net deviation at month t and issuance flow averaged over the following six months. The coefficients for the panel regression and for the individual regressions of EUR, GBP, JPY, and CHF are all significant while they are insignificant for AUD, and CAD. One possible interpretation is that while issuance flow is an important source of arbitrage capital in some currency pairs, it is not a dominant force of arbitrage capital for others. Instead, the coefficients on interest rate differential, which represent unhedged carry trade returns, is highly significant for AUD and CAD. This indicates that issuers might be issuing unhedged in these two currencies for reasons unexplored in this paper. Correspondingly, CIP deviations in AUD and CAD relative to USD are less correlated with their credit spread differentials as can be seen in Figure 5 and Table 2.

The coefficient on net deviation for EUR-USD issuance flow is the largest and most significant. This is perhaps because the euro and dollar corporate credit markets are highly developed, and issuers are relatively flexible to issue between the two markets. It is also a reflection of the data that is concentrated on EUR- and USD- denominated bonds.

To explore the dynamics of slow moving capital, I conduct a VAR study on issuance flow and the net deviation as I had done with the individual credit and CIP deviations in earlier section. Figure 13 presents the orthogonalized impulse response function of issuance flow upon a shock to the net deviation assuming issuance respond with a lag to changes in net deviation. The impulse response shows that issuance flow continues to be significant up to 10 months after a shock to the net deviation.

5.3.1 Firm-level panel

The aggregate results showing the response of capital flow to the two LOOP violations and to the net deviation can equivalently be tested using a panel of firm-specific credit spread differentials and net deviations. I explore the decision of firm’s currency debt choice with a linear probability model and present the results in Table 4. The predictions in the aggregate data are supported by the firm-level regressions with controls for time, currency, and firm fixed effects. These firm-level panel regressions serve as robustness checks to the aggregate result.

5.4 Prediction 3: Total issuance 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 towards infinity, we would expect the net deviation to converge to zero. In this section, I analyze whether changes in the amount of arbitrage capital affect the net deviations by first testing in an OLS regression followed by instrumental variable approach that uses the amount of debt maturing to instrument for the need to rollover and refinance through new debt issuance. Specifically, I run a change-on-change regression of the following form

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

where $\Delta|c - b|_{t,c}$ 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, not the outstanding amount of debt.

Conceptually, the analysis relies on the assumption that firms are being opportunistic on the relative allocation of issuance in different currencies rather than being opportunistic on varying the issuance size in market timing. While the latter motive is important and documented in a number of studies (Baker and Wurgler [2000], Greenwood, Hanson, and Stein [2010], Ma [2015], etc.), 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 endogenous debt issuance decision, I instrument debt issuance amount with 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 currency of denomination 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 for EUR, JPY, CHF, and GBP²⁸. For each billion-dollar increase in amount of total maturing debt, the net deviation is reduced by roughly 0.1 basis points. While statistically significant, the economic magnitude of this estimate is small. This is likely because market participants can anticipate large issuance needs from maturing debt given that the debt maturities are easily observable.

5.5 Prediction 4: Spillover of Limits to Arbitrage

Lastly, I discuss possible tests of the prediction on the spillover of limits to arbitrage. The model suggests that frictions constraining in one market can also be constraining for the other market. These limits to arbitrage frictions can be either directly observable frictions, such as transaction costs, or hard to observe frictions, such as agency frictions. In the model, these constraints are represented by FX swap collateral haircut γ in Equation 7 and the ratio of bond risk to risk tolerance $\frac{V}{\gamma}$ in Equation 8. The FX haircut is a direct cost while the latter might proxy for indirect agency costs associated with holding an arbitrage position that could become more dislocated before converging as in Shleifer and Vishny (1997).

The empirical measures of these two types of Limits to Arbitrage are difficult to obtain. FX collateral haircut for derivative transactions depends on the currency, maturity and counterparty. The cost of holding LOOP arbitrage positions to maturity are also difficult to quantify. As a rough proxy, I analyze the impact of broker-dealer leverage, proxying for γ , and the VIX index, proxying for $\frac{V}{\gamma}$, on the absolute level of credit spread differential and CIP deviation. The results are in line with Prediction 4. However, these two proxies are imprecise and thus the results are relegated to the Internet Appendix.

²⁸AUD and CAD are excluded in this analysis since hedged issuance is less relevant for the determination of deviations in these two currencies as discussed earlier in Section 5.3.

6 Conclusion

This paper examines the connection between violations of covered interest rate parity and price discrepancy of credit risk for bonds of different denominating currencies. I document that these two forms of LOOP violations are substantial and persistent since the financial crisis. Moreover, the two violations are highly aligned in magnitude and direction in both time series and cross section of currencies. I develop a model of market segmentation along two dimensions – in credit market along currency denomination and in FX market between spot and forward exchange rates. Arbitrage processes are imperfect in either markets but capital flow, such as corporate bond issuance, ensures that the two types of LOOP violations are intimately connected.

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7 Figures

Figure 2 Residualized foreign currency credit spreads relative to dollar credit spread

This figure presents the residualized credit spreads in each currency relative to dollar credit spread. To construct this measure, I estimate the following cross-sectional regression at each date t

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

where S_{it} is the yield spread over the swap curve for bond i that is issued in currency c , by firm f , with maturity m and rating r . The residualized credit spread of currency c relative to dollar is defined as $\hat{\alpha}_{c,t} - \hat{\alpha}_{usd,t}$. Details of the measure's construction are provided in Section 1.2.

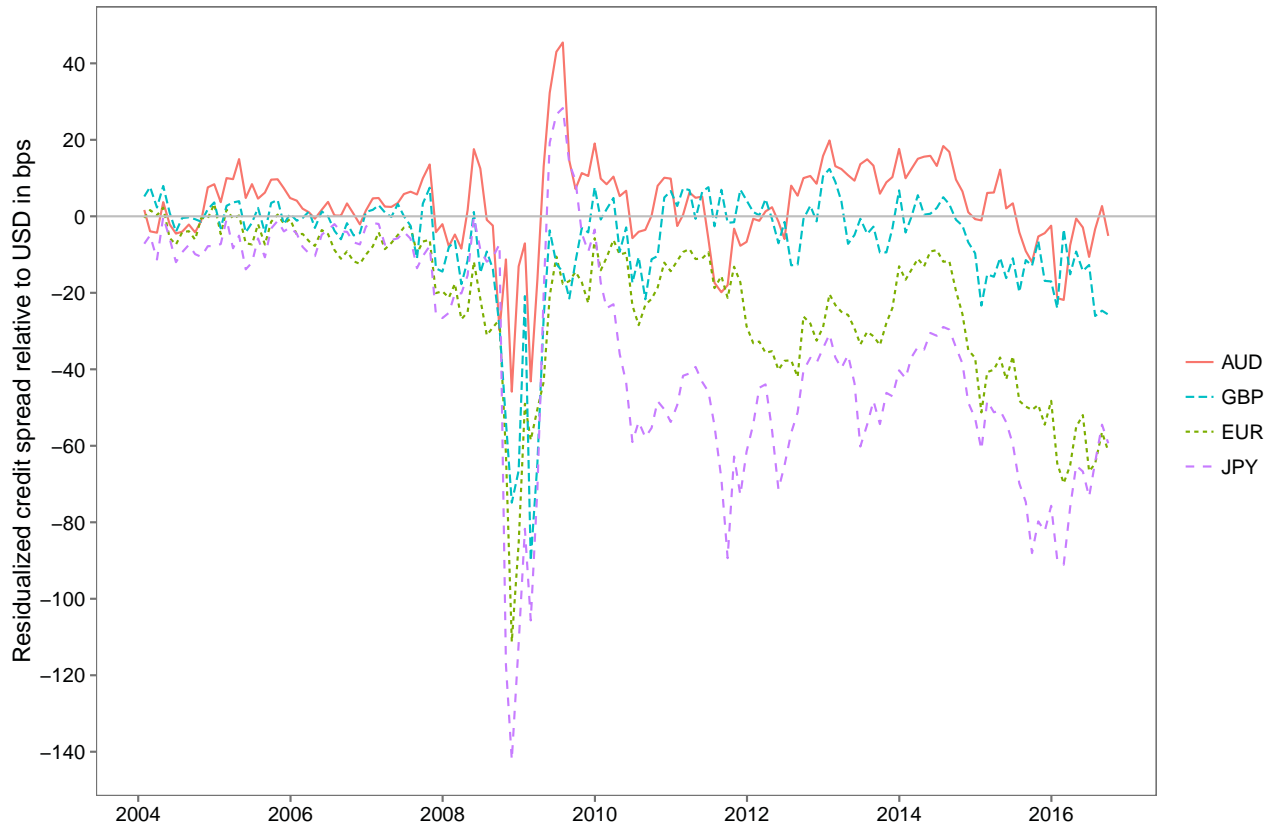


Figure 3 Comparison of residualized credit spread differential (EU-US) with un-residualized benchmarks

This figure compares the EU-US residualized credit spread differential (dashed blue) with un-residualized credit spread differentials from Bank of America Merrill Lynch Single A Corporate index (BAML, dotted green) and Barclays Single A Corporate index (solid red). The un-residualized euro minus dollar credit spread differential is the difference between dollar-denominated single A aggregate option adjusted spread (OAS) and euro-denominated single A OAS benchmarks published by BAML and Barclays.

To construct estimates of residualized credit spread, I estimate the following cross-sectional regression at each date t

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

where S_{it} is the yield spread over the swap curve for bond i that is issued in currency c , by firm f , with maturity m and rating r . The residualized credit spread of euro relative to dollar is defined as $\hat{\alpha}_{eur,t} - \hat{\alpha}_{usd,t}$. Details of the measure's construction are provided in Section 1.2.

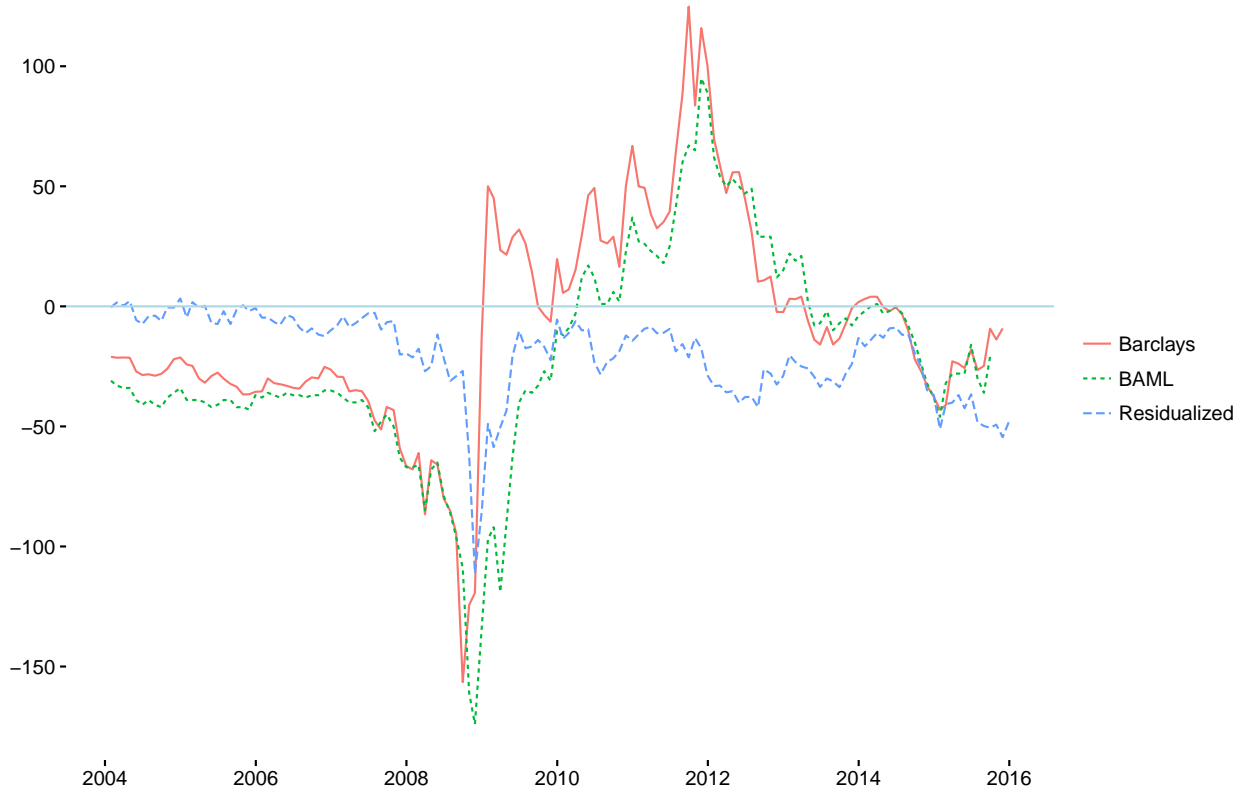


Figure 4 Covered Interest Rate Parity deviations at the 5-year horizon

This figure presents the violations of covered interest rate parity at the 5-year horizon between each of the four major free-floating funding currencies - EUR, GBP, JPY, AUD - and USD. Deviations from CIP are measured as the FX-implied local funding rate minus the actual local funding rate. Details of this measure are provided in Section 2.

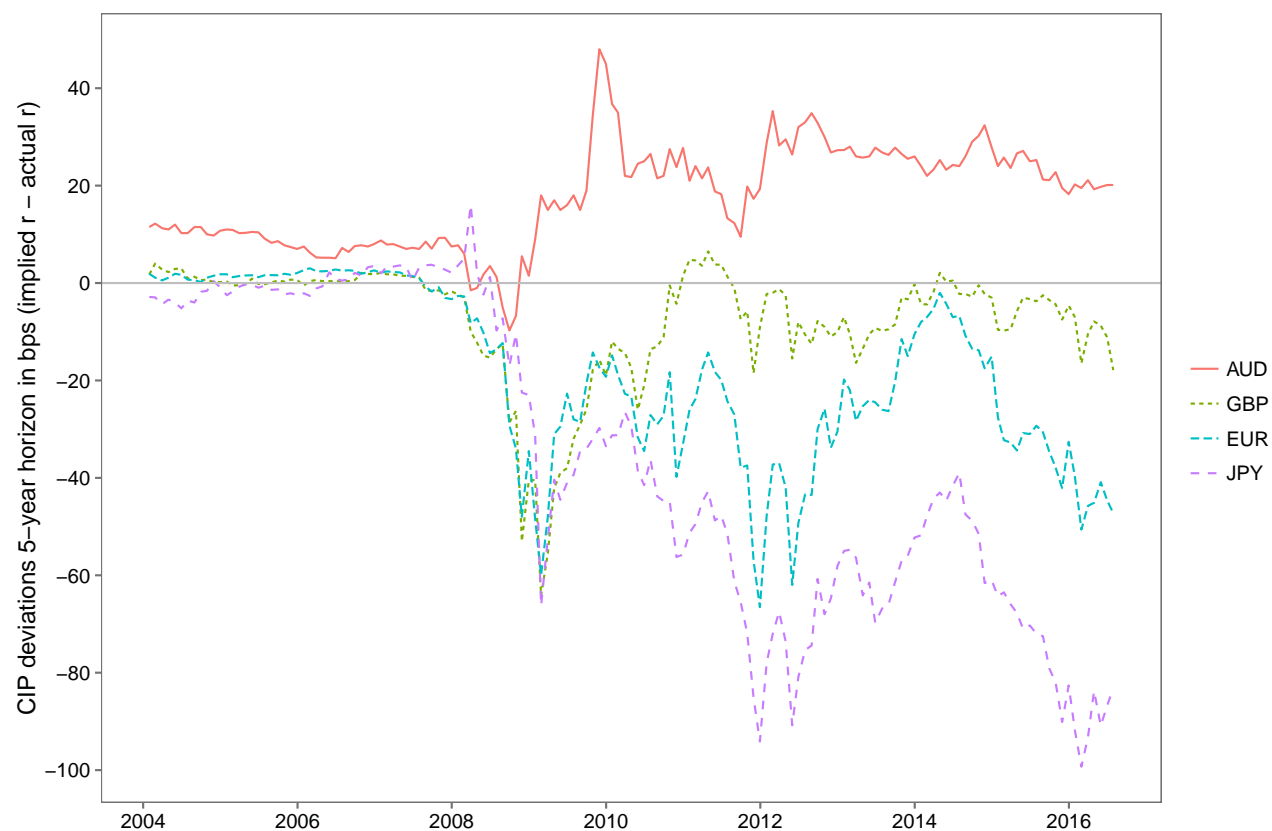


Figure 5 Credit spread differential and CIP violation relative to USD

This figure presents the residualized credit spread differentials ($\alpha_c - \alpha_{USD}$) and CIP deviations ($r_c^{\text{FX implied}} - r_c$) relative to USD for six major funding currencies ($c = \text{EUR, GBP, JPY, AUD, CHF, CAD}$). The CIP deviations are in solid red. Credit spread differentials are in dotted blue. Vertical bars (grey) represent the 95% confidence interval for the estimated credit spread differentials constructed using robust standard errors clustered at the firm level. Details of the measures' construction are provided in Section 1.2 and 2.

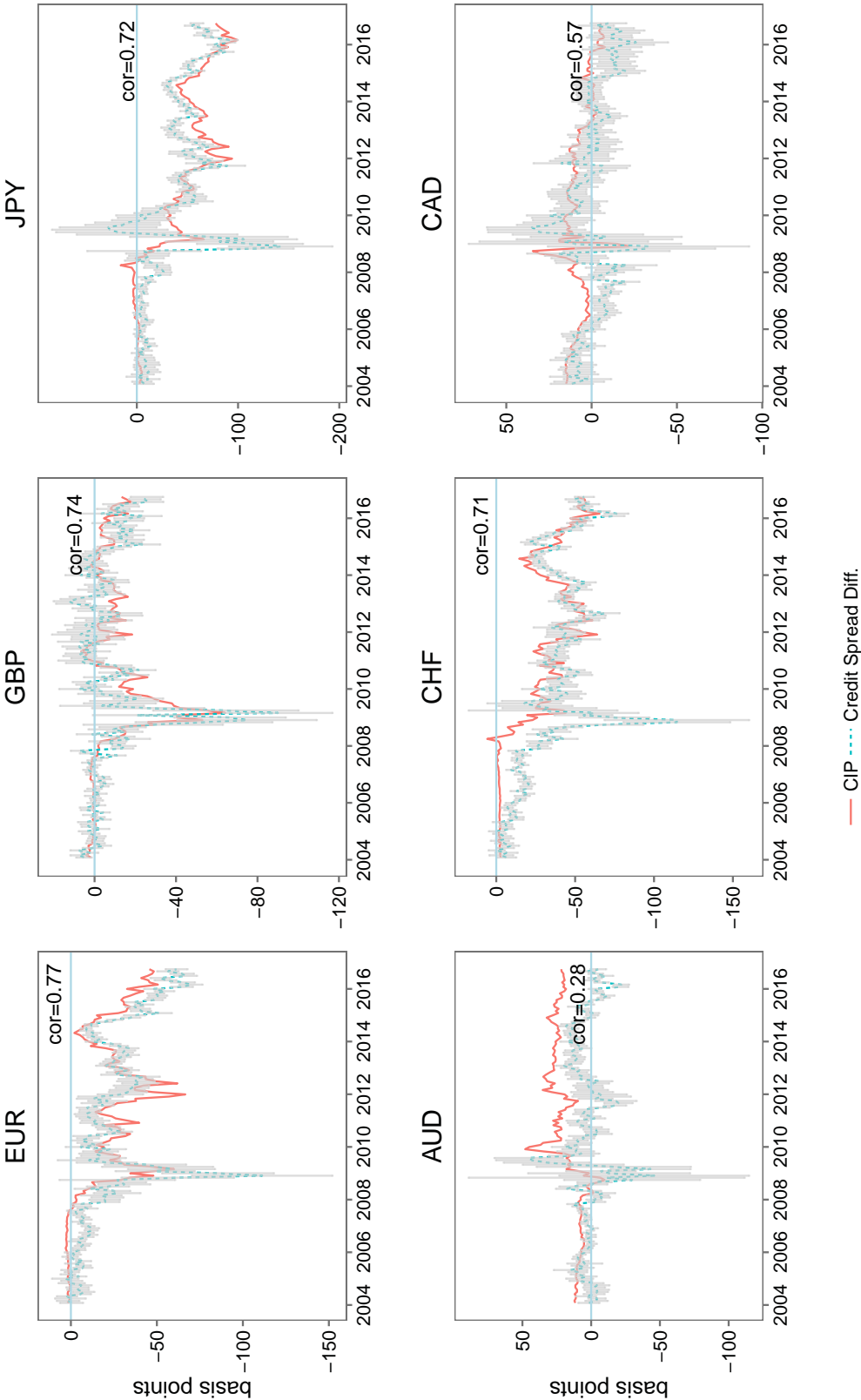


Figure 6 Credit spread differential and CIP violation

This figure presents the residualized credit spread differential and CIP violations relative to USD for EUR, GBP, JPY, AUD, CHF and CAD. Details of each measures' construction are provided in Section 1.2 and 2.

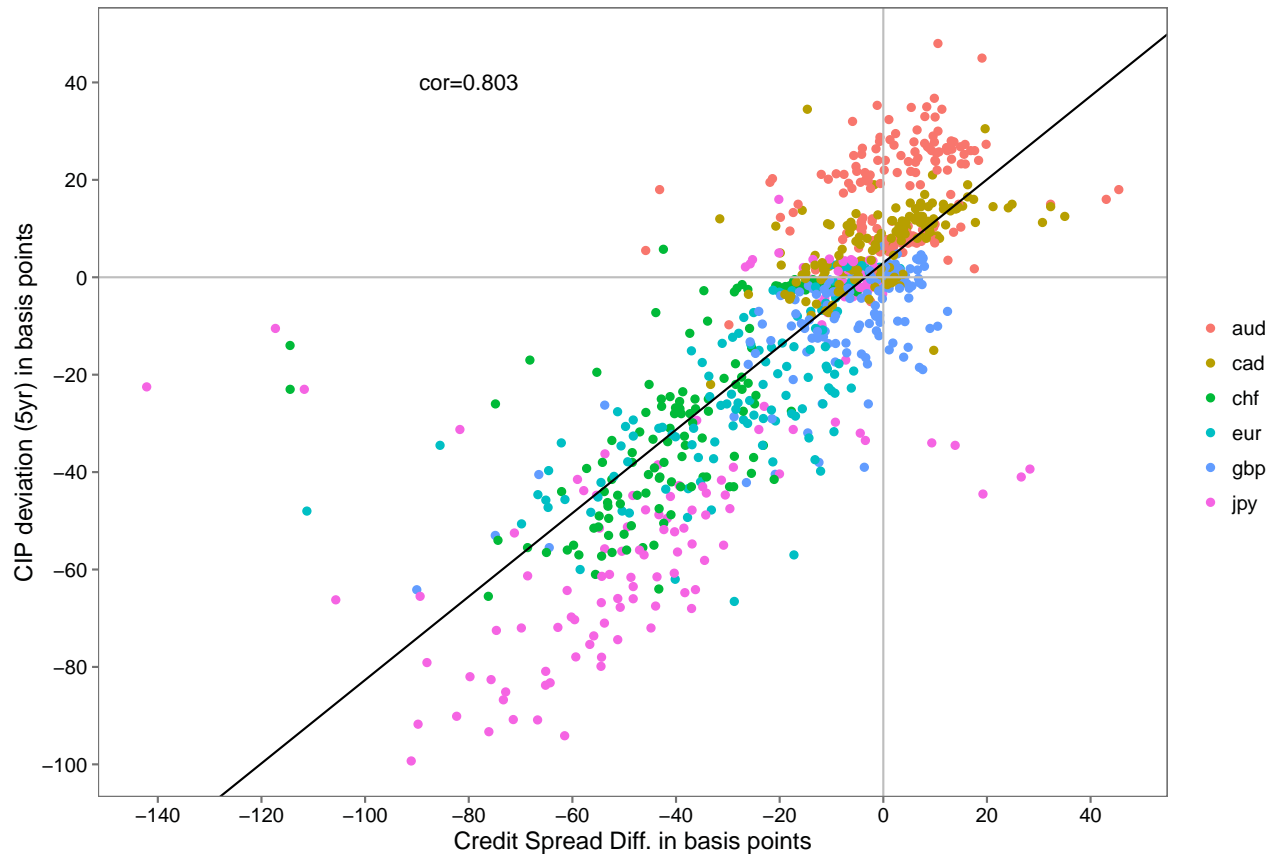


Figure 7 Schematic of institutional details

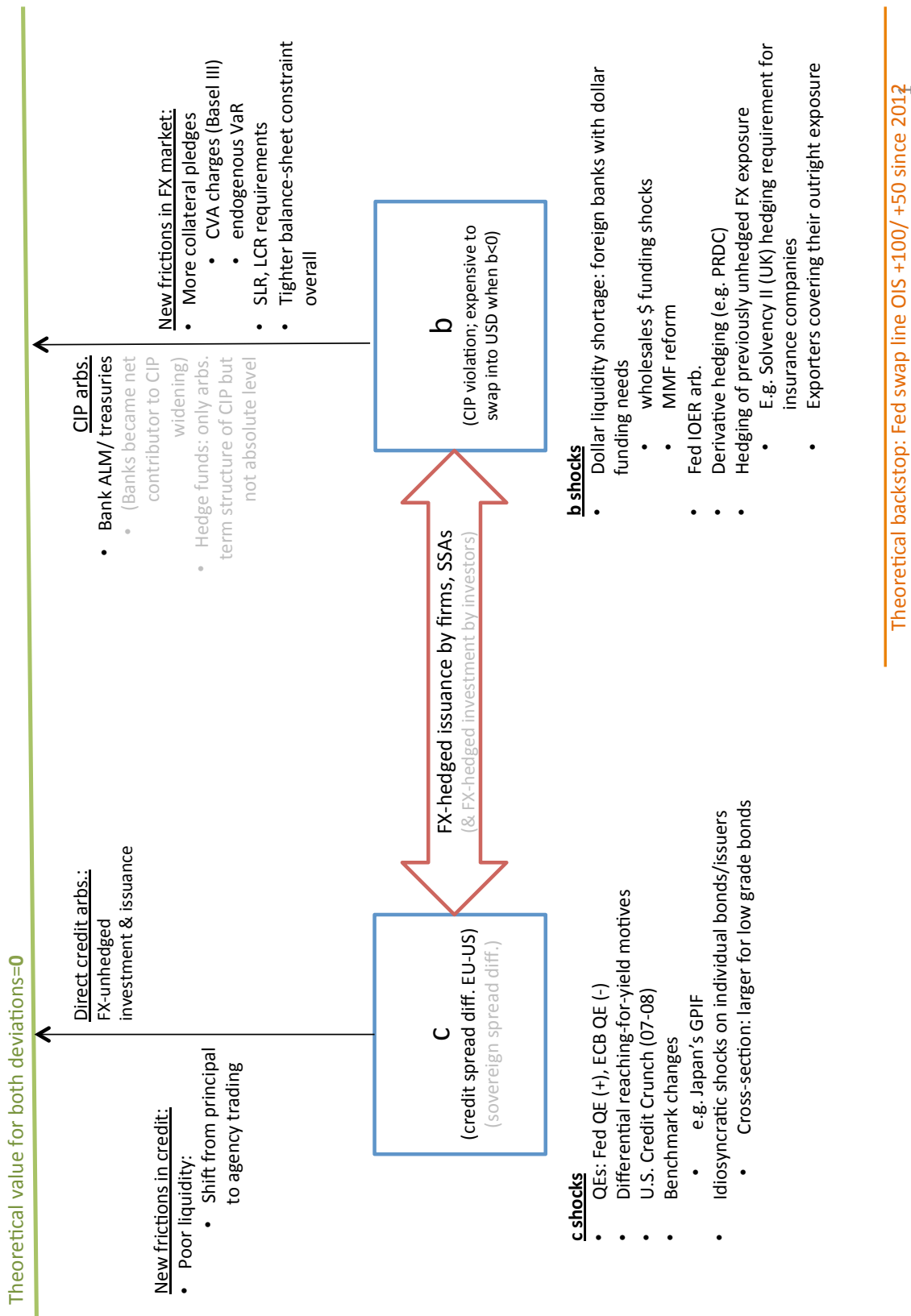
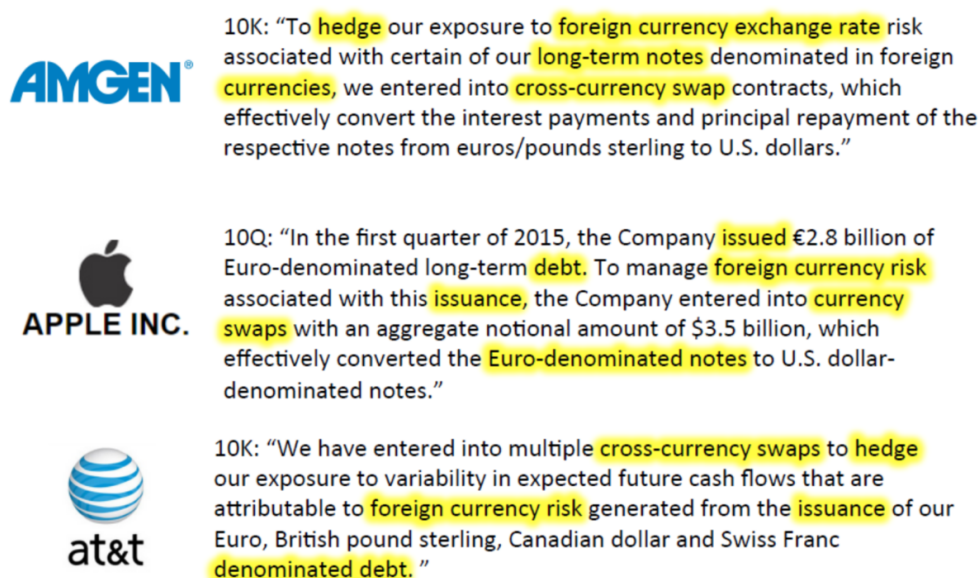


Figure 8 Textual analysis of FX-hedged foreign debt issuance for S&P 500 firms

This figure presents a textual analysis of SEC filings for S&P500 firms that had indicated cross-currency debt issuance in their annual 10-K filings. Panel A shows three examples of firms that have mentioned in their SEC filings that they engaged in currency-hedged foreign debt issuance. Panel B presents the fraction of SEC 10K filings of S&P500 firms with mentions of words relating to 1) “debt”, 2) “exchange rate”, 3) “hedging” and 4) “derivative” in the same sentence by year.

Panel A: Examples of SEC filings with mentions of currency-hedged debt issuance



Panel B: Fraction of 10K filings with mentions of currency-hedged debt issuance

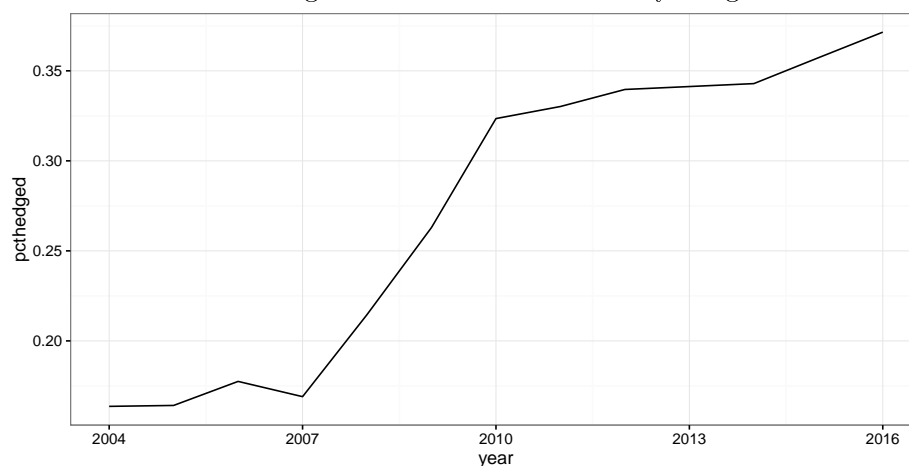


Figure 9 Net deviation

This figure presents the net deviation or the effective residualized credit spread (credit spread differentials minus CIP deviations with matching maturities) for EUR, GBP, JPY, AUD, CHF and CAD relative to USD. Vertical bars (grey) represent the 95% confidence interval for the estimated net deviation. To construct the net deviation, I estimate the following cross-sectional regression at each date t

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

where S_{it}^{adj} is the yield spread over the CIP-adjusted swap curve for bond i that is issued in currency c , by firm f , with maturity m and rating r . The CIP-adjustment is calculated by subtracting maturity-specific CIP deviation from each bond's yield spread. The net deviation or effective residualized credit spread for currency c relative to dollar credit spread is calculated as $\hat{\alpha}_{c,t} - \hat{\alpha}_{usd,t}$. Details of net deviation's construction are provided in Section 5.1.2.

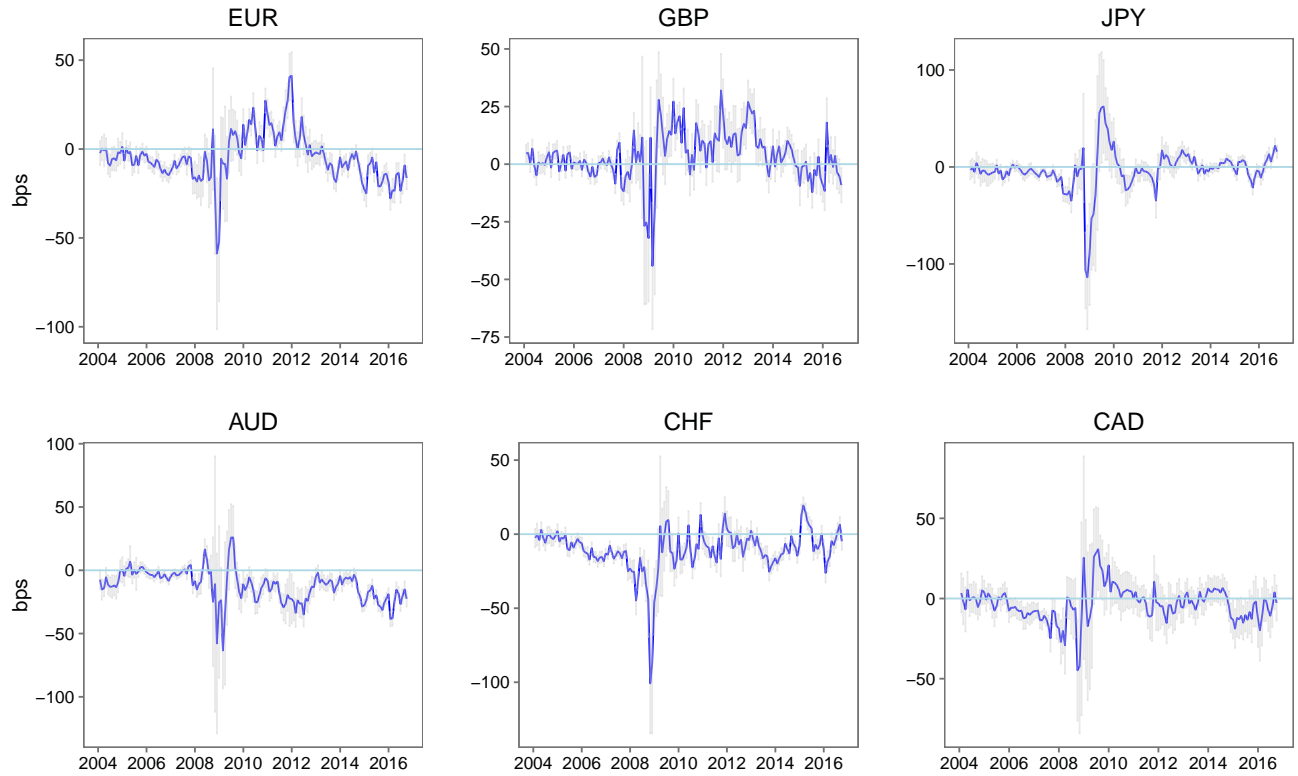


Figure 10 Spillover of deviations: orthogonalized impulse responses of deviations and issuance flow for EURUSD

I estimate a first order vector autoregression (VAR) of the form

$$\begin{bmatrix} 1 & 0 & 0 \\ a_{c\mu} & 1 & 0 \\ a_{b\mu} & a_{bc} & 1 \end{bmatrix} \begin{bmatrix} \mu_t \\ c_t \\ b_t \end{bmatrix} = B \begin{bmatrix} \mu_{t-1} \\ c_{t-1} \\ b_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{\mu,t} \\ \varepsilon_{c,t} \\ \varepsilon_{b,t} \end{bmatrix}$$

where μ_t is the bilateral issuance flow (defined in Section 5.1.1), c_t is the credit spread differential and b_t is the CIP deviation. I apply Cholesky Decomposition by ordering the variables as μ , c and b . This ordering assumes that issuance responds with a lag to both ε_c and ε_b shocks, and CIP violation respond with a lag to credit shock. (An alternative ordering of credit spread differential lagging CIP violation and a partial identification ordering are presented in the Internet Appendix) The orthogonalized impulse responses to ε_c and ε_b shocks are graphed below. The choice of lag 1 is selected by Bayesian Information Criteria. 95% confidence intervals are shown in gray.

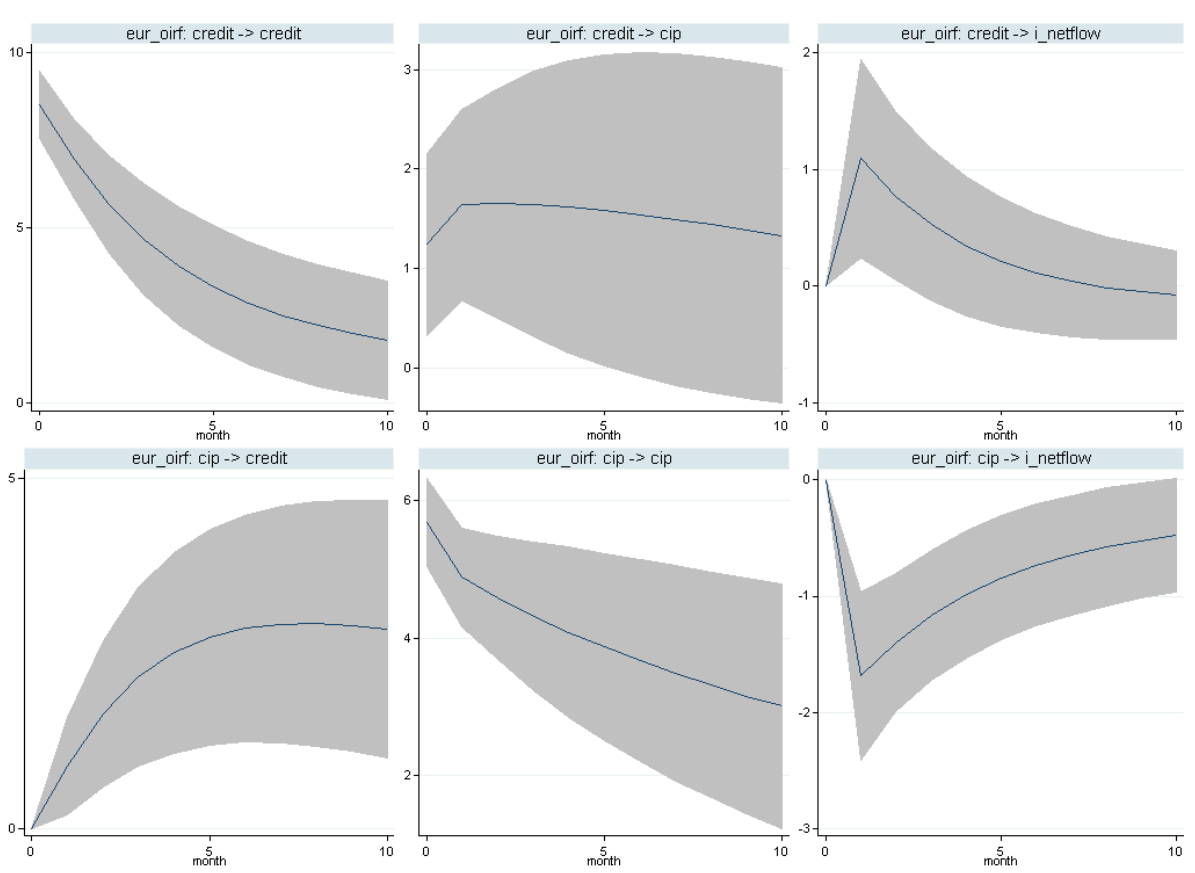


Figure 11 Spillover of deviations: Panel VAR

I estimate a first order panel vector autoregression (PVAR) for the six currency pairs ($i =$ EURUSD, GBPUSD, JPYUSD, AUDUSD, CHFUSD, CADUSD)

$$\begin{bmatrix} 1 & 0 & 0 \\ a_{c\mu} & 1 & 0 \\ a_{b\mu} & a_{bc} & 1 \end{bmatrix} \begin{bmatrix} \mu_{i,t} \\ c_{i,t} \\ b_{i,t} \end{bmatrix} = B \begin{bmatrix} \mu_{i,t-1} \\ c_{i,t-1} \\ b_{i,t-1} \end{bmatrix} + \begin{bmatrix} \delta_{i,\mu} \\ \delta_{i,c} \\ \delta_{i,b} \end{bmatrix} + \begin{bmatrix} \varepsilon_{i,\mu,t} \\ \varepsilon_{i,c,t} \\ \varepsilon_{i,b,t} \end{bmatrix}$$

where μ_t is the bilateral issuance flow (defined in Section 5.1.1), c_t is the credit spread differential, b_t is the CIP deviation and δ_i is a vector of fixed effects. I apply Cholesky Decomposition by ordering the variables as μ , c and b . This ordering assumes that issuance responds with a lag to both ε_c and ε_b shocks, and CIP violation respond with a lag to credit shock. Confidence intervals at the 95% level using bootstrapped standard errors are shown in gray.

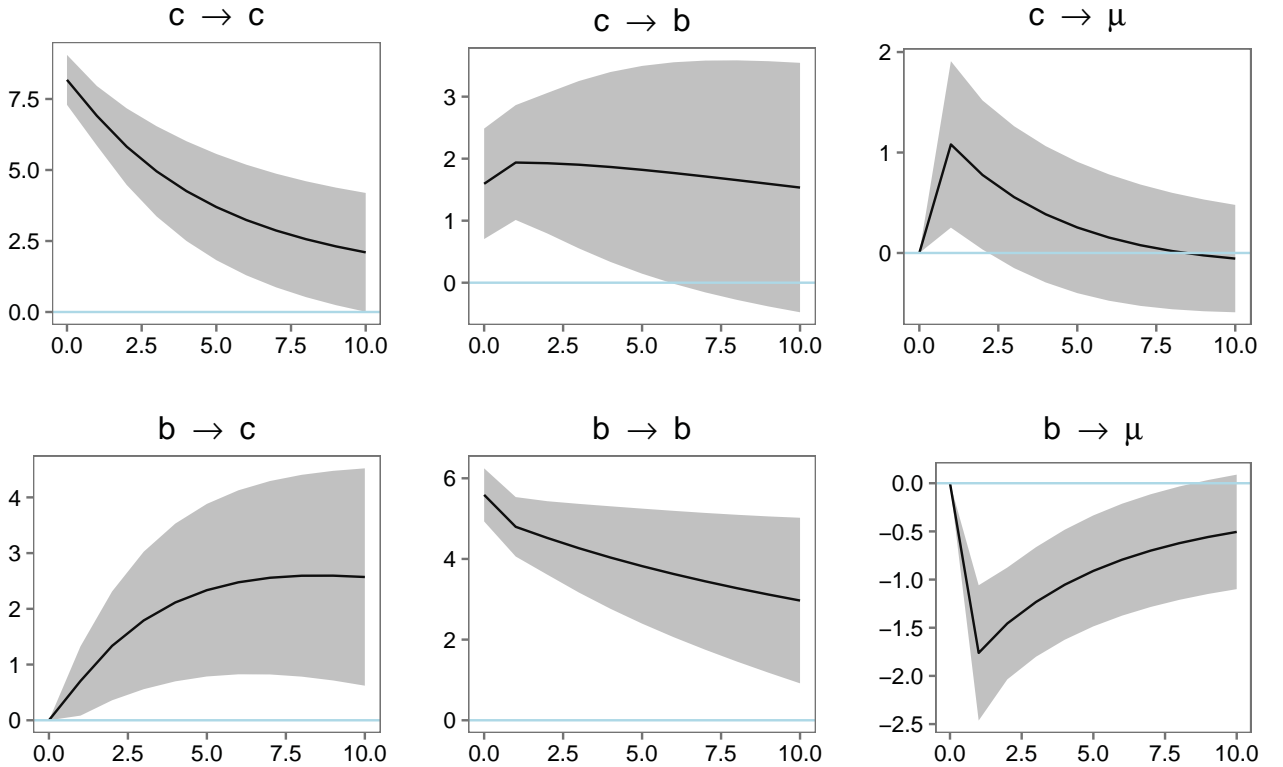


Figure 12 Issuance flow and net deviation between Europe and the U.S.

This figure presents issuance flow between the Eurozone and the U.S. and the net deviation (effective residualized credit spread difference) between the euro and the dollar . To construct the net deviation, I estimate the following cross-sectional regression at each date t

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

where S_{it}^{adj} is the CIP-adjusted yield spread over the swap curve for bond i that is issued in currency c , by firm f , with maturity m and rating r . The CIP-adjustment is calculated by subtracting maturity-specific CIP deviation from each bond's yield spread. The net deviation or effective residualized credit spread for euro relative to dollar credit spread is calculated as $\hat{\alpha}_{eur,t} - \hat{\alpha}_{usd,t}$. Details of net deviation's construction are provided in Section 5.1.2.

Issuance flow is defined as the amount of dollar debt issuance by Eurozone firms minus the amount of euro debt issuance by U.S. firms. I express this measure as a percentage of total issuance between the two countries. Details of the issuance flow's construction are provided in Section 5.1.1.

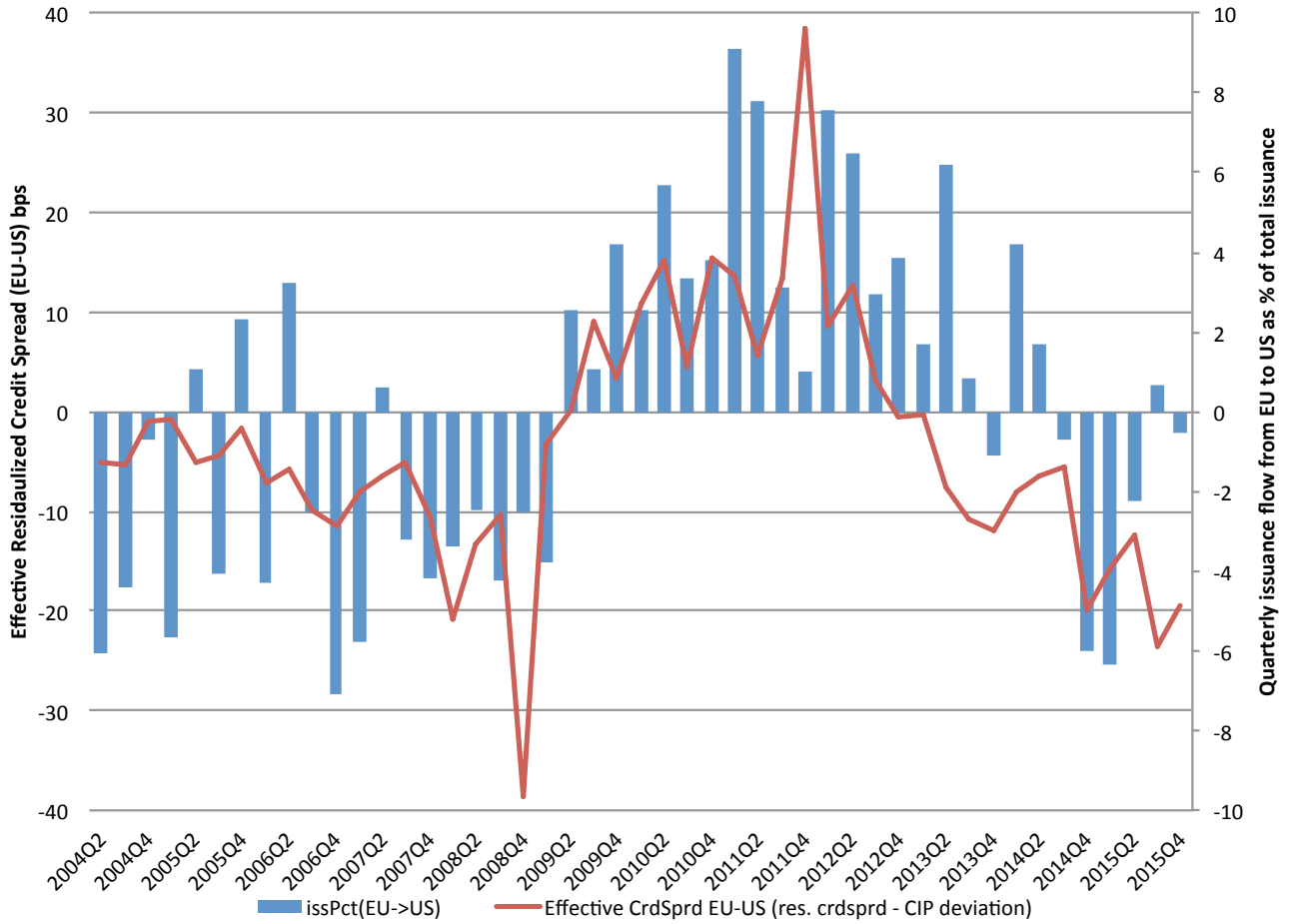
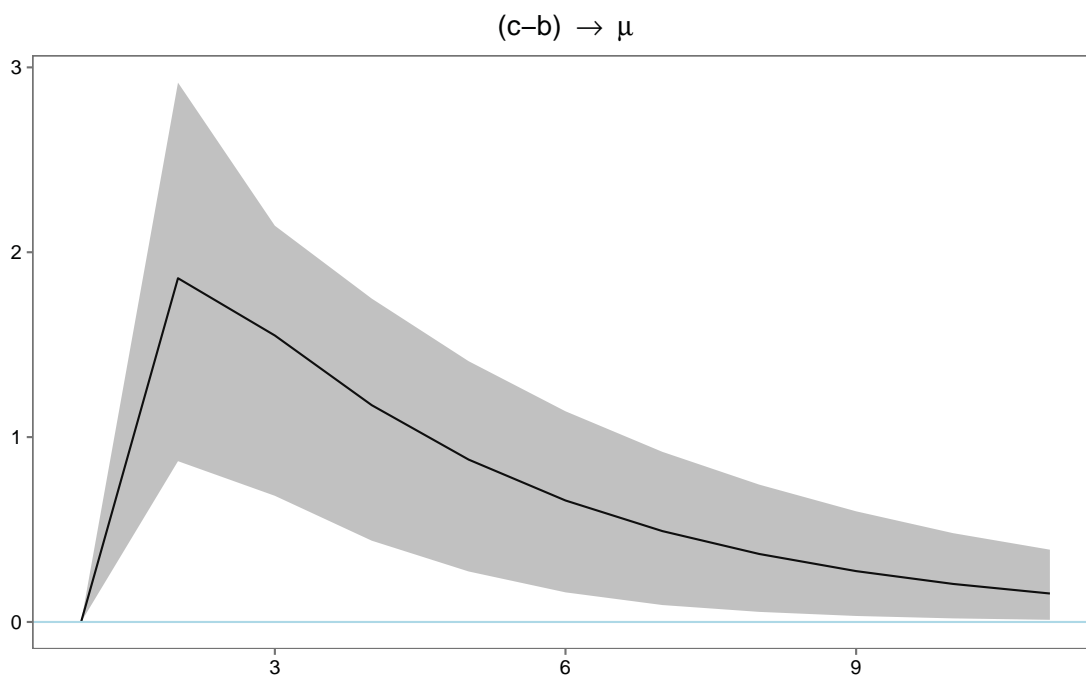


Figure 13 Orthogonalized impulse response of monthly issuance flows to shock to net deviation for EURUSD

I estimate a first order vector autoregression (VAR) of the form

$$\begin{bmatrix} 1 & 0 \\ a_{c-b,\mu} & 1 \end{bmatrix} \begin{bmatrix} \mu_t \\ c_t - b_t \end{bmatrix} = B \begin{bmatrix} \mu_{t-1} \\ c_{t-1} - b_{t-1} \end{bmatrix} + \varepsilon_t$$

where μ_t is the bilateral issuance flow (defined in Section 5.1.1), c_t is the credit spread differential and b_t is the CIP deviation. I plot the impulse response of issuance flow μ to shocks to the net deviation $c_t - b_t$. I conduct Cholesky Decomposition by assuming that issuance responds with a lag to shocks to the net deviation. The choice of lag 1 is selected by Bayesian Information Criteria. Confidence intervals at 95% level are shown in gray.



8 Tables

Table 1 Bond data summary

This table presents a summary of the bond data used in the main analyses. Bond characteristics are from Thompson One SDC Platinum.

		All bonds		Global issuers only	
		Number	Notional \$bil	Number	Notional \$bil
currency	all	35,204	15,937	24,090	12,294
	usd	12,772	6,443	7,954	4,561
	eur	8,625	5,446	6,653	4,556
	jpy	8,152	1,969	5,316	1,474
	gbp	1,492	766	1,238	678
	cad	1,124	516	700	419
	chf	2,017	478	1,301	304
	aud	1,022	319	928	302
rating	AA- or higher	12,060	7,331	10,528	6,741
	A+ to BBB-	13,732	5,796	8,593	3,782
	HY (BB+ or lower)	1,932	899	1,057	541
	NA	7,480	1,912	3,912	1,230
maturity	<3yrs	1,268	807	1,012	691
	3-7 yrs	14,850	7,173	10,415	5,702
	7-10 yrs	4,755	1,904	3,141	1,396
	10yr+	14,331	6,054	9,522	4,505

Table 2 Descriptive regression of Credit Spread Differential on CIP Deviations

This table presents regressions of credit spread differential on CIP deviations at the 5-year horizon for six major currencies each 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, 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 6, t -statistics in brackets are based on Newey-West standard errors with lag selection following Newey-West (1994).

$$crd_{ct} = a + b \cdot cip_{ct} + \varepsilon_{ct} \quad (1)$$

$$crd_{ct} = a_t + b \cdot cip_{ct} + \varepsilon_{ct} \quad (2)$$

$$crd_{ct} = a_c + b \cdot cip_{ct} + \varepsilon_{ct} \quad (3)$$

$$crd_{ct} = a_{ct} + b_{ct} \cdot cip_{ct} + \varepsilon_{ct} \quad (4 - 9)$$

Residualized credit spread differential									
	(1) Pooled	(2) Time FE	(3) ccy FE	(4) EUR	(5) GBP	(6) JPY	(7) AUD	(8) CHF	(9) CAD
CIP	0.737 [18.62]	0.683 [31.72]	0.704 [11.32]	0.799 [5.22]	0.821 [4.34]	0.688 [13.02]	0.292 [2.78]	0.705 [7.87]	0.918 [3.73]
_cons	-7.36 [-5.16]			-5.94 [-3.67]	0.888 [0.64]	-9.65 [-2.41]	-2.4 [-0.97]	-14.3 [-3.79]	-7.1 [-3.56]
rsq	0.65	0.82	0.48	0.56	0.50	0.53	0.07	0.52	0.36
N	906	906	906	151	151	151	151	151	151

Table 3 Issuance flow and net deviation

This table presents forecasting regressions of future issuance flow using effective residualized credit spread differentials (net deviation). $issPct^{Foreign \rightarrow US}_{6m.avg.}$ 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 expressed as a percentage of total issuance. 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).

$$issPct^{Foreign \rightarrow US}_{6m.avg.} = \beta_0 + \beta_1 netdev_t + \beta_2 ratediff_t + \varepsilon_{t+1}$$

	Net issuance flow (Foriegn→US) /total issuance pct.					
	EUR	GBP	JPY	AUD	CHF	CAD
net dev.	0.247	0.157	0.0353	0.00709	0.119	-0.0534
	[5.08]	[2.11]	[2.10]	[0.07]	[3.47]	[-0.75]
rate diff.	0.0175	-0.0165	0.0256	0.0271	0.00675	0.093
	[1.65]	[-0.77]	[5.50]	[3.52]	[1.14]	[5.32]
_cons	0.984	9.51	5.94	2.26	0.266	7.32
	[0.99]	[4.92]	[4.46]	[1.49]	[0.31]	[6.63]
rsq	0.39	0.13	0.45	0.18	0.29	0.33
n	151	151	151	151	151	151

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:

$$D_{fct}^{\text{iss}} = \beta_0 + \beta_1 \text{Crddiff}_{fct} + \beta_2 \text{CIP}_{ct} + \varepsilon_{fct}$$

D_{fct}^{iss} is a dummy that equals to 1 if firm f issues in currency c in quarter t , Crddiff_{fct} is the firm-specific residualized credit spread estimated as $\hat{\alpha}_{ct} + \hat{\alpha}_{ct} \cdot \hat{\delta}_{ft}$ in the following 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 yield spread over the swap curve for bond i issued in currency c , by firm f . In column 2, I estimate the following regression:

$$D_{fct}^{\text{iss}} = \beta_0 + \beta_1 \text{NetDiff}_{fct} + \varepsilon_{fct}$$

where $\text{NetDiff}_{fct} = \text{Crddiff}_{fct} - \text{CIP}_{ct}$. t -statistics in brackets are based on robust standard errors clustered by firm and time.

	probability of issuing in ccy c	
	(1)	(2)
credit dev. c	-0.0727 [-5.41]	
cip	0.135 [3.19]	
net dev. (c-b)		-0.074 [-5.53]
firm FE	x	x
time FE	x	x
ccy FE	x	x
rsq	0.18	0.18
n	28726	28726

Table 5 Debt issuance amount and deviation alignment

This table presents regressions of the monthly change in the absolute value of net deviation ($c - b$) on total debt issuance amount (including both domestic and cross-currency debt) in the same month. The regression is specified as follows

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

where $D_{c,t}$ is the total amount of debt issued in both currency c and USD expressed in \$billions, where $c = \text{EUR,GBP,JPY, or CHF}$. The amount of debt issued is further 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.

	$\Delta c - b _{c,t}$			
	OLS	Reduced Form	1st stage	IV
$D_{c,t} (\hat{D}_{c,t})$	-0.080 [-3.98]			-0.0939 [-2.05]
$M_{c,t}$		-0.0500 [-2.42]	0.525 [4.94]	
$\Delta c - b _{c,t-1}$	-0.089 [-1.44]	-0.073 [-1.16]		-0.0929 [-1.29]
ccy fe	x	x	x	x
rsq	0.05	0.01	0.63	0.05
n	1180	1180	1198	1180