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International Finance Discussion Papers
Board of Governors of the Federal Reserve System

Number 1255
August 2019

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Abstract: This paper examines the connection between deviations in covered interest rate parity and differences in the credit spread of bonds of similar risk but different currency denomination. These two pricing anomalies are highly aligned in both the time series and the cross-section of currencies. The composite of these two pricing deviations – the corporate basis – represents the currency-hedged borrowing cost difference between currency regions and explains up to a third of the variation in the aggregate corporate debt issuance flow. I show that arbitrage aimed at exploiting one type of security anomaly can give rise to the other.

Keywords: Covered interest rate parity, limits of arbitrage, credit market segmentation, debt issuance, dollar convenience yield, foreign exchange rate hedge
 JEL Code: E44, F3, F55, G12, G15, G23, G28, G32.

Introduction

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

I relate my findings in three parts. First, I show large and persistent differences in the aggregated credit spreads of corporate bonds denominated in different currencies over their respective risk-free rates. These pricing differences are due to neither differences in fundamentals nor the covariance between exchange rate movement and default risk, as analyzed later in the paper. Instead, the pricing difference suggests that the credit market is segmented along currency lines. Attesting to previous studies that suggest local supply and demand shocks as determinants of credit spreads[2], this paper is the first to my knowledge to document a currency-denomination pricing anomaly for the aggregate corporate bond market.

As an example, AT&T, the BBB-rated and U.S.-based telecommunication giant, had a credit spread of 203 basis points on its 15-year U.S. dollar-denominated bond in November 2014. At the same time, its euro-denominated bond of similar maturity had a credit spread of 129 basis points. The two bonds share the same rating, maturity, seniority, and jurisdiction. AT&T's credit risk is therefore priced differently in USD and EUR. Because few bonds are perfectly alike, it is difficult to generalize from this example in the aggregate. Different terms of maturity, rating, liquidity, and firm-specific characteristics make comparisons challenging. I construct an aggregate measure of currency-specific pricing of credit risk that controls for other bond characteristics using a regression approach on a large panel of credit spreads. I refer to this measure as the *residualized credit spread*.

Second, I show that residualized credit spread differentials align in direction and size with deviations from covered interest rate parity such that the overall borrowing costs including FX-hedging costs are largely equilibrated across currencies. CIP is a textbook no-arbitrage

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[1]Du,Tepper, & Verdelhan (2017), Sushko, et al. (2016), Avdjiev, et al. (2018), Rime, Schrimpf, and Syrstad (2017), Ivashina, Scharfstein, and Stein (2015), among others.

[2]For instance, Collin-Dufresne, Goldstein, and Martin, 2001; Huang and Huang, 2012.

condition asserting that the interest rate differential between two currencies in the cash market should equal the differential between the forward and spot exchange rates. A deviation from the CIP condition constitutes an additional cost (or benefit) of FX hedging beyond those implied by the cash funding rates. Although the CIP condition held tightly before 2008, large deviations appeared in the aftermath of the financial crisis and have persisted through 2017. This anomaly is large given the size of the FX swap and forward market, which has an average daily turnover of \$3.1 trillion and an outstanding notional of \$58 trillion[3].

Figure 1 Credit spread differential and CIP deviation

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

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

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

——— CIP deviation (5 yr) – – Residualized credit spread differential (EU–US)
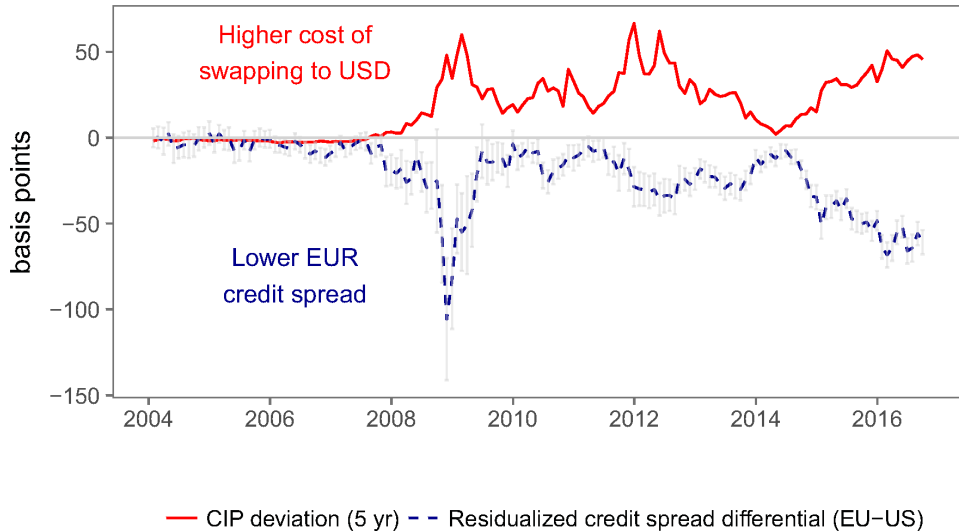
Fig. 1 shows the time series of residualized credit spread differential and long-term CIP deviation between EUR and USD. Both of these deviations were close to zero before the Global Financial Crisis. Since 2008, however, these spreads have been large even in tranquil market conditions. The residualized credit spread difference between EUR- and USD- denominated bonds had reached over 70 basis points in 2016, which is equivalent to

[3]Bank of International Settlement (2016)

$25 billion, or 84% of net (12% of gross) annual issuance in the EUR corporate bond market. Periods in which the residualized credit spread is lower in EUR (more negative dashed blue line) tend to coincide with larger CIP violations in the direction of dollar funding scarcity (more positive red solid line). The two pricing disconnects share similar magnitudes and are highly correlated (-75%). This co-movement of pricing anomalies also appears in other developed country currencies (Japanese yen, JPY; U.K. sterling, GBP; Swiss franc, CHF; Canadian dollar, CAD; and Australian dollar, AUD).

Figure 2 Corporate basis and issuance flow

This figure shows the corporate basis and the bilateral debt issuance flow between the European Monetary Union (EMU) and the U.S. The corporate basis is the FX-hedged borrowing cost differential estimated as the currency fixed effects in the cross-sectional regression $S_{it}^{FXhedged} = \alpha_{ct} + \beta_{ft} + \gamma_{mt} + \delta_{rt} + \varepsilon_{it}$, where $S_{it}^{FXhedged}$ is the CIP-adjusted credit spread at time t for bond i that is issued in currency c, by firm f, with maturity m and rating r. Issuance flow is defined as the amount of USD debt issued by EMU firms minus the amount of EUR debt issued by U.S. firms scaled by the total amount of debt issuance each quarter. Details on the two measures are provided in Sections 3 and 5.
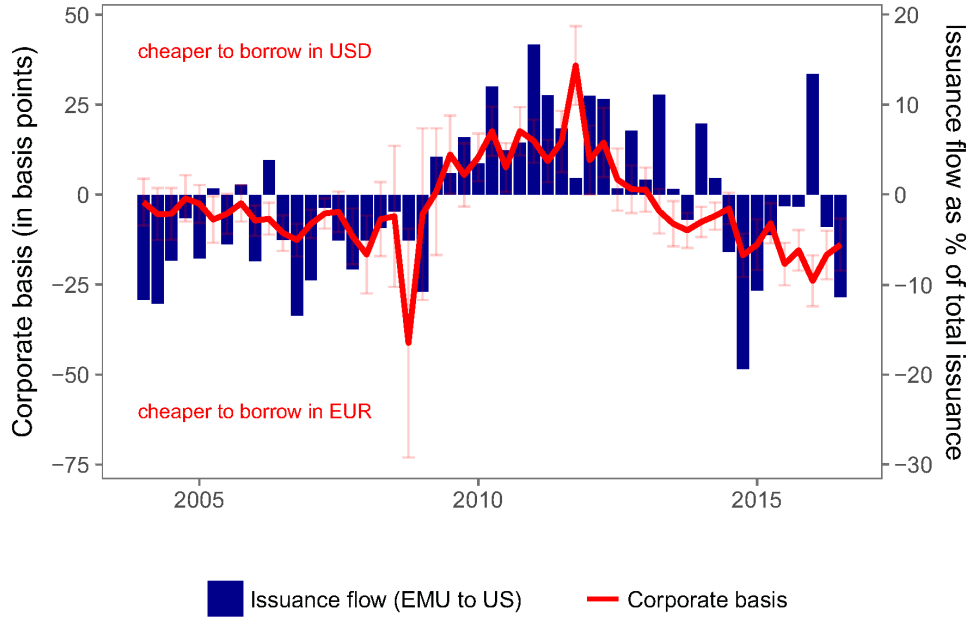
Third, I show that debt issuance flow responds to the overall difference in FX-hedged borrowing cost — the sum of the CIP deviation and residualized credit spread differential. I refer to this FX-hedged corporate borrowing cost differential as the *corporate basis*. Fig. 2 shows that the corporate basis covaries with the aggregate debt issuance flow between the two currency regions for large global issuers. When the corporate basis is positive – the overall FX-hedged borrowing cost is cheaper in USD (red line), firms issue more in USD (blue bars), and vice versa. Even though the corporate basis is small ex-post, the amount

of cross-currency borrowing by firms to keep the CIP basis and credit spread aligned can be large. Empirically, I find that each standard deviation change in the corporate basis induces around a 4% shift in bilateral issuance flow (as a fraction of total issuance) and the corporate basis explains up to 34% of the variation in bilateral issuance flow. In equilibrium, debt issuance flow responds to the marginal cost savings and tie together the credit spread differential and CIP deviation.

I develop a model of market segmentation to show that the reduction of either the credit spread differential or the CIP deviation necessitates arbitrageurs to engage in distorting the other. When markets are segmented, the price of risk in one market may be disconnected from those in other markets. Specialization of risk-taking contributes to market segmentation, as it has been studied in other contexts[4]. The two pricing anomalies studied in this paper reflect distinct market segmentations along two dimensions — the credit market is segmented by the denomination currencies, and the CIP violation is a disconnect between the spot and forward exchange rates. The arbitrageur is risk-averse and thus desires to isolate the arbitrage spread while avoiding other risks. However, each of the two deviations serves as a "short-sell" constraint to the other. To take advantage of the credit spread differential, the arbitrageur needs to hedge FX risk through trading forwards or swaps. To arbitrage the CIP deviation, she needs to borrow and lend in different currencies.

Global debt issuers and investors are natural cross-market arbitrageurs as their activities straddle the credit and FX markets. I focus on issuers for three main reasons. One, firms issue a substantial amount of cross-currency debt with FX hedge. A textual analysis of 10K filings of S&P 500 firms indicates that around 40% of the firms have issued FX-hedged foreign debt in recent years (Section 5.1 presents this analysis). Two, investors have a strong home-currency bias that incentivizes firms to take a more active role in facilitating debt capital flow across currency regions. In suppor of this rationale, Maggiori, Neiman, and Schreger (2019) find that investors have home-currency bias to such an extent that each country holds the bulk of all foreign debt securities denominated in their home currency regardless of the nationality of the issuer. Three, firms are natural cross-market arbitrageurs that can overcome limits of arbitrage problems as shown by previous studies under other settings[5].

What might be drivers of the two deviations in the first place? Local credit market shocks could emanate from quantitative easing (such as ECB corporate bond purchase), liability-

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[4]For instance, in MBS (Gabaix, Krishnamurthy, and Vigneron, 2007), options (Garleanu, Pedersen, and Poteshman, 2009), and bonds (Greenwood and Vayanos, 2014)

[5]For example, Baker and Wurgler (2000), Baker, Foley, and Wurgler (2009), Greenwood, Hanson, and Stein (2010), and Ma (2015).

driven investments (e.g. pension fund benchmark changes)[6], and credit sentiments[7]. FX hedging demand shocks unrelated to debt could arise from bank funding shocks[8], regulatory changes (such as the Solvency II directive on insurance firms and U.S. money market fund reform[9]) and structured products. The model presented in this paper highlights that shocks to either the credit market or the FX hedging market are transmitted from one to the other through currency-hedged debt flows.

Additional empirical analyses support the model predictions. First, a counterintuitive implication of the model, which also appears in the data, is that the corporate basis is small even when deviations in both CIP and credit are large individually. When the two deviations are meaningfully large (greater than 20 basis points), the absolute level of the corporate basis is only around one-fourth the size of the two individual deviations. Second, cross-currency issuance flow co-varies with the corporate basis in predictable directions at the aggregate and the firm level. Additionally, I show through an event study approach that large cross-currency debt issuances have a price impact on CIP deviations. Third, an exogenous increase in cross-market arbitrage capital (bond issuance) aligns the two deviations more closely. To test this prediction, I instrument total debt issuance with the amount of maturing debt since maturing debt is often refinanced into new debt. An exogenous increase in borrowing needs provides firms with the capital with which to optimize the currency composition of issuance and integrate the markets.

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

This study relates to papers on international portfolio holdings, borrowings, and exchange rates. The findings of credit market segmentation and issuers reaching across currency boundaries to cater to investor demand echo the results of investor home-currency

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[6]Greenwood and Vayanos (2010), Greenwood and Vissing-Jorgensen (2018)

[7]Studies on credit sentiments include López-Salido, Zakrajšek and Stein (2017), Bordalo, Gennaioli, and Shleifer (2018), Greenwood, Hanson, and Jin (2019), and Greenwood and Hanson (2013).

[8]Ivashina, Scharfstein, and Stein (2015) document wholesale dollar funding shocks that led to European banks to substitution wholesale funding with FX-swapped funding during 2011-2012.

[9]Anderson, Du, and Schlusche (2019) discuss the impact of the 2016 U.S. money market fund reform.

bias (Maggiori, Neiman, and Schreger, 2019; Burger, Warnock and Warnock, 2018). The influence of debt issuance flows on the CIP deviation resonates with the theory of exchange rate determination that emphasizes capital flow in imperfect financial markets (Gabaix and Maggiori, 2015). Other works have examined local versus foreign currency borrowing by firms in different contexts (Bruno and Shin, 2014, 2017; Gozzi et al. 2015; Hale, Jones, and Spiegel, 2016). Bruno and Shin (2017) find carry trade motives for emerging market firms that issue in dollars without FX hedging. My result on corporate issuance flow being sensitive to the corporate basis at the aggregate level also expands upon the message by McBrady and Schill (2007), which finds an opportunistic motive for foreign currency borrowing by sovereign government and agency issuers.

The CIP condition at the short- and long- maturities has been empirically validated in several early papers[10]. A set of papers also examined short-term CIP violations during the financial crisis[11]. The general conclusion from earlier work is that any CIP violations were short-lived before and during the financial crisis. My finding of FX-hedged corporate bond pricing differences parallels studies that examine sovereign bond pricing differences in currencies of different denominations[12]. The result that the corporate basis is relatively small in comparison to CIP deviation based on interbank funding rates accords with the findings of Rime, Schrimpf, and Syrstad (2017) that CIP holds well for most potential arbitrageurs when applying their marginal funding rates.

More closely related to this paper are Ivashina, Scharfstein, and Stein (2015), Du, Tepper, and Verdelhan (2018), and Sushko et al. (2016). Ivashina, Scharfstein, and Stein (2015) examine USD funding and lending behaviors of European banks during the Eurozone Sovereign Crisis and explore how the shrinkage of wholesale USD funding compelled banks to swap their EUR funding into USD, which in turn generated CIP violations and affected lending[13]. Du, Tepper, and Verdelhan (2018) study persistent deviations from CIP in recent periods and propose an explanation relating to bank regulatory costs that lead to large quarter-end spikes in deviations. Sushko et al. (2016) examine the role of hedging demands and costly balance sheets in the determination of CIP violations. This paper contributes in explaining

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[10]Frenkel and Levich (1975, 1977), Dooley and Isard (1980), Popper (1993), and Fletcher and Taylor (1996).

[11]Baba, Packer, and Nagano (2008), Coffey, Hrung, and Sarkar (2009), Griffoli and Ranaldo (2011) Levich (2012).

[12]Buraschi, Sener and Menguturk (2015) explore the relative pricing of emerging market sovereign bonds issued in USD and EUR during the 2007-08 financial crisis. Du and Schreger (2016) study emerging market sovereign credit risk by synthetically creating local currency risk-free rates using currency swaps. Corradin and Rodriguez-Moreno (2016) compare a small matched sample of European sovereign bonds issued in both EUR and USD and study the effect of ECB collateral and liquidity factors.

[13]Bräuning and Ivashina (2016) further explore the role of monetary policy in affecting funding sources of global banks and the use of FX hedges.

the joint determination of both long-term CIP violations and price discrepancies in corporate bonds of different denomination currencies. I show that the two deviations need to be considered jointly in formulating an explanation for the equilibrium prices and debt capital flows.

This paper also contributes to the understanding of the U.S. Treasury basis or "convenience yield" over other sovereign yields examined in recent studies (Du, Im and Schreger, 2018; Jiang, Krishnamurthy and Lustig, 2018, 2019; Avdjiev et al., 2018)[14]. Using bonds from the same issuer but in multiple currencies, my analysis disentangles the currency effect from the entity effect in comparing currency-hedged yield differentials. I show that a large part of the U.S. Treasury hedged borrowing cost advantage relative to other developed market sovereigns is common to corporate borrowers of the dollar rather than attributable to the specialness of the U.S. Treasury. The premium is large for high-grade, short-maturity corporate debt and the time variation is similar to those calculated from Treasuries.

1   Credit spread, CIP deviation, and corporate basis

To facilitate discussions, I define the corporate basis in relation to the credit spread differential and the CIP deviation based on the risk-free rates. Let $y_t^{\text{€}}$ and $y_t^{\$}$ be risky bond yields in the respective currencies, and f_t and s_t be the forward and spot (log) exchange rate quoted in dollar per euro. For simplicity, we work with short-term interest rates and suppress terms indicating maturity. Corporate basis Ψ_t is the FX-hedged bond yield difference between bonds denominated in the EUR and the USD:

$$\Psi_t \equiv \underbrace{\left(y_t^{\text{€}} - y_t^{\$}\right)}_{\text{risky yield diff.}} + \underbrace{\left(f_t - s_t\right)}_{\text{forward premium}} \quad . \tag{1}$$

Adding and subtracting the risk-free rates, $r_t^{\text{€}}$ and $r_t^{\$}$, Ψ_t can be rewritten as

$$\Psi_t = \underbrace{\left[\left(y_t^{\text{€}} - r_t^{\text{€}}\right) - \left(y_t^{\$} - r_t^{\$}\right)\right]}_{\substack{\kappa_t,\, \text{credit spread differential} \\ \text{over the respective risk-free rate}}} + \underbrace{\left[r_t^{\text{€}} - r_t^{\$} + \left(f_t - s_t\right)\right]}_{\substack{x_t,\, \text{CIP deviation for} \\ \text{risk-free rates}}} \tag{2}$$

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[14]Du, Im, and Schreger (2018) calculate a treasury basis, also referred to as convenience yield, associated with holding U.S. Treasury over other developed-country government bonds when swapped into dollar. Jiang, Krishnamurthy, and Lustig (2018) develop a model of safe asset demand that generates co-movement between the convenience yield and the dollar exchange rate. Avdjiev et al. (2018) show that the dollar is a key barometer of risk-taking capacity that underpins the relationship between deviation from CIP and cross-border bank lending in the dollar. Jiang, Krishnamurthy, and Lustig (2019) rationalize the outsize impact of the dollar on the global financial cycle in the context of dollar safety demand.

Therefore, corporate basis Ψ_t can be decomposed into credit spread differential κ_t and CIP deviation based on risk-free rates x_t. Ψ_t can also be loosely interpreted as CIP deviation on corporate yields.

If the global credit market is relatively efficient in equalizing the FX-hedged bond yields (if $|\Psi_t|$ is small), shocks to x_t would be offset by movements in κ_t, and vice versa. This intuition is examined throughout this paper, which proceeds as follows. Section 2 measures κ_t empirically, using bond yield spreads adjusted for differences in bond characteristics. This section also presents the stylized facts that κ_t varies significantly across time and currencies and κ_t and x_t are highly aligned in offsetting each other. Section 3 studies the corporate basis Ψ_t, its heterogeneity across different bond characteristics, and its relation to the treasury basis that other studies have used to measure convenience yield. Section 4 provides a model that determines κ_t and x_t in equilibrium with cross-currency debt issuance flow. This is followed by a discussion of firms as arbitrageurs and further empirical tests of model predictions in Section 5.

2 Residualized credit spread differentials

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

2.1 Data

I obtain yields on individual bonds from Bloomberg and bond attributes from the Financial Securities Data Company (SDC) Platinum Global New Issues data set and Moody's Default & Recovery Database. The selection of bonds is as exhaustive as possible. The sample data contains more than 35,000 corporate bonds in seven major funding currencies (USD, EUR, GBP, JPY, AUD, CHF, and CAD) from 2004 to 2016. The selection includes all fixed-coupon, non-callable, bullet corporate bonds with outstanding amounts of at least $50 million and original maturities of at least one year[15]. The total notional of the data set is

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[15]Securities with a remaining maturity of less than one year or ten percent of original maturity are excluded from the sample as liquidity tends to be poor and pricing observations are often missing. Excluding debt of

$23 trillion and the outstanding notional as of June 2016 is $12 trillion. These bonds were issued by more than 3,800 entities, including supranationals (such as the World Bank) and sovereign agencies (such as state-owned banks[16]) that are generally considered a part of the corporate bond market. I use the yield spread against the LIBOR swap curve to measure credit spread. An alternate measure using the yield spread against the overnight index swap curve (e.g., swaps based on EONIA and fed fund effective rates) generates similar residualized credit spread differential (since the termed LIBOR-OIS spreads in different currencies are mostly netted out). Details of the data sample and a descriptive summary of the bond data are presented in the Internet Appendix.

2.2 Matrix pricing of corporate credit

To assess the impact of denomination currency on the pricing of credit risk, I estimate the following cross-sectional regression separately at each date t[17]

$$S_{it} = \alpha_{ct} + \beta_{ft} + \gamma_{mt} + \delta_{rt} + \varepsilon_{it} \tag{3}$$

where S_{it} is the credit spread 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 bucket[18] m and rating bucket r respectively at date t. The firm fixed effect is particularly important because it controls for other bond characteristics that are present at the firm level. The data sample is limited only to bonds belonging to multi-currency issuers. The currency fixed effect α_{ct} thus measures the *residualized* credit spread for bonds denominated in currency c. This method of attribution is analogous to the standard industry practice of matrix pricing in which a bond with unknown prices is assessed against other bonds with similar maturity and rating.

The residualized credit spread differential between currency c and USD is denoted as

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less than one year also effectively rules out short-term funding instruments such as commercial paper.

[16]Mortgage-backed agency bonds are excluded.

[17]The equivalent panel regression approach estimates the following

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

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

[18]The maturity of the bond at each pricing date t is categorized into four buckets (1 to 3 years, 3 to 7 years, 7 to 10 years and beyond 10 years). Alternative specification that includes maturity as a linear control is also tested and produce similar results.

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$\kappa_{c,t}$ and estimated[19] as $\kappa_{c,t} = \alpha_{ct} - \alpha_{USDt}$. Fig. 3 presents time series of $\kappa_{c,t}$ estimated at the end of each month for EUR, GBP, JPY, AUD, CAD, and CHF relative to USD. The currency fixed effect coefficients are estimated with relative precision given the large sample size (median number of observations each month: 5504). The median firm-clustered standard error on the currency fixed effects is 3.6 basis points (mean: 4.8 basis points)[20]. The mean and median R-squared are both 82%. This suggests that the regression specification captures most of the variation in bond pricing.

Figure 3 Residualized credit spread differential
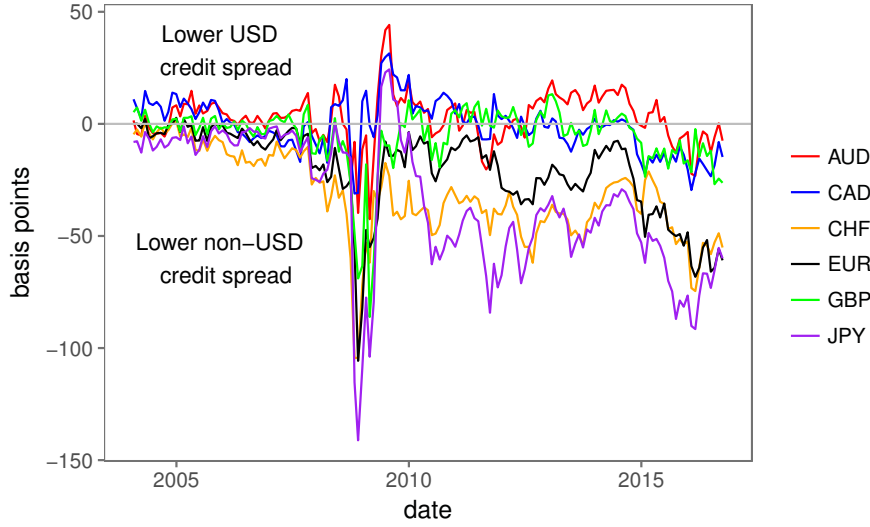
This figure presents the residualized credit spreads relative to the dollar credit spread $\kappa_{c,t}$ for $c \in \{AUD, CAD, CHF, EUR, GBP, JPY\}$. The $\kappa_{c,t}$ is estimated with the following cross-sectional regression at each month, $S_{it} = \alpha_{ct} + \beta_{ft} + \gamma_{mt} + \delta_{rt} + \varepsilon_{it}$, where S_{it} is the credit spread at time t for bond i that is issued in currency c, by firm f, with maturity m and rating r.

The credit spread differentials were small from 2004 to 2007 but increased significantly during the Global Financial Crisis (GFC). Foreign credit spreads tightened considerably relative to the dollar credit spread during the crisis period. In particular, EUR and JPY credit spread differentials reached deviations beyond negative 100 basis points during the peak of the crisis. The deviations briefly reversed after the crisis. However, since 2010, the credit spread differentials have widened again. In the cross-section, the spread differentials for each market have been persistent in both sign and relative magnitude. JPY credit (purple) has been the cheapest to borrow (negative spread differential) relative to USD credit, and AUD credit (red) has been the most expensive to borrow (positive differential). Against the

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[19]In the currency fixed effects, the dummy variable associated with the dollar is omitted. Therefore, the coefficient estimates on other currency dummies are directly interpreted as estimates of the differential.

[20]Confidence intervals constructed with firm-clustered standard errors are presented in Fig. 6.

backdrop of more aggressive ECB QE, the EUR credit spread differential (black) trended more negatively starting in 2014 and had reached negative 70 basis points in 2016.

2.3 Additional controls

I conduct a number of robustness checks of the estimation of the residualized credit spread differential. In addition to the bond-level covariates and firm fixed effects in Eq. 3, I augment the regression specification with additional controls – amount outstanding, bond age relative to initial maturity, seniority, and governance law. The first two controls serve as liquidity proxies. Larger bond issuance size and newly issued bonds are known to be more liquid. On-the-run bonds, or newly issued bonds, have a premium when compared to off-the-run bonds of similar maturities (Krishnamurthy, 2002). To capture this effect, the control for bond age is defined as the ratio of remaining maturity to initial maturity. I also control for the governing law of bonds. Kim and Stulz (1988) find positive abnormal returns associated with issues in the Eurobond market, which refers to the offshore market that has less regulatory oversight (not to be confused with the currency denomination of the bond). Additionally, I control for bond seniority (e.g. senior secured, unsecured, subordinate, etc), which I obtain from Moody's Default & Recovery Database.

These controls make little difference in the residualized credit spread differentials (comparison provided in the Internet Appendix). This is unsurprising because other unobserved bond attributes should not affect the *aggregate* residualized credit spread differential as they are likely idiosyncratic in nature. One notable piece of supportive evidence is that $\kappa_{c,t}$ were small before the GFC. It is unlikely that the bond-specific unobservables only begin to vary *systematically* across currencies after the GFC. Since many bonds have missing values for the additional controls (especially for bonds not denominated in USD and EUR), the baseline specification is used throughout the text to maintain the most comprehensive sample.

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

Internet Appendix). The residualized credit spread differential persists in the sub-samples.

2.4 Covariance of debt repayment and FX return

One potential concern is that the covariance of debt default and currency depreciation can affect the residualized corporate credit spread differential. This default-deprecation covariance, sometimes referred to as the quanto adjustment, has been studied in the sovereign debt context by papers including Buraschi, Sener and Menguturk (2015), Du and Schreger (2016), Augustin, Chernov, and Song (2018), and Lando and Nielsen (2018)[21].

In contrast to sovereign defaults that often indicate economic malaise at the country level and thus coincide with local currency depreciation, corporate defaults are mostly idiosyncratic in nature. This section shows that the residualized corporate credit spread differential cannot be explained by this covariance.

I begin by formalizing the effect of the default-deprecation covariance. Let M_{t+1} and M^*_{t+1} denote the domestic (dollar) and the foreign (euro) stochastic discount factors (SDFs). I use $*$ to denote foreign association. In a complete market, the two SDFs are related by

$$M^*_{t+1} = M_{t+1} \frac{Q_{t+1}}{Q_t}, \tag{4}$$

where Q_t is the exchange rate quoted in dollar per euro (Campbell 2017). An increase in Q_t corresponds to an appreciation of the euro. Let L_{t+1} be a random variable that denotes the default loss as a fraction of the bond face value at time $t+1$ when the bond matures. The price of a risky dollar bond is $P_t = \mathbb{E}\left[M_{t+1}\left(1 - L_{t+1}\right)\right]$, and the price of a risky foreign bond is $P^*_t = \mathbb{E}\left[M^*_{t+1}\left(1 - L^*_{t+1}\right)\right]$. Substituting in Eq. 4, the foreign bond price is

$$P^*_t = \mathbb{E}\left[M_{t+1} \frac{Q_{t+1}}{Q_t}\left(1 - L^*_{t+1}\right)\right], \tag{5}$$

or equivalently

$$P^*_t = \mathbb{E}\left[M_{t+1}\left(1 - L^*_{t+1}\right)\right] \mathbb{E}\left[\frac{Q_{t+1}}{Q_t}\right] + Cov\left(M_{t+1}\left(1 - L^*_{t+1}\right), \frac{Q_{t+1}}{Q_t}\right). \tag{6}$$

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[21]These previous studies present mixed results on the effect of quanto risk on sovereign debt. Buraschi, Sener and Menguturk (2015) conclude that the quanto effect is minimum for a set of emerging market countries in their sample from 2005 to 2010. Du and Schreger (2016) show that the quanto adjustment can explain the large persistent level differences between the local currency and foreign currency credit spreads of emerging market sovereign bonds. Augustin, Chernov, and Song (2018) find that the quanto adjustments of Eurozone sovereigns were substantial during the 2011-12 European sovereign crisis due to the risk of simultaneous EUR depreciation and bond default.

Thus, a positive covariance of debt repayment (default) and foreign currency appreciation (depreciation) leads to a higher foreign bond price or lower yield.

To relate prices to credit spreads, the pricing equations above can be rewritten under risk-neutral expectation and converted to yields after taking logs. Du and Schreger (2016) derive the following proposition, which I restate below[22].

Proposition. *Let L_{t+1} and L^*_{t+1} denote default loss of dollar and non-dollar bond at time $t+1$ as a fraction of the face value in the respective currencies. Let $\mathbb{E}^{\mathbb{Q}}$ denote expectation under the dollar risk-neutral measure. In a complete market, the (non-dollar minus dollar) credit spread differential is*

$$\kappa_t \equiv (y^*_t - r^*_t) - (y_t - r_t) \approx \mathbb{E}^{\mathbb{Q}}_t \left[L^*_{t+1} \right] - \mathbb{E}^{\mathbb{Q}}_t \left[L_{t+1} \right] - q_t \tag{7}$$

where $q_t = \frac{Cov^{\mathbb{Q}}_t(\frac{Q_{t+1}}{Q_t}, 1 - L^*_{t+1})}{\mathbb{E}^{\mathbb{Q}}_t \left[\frac{Q_{t+1}}{Q_t} \right] \mathbb{E}^{\mathbb{Q}}_t \left[1 - L^*_{t+1} \right]}$ is the quanto adjustment.

Note that because L_t and L^*_t are both losses expressed as a fraction of face value, L_{t+1} and L^*_{t+1} are equal for debt of the same entity under pari pasu clauses that are typical of corporate debt contracts. The regression-based approach of estimating κ_t is aimed precisely at residualizing for the term $\mathbb{E}^{\mathbb{Q}}_t \left[L^*_{t+1} \right] - \mathbb{E}^{\mathbb{Q}}_t \left[L_{t+1} \right]$. I proceed with empirically testing whether the relationship $\kappa_t \approx -q_t$ holds in the data.

I test the above frictionless benchmark in two ways. First, I test if systematic covariance between default risk and currency returns are priced in the currency cross-section of κ_t. Second, I use quanto CDS contracts with payout in multiple currencies to obtain forward-looking market pricings of the default-depreciation covariance.

The cross-sectional test examines whether currencies with higher exposures to credit risk have lower credit spreads on average. First, betas are estimated from a time-series regression of currency returns on the excess returns of corporate bonds,

$$r_{c,t} = \alpha + \beta_c \, r_{corp,t} + \varepsilon_{c,t},$$

where $r_{c,t}$ is the return of currency c relative to the dollar and $r_{corp,t}$ is the excess return on

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[22]Taking expectation of Eq. 4 and converting to the risk-neutral measure, the SDF relation becomes $e^{-r^*_t} \mathbb{E}^{\mathbb{Q}^*}_t [1] = e^{-r_t} \mathbb{E}^{\mathbb{Q}}_t \left[\frac{Q_{t+1}}{Q_t} \right]$. In the risk-neutral form, the price of dollar bond is $P_t = e^{-r_t} \mathbb{E}^{\mathbb{Q}} [1 - L_{t+1}]$. Taking the log of both sides, the credit spread is $y_t - r_t \approx \mathbb{E}^{\mathbb{Q}} [L_{t+1}]$, where the approximation comes from $-\ln \mathbb{E}^{\mathbb{Q}} \left[1 - L^*_{t+1} \right] \approx \mathbb{E}^{\mathbb{Q}} \left[L^*_{t+1} \right]$. For the non-dollar bond, Eq. 5 in log risk-neutral form becomes $-y^*_t \approx -r_t + \ln \mathbb{E}^{\mathbb{Q}}_t \left[\frac{Q_{t+1}}{Q_t} \right] - \mathbb{E}^{\mathbb{Q}}_t \left[L^*_{t+1} \right] + q_t$, where $q_t = \frac{Cov^{\mathbb{Q}}_t(\frac{Q_{t+1}}{Q_t}, 1 - L^*_{t+1})}{\mathbb{E}^{\mathbb{Q}}_t \left[\frac{Q_{t+1}}{Q_t} \right] \mathbb{E}^{\mathbb{Q}}_t \left[1 - L^*_{t+1} \right]}$. Substituting in the risk-neutral log SDF relation, we obtain $y^*_t - r^*_t \approx \mathbb{E}^{\mathbb{Q}}_t \left[L^*_{t+1} \right] - x_t - q_t$.

a benchmark credit index. Then I run a cross-sectional regression,

$$\bar{k}_c = \lambda \hat{\beta}_c + \alpha_c,$$

where λ is the cross-sectional compensation for bearing the credit-FX covariance risk. According to theory, λ should be negative if the default-depreciation covariance is positive. In other words, high credit-beta currencies should have lower credit spread. In contrast to the theory, λ is positive empirically. Fig. 4 shows the cross-sectional relation. The x-axis shows the betas between FX return and credit sector return. The y-axis shows the average residualized credit spread for each currency versus the dollar. AUD and CAD have the highest credit betas – they tend to depreciate the most when the credit market sells off. Under the benchmark model above, this higher credit beta should translate into lower credit spread κ. Likewise, JPY and CHF are two safe-haven currencies that, according to the model, should have the highest credit spreads, but we observe the opposite in the data. The cross-sectional evidence directly refutes the idea that the covariance between bond repayment and local currency return is the main determinant of κ.

Figure 4 Cross-sectional test for covariance adjustment
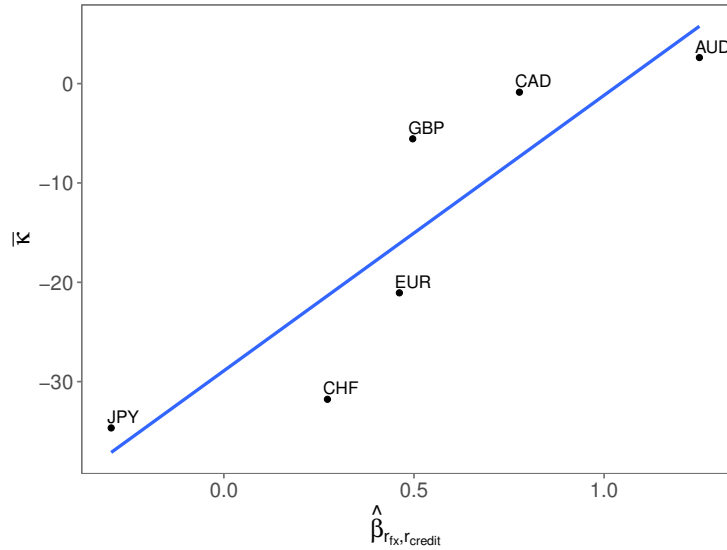
This figure shows the cross-sectional relationship between the residualized credit spread differential and credit betas for each currency. $\bar{\kappa}$ is the time averaged residualized credit spread differential for each currency as shown in Fig. 3. $\hat{\beta}_c$ is estimated from the time series regression $r_{c,t} = \alpha + \beta_c \, r_{corp,t} + \varepsilon_t$, where $r_{c,t}$ is the monthly (log) return of currency c against the dollar, and $r_{corp,t}$ is the monthly (log) return of the ICE Bank of America Merrill Lynch Corporate Bond Master Index in excess of the five-year treasuries return. The sample period for the betas estimate is from 1999:01 (when the EUR was introduced) to 2016:12.

In addition to the cross-sectional test, time serial variations in κ also do not match the intuition of the covariance risk. For instance, the JPY-USD residualized credit spread differential became very negative (more than the EUR-USD spread) during the 2011-2012 Eurozone crisis despite the JPY being a safe-haven currency that appreciated during this period. Furthermore, both JPY-USD and EUR-USD residualized credit spreads were larger in 2016 — a relatively calm market period. Moreover, the residualized credit spread differentials were small before 2008 but have been persistently large since, whereas the covariance risk would have been priced in before 2008 if it were the main contributor to the credit spread difference.

The second test that assesses the default-depreciation covariance follows an established method that uses Credit Default Swap (CDS) contracts with payout in multiple currencies. This methodology has been used by a number of recent papers[23] to quantify the implied currency depreciation associated with sovereign debt defaults. Quanto CDS contracts have a payout in a different currency than the underlying debt obligation. A credit event on an entity triggers all CDS contracts of the same doc clause regardless of the currency of the payout[24]. The differences in the CDS premiums of the same reference entity but with payout in different currencies measure the quanto adjustment.

The quanto CDS spreads for entities based in the European Monetary Union (EMU) and Japan are calculated using the five-year CDS spreads obtained from Markit, a pricing service provider that aggregates contributed quotes from dealers. This analysis is applied to entities with at least 3 dealer quotes in both the dollar and the non-dollar contract on 95% of the observation days. This selection criteria results in 147 European firms, which are quoted by 7.1 dealers on average, and 82 Japanese firms, which are quoted by 5.9 dealers on average. The number of quotes is large given that CDS market-marking activities are concentrated among a handful of dealers (Giglio, 2014, Siriwardane, 2019). With CDS contracts matched for the same firm and contractual terms (doc clause and tier) but different denomination currencies, the euro depreciation-upon-default for each matched pair is calculated as $(CDS(\$) - CDS(\unicode{x20AC}))/CDS(\$)$ (similarly for the yen). The intuition is the following: Suppose Italy's default is associated with a 40% depreciation in the euro, then Italy's euro CDS premium has to be priced at a 40% discount to its dollar CDS in order for the euro CDS buyer to purchase additional contracts and achieve equivalent payout as the

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[23]Mano (2013), Buraschi, Sener and Menguturk (2015), Della Corte, et al (2016), Du and Schreger (2016), Augustin, Chernov, and Song (2018), and Lando and Nielsen (2018)

[24]CDS contracts are written on standardized contract terms categorized by doc clauses that ISDA periodically updates. The most recent update implemented in 2014, for instance, resulted in possible redenomination risk of the euro (Kremens, 2018). I match CDS contracts of the same doc clause for the same entity in calculating quanto spreads.

dollar CDS. The same logic applies to a corporate entity, although corporate defaults are more idiosyncratic and less associated with currency movement. A formal treatment and discussion of this measure is provided in Mano (2013) and Du and Schreger (2016). [25]

Table 1 shows the summary statistics of the implied depreciation of the local currency calculated from quanto CDS spreads. The sample period starts in August 2010, when data on the euro quanto CDS contracts became available on Markit[26]. In the first two rows, the median implied depreciations of EUR and JPY are close to zero. The mean for the Eurozone firms is also close to zero, while the mean for the Japanese firms is around 7%. In contrast, the last two rows show that the European sovereign (average of 12 Eurozone countries) and Japanese government CDS contracts price a substantial amount of depreciation-upon-default. The implied depreciation of the euro is around one-third on average in the event of a sovereign default, and it is around two-thirds for the yen. This pricing indicates that the yen would lose its safe-haven currency status if the Japanese government defaults. These sharply contrasting results between firms and sovereigns suggest that individual firm defaults mostly reflect idiosyncratic risk while sovereign defaults are reflective of systematic economic risk linked with local currency depreciation.

Table 1 Quanto CDS implied currency depreciation

Entity type	N	# dealers mean	# dealers s.d.	% depre. median	% depre. mean	% depre. s.d.
Eurozone firms	147	7.13	2.53	0.00	-0.02	0.53
Japan firms	82	5.91	1.76	1.6	7.3	15.2
Eurozone gov.	12	4.95	1.93	31.4	35.4	25.1
Japan gov.	1	5.74	1.78	65.2	67.8	14.0

This table shows the implied local currency depreciation upon default using CDS contracts that are matched for the same entity, doc clause, and tier. The implied depreciation for the local currency (LC) is calculated as $(CDS(\$) - CDS(LC))/CDS(\$)$ and expressed as a percentage. The sample period is from 2010:08-2017:07. The summary statistics are calculated pooling across time and entities in each category.

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[25]Recent studies by Augustin, Chernov, and Song (2018) and Lando and Nielsen (2018) suggest that this simplified one-period measure overestimates depreciation-up-on-default since the quanto CDS spread reflects both a jump risk and covariance between exchange rate and default risk absent of credit event realization. I set aside this distinction since an overestimation of depreciation-upon-default is the conservative approach for ruling out the covariance effect.

[26]The Markit data before August 2010 have identical prices for euro quanto CDS contracts and dollar contracts.

2.5 Alignment of the credit spread differential and CIP deviation

Having established that quanto risk is small, I next show that the residualized credit spread differential mainly reflects CIP deviation. This empirical result suggests that distortions in the FX forward market can affect the pricing of credit risk in local currencies, and vice versa.

I measure CIP deviation empirically using LIBOR-based cross-currency basis swap, consistent with other papers[27]. A cross-currency basis swap is a bilateral market instrument that allows the market participant to simultaneously borrow in one currency and lend in another currency at the respective floating interest rates. The counterparty of the swap agrees to take on the reverse position. The currency basis is a market-determined adjustment to the reference floating cash funding rates — by convention, the inter-bank borrowing rates (LIBOR). As defined in Eq. 2, $x_t \equiv r_t^{\text{€}} - r_t^{\$} + (f_t - s_t)$. x_t is the CIP deviation with a positive sign indicating expensiveness of swapping to the dollar, and x_t is measured as the level of cross-currency basis swap multiplied by negative one (the market convention is to quote the swap as a basis to the non-dollar cash funding rate). Alternatively, using overnight index swap (OIS) rates with reference to transactional short rates, such as the Fed Fund Effective Rate and the EONIA rate, produces generally similar bases. See the Internet Appendix for comparison. Calculating CIP deviations using FX forward and spot rates also produces similar results. Since the LIBOR-based cross-currency basis swap is the most liquid FX-hedging instrument for maturities greater than a year and has the most comprehensive data across maturities and currencies, I focus on this measure in the main analysis. Details of the cross-currency basis swap, its relation with forwards and CIP violation at different maturities are discussed in the Internet Appendix[28].

Fig. 5 shows deviations from CIP at the five-year horizon for AUD, CAD, CHF, EUR, GBP, and JPY relative to the USD. The CIP condition held tightly before 2008. However, large deviations from the CIP relation appeared in the aftermath of the financial crisis and persisted through 2016. For most of the post-GFC period, it was relatively expensive to swap EUR, JPY, CHF, and GBP to USD (to buy the foreign currency against selling USD in the forward market). In contrast, AUD and CAD CIP deviations have had the opposite sign, reflecting the fact that it was expensive to swap from USD to these currencies. Du, Tepper, and Verdelhan (2018) provide a detailed exposition of post-crisis CIP violation and document a strong quarter-end effect in short-term CIP deviation that indicates regulatory window dressing. Here, I examine CIP deviations at longer maturities that match the bond

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[27]Du, Tepper, and Verdelhan, (2018); Sushko, et al., (2016); Iida, Kimura, and Sudo, (2016).

[28]In the Internet Appendix, I show that T-horizon CIP deviation $x_{t,T}$ is related to cross-currency basis swap rate B_T by the following approximation, $x_{t,T} \approx -B_T \left[\sum_{\tau=1}^{T} \left(1 + Z_\tau^* \right)^{-t} \right] \frac{1+Z_T^*}{T}$ where Z_τ^* denotes the foreign zero-coupon rate with maturity τ.

maturities.

Figure 5 Long-term covered interest rate parity deviations
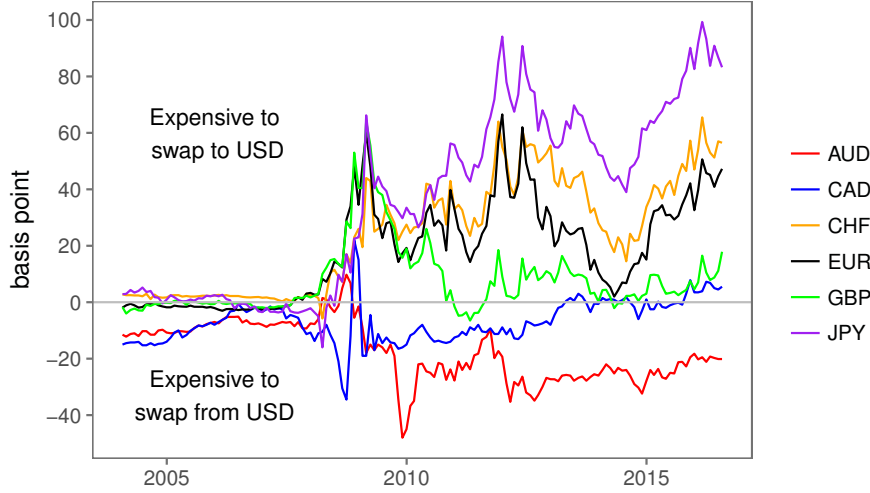
This figure presents covered interest rate parity deviations, $x_{c,t}$, at the 5-year maturity for $c = \{AUD, CAD, CHF, EUR, GBP, JPY\}$ relative to the USD. 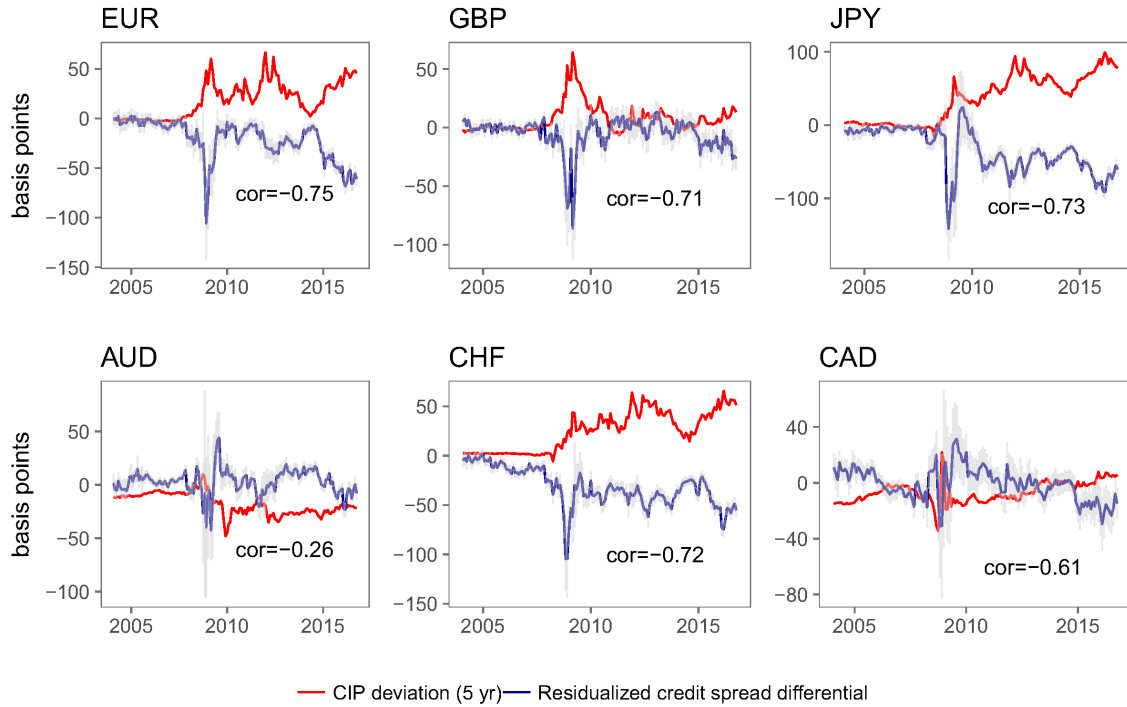The deviations are measured using cross-currency basis swap levels and expressed as the difference between local currency inter-bank funding rate and the FX-implied funding rate.

CIP violations and the residualized credit spread differentials are highly aligned in the time series and the cross-section. Fig. 6 graphs the time series of credit spread differential and CIP deviations at the five-year horizon (matching the average bond maturity) for six major funding currencies relative to the USD. The time series of the two deviations match closely in magnitude and direction for each currency, especially outside of the crisis period. The correlation in the cross-section is also high. Pooling the observations across time and currency, the two violations have a correlation of -81%.

Fig. 7 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-serial correlation between the two deviations. The high correlation and high persistence in the two pricing discrepancies are striking. Japan (purple), mostly plotted in the upper left quadrant, has had positive CIP deviation and negative credit spread relative to the dollar. Australia (red), on the other hand, mostly in the bottom right, has had higher credit spread relative to the USD and negative CIP deviation — indicating cheapness to swap to USD.

Descriptive regressions further validate the statistical significance of the relationship above. Table 2 presents the relationship between the two pricing anomalies in panel and individual regressions. Most coefficients range from 0.7 to close to 1 and are highly significant. Columns 2 and 3 present regressions controlling for time and currency fixed effects.

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Figure 6 Credit spread differential and CIP violation relative to the USD

EUR · GBP · JPY · AUD · CHF · CAD

cor=−0.75 · cor=−0.71 · cor=−0.73 · cor=−0.26 · cor=−0.72 · cor=−0.61

— CIP deviation (5 yr) — Residualized credit spread differential

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

Figure 7 Credit spread differential and CIP violation
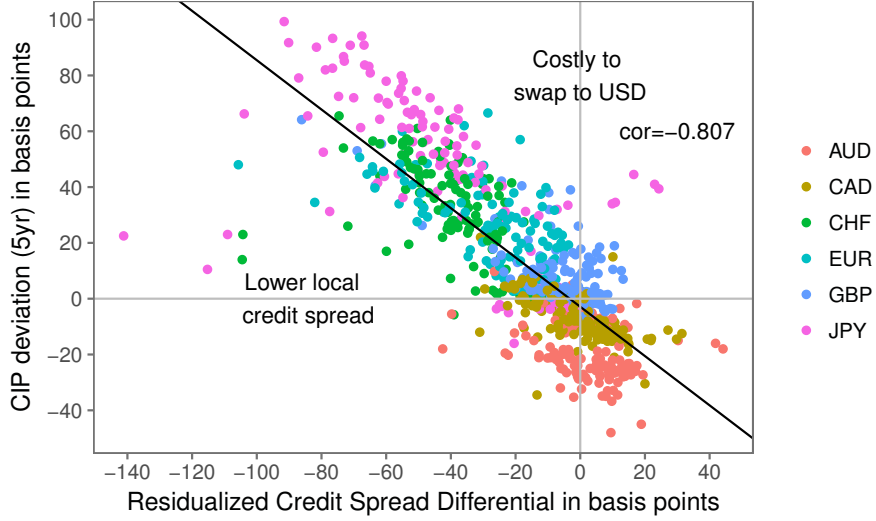
This figure presents the residualized credit spread differential $\kappa_{c,t}$ (horizontal axis) and CIP violations $x_{c,t}$ (vertical axis) for $c = \{EUR, GBP, JPY, AUD, CHF, CAD\}$ relative to USD. Each point is an observation at the currency-month level.

While these regressions cannot be interpreted as causal, they nonetheless demonstrate the close alignment of the two anomalies. Among the individual currencies, AUD and CAD have the weakest relation (columns 7 and 9). This is an observation that is discussed later in the context of the strength of cross-currency debt issuance flow.

This close alignment between the two anomalies does not arise mechanically from changes in the risk-free rates. Naively taking partial derivatives on credit spread differential κ and CIP basis x with respect to the foreign funding rate r^* would yield $\frac{\partial \kappa}{\partial r^*} < 0$ and $\frac{\partial x}{\partial r^*} > 0$. This is, however, not true in the data. Event studies using intraday prices around ECB policy announcements shown by Du, Tepper, and Verdelhan (2018) suggest that x_{EUR} decreases when there is a positive shock to the EUR interest rate.

Table 2 Descriptive regression of credit spread differential on CIP deviations

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

	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 basis	-0.737	-0.683	-0.704	-0.799	-0.821	-0.688	-0.292	-0.705	-0.918
	[-18.62]	[-31.72]	[-11.32]	[-5.22]	[-4.34]	[-13.02]	[-2.78]	[-7.87]	[-3.73]
_cons	-7.36			-5.94	0.888	-9.65	-2.4	-14.3	-7.1
	[-5.16]			[-3.67]	[0.64]	[-2.41]	[-0.97]	[-3.79]	[-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

3 Corporate bases

To understand the overall currency-hedged yield difference between similar bonds denominated in different currencies, I examine the combined measure of the residualized credit spread differential $\kappa_{c,t}$ and the risk-free CIP deviation $x_{c,t}$. As defined earlier in Eq. 2, this combined measure is the corporate basis, $\Psi_{c,t} \equiv \kappa_{c,t} + x_{c,t}$. The corporate basis measures the incentives for firms to borrow and investors to invest in one currency versus another. These decisions ultimately aggregate into predictable flows of debt issuance across currency boundaries, a topic that is examined in later sections.

Since the maturity of each bond is different, I calculate the corporate basis from maturity-matched $k_{c,t}$ and $x_{c,t}$ using the following procedure. I first adjust the non-dollar yield curves by the corresponding CIP deviations at each maturity. I calculate each bond's CIP-adjusted credit spreads, $S_{it}^{FXHedged}$, as the difference between the bond yield and the CIP-adjusted risk-free yield curve linearly-interpolated to each bond's maturity. Lastly, I estimate a cross-sectional regression similar to Eq. 3 but with $S_{it}^{FXHedged}$ as the dependent variable,

$$S_{it}^{FXHedged} = \alpha_{ct} + \beta_{ft} + \gamma_{mt} + \delta_{rt} + \varepsilon_{it} \tag{8}$$

As in the case of $\kappa_{c,t}$ before, I take the currency fixed effects as estimates of the corporate bases, $\Psi_{c,t} = \alpha_{ct} - \alpha_{USD,t}$. Empirically, the estimated $\Psi_{c,t}$ from the procedure above are similar to measures that directly subtract the five-year CIP deviations from the residualized credit spread differentials since the average maturity of the bond portfolio is around five years.

Fig. 8 shows the corporate bases for the six currencies relative to the dollar. Corporate bases are on average smaller relative to the risk-free CIP deviations and credit spread differentials, since $x_{c,t}$ and $k_{c,t}$ tend to offset one another. This indicates that the currency-hedged corporate bond yields are largely equalized across currencies. That is, the corporate CIP relationship accessible to firms and investors holds much better than the risk-free CIP condition based on LIBOR or OIS rates that might not reflect the true borrowing or investment rates of many institutions.

As the figure shows, the corporate bases were generally small except during the GFC when they were sharply negative, indicating that $\kappa_{c,t}$ had larger (more negative) spikes than $x_{c,t}$. These negative spikes potentially reflect the capping of CIP deviations when the Federal Reserve established swap lines with other central banks to alleviate strains in dollar liquidity (Goldberg, Kennedy, and Miu, 2010; McGuire and von Peter, 2012; Bahaj and Reis, 2018). In contrast, credit market distortions were exacerbated during this period by the lack of liquidity in the fixed income market.

Figure 8 Corporate bases

This figure presents the corporate basis $\Psi_{c,t}$ for EUR, GBP, JPY, AUD, CHF, and CAD relative to the USD. The $\Psi_{c,t}$ is estimated with the following cross-sectional regression at each month, $S_{it}^{FXHedged} = \alpha_{ct} + \beta_{ft} + \gamma_{mt} + \delta_{rt} + \varepsilon_{it}$, where $S_{it}^{FXHedged}$ is the credit spread adjusted for CIP deviation at time t for bond i that is issued in currency c, by firm f, with maturity m and rating r. Vertical bars (gray) represent the 95% confidence interval with firm-level clustering.

Heterogeneity in the sub-samples The corporate bases in Fig. 8 are estimated on the entire sample of corporate bonds. Dissecting into different types of bonds or issuers can shed light on which segments of the market are more distorted and who might stand to benefit more from arbitrage. I limit this sub-sample exercise to the euro and the dollar bond markets since they are the largest in size.

Fig. 9 shows the comparison of corporate bases for different sub-samples. Panel A shows the comparison of the corporate basis for financial versus non-financial issuers. Both types of issuers have similar magnitude and variation. This is somewhat surprising since one would expect financials to be more active in arbitraging their own borrowing cost differential, and as a result, might have a smaller basis. The similarity of the two sectors suggests that bonds from non-financials are equally well-arbitraged by either the issuers themselves or investors. Panel B compares bonds of U.S. and non-U.S. investors. The generally positive corporate basis for U.S. issuers suggests that the U.S. issuers enjoy cheaper dollar funding relative to euro funding swapped into the dollar. In contrast, non-U.S. issuers face higher dollar funding cost — often more so than the cost of funding in euro and swapping into the dollar. This difference suggests that local issuers have home advantage in attracting local currency debt investors who might be more familiar with the issuers, and this advantage is particularly strong for the U.S. issuers. Panel C shows that high-grade bonds (AA- or better rated) typically have a positive corporate basis, translating into lower dollar yields relative to synthetic dollar yields. In comparison, low-grade bonds generally have a lower and more volatile basis. Panel D shows that bonds with shorter maturities (less than 7 years) generally have a lower dollar yield relative to synthetic dollar yields. The last two comparisons combined suggest that bonds with high ratings and short maturities — two attributes commonly associated with safe assets — have a dollar funding premium (cheaper to directly borrow in the dollar).

Comparison to treasury basis The treasury basis, calculated as the FX-hedged yield differential of developed-country sovereign bonds relative to the U.S. treasury, has been referred to by recent studies as a measure of "convenience yield" or safety premium (Du, Im and Schreger, 2018, and Jiang, Krishnamurthy, and Lustig, 2018). The premise for these characterizations is that excess demand for the U.S. treasury as a liquid, safe security causes the yields to be relatively low. Therefore, a positive treasury basis, defined similarly as corporate basis $\Psi^{sov} \equiv k^{sov} + x$, indicates an "Exorbitant Privilege" of a lower borrowing cost for the U.S., echoing earlier papers that studied the return differentials between the U.S. and the rest of the world (Gourinchas and Rey, 2007a,b). However, studies thus far have not separated the entity effect from the currency effect on the treasury basis because

Figure 9 Corporate bases comparisons

These figures compare corporate bases for EUR-USD for different bond sub-samples. Panel A compares bond of financials versus non-financials issuers. Panel B compares bonds of U.S. vs non-U.S. based issuers. Panel C compares high grade (AA- or better) vs low grade bonds (worse than AA-). Panel D compares short-maturity (less than 7 year) vs long-maturity bonds (7 years or greater). The bases are estimated following the regression method described in the text, with the adjustment that removes rating fixed effects in the regression for panel C and maturity fixed effects for panel D.

A. financials vs non-financials

B. U.S. vs non-U.S. issuers

C. high vs low grade

D. short vs long maturity
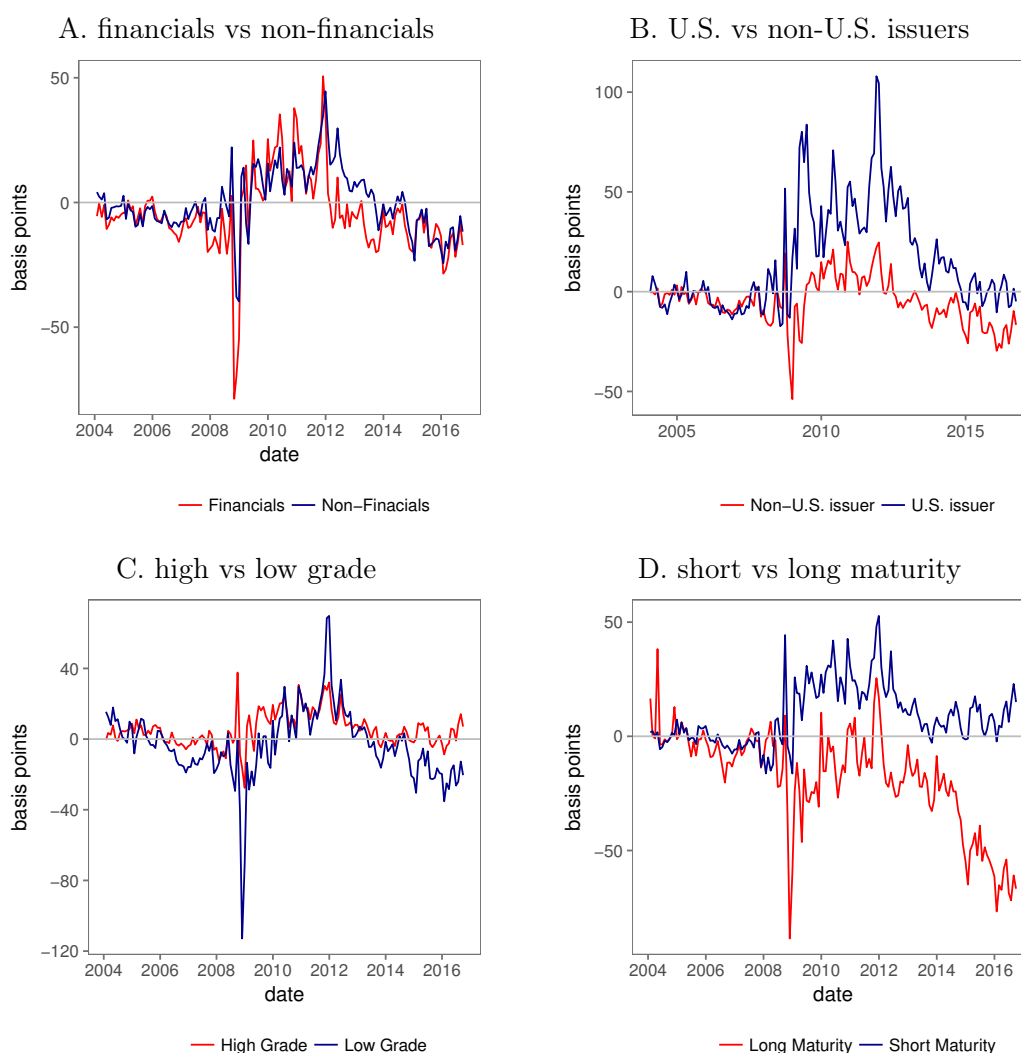
developed market sovereigns typically only issue in their home currency. The advantage of the corporate basis is that the entity-specific effects are removed through the residualizion of the bond prices of multi-currency issuers, so that the corporate basis is due to currency denomination alone.

My result suggests that the treasury basis and the corporate basis share a large common component associated with dollar denomination and that the highest "convenience" appears in short-maturity, highly rated bonds. Fig. 10 presents a comparison of the treasury basis and the "safe" — high rating, short-maturity— corporate basis. The treasury basis is from Jiang, Krishnamurthy, and Lustig (2018) and is averaged across a sample of developed market sovereign bonds with one-year constant maturity[29]. The corporate basis is estimated using the procedure discussed earlier on a sample of high-grade, short-maturity bonds pooling the estimation of the six currencies together relative to the dollar[30]. The two types of bases are highly correlated and positive throughout most of the sample period, indicating a relative cheapness of borrowing in the dollar. The gray shading plots the one-year CIP deviation averaged over the six currencies. The CIP deviation appears to be a common component of both the treasury and corporate bases in the post-GFC period. This is unsurprising since the definitions for both bases can be decomposed into a CIP deviation component (x) and a credit risk component (κ^{corp} or κ^{sov}). Yet, it is worth highlighting that the credit component is meaningful in generating heterogeneity in the treasury and corporate bases.

The treasury basis is on average higher than the corporate bases, which indicates relatively more safety or convenience under safe asset demand theories. Interestingly, the treasury basis was also large and positive before the GFC, whereas the corporate bases were smaller; neither can be explained by CIP deviations that were close to zero and slightly negative. The 1-3Y corporate basis estimated with bonds with the highest credit ratings is on average the next highest and aligns well with the Treasury basis. The 1-7Y corporate basis estimated from a larger range of maturity and credit ratings shows a lower premium on average. This result is in line with the finding from Du, Im, and Schreger (2018) that the term structure of the treasury basis has been downward-sloping in recent years.

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[29]Du, Im and Schreger (2018) calculate equivalent convenience yields for a large number of countries at different maturities.

[30]Specifically, the estimate is of an indicator variable for dollar-denomination with other currencies classified together as non-dollar.

Figure 10 Treasury and corporate bases
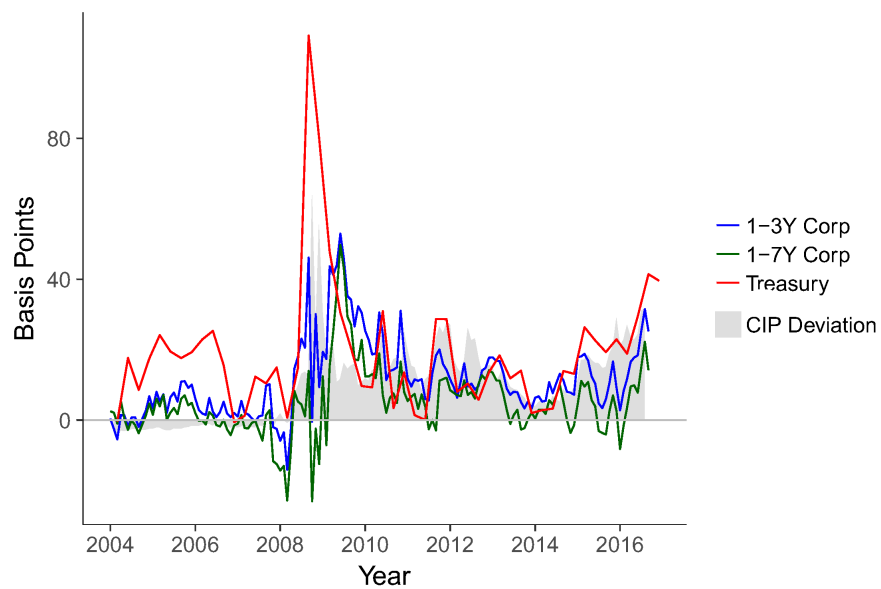
The Treasury basis is the spread between 1-year foreign government bond yields swapped into dollars and U.S. Treasury bonds. The 1-3Y corporate basis is estimated from bonds with credit ratings from AA- to AAA and maturities of 1 to 3 years. The 1-7Y corporate basis is estimated from bonds with credit ratings from BBB- to AAA and maturities from 1 to 7 years. Foreign in both cases is a sample of developed economies. CIP deviation is of one-year maturity and averaged over six currencies against the dollar.

4 A model of aligned deviations in credit and FX markets

The frictionless benchmark presented in Section 2.4 shows that in the absence of quanto risk, the same debt obligations in different currencies should have the same credit spread. The existence of a non-zero residualized credit spread differential κ suggests that markets are incomplete. The empirical evidence also motivates a theory that links κ to CIP deviation x.

In this section, I present a model that explains the high degree of alignment between k and x, as well as their relation to cross-currency debt issuance flow. We take market segmentation as given in a setup similar to Gromb and Vayanos (2002). There are two risky assets – a bond denominated in the euro and a bond denominated in the dollar. The markets for these two assets are segmented in that EMU investors can only invest in the euro-denominated risky bond and riskless asset, and U.S. investors can only invest in the dollar-denominated bond and riskless asset.

Additionally, there are cross-market arbitrageurs who can trade in both markets. The cross-market arbitrageur is an issuer that sells debt, although this arbitrageur can broadly be interpreted as a global investor (investors buy instead of sell bonds as if they are firms with negative issuance amounts). The issuer avoids currency mismatch by trading FX forward to hedge currency exposure. Therefore, the issuer is a cross-market arbitrageur in the sense of both connecting the euro and dollar debt markets and connecting the credit market with the FX forward market.

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

4.1 Issuer

In this static model, a representative price-taking firm needs to raise a fixed debt amount D for dollar-based investments. The firm observes its dollar bond yield $Y_\$$, a credit spread differential between its EUR- and USD- denominated bonds κ, and a CIP deviation x. As presented earlier, CIP deviations reflect hedging costs beyond the risk-free rate differentials. The firm fully hedges FX exposure and eliminate currency mismatches between the asset and the liability side of its balance sheet[31]. The exchange rate is normalized to one as it does not enter into the decision. Therefore, the cost difference between borrowing in the two

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[31]We can relax the simplification that the firm only has dollar asset and must fully hedge FX risk. The Internet Appendix shows an extension in which the firm has a desired dollar funding ratio m; $(1-m)$ fraction of its asset is in EUR and serves as a natural hedge. The firm decides on the deviation from its optimal debt currency mix $(\mu - m)$ and a FX hedging ratio h.

currencies is the corporate basis Ψ, which is expressed as the individual components $\kappa + x$, in order to focus on the interactions between κ and x. The firm chooses dollar debt issuance share μ to minimize borrowing cost: $\min_{\mu} [Y_{\$} - (\kappa + x) \mu] D$. The issuer's currency decision is binary:

$$
\mu = \begin{cases} 1 & \text{if } \kappa + x > 0 \\ 0 & \text{otherwise} \end{cases} \tag{9}
$$

If the corporate basis is positive, $\kappa + x > 0$, then the firm shifts its issuance entirely to USD. Otherwise, it issues in EUR. Thus, μ is loosely interpreted as debt issuance flow.

The extended model, shown in the Internet Appendix, introduces capital structure friction, natural asset hedges, and partial FX-hedging. With these extensions, the model also produces an interior solution. The main result and intuition carry through with these extensions.

4.2 Credit markets

In order to understand how deviation in one market spills over to the other market, we endogenize κ and x. We start by endogenizing κ.

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

Local active investors Investors have a funding cost equal to the domestic short rate, r_i, and purchase bonds with a promised net yield of Y_i, where $i = \text{€}$ for EUR or $\$$ for USD. The two bonds have identical default probability π and loss-given-default L. The payoff of bonds has a variance of V, which is treated as an exogenous constant in the model for tractability[32]. The investors have a mean-variance preference with identical risk tolerance τ and choose investment amount X_i to solve: $\max_{X_i} \left[X_i \left((1 - \pi) Y_i - \pi L - r_i \right) - \frac{1}{2\tau} X_i^2 V \right]$. This has the solution $X_i = \frac{\tau}{V} \left((1 - \pi) Y_i - \pi L - r_i \right)$.

Exogenous demand In addition to the active local investors, there are exogenous bond demand shocks ε_i, for $i \in \{\text{€}, \$\}$. The source of these demand shocks can originate from quantitative easing (such as ECB corporate bond purchase program), changes to preferred-habitat investors (e.g. liability-driven investments, pension fund benchmark changes), and credit market sentiment.

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[32] A 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 bonds.

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

The difference between the two promised bond yields can be expressed as a credit spread difference and interest rate difference, $Y_€ - Y_\$ \equiv \kappa + (r_€ - r_\$)$. Solving for the credit spread differential using the market clearing conditions, we obtain: $\kappa = \left(\frac{1}{1-\pi}\right)\frac{V}{\tau}\left((1-2\mu) D - \varepsilon_\kappa\right) + \left(\frac{\pi}{1-\pi}\right)(r_€ - r_\$)$, where $\varepsilon_\kappa \equiv \varepsilon_€ - \varepsilon_\$$ is defined as the relative excess EUR credit demand. The coefficient on the second term, $\frac{\pi}{1-\pi}$, is negligible given realistic default probabilities for large firms in developed countries[33]. To focus on studying meaningful drivers in the variations of κ, we apply a first-order Taylor approximation for π around 0 and express credit spread differential as:

$$\underbrace{\kappa}_{\substack{\text{credit spread} \\ \text{differential}}} = \underbrace{\frac{V}{\tau}}_{\substack{\text{elasticity of} \\ \text{bond demand}}} \left(\underbrace{(1-2\mu) D}_{\text{relative debt issuance}} - \underbrace{\varepsilon_\kappa}_{\text{exog. EUR credit demand}} \right) \quad (10)$$

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

4.3 Currency swap market

Next, I endogenize the CIP deviation x and describe the dynamics of the currency swap market. The intuition here is similar to that of the credit market above, but instead of investor risk preference determining the slope of the demand curve, the FX trader's collateral and capital constraints limit arbitrage in CIP deviation. There are two main players in this market: issuers and currency swap traders.

Currency swap trader The currency swap trader chooses the amount of capital to devote to either CIP deviations x, or to an alternative investment opportunity with a profit of $f(I)$, where I is the amount of investment.

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

---

[33]The annual default rate averages less than 0.1% for investment grade bonds and 4.1% for high yield bonds in the U.S. from 1981 to 2016 (S&P Global).

$\max_s xs + f(W - \gamma|s|)$. The solution, $x = sign[s]\gamma f'(W - \gamma|s|)$, provides the intuition that the expected gain from conducting a unit of additional CIP arbitrage is equal to the marginal profitability of the alternative investment. A simple case is when the alternative investment activity is quadratic, $f(I) = \phi_0 I - \frac{1}{2}\phi I^2$. In this case, $x = sign[s]\gamma(\phi_0 - \phi W + \gamma\phi|s|)$.

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

Exogenous demand The representative firm from earlier in this paper uses the FX market to convert its EUR issuance proceeds, $D(1 - \mu)$ to USD. Additionally, there are exogenous shocks to CIP basis ε_x that represent other non-debt-related uses of FX swaps. The ε_x shocks can emanate from banks' dollar funding through the FX market, regulatory-driven hedging demand, and structured note hedging, among others. The Internet Appendix provides further discussions on sources of ε_x shocks.

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

$$\underbrace{x}_{\text{CIP basis}} = \underbrace{\gamma^2}_{\substack{\text{haircut} \\ \text{on collateral}}} \underbrace{(D(1 - \mu) + \varepsilon_x)}_{\substack{\text{net hedging demand} \\ \text{to swap EUR into USD}}} \tag{11}$$

CIP deviation x is proportional to net hedging demand (quantity of risk) multiplied by the collateral haircut (price of risk). A higher haircut γ amplifies the impact of hedging demand, but without net hedging demand, x is zero.

Debt issuance related hedging demand $D(1 - \mu)$ can have a different sign from other hedging demand ε_x. In the case $sign[\varepsilon_x] \neq sign[D(1 - \mu)]$ and $|\varepsilon_x| > |D(1 - \mu)|$, the issuer provides (rather than demands) liquidity in the FX swap market and incurs an additional benefit (instead of cost) through hedging.

4.4 Predictions

The market clearing conditions in credit (Eq. 10) and FX hedging (Eq. 11) combined with issuer currency choice (Eq. 9) deliver the following propositions.

Proposition 1. *(Spillover of deviations)* If $\varepsilon_\kappa \uparrow$, then $\kappa \downarrow \Rightarrow \mu \downarrow \Rightarrow x \uparrow$. If $\varepsilon_x \uparrow$, then $x \uparrow \Rightarrow \mu \uparrow \Rightarrow \kappa \downarrow$. Shocks to one market are transmitted to the other through debt issuance flows. Credit spread differentials κ and CIP deviations x respond in the opposite direction to either credit demand shocks ε_κ or FX swap demand shocks ε_x[34].

Proposition 1 clearly predicts that κ and x comove oppositely to each other, but the sign of μ is ambiguous without distinguishing whether the shock is ε_κ or ε_x. Nonetheless, the relation between μ and the corporate bases $\kappa + x$ is unambiguous, leading to the following:

Proposition 2. *(Corporate basis and issuance flow)* $\kappa + x \uparrow \implies \mu \uparrow$ Corporate basis comoves positively with issuance flow into the dollar.

Another related prediction that follows from the above is that increased cross-market arbitrage capital reduces the corporate basis and the two deviations are perfectly offset in the limit.

Proposition 3. *(Arbitrage capital and corporate basis)* $D \uparrow \Rightarrow |\kappa + x| \downarrow$ and $\lim_{D \to \infty} \kappa + x = 0$. An increase in the total amount of debt issuance decreases the absolute value of the corporate basis. As the total amount of debt increases toward infinity, the corporate basis converges to zero.

Lastly, the model demonstrates how frictions in one market can constrain the other market with the following comparative statics.

Proposition 4. *(Limits to arbitrage spillover)* Comparative statics with respect to parameters reflecting prices of risk:

	FX haircut $\gamma \uparrow$	Credit investor risk tol. $\tau \uparrow$	bond risk $V \uparrow$
$|\kappa|$	$\uparrow$	$\downarrow$	$\uparrow$
$|x|$	$\uparrow$	$\downarrow$	$\uparrow$

The comparative statics suggest that limits of arbitrage are carried over from one market to the other. For instance, the FX swap haircut γ directly affects not only the CIP deviation

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[34]These transitions occur discretely at the boundary when $\kappa + x$ changes sign. A small amount of friction to the firm's capital structure would generate an interior solution as shown in the Internet Appendix.

x, but also indirectly affects the credit spread differential κ through the action of the cross-market arbitrageur. Similarly, the risk tolerance of bond investors τ and bond risk V also affect CIP deviation. Thus, limits of arbitrage from one market can spill over to a completely different market.

4.5   Distinction from intermediary-based asset pricing

The model developed above is also useful for assessing alternative explanations of the alignment between the two anomalies. One alternative hypothesis is based on intermediary-based asset pricing. Under this alternative, a financial intermediary with financing constraints trades in both the FX market and credit market[35]. Deviations might be correlated when there are fluctuations in the binding constraints for the common intermediary. A way of incorporating this alternative in the framework above is to define a common intermediary constraint λ that captures the constraints faced by the FX trader and active credit investors, i.e. $\lambda \equiv \gamma^2 = c\frac{V}{\tau}$, where c is a constant. In the presence of a shock to λ, both κ and x would be affected.

There are three reasons to falsify this alternative hypothesis in explaining the relationships among κ, x, and μ. First, without 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., $\frac{\partial |x|}{\partial \lambda} \propto \frac{\partial |\kappa|}{\partial \lambda}$), changes in λ would not explain the *direction* and *magnitude* of x and κ over time and across currencies. Lastly, changes in λ do not speak to the co-movement of the corporate basis $\kappa + x$ with issuance flow μ. Therefore, the model above is distinct from one that focuses on fluctuations in λ.

5   Tests of model predictions on issuance flow

In this section, I provide further validation of the theoretical framework using data on bond issuance. I first discuss reasons to focus on debt issuance. I then present evidence on the interactions among issuance flows, credit spreads, and CIP deviations that support the model.

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[35]Examples of this type of model are Gromb and Vayanos (2002, 2017), Gârleanu and Pedersen (2011), He and Krishnamurthy (2013). The insufficient dealer arbitrage of CIP violation is rationalized in the context of Funding Valuation Adjustments by Andersen, Duffie, and Song (2019).

5.1 Firms as natural cross-market arbitrageurs

While both currency-hedged investors and issuers can exploit a non-zero corporate basis, I focus the analysis on firms, as their currency-hedged issuance is substantial and they are well-suited as arbitrageurs. In this section, I first present evidence of currency-hedged issuance. Second, I discuss reasons for why we observe firms opportunistically issuing in different currencies rather than investors providing sufficient arbitrage capital to equalize the borrowing cost difference.

Firms can issue debt denominated in different currencies for reasons unrelated to cheaper FX-hedged borrowing costs. Firms with global operations might raise debt denominated in a different currency to match currency exposure in their cash-flows or local assets. Additionally, some firms might issue debt in a currency with a lower interest rate but bearing the currency risk, effectively engaging in a carry trade. Demonstrating the existence of large cross-currency issues is paramount in establishing the role of issuers in linking the credit market and CIP deviations.

I find evidence of firms engaged in FX-hedged debt issuance with a textual analysis of SEC filings by S&P 500 firms. Fig. 11 graphs the fraction of 10K filings with mentions of words relating to (1) "debt", (2) "exchange rate", (3) "hedging", and (4) "derivatives" in the *same* sentence. This restriction of having all four groups of words appear in a single sentence likely underestimates the actual disclosure of currency-hedged issuance since the disclosure could be noted in multiple sentences. While this proxy might be imperfect, it nonetheless indicates that a substantial fraction of S&P 500 firms have 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 credit spreads and CIP first begin to emerge. This analysis attests to the pervasiveness of firms acting as cross-market arbitrageurs between the credit market and the FX market in recent years.

Figure 11 Textual analysis of FX-hedged foreign debt issuance for S&P 500 firms

This exhibit presents a textual analysis of 10K filings by firms in the Standard and Poor 500 index from 2004 to 2016. Panel A provides three examples of filings with mentions of currency hedged debt issuance. Panel B shows the percentage of firms that have words relating to (1) "debt", (2) "exchange rate", (3) "hedging", and (4) "derivatives" in the *same* sentence (separated by common punctuation or paragraph denotation) for 10K filings in each year.

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

AMGEN
10K: "To hedge our exposure to foreign currency exchange rate risk associated with certain of our long-term notes denominated in foreign currencies, we entered into cross-currency swap contracts, which effectively convert the interest payments and principal repayment of the respective notes from euros/pounds sterling to U.S. dollars."

APPLE INC.
10Q: "In the first quarter of 2015, the Company issued €2.8 billion of Euro-denominated long-term debt. To manage foreign currency risk associated with this issuance, the Company entered into currency swaps with an aggregate notional amount of $3.5 billion, which effectively converted the Euro-denominated notes to U.S. dollar-denominated notes."

at&t
10K: "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."

B. Percentage of 10K filings with mentions of currency-hedged debt issuance

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If firms' issuance flow are arbitrage capital, it must be the case that investors are not supplying sufficient arbitrage capital. Most institutional investors have rigid portfolio benchmarks and restrictions on derivatives use that might hinder their ability to exploit the corporate basis. In support of this view, Maggiori, Neiman, and Schreger (2019) show that investors have a strong bias in investing in their home currencies beyond the home-country bias. Hedge funds and dealers also face constraints due to balance-sheet frictions[36], transaction cost[37], and limits to arbitrage associated with delegated investment managers (Shleifer and Vishny, 1997).

Firms are natural arbitrageurs to exploit capital-intensive, slow-convergence arbitrage opportunities. They can bear noise-trader risk and endure long investment horizons. Previous papers have examined the role of corporate arbitrageurs in other contexts (Baker and Wurgler, 2000; Greenwood, Hanson, and Stein, 2010; and Ma, 2015). Because firms have stable cash flows and do not face redemption, a one-time issuance and hedging choice is equivalent to holding an arbitrage trade to maturity.

An additional reason to focus the empirical analysis on debt issuance is the availability and comprehensiveness of the data. Debt offerings are typically recorded in public filings and broadly advertised to investors even for private issuance.

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

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

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[36]Du, Tepper, and Verdelhan (2018) document a strong quarter-end effect suggestive of bank balance-sheet constraints. Andersen, Duffie, and Song (2019) show that Funding Valuation Adjustments can be a cost for CIP arbitrage.

[37]A long-short strategy requires repo borrowing to fund bond purchase in one currency and reverse-repo lending to short the bond in the other currency while also hedging FX risk.

This variable definition aims to capture the issuers' active behavior of reaching across currency boundaries to cater to investor demand. An alternative measure is the ratio of all debt issuance in a currency to total issuance. However, this alternative measure is less representative of the issuers' active currency denomination choice as it is confounded by changes in overall financing needs in the currency regions.

Issuance price impact I find evidence of a price impact on CIP deviations from large issuances, a phenomenon consistent with the model of deviation alignment. Large cross-currency debt issuances are a recurrent source of FX-hedging demand and a laboratory for studying price impact. Debt issuance is announced ahead of the actual issuance date and anticipated by market participants. Anecdotal accounts of FX traders front running large cross-currency issuance and issuers' placement agents pre-hedging in advance of the actual debt offering date would suggest possible FX swap price movements prior issuance date. I conduct an event study that examines changes in CIP deviation around days with large cross-currency issuance. The event dates are defined for each currency pair as dates on which there are large total issuances (greater than $500mm) of dollar-denominated bonds by foreign firms (often referred to as Yankee bonds[38]) and dates on which there are large foreign-currency bond issues by U.S. firms (Reverse Yankee bonds). For instance, if the sum of USD-denominated bond issued by Australian firms is greater than $500mm on a particular date, this date is categorized as a large Yankee bond issuance date for AUDUSD. Defining event dates using other issuance size cutoffs of significant size, i.e. $250 million, $1 billion, yields similar results[39]. With an issuance size cutoff of $500 million, 7.8% of the trading days qualify as large Yankee issuance events and 2.5% of the sample qualifies as large reverse Yankee issuance events averaged across the six currencies.

Fig. 12 presents the event study result. On the days before large dollar bond issuance by foreign firms, the price of swapping bond proceeds from USD to the foreign currency gradually increases until the event date (red line). The reverse price action can be observed for large non-dollar issues of U.S. firms (blue line).

Similar to the price impact on CIP deviations, new debt supply also has an impact on the credit spread at the individual firm and the aggregate level. For instance, Newman and

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

[39]Alternatively, defining large cross-currency issuance event days by quantile for each of the currencies separately also produce similar results. For instance, I define event dates as the top 1% of days with large dollar bond issuance by firms originating in the EMU (the corresponding absolute cutoff size is $8 billion). I also perform additional robustness checks by removing the impact of large outliers, defining event dates as ones that have cross-currency issuance of size between $500 mm and $3 billion.

Figure 12 Impact of large cross-currency issuance on CIP deviation

This figure graphs changes in five-year CIP deviation around dates with large cross-currency issuance for EUR, GBP, AUD, JPY, CHF, and CAD relative to USD. Yankee bond issuance refers to dollar denominated bond issuance by non-U.S. firms and reverse Yankee issuance refers to non-dollar denominated bond issuance by U.S. firms. The dashed lines represent the 95% confidence interval from bootstrapping with 1,000 draws.

Rierson (2004) show that the issuance of 15.5 billion euros of bonds by Deutsche Telekom had a sizable pricing impact on the entire European telecom debt sector. Since the residualized credit spread differential is estimated with a standard error, the event study approach on the residualized credit spreads cannot be as easily applied.

Another piece of evidence supporting the existance of spillovers between FX hedging and credit market comes from shocks to FX hedging costs. Bahaj and Reis (2018) find that lowering the cap on CIP deviations (by cutting the central bank swap line rate) impacts bond yields and holdings of currency-hedged debt in directions consistent with the model presented in this paper. During the Eurozone sovereign crisis in November 2011, the Federal Reserve coordinated with five other central banks to cut the central bank swap line rate from OIS+100 basis points to OIS+50 basis points. The goal was to increase the take-up of central bank swap lines, which provided an alternative to traded FX swaps[40]. Bahaj and Reis (2018) argue that the exact timing and size of the swap line rate cut had some exogeneity. They present evidence showing that the central bank swap line rate cut resulted in 1) a decline in CIP deviation (cheaper cost of hedging dollar asset by foreign entities), 2) an increase in dollar-denominated corporate bond purchases by EEA regulated banks[41], and 3) a reduction in dollar corporate bond yields as a result of the bond purchase price pressure. The one-week pass-through from the CIP shock to corporate bonds is around 40%[42]. Given the effect of slow-moving capital (Duffie 2010; Hanson, Greenwood, and Liao, 2018), the long-term spillovers could be much higher.

5.2   Issuance flow and corporate basis

Another prediction from the model is that issuance flow fluctuates with the corporate basis in predictable directions. As firms observe differences in the FX-hedged cost of borrowing, they shift issuance from the more expensive borrowing currency to the cheaper ones.

The reaction of issuance flow to the corporate basis can be tested using forecasting regressions. Table 3 presents regression results showing this relationship. To account for the gradualness in issuance response, I regress issuance flow averaged over six months following observations of the corporate basis at month t.

The coefficient on the corporate basis for EMU-U.S. bilateral issuance flow in the first column is economically and statistically significant. For each basis point increase in the cor-

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[40]Central bank swap line allows non-U.S. banks to borrow dollar from their respective home central bank, which in turn obtains the dollar via FX swap with the U.S. Federal Reserve.

[41]EEA-regulated banks include banks and foreign banking branches in the European Economic Area and the U.K.

[42]The impact on CIP deviation is from the baseline estimates in Table 1 in Bahaj and Reis (2018), and the impact on dollar corporate bonds is from the exact match estimates in Table 4 in their paper.

porate basis (indicating more attractive borrowing costs in USD), firms tilt their borrowing toward USD-denominated debt by 0.285 percent of their total issuance. This corresponds to an increase of 4% in dollar borrowing for each standard deviation increase in the corporate basis. The r-squared in this univariate regression (column 1) is 0.34, indicating that the corporate basis explains a sizable portion of issuance flow variation. The coefficients for GBP, JPY, and CHF (columns 2, 3, and 5) are also positive and suggest that issuance flow responds to the corporate basis, corroborating model prediction. The smaller size of the coefficients for these three currencies indicates a weaker bilateral flow responses and reflects smaller bond markets (as the issuance flow is scaled by the total size of issuance in USD and the alternate currency).

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

Columns 13 to 18 show the issuance response to CIP deviation and credit spread differential separately. The directions of the response match model predictions. The positive coefficients on CIP deviation indicate that firms issue more in USD when it is more costly to swap from other currencies to the U.S. dollar. The positive coefficients on credit differential indicate that when credit spread is wide in the other currency relative to the dollar, firms issue more debt in the dollar.

In contrast to the statistically significant corporate basis coefficients for EUR, GBP, JPY, and CHF, the coefficients for the corporate basis for AUD and CAD are close to zero (columns 4 and 6). One possible interpretation is that issuance flow is an important source of arbitrage capital in some currency pairs, but it is not a dominant force of arbitrage capital for other currency pairs. Interestingly, the coefficients on interest rate differential (in columns 10 and 12) are highly significant for AUD and CAD. As local interest rate differential proxies unhedged carry-trade returns, these coefficients indicate that issuers might be issuing unhedged foreign debt for carry trade motives, a phenomenon that Bruno and Shin (2017) documented for corporate issuers in emerging markets. Related to this hypothesis, CIP deviations in AUD and CAD relative to USD are less correlated with their credit spread differentials, as presented earlier in Fig. 6 and Table 2.

Table 3 Issuance flow response

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

$$issPct^{Foreign \to US}_{6m.avg.} = a + b'X_t + \varepsilon_{t+1}$$

	Issuance flow to dollar credit market by currency region origin																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	EUR	GBP	JPY	AUD	CHF	CAD	EUR	GBP	JPY	AUD	CHF	CAD	EUR	GBP	JPY	AUD	CHF	CAD
Ψ corp.basis	0.285	0.164	0.0462	-0.011	0.115	0.0241	0.247	0.157	0.0353	0.00709	0.119	-0.0534						
	[4.70]	[2.48]	[1.79]	[-0.10]	[3.44]	[0.31]	[5.08]	[2.11]	[2.10]	[0.07]	[3.47]	[-0.75]						
r^*-r							0.0175	-0.0165	0.0256	0.0271	0.00675	0.093						
							[1.65]	[-0.77]	[5.50]	[3.52]	[1.14]	[5.32]						
x CIP dev.													0.371	0.382	0.154	-0.0804	0.151	0.243
													[6.75]	[4.72]	[6.94]	[-0.92]	[3.90]	[1.32]
κ credit sprd.													0.219	0.12	0.0194	0.0215	0.0957	-0.00541
													[4.92]	[1.97]	[1.15]	[0.16]	[2.12]	[-0.07]
_cons	0.406	8.72	0.558	7.88	-0.704	7.6	0.984	9.51	5.94	2.26	0.266	7.32	-2.25	6.21	-3.35	6.73	-2.07	8.53
	[0.44]	[7.63]	[0.67]	[4.08]	[-1.34]	[4.67]	[0.99]	[4.92]	[4.46]	[1.49]	[0.31]	[6.63]	[-2.47]	[5.44]	[-5.13]	[4.16]	[-2.42]	[4.81]
rsq	0.34	0.11	0.04	0	0.26	0	0.39	0.13	0.45	0.18	0.29	0.33	0.48	0.36	0.54	0.02	0.34	0.03
n	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151	151

Table 4 presents the response of issuance flow sensitivity pre- and post- GFC. The dependent variable is the aggregated issuance flow between the U.S. and the combined four currency regions (EMU, U.K., Japan, and Switzerland) that have an issuance response to deviations. The pre-crisis sample displays insignificant issuance response to deviations (column 2 and 5). This is in contrast with the strong issuance flow response to deviations post-crisis (column 3 and 6). The result suggests that debt issuing firms started to arbitrage the deviations at the aggregate level only after the crisis, possibly because the deviations were smaller in the pre-crisis period and that traditional institutions such as banks played a larger role in arbitrage activities.

Table 4 Pre- and post-crisis issuance flow sensitivity

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

	Issuance flow to dollar credit market					
	1	2	3	4	5	6
	full sample	Pre-2009	Post-2009	full sample	Pre-2009	Post-2009
Ψ corp. basis	0.155	-0.00507	0.132			
	[3.61]	[-0.19]	[3.09]			
x CIP dev.				0.224	0.0484	0.171
				[7.23]	[0.66]	[3.25]
κ credit sprd.				0.112	0.0182	0.12
				[4.07]	[0.43]	[2.59]
_cons	0.757	-2.72	2.3	-1.36	-2.6	0.751
	[1.28]	[-5.52]	[3.37]	[-2.52]	[-4.88]	[0.47]
rsq	151	60	91	151	60	91
n	0.29	0.00	0.31	0.54	0.01	0.34

Firm-level analysis The aggregate results showing the response of issuance flow to the pricing anomalies can also be tested using a panel of firm-specific credit spread differentials. I examine firms' decisions on debt currency denomination with a linear probability model. This firm-level study exploits variations within firm and cross-sectionally within time period. Therefore, it serves as validation of the aggregate result. To construct firm-specific credit spread differentials, I estimate the cross-sectional regression at each date t, $S_{it} = \alpha_{ct} + \delta_{ft} + \alpha_{ct} \cdot \delta_{ft} + \varepsilon_{it}$, where S_{it} is the credit spread for bond i issued in currency c, by firm f. α_{ct} and δ_{ft} are currency and firm fixed effects. The firm-specific residualized credit spread differential is estimated as $\kappa_{fct} = \hat{\alpha}_{ct} + \hat{\delta}_{ft} + \hat{\alpha}_{ct} \cdot \hat{\delta}_{ft}$. I also construct a firm-specific corporate basis Ψ_{fct} using the same approach, but with the credit spread adjusted for CIP deviation $S_{it}^{FXhedged}$ as

the dependent variable. Table 5 presents the result of the firm-level currency choice analysis. Column 1 shows that a firm's debt currency choice is sensitive to both its own credit spread and the cash CIP deviation common to all market participants. Each standard deviation increase in the firm-specific credit spread differential κ_{fct} is associated with a 1.6% decrease in the probability of issuing that that currency. Each standard deviation increase in x_t (the cost of swapping to USD) is associated with a 7.2% decrease in the probably of issuing in the non-USD currency. Column 2 shows that the impact of the firm-specific corporate basis is equally large. A one standard deviation increase in the corporate basis (more expensive FX-hedged non-USD borrow cost) reduces foreign currency debt issuance by 3.6%.

Table 5 Firm-level issuance choice and violations in credit and CIP

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

$$I_{fct} = \beta_0 + \beta_1 \kappa_{fct} + \beta_2 x_{ct} + \mathbf{X}'_{it}\beta + \varepsilon_{fct},$$

I_{fct} is an indicator variable that equals 1 if firm f issues in currency c in quarter t. κ_{fct} is the firm-specific residualized credit spread differential defined in the text. In column 2, I estimate the regression with corporate basis as the independent variable,
$I_{fct} = \beta_0 + \beta_1 \Psi_{fct} + \mathbf{X}'_{it}\beta + \varepsilon_{fct}$, where corporate basis Ψ_{fct} is estimated similarly to κ_{fct}. t-statistics in brackets are based on robust standard errors clustered by firm and time.

	probability of issuing in ccy c	
	(1)	(2)
credit diff κ_{fct}	-0.0727	
	[-5.41]	
cip x	-0.135	
	[-3.19]	
corp. basis (Ψ)		-0.074
		[-5.53]
firm FE	x	x
time FE	x	x
rsq	0.18	0.18
n	28726	28726

5.3 Arbitrage capital and deviation alignment

The model shows that an exogenous increase in debt issuance amount D allows firms to deploy more arbitrage capital and reduces the corporate basis. In this section, I analyze

whether changes in the amount of arbitrage capital affect the corporate basis with an instrumental variable approach that uses the amount of maturing debt to instrument for the need to roll over and refinance through new debt issuance. Specifically, I run a regression with the following form:

$$\Delta|\Psi|_{c,t} = \alpha_c + \beta_1 D_{c,t} + \varepsilon_{c,t},$$

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

Conceptually, the analysis relies on the assumption that firms are opportunistic regarding the relative currency allocations of their debt issuance, as opposed to engaging in market timing and adjusting their total issuance amount. While the market timing motive is important and widely documented in many studies, it does not obviate a firm's decision regarding the relative currency allocation of their debt issuance, once they have decided the total amount to issue.

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

Table 6 presents the result of this analysis. Column 1 shows the OLS regression estimates and column 4 shows the IV result. The coefficients on the debt issuance amount are significant and economically meaningful. For each standard deviation ($25 billion) increase in the total issuance amount in USD and EUR debt, the corporate basis is reduced by around two basis points. This price elasticity is likely an underestimate due to the anticipatory effect of debt issuance and front-running by other market participants. Debt issuance and rollovers are pre-announced (through roadshows, dealers and regulatory filings) and anticipated by investors and hedge funds. The full unanticipated effects are likely larger.

Table 6 Debt issuance amount and deviation alignment

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

$$\Delta|\Psi_{c,t}| = \alpha_c + \beta_1 D_{c,t} + \varepsilon_t,$$

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

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

6   Conclusion

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

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