1 Data description

I create a merged data set on corporate bond issuance, attributes and yields using data from SDC Global New Issuance database, Moody’s Default & Recovery database and Bloomberg. The data merge uses ISIN and CUSIP when possible. If neither of the identifiers are available, the merge is performed using issuer ticker, coupon, and maturity. The merged data set contains corporate bonds that are non-floating, non-perpetual and have no-embedded options (straight, bullet bonds). Securities with remaining maturity less than one year and less than ten percent of the original maturity are excluded since the liquidity for these bonds are poor and pricing are often missing. This also effectively rules out short-term funding instruments such as commercial paper. Loans, convertible bonds, and asset backed securities (such as CMBS) are also excluded in the data set. Since the analyses focus on cross-currency issuers in major currencies (USD, EUR, JPY, GBP, CHF, AUD, and CAD), I only include a bond in the data set if the ultimate parent of the issuer has at least one other bond denominated in a different currency outstanding. I also exclude bonds with less than $50mm notional at issuance. Bond yields are obtained from Bloomberg and winsorized at 1% to remove erroneous prices. Table 1 provides a summary of the bond data.

The credit spread is calculated as yield-yield asset swap spread against the benchmark LIBOR-based swap curve. To calculate this credit spread, I subtract the individual bond yield by the maturity-matched swap yield linearly interpolated from swaps with maturities of 1, 2, 5, 7, 10, 12, 15, 20, and 30 years. Using spline interpolation (instead of linear interpolation) does not result in noticeable difference in the residualized credit spreads. Using OIS-based swaps also does not result in a large difference in the overlapping sample. OIS-based swaps lack pricing observations for a large part of the earlier sample and for certain currency and maturities.

2 Additional robustness checks on residualized credit spread and CIP deviation

Additional controls in the measurement of credit spread differential Fig. 1 presents the comparison of the estimates from the augmented model and the main regression specification. The augmented model includes controls for amount outstanding, bond age relative to initial maturity, seniority, and governance law.

Heterogeneity for different credit ratings Fig. 2 presents the residualized credit spread differentials constructed with high-grade and low-grade bonds separately for each of the currencies. High-grade bonds are defined as bonds with single A or better Moody’s rating. This split allows roughly equal number of bonds with high grade vs. low grade. When the sample is restricted to low-grade bonds only, the credit
spread differentials are larger in magnitude than those of high-grade bonds. Since low-grade bonds have higher credit spreads to begin with, the credit spread differential are also larger.

**Non-mechanical comovement** A possible concern is that the high comovement between the two deviations are driven mechanically since the funding rate (swap rate) appears in the calculation of credit spread and CIP deviation. This mechanical linkage does not appear to be in the correct direction. Credit spreads generally do not mechanically narrow and widen with changes in the risk-free rate. That is, a decline in risk-free rate does not mechanically widen credit spread. A decline in the risk-free rate over a sustained period of time can lead to credit spread compression through the channel of investors reaching-for-yield, a motive that had been studied by Becker and Ivashina (2015) and Choi and Kronlund (2017). However, the reach-for-yield effect occurs gradually and is far from mechanical. I consider such effect to be a source of credit demand shock $\varepsilon_k$.

For CIP basis, which is defined as FX-implanted non-USD funding rate minus actual foreign funding rate, $b_{EUR} \equiv r_{EUR}^{\text{FX-implied}} - r_{EUR}^{\text{actual}}$, the mechanical effect of an increase in $r_{EUR}^{\text{actual}}$ would result in an immediate decline in $b_{EUR}$. However, event study using intraday data around ECB policy announcements shown by Du, Teppner, and Verdelhan (2018) suggests that $b_{EUR}$ increases when there is a positive shock to two-year German bund yield. This evidence goes against a mechanical effect that would result in the correlation of $\kappa$ and $b$. Additionally, Fig. 2 illustrates the comparison of the two deviations with swap rate differential. If the funding rate is the main driver for both CIP deviation and credit spread, we would expect that all three time series (swap rate differential, credit spread differential, and CIP deviation) to perfectly covary. This does not appear to be the case in the data.

**Non-USD currency bases** In the main text, we have analyzed both credit spread differentials and CIP violations for six major currencies all against the U.S. dollar. These deviations can also be analyzed against other currencies. Fig. 4 and 5 graph the credit spread differentials and CIP violations against EUR and GBP. These graphs also show high level of correlation and alignment in direction and magnitude for the two deviations.

The transformed graphs of the two deviations offer additional insights. For instance, Fig. 4 shows that all credit spreads against EUR has widened since 2014. With the exception of JPY, euro credit spread is tighter than all other credit spreads. This perhaps indicates a euro-specific factor.

### 3 Cross-currency basis as CIP deviation

Cross-currency basis $B$ is defined as the fair exchange of $\$\text{LIBOR}$ for $\text{Foreign LIBOR + B}$. Alternatively, OIS rate can be used instead of LIBOR. The following derivation establish the relation between cross-currency basis swaps and CIP deviation. Fig. 6 illustrates the cash flow of a cross-currency basis swap.

Variable definitions:

- $Z_T$: Domestic zero rate
- $Z^*_T$: Foreign zero rate
- $R$: Dollar par swap rate
- $R^*$: Foreign par swap rate
• \( S \): Spot currency exchange rate at time 0. Dollar per 1 unit of foreign currency. e.g. EURUSD

• \( F_T \): Forward currency exchange rate at time 0

• \( T \): Maturity

• \( B \): A swap of 3-month dollar LIBOR is fair against 3-month foreign LIBOR +\( B \)

Without CIP deviation, the forward exchange rate can be expressed as

\[
F = S \frac{(1 + Z)^T}{(1 + Z^*)^T}.
\]

A simplified definition of CIP deviation can be expressed as \( \Delta \) in the following equation

\[
F = S \frac{1 + r}{1 + r^* - \Delta}.
\]

Using a replication portfolio similar in methodology as Tuckman and Porfriro (2003), I show that

\[
F = S_0 \frac{(1 + Z)^T}{(1 + Z^*)^T} \left(1 + B \left[ \frac{(1 + Z^*)^T - 1}{R^* (1 + Z^*)^T} \right] \right)^{-1}.
\]

Consider the following replicating portfolio for a cross-currency basis swap

Positive=Receive, Negative=Pay

<table>
<thead>
<tr>
<th>Transaction</th>
<th>t0 ($)</th>
<th>Interim ($)</th>
<th>T ($)</th>
<th>t0 (F)</th>
<th>Interim (F)</th>
<th>T (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rec. Euribor + ( B ) vs pay $LIBOR cross-currency swap</td>
<td>( +S_0 )</td>
<td>(-S_0 L_t )</td>
<td>(-S_0 )</td>
<td>(-1 )</td>
<td>( L_t^* + B )</td>
<td>(+1 )</td>
</tr>
<tr>
<td>Spot FX</td>
<td>(-S_0 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign: Pay fixed/rec. floating par swap in amount ( \frac{B}{R^*} )</td>
<td></td>
<td></td>
<td></td>
<td>( B/R^* [L_t^* - R^*] )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign: Pay floating zero coupon swap [ZCS] in amount ( \frac{1 + R^<em>}{B/R^</em>} )</td>
<td></td>
<td></td>
<td></td>
<td>(-L_t^* (1 + \frac{B}{R^*}) )</td>
<td>( (1 + \frac{B}{R^<em>}) \left[(1 + Z^</em>)^T - 1\right] )</td>
<td></td>
</tr>
<tr>
<td>Dollar: Rec. floating ZCS in amount ( S_0 )</td>
<td>( S_0 L_t )</td>
<td>(-S_0 )</td>
<td>((1 + Z)^T - 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sell foreign fwd. of in amount ( \frac{S_0 (1 + Z)^T}{F} )</td>
<td>( \frac{S_0 (1 + Z)^T}{F} )</td>
<td></td>
<td></td>
<td></td>
<td>(- \frac{S_0 (1 + Z)^T}{F} )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Setting the foreign cash flow in time $T$ equal to 0, we get

$$
\left(1 + \frac{B}{R^*}\right) \left[(1 + Z^*)^T - 1\right] + 1 = \frac{S_0 \left(1 + Z\right)^T}{F}
$$

$$(1 + Z^*)^T + \frac{B \left[(1 + Z^*)^T - 1\right]}{R^*} = \frac{S_0 \left(1 + Z\right)^T}{F}
$$

$$1 + \frac{B \left[(1 + Z^*)^T - 1\right]}{R^* \left(1 + Z^*\right)^T} = \frac{S_0 \left(1 + Z\right)^T}{F \left(1 + Z^*\right)^T}
$$

$$F = \frac{S_0 \left(1 + Z\right)^T}{\left(1 + Z^*\right)^T} \left(1 + \frac{B \left[(1 + Z^*)^T - 1\right]}{R^* \left(1 + Z^*\right)^T}\right)^{-1}
$$

$$F_{d/f} = \frac{S_{d/f} \left(1 + Z\right)^T}{\left(1 + Z^*\right)^T} \left(1 + PV^* \left|B\right|\right)^{-1}
$$

Now relating this to the simplified definition

$$F = S \frac{(1 + Z)^T}{\left(1 + Z^* - \Delta\right)^T}
$$

We set the two relations equal to each other and obtain

$$\frac{1}{\left(1 + Z^* - \Delta\right)^T} = \frac{1}{\left(1 + Z^*\right)^T} \left[1 + \frac{B \left[(1 + Z^*)^T - 1\right]}{R^* \left(1 + Z^*\right)^T}\right]^{-1}
$$

$$(1 + Z^* - \Delta)^T = \left[1 + \frac{B \left[(1 + Z^*)^T - 1\right]}{R^* \left(1 + Z^*\right)^T}\right] \left(1 + Z^*\right)^T
$$

Left hand side can be Taylor approximated around $B = 0$ as $(1 + Z^*)^T + T \left(1 + Z^*\right)^T \Delta - B$, therefore

$$(1 + Z^*)^T + T \left(1 + Z^*\right)^T \Delta \approx \left[1 + X \frac{(1 + Z^*)^T - 1}{R^* \left(1 + Z^*\right)^T}\right] \left(1 + Z^*\right)^T
$$

$$\frac{T \Delta}{1 + Z^*} \approx -B \left(1 + Z^*\right)^T \left(1 + Z^*\right)^T \Delta \approx -B \left(1 + Z^*\right)^T \left(1 + Z^*\right)^T \frac{1 + Z^*}{T}
$$

With the definition of a swap $R^* = \frac{1 - (1 + Z^*)^{-T}}{\sum_{t=1}^{T} (1 + Z_{0,t}^*)^{-t}}$, we get

$$\Delta \approx -B \left[\sum_{t=1}^{T} (1 + Z_{0,t}^*)^{-t}\right] \frac{1 + Z^*}{T}
$$

Suppose zero rate for different maturities are constant, $Z_{0,t} = Z_{0,T} = z$, i.e. the zero curve is flat (this also implies flat swap curve). Generally, zero coupon curves are upward sloping. Assuming a flat curve bias
the discount factor to be smaller, thus making a more conservative estimation. Then the PV becomes

\[
\sum_{t=1}^{T} (1 + z^*)^{-t} = -\frac{(z^* + 1)^{-T} - 1}{z^*}
\]

and \(\Delta\) becomes

\[
\Delta \approx -PV \frac{1 + z^*}{T} B
\]

\[
\approx \left[ \frac{(z^* + 1)^{-T} - 1}{z^* T} (1 + z^*) \right] B
\]

\[
\approx - \left[ 1 + \frac{1}{2} (1 - T) z^* + 1/6(T^2 - 1) (z^*)^2 \right] B
\]

where the last line applies 3rd order Taylor approximation.

**Cross-currency basis swap with OIS rate** Most cross-currency basis swaps traded in the market are Libor-based. Combining the Libor cross-currency basis swap with other swaps such as Libor-OIS swap or Fixed-for-Floating Libor swap allows the end user to customize the resultant swap to their particular needs. OIS-based cross-currency basis swaps have also been traded directly in the market, although far less frequently and only on a few currencies. The maturity of the OIS-based swaps is also incomplete for certain currencies. Fig. 7 shows the comparison of the five year Libor-based cross-currency basis and the five-year OIS-based cross currency basis for EURUSD. The two time series are similar. This is a reflection that the five-year dollar Libor-OIS swap spread and the equivalent spread in EUR are similar.

## 4 Extended model

This section provides a model extension from the model in the main text. The key extensions are made on the global issuers. In contrast to the simple model in the main text, the extension allows firms to choose their FX hedging ratio with possible carry trade motive. In addition, the extension incorporates the possibility that firms have natural exchange rate hedges, e.g. cash flow or asset denominated in the currency of debt issued. The main model predictions also emerge in the extended model along with additional implications. Fig. 8 presents a schematic of the model.

### 4.1 Credit markets

In this static model, there are two credit markets: the euro-denominated corporate bond market and the dollar-denominated corporate bond market, and three main credit market players: specialist local investors in EUR debt, specialist local investor in USD debt and a representative firm that has access to both debt markets.

**Local investors** The active local investors are specialized in investments in their home currency. U.S. active investors specialize in the investment of corporate bonds denominated in dollars. They borrow at the domestic short rate, \(r_U\), and purchase bonds with a promised net yield of \(Y_U\). With fixed probability \(\pi\), the bonds default and lose \(L\) in value. The payoff of the bonds has a variance of \(V_C\), which is treated as
an exogenous constant in the model for tractability\footnote{A Bernoulli default distribution with probability \( \pi \), loss-given-default \( L \) and promised yield \( Y_U \) implies that \( V_C = \pi (1 - \pi) (Y_U + L)^2 \). The solution to the investors’ problem would contain a quadratic root. To keep the model tractable, \( V_C \) is assumed to be an exogenous constant.}. Investors have a mean-variance preference with risk tolerance \( \tau_i \) and choose investment amount \( X_U \) to solve the following

\[
\max_{X_U} \left[ X_U ((1 - \pi) Y_U - \pi L - r_U) - \frac{1}{2\tau_i} X_U^2 V_C \right]
\]

which has the solution

\[
X_U = \frac{\tau_i (1 - \pi) Y_U - \pi L - r_U}{V_C}.
\]

Similarly, the European credit investors are constrained to invest in euro-denominated bonds. For simplicity, assume that the default probability, loss given default and payoff variance are the same for bonds in both markets\footnote{Given common default probability \( \pi \) and loss-given-default \( L \), payoff variance \( V_C \) of euro-denominated and dollar-denominated bonds can only be the same if the promised yields \( Y_U \) and \( Y_E \) are also identical. With a small difference in \( Y_U \) and \( Y_E \) in comparison to \( L \), \( V_C \) is assumed to be the same for both markets.}. European credit investors have a demand of

\[
X_E = \frac{\tau_i (1 - \pi) Y_E - \pi L - r_E}{V_C}.
\]

**Exogenous credit demand shocks** In addition, I introduce idiosyncratic demand shocks of \( \varepsilon_U \) in dollar bonds and \( \varepsilon_E \) in euro bonds. These shocks are exogenous to the model and perhaps represent demand shocks that originate from Quantitative Easing or preferred-habitat investors with inelastic demands such as pension funds, insurance companies and endowments. The sources of exogenous shocks are discussed in Section 5.

**Firm** The representative global firm needs to issue a fixed debt amount \( D \). The firm chooses a share \( \mu \) of the debt to be issued in dollar at a cost of \( Y_U \). The remainder \( 1 - \mu \) of the debt is issued in euro promising a coupon of \( Y_E \). The firm is a price taker, and its decision is analyzed in Section 4.3.

**Market clearing conditions** in the dollar and euro credit market are

\[
X_U + \varepsilon_U = \mu D
\]

\[
X_E + \varepsilon_E = (1 - \mu) D.
\]

Combining the demand equations with the market clearing conditions and applying first-order Taylor approximation for \( \pi \) around 0, we can write the difference in promised yield between euro and dollar bonds as a credit spread difference, \( \kappa \), and a risk-free rate difference, \( \rho \).

\[
Y_E - Y_U = \frac{V_C}{\tau_i} \left( (1 - 2\mu) D - \varepsilon_\kappa \right) + \left( r_E - r_U \right).
\]

\[
\equiv \kappa + \rho
\]

where \( \varepsilon_\kappa \equiv \varepsilon_E - \varepsilon_U \) is the relative idiosyncratic euro credit demand. The credit spread differential, \( \kappa \), is a function of dollar issuance share \( \mu \), local investor risk preference \( \tau_i \), payoff variance \( V_C \) and relative credit
demand shock $\kappa$ represent a price discrepancy of credit risk since the default probability and loss given default are identical across the two markets.

The cross-currency issuer has limited ability to influence the relative credit spread. If it chooses all of its debt to be issued in euro instead of dollar, i.e. $\mu = 0$, then the relative credit spread in euro would widen as a result of the additional debt supply. The issuer’s impact is limited, however, by the size of its total debt issuance $D$ given the restriction that $\mu \in [0, 1]$.

4.2 Currency swap market

Next, I describe the dynamics of the currency swap market. There are two main players in this market: currency swap traders and issuers.

**Currency swap traders** Currency swap traders choose amount of capital to devote to either CIP deviations, denoted as $b$, or alternate investment opportunity with profit of $f(I)$, where $I$ is the amount of investment. When $b$ is positive, the FX-implied euro funding rate is high relative to the actual euro funding rate. Therefore, FX swap traders simultaneously lend out euro and borrow dollar through purchasing dollar in the spot market and selling dollar in the forward market. They enter into a swap size of $s$, where $s > 0$ when the trader is lending out euro. When $b$ is negative, the FX-implied euro funding rate is low, and FX swap trader borrows in euro and lends in dollar by entering into a swap position with $s < 0$.

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

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

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

I make an additional simplifying assumption that CIP deviation $b$ disappears when there is no net demand for swaps, but as soon as there is net demand for swaps, $b$ becomes non-zero. This assumption is equivalent to stating $\frac{\partial b}{\partial s} = W$, which means that arbitrageur has just enough wealth $W$ to take advantage of all positive-NPV investment opportunities in the alternative project $f(I)$. Simplifying with this assumption remove the constant intercept term in the equation above for $b$, and we obtain that CIP deviation is proportional to swap trader position,

$$b = \phi\gamma^2 s.$$ 

This model of swap traders is analogous to that of Ivashina, Scharfstein, and Stein (2015) which modeled the outside alternative activity with a log functional form.

**Firm** The same representative firm from the credit market also engages in FX swap transactions as a price taker. The issuer has a desired dollar funding ratio of $m$ and euro funding ratio of $1 - m$. This target could represent the firm’s operational exposures in different currencies. For instance, AT&T would has $m = 1$ since its operations in entirely in the U.S. The issuer thus has an exchange rate exposure of $(m - \mu)$ given its choice of dollar issuance share $\mu$. It chooses a hedging ratio $h \in [0, 1]$ for a total amount of hedged foreign issuance $(m - \mu)hD$. From the perspective of a U.S.-based issuer with $m = 1$, e.g. AT&T,
the hedging amount \((1 - \mu) hD\) is positive and represents the issuer’s dollar borrowing via the FX market. AT&T buys dollar in the spot market for conversion of euro issuance proceed into dollars and sells dollar in the forward market for future repayment of debt. The currency swap trader must hold the opposite position, that is, lending dollar to AT&T by selling dollar in the spot market and buying dollar in the forward market.

**Exogenous FX swap demand** In addition, there is a source of exogenous shock \(\varepsilon_F\) that represents other non-issuance-related use of FX-swaps. One source of \(\varepsilon_F\) shock in recent period has emanated from regulatory changes. For instance, U.S. money market reform has reduced the availability of wholesales dollar funding to foreign banks and increased their reliance on funding via currency swaps (Pozsar 2016). Other sources of exogenous shocks are discussed in Section 5.

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

\[
b = -\gamma^2 \phi \left( D (m - \mu) h + \varepsilon_F \right)
\]

The negative sign arise since the swap trader take the opposite position of the hedging demand. Equation 8 provides several intuitive comparative statics. First, CIP deviation \(b\) is proportional to the total amount of hedging demand \(D (m - \mu) h + \varepsilon_F\). \(b\) is negative when there is a net hedging demand for borrowing dollar/lending euro, that is when \(D (m - \mu) h + \varepsilon_F > 0\). This can occur if the issuer has a dollar funding shortfall, \(m > \mu\), e.g. AT&T issues a fraction of its bond in euro but has its entire funding need in U.S. dollar, and therefore needs to borrow dollar/lend euro via the FX market. On the other hand, \(b\) is positive when the net hedging demand is for borrowing euro/lending dollar. Second, more stringent haircut requirements \(\gamma\) intensifies the impact of hedging demand for either positive or negative deviations.

One additional insight on the role of the issuer in the above setup is that debt issuer hedging demand \(D (m - \mu) h\) does not have to have the same sign as other exogenous hedging demand, \(\varepsilon_F\). If \(\varepsilon_F\) has the opposite sign as and larger in magnitude than the issuer demand, the issuer would incur an additional benefit (instead of cost) through hedging. In this case, the firm would contribute to the elimination of CIP deviation and act as a provider of liquidity in the currency forward market.

### 4.3 The Firm’s Problem

Putting it all together, I describe the firm’s optimization problem and first order conditions. The representative firm has a mean-variance preference and wants to minimize the total cost of issuance while avoiding exchange rate volatility. It chooses fraction \(\mu\) of the debt to be issued in dollar and hedging ratio \(h\) to minimize the total financing cost. Dollar debt carries a promised yield of \(Y_U\), and the reminder are issued in euro at a yield of \(Y_E = Y_U + \kappa + \rho\). I assume for simplicity that Uncovered Interest Rate Parity (UIP) holds, therefore the difference of unhedged funding cost between issuing in EUR and USD is \(\kappa\). This assumption can be relaxed without modifying the main results. Under UIP deviation, the unhedged cost difference is \(\kappa + \rho\), where \(\rho\) the interest rate differential is the gain from FX carry trade. The unhedged issuance that deviate from the firm’s desired currency mix \(m\) exposes the firm to exchange rate variance \(V_F\) and incurs a cost reflecting distaste for volatility \(\tau_F\). Since \(D (m - \mu)\) is the currency mismatch and \(1 - h\) fraction of this mismatch is unhedged, the cost due to FX volatility is \(\frac{1}{2\tau_F} D^2 (m - \mu)^2 (1 - h)^2 V_F\). FX hedging imposes an

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\(\text{\textsuperscript{3}}\)The incentive to hedge volatile cash flows can be rationalized in the framework of costly external finance and firm’s incentive to keep sufficient internal funds available to take advantage of attractive investment opportunities (Froot, Scharfstein, and Stein 1992).

7
adjustment to debt servicing cost equal to the amount of hedging need \((m - \mu)h\) multiplied by the per-unit price of hedging \(b\), which is the deviation from CIP.

Given the above setup, the firm solves

$$
\min_{\mu, h} D \left[ \mu Y_U + (1 - \mu) (Y_U + \kappa) + (m - \mu) hb + \frac{1}{2\tau_F} (m - \mu)^2 (1 - h)^2 V_F \right]. \tag{9}
$$

Cross-currency issuers are taken to be a representative firm that is a price taker in the credit and FX swap markets. That is, there can be many other identical firms of total measure one solving the same optimization problem. Their debt issuance in each market determines the bond yields and currency swap levels but they take the equilibrium prices as given when solving their optimizing problem.

We first analyze the partial equilibrium solution in the firm’s problem before considering the general equilibrium in section (4.4). The firm’s first order conditions are

$$
\mu^* = m + \frac{\tau_F (\kappa - bh^*)}{D (h^* - 1)^2 V_F}, \tag{10}
$$

and

$$
h^* = 1 + \frac{\tau_F b}{(m - \mu^*) D V_F}. \tag{11}
$$

Equation (10) says that the issuer has a natural inclination to issue a fraction \(m\) of the total debt in dollar to obtain the optimal capital structure. With credit market frictions, dollar issuance share increases in the relative euro credit spread \(\kappa\). That is, if AT&T's euro credit spread were wide relative to dollar, then it is more incentivized to issue in dollar. Similarly, segmentation in the FX market also affect the equilibrium share of issuance in dollar. When the cost of borrowing dollar in the FX market is large, \(b \ll 0\), AT&T is reluctant to issue in euro and engage in the swapping of proceeds to dollar, therefore dollar issuance ratio \(\mu^*\) is high.

Equation (11) expresses the optimal hedging ratio in terms of the optimal share of dollar issuance. I impose the assumption that the issuer cannot make a pure exchange rate bet, thus \(h \in [0, 1]\). When there is a dollar financing shortfall \((m > \mu^*)\), hedging is incomplete \((h < 1)\) if there is a costly CIP deviation for borrowing dollar via the FX market \((b < 0)\). Similarly, when there is a euro financing shortfall \(m < \mu^*\), hedging is incomplete when it is costly to borrow euro via the FX market \((b > 0)\). Furthermore, hedging ratio approaches unity when the firm has zero risk tolerance \(\tau_F\), large amount of issuance-driven FX exposure \((m - \mu^*) D\), or when FX volatility is high. In sum, hedging is incomplete when it is costly and more complete when the firm is averse to large risks.

### 4.4 Perfect alignment of deviation

Rewriting equations (6), (9), (10), and (11), we have four equilibrium conditions and four endogenous variables \((b, \kappa, \mu, h)\) summarized again below:
• Credit spread difference (euro minus dollar credit spreads)
\[ \kappa = \frac{V_C}{\tau_i} \left( (1 - 2\mu) D + \varepsilon_\kappa \right) \]  

(6)

• CIP violation (FX-implied minus actual euro funding rate)
\[ b = -\gamma^2 \phi \left( D (m - \mu) h + \varepsilon_F \right) \]  

(8)

• Issuance share in dollar
\[ \mu = m + \frac{\tau_F (\kappa - bh)}{D(h-1)^2V_F} \]  

(10)

• Hedging ratio
\[ h = 1 + \frac{\tau_F b}{(m - \mu)DV_F} \]  

(11)

The first two equations represent equilibrium conditions that determine the price deviations in the FX and credit markets. The last two equations are FOCs from the firm’s issuance and hedging decisions. Two types of shocks are exogenous to the system: credit demand shock \( \varepsilon_\kappa \) (positive indicates relative demand for euro credit) and FX swap demand shock \( \varepsilon_F \) (positive indicates dollar-borrowing demand).

We can solve the model and obtain the general equilibrium solutions for \( \kappa, b, \mu, \) and \( h \). We analyze the solution for \( \kappa \) and \( b \), and especially focuses on the shock terms.

The solutions can be written in matrix form as

\[
\begin{bmatrix} \kappa \\ b \\ \mu \end{bmatrix} = \Lambda \begin{bmatrix} - (\tau_F V_C + \tau_s V_C V_F) - \tau_i V_C V_F D \\ - \tau_i V_C V_F D \\ - \tau_i (\tau_F V_C + \tau_s V_C V_F) \end{bmatrix} \begin{bmatrix} -2\tau_i V_C V_F D \\ -\tau_i V_F - 2\tau_i V_C V_F D \\ \tau_i \tau_i V_F \end{bmatrix} \begin{bmatrix} \varepsilon_\kappa \\ \varepsilon_F \end{bmatrix}^T + \text{const.}
\]  

(12)

where
\[
\Lambda = [D\tau_i (2V_C (\tau_F + V_F \tau_s) + V_F \tau_i) + \tau_i (\tau_F + V_F \tau_s)]^{-1}
\]

\( \Lambda \) decreases with risk tolerance and debt amount. Intuitively, the absolute level of deviations is reduced when there are more capital devoted to cross-market arbitrage or agents are more risk tolerant.

While comparative statics with respect to the terms that appear in \( \Lambda \) cannot be seen easily in the above expression, it is informative to examine the direction and relative magnitude of the impact of \( \varepsilon_\kappa \) and \( \varepsilon_F \) shocks on \( \kappa, b \) and \( \mu \). A positive \( \varepsilon_\kappa \) shock (more demand for euro credit) compresses the relative euro credit spread \( \kappa \) as well as lowers \( b \). The credit shock’s effect on CIP deviation \( b \), indicated by the term \(-\tau_i V_C V_F D \Lambda\), is generated by the issuer’s conversion of its euro bond issuance proceeds into dollar, effectively lending euro and borrowing dollar via the FX market. Given limited FX swap arbitrageur capital, the demand to borrow dollar and lend euro exerts a price pressure on FX forward relative to spot exchange rate, creating the deviation in CIP as a result. The credit shock’s differential impact on \( \kappa \) and \( b \) is \(- (\tau_F V_C + \tau_s V_C V_F) \Lambda\), which represent the shock impact on the net deviation. This net deviation is precisely what motivates the firm to shift the currency of issuance to lean against the shock. Therefore, \( \mu \), the share of issuance denominated in dollar, declines proportionally to the impact on net deviation in amount \(-\tau_i (\tau_F V_C + \tau_s V_C V_F) \Lambda\), which corresponds to the partial equilibrium solution Equation 10.
Similarly, a $\varepsilon_F$ shock to the FX swap market also has multitudinous effects on the two LOOP violations and issuance currency choice. A positive $\varepsilon_F$ shock represents demand for borrowing dollar/lending euro (buy dollar spot/sell dollar forward) via the FX market. Therefore, the $\varepsilon_F$ shock lowers $b$, making it more costly to swap euro into dollar. Facing this higher cost of conversion, the firm has less incentives to issue in euro, and its share of dollar issuance increases by $\tau_x \tau_i V_F \Lambda$. With an inward shift in the supply of euro credit, the price of euro credit increases as well, or equivalently $\kappa$ falls. Again, the change in the equilibrium issuance share in dollar, $\tau_x \tau_i V_F \Lambda$, is proportional to the coefficient on $\kappa - b$, the net deviation.

In equilibrium, issuance share in dollar $\mu$ co-moves with the net deviation $\kappa - b$. This co-movement is robust to the presence of either type of shocks. Suppose $\tau_x \gg 0$ that the firm is very tolerant of concentration risk, then any small net deviation would motivate the firm to change its currency mix substantially to take advantage the net deviation. In the limiting case under which the firm is unrestricted in FX-hedged cross-currency issuance, the net deviation would disappear entirely, i.e. $\lim_{\tau_x \to \infty} \kappa - b = 0$. The preference for a diverse currency mix and limited issuance amount prevents the firm from completely arbitrating away the net deviation.

### 4.5 Imperfect alignment of deviations

In the earlier section, I introduced the model to show a simple case of perfect alignment between the two deviations. Next, I explore more realistic case in which there are imperfect alignment. Since the firm integrates the two deviations, there must be some frictions that prevent the firms from completely aligning the two deviations.

\[
\min_{\mu, h} \begin{bmatrix} -\mu \kappa \\ \frac{1}{\tau_x} (m - \mu)^2 \\ (m - \mu) h + \frac{1}{2\tau_F} D (m - \mu)^2 (1 - h)^2 V_F \end{bmatrix} = \Lambda \begin{bmatrix} -\tau_x \gamma^2 \phi V_F D + \gamma^2 \phi \tau_F + V_F \\ -\tau_x \gamma^2 \phi V_F D V_C \\ - (\gamma^2 \phi \tau_F + V_F) V_C \\ -\gamma^2 \phi (2\tau_x V_C D + \tau_i) V_F \\ \gamma^2 \phi \tau_i V_F \\ \tau_x \gamma^2 \phi \tau_i V_F \end{bmatrix} \left[ \begin{bmatrix} \varepsilon_{\kappa} \\ \varepsilon_F \end{bmatrix} \right]^T + \text{const.}.
\]

(13)

The term $\frac{1}{\tau_x} (m - \mu)^2$ comes from refinancing risk due to the concentration of bond ownership (Boermans, Frost, and Bisscop, 2016), or collateral constraints for hedging (Rampini and Viswanathan, 2010). Loosely speaking, $\tau_x$ represent balance sheet strength.

Partial equilibrium; FOC condition for $\mu^*$

\[\mu^* = m + \tau_x (\kappa - b)\]

(14)

$h^*$ is the same as before.

The solution can be written in matrix form,

\[
\begin{bmatrix} \kappa \\ b \\ \kappa - b \\ \mu \end{bmatrix} = \Lambda \begin{bmatrix} \begin{bmatrix} -\tau_x \gamma^2 \phi V_F D + \gamma^2 \phi \tau_F + V_F \\ -\tau_x \gamma^2 \phi V_F D V_C \\ - (\gamma^2 \phi \tau_F + V_F) V_C \\ -\gamma^2 \phi (2\tau_x V_C D + \tau_i) V_F \\ \gamma^2 \phi \tau_i V_F \\ \tau_x \gamma^2 \phi \tau_i V_F \end{bmatrix} \left[ \begin{bmatrix} \varepsilon_{\kappa} \\ \varepsilon_F \end{bmatrix} \right]^T + \text{const.} \end{bmatrix}
\]

(15)

where

\[
\Lambda = \left[ \gamma^2 \phi (2DV_C \tau_x + \tau_i) + D_F \tau_i \tau_x \right]^{-1}
\]
The solution model yields the following propositions.

**Proposition 1. (The alignment of deviations)** When firms are relatively unconstrained by capital structure considerations, \( \tau_X \gg 0 \), the credit spread differential and CIP deviations respond similarity to shocks to either credit or FX swap demand, \( \frac{\partial \kappa}{\partial \varepsilon_X} \approx \frac{\partial b}{\partial \varepsilon_X} \) and \( \frac{\partial \kappa}{\partial \varepsilon_F} \approx \frac{\partial b}{\partial \varepsilon_F} \). The two deviations also has similar magnitude, \( \kappa \approx b \). When firms are completely unconstrained in capital structure, \( \lim_{\tau_X \to \infty} c = \lim_{\tau_X \to \infty} b \).

As we have already seen in Equation [15] the two violations share common loadings on \( \varepsilon_F \) and \( \varepsilon_k \) shocks. Rewriting the comparative statics of the violations with respect to the shocks, we have

\[
\frac{\partial \kappa}{\partial \varepsilon_X} = \frac{\partial b}{\partial \varepsilon_X} + \frac{1}{\tau_X} \frac{\partial \mu}{\partial \varepsilon_X},
\]

and

\[
\frac{\partial \kappa}{\partial \varepsilon_F} = \frac{\partial b}{\partial \varepsilon_F} + \frac{1}{\tau_X} \frac{\partial \mu}{\partial \varepsilon_F}.
\]

When the issuer is completely unrestricted in the choice of issuance currency, the two deviations are perfectly aligned in response to shocks, i.e. \( \lim_{\tau_X \to \infty} \frac{\partial \kappa}{\partial \varepsilon_X} = \lim_{\tau_X \to \infty} \frac{\partial b}{\partial \varepsilon_X} \) and \( \lim_{\tau_X \to \infty} \frac{\partial \kappa}{\partial \varepsilon_F} = \lim_{\tau_X \to \infty} \frac{\partial b}{\partial \varepsilon_F} \).

Empirically, the two time series have a high level of correlation but not perfectly correlated. This indicates that issuers have a \( \tau_X \) that is high but not infinite.

**Proposition 2. (The co-movement of cross-currency issuance with net deviation)** \( \text{Sign} \left[ \frac{\partial \mu}{\partial \varepsilon} \right] = \text{Sign} \left[ \frac{\partial (\kappa - b)}{\partial \varepsilon} \right] \) and \( \text{Sign} \left[ \frac{\partial \mu}{\partial m} \right] = -\text{Sign} \left[ \frac{\partial (\kappa - b)}{\partial m} \right] \). Dollar issuance ratio \( \mu \) is positively correlated to the net deviation \( \kappa - b \) when shocks originate from the demand for credit or FX forward. \( \mu \) is negatively correlated to \( \kappa - b \) when shocks originate from exogenous changes in the desired issuance currency mix \( m \) (supply shocks)\(^4\).

Suppose AT&T is thinking of expanding into Europe and needs raise funding in EUR. Effectively, its dollar target funding ratio \( m \) is dropped. When it attempts to raise fund in EUR, it does so by both issuing in EUR and swapping dollar issuance into EUR. With more euro issuance, it’s dollar funding ratio \( \mu \) is dropped. Issuing in Euro increases its euro credit spread, so \( \kappa \) is higher. Borrowing euro via FX swap increases the borrowing cost of euro, that is \( b \) increases, however, this increase is less than the increase in \( \kappa \) since transmission of shock is imperfect. Therefore \( \frac{\partial (\kappa - b)}{\partial (m_0)} > 0 \) while \( \frac{\partial \mu}{\partial (m_0)} < 0 \). I show this in general equilibrium in the appendix.

**Proposition 3. (The cross-section of issuance-based arbitrage)** \( \frac{\partial^2 \mu}{\partial \varepsilon_X \partial \tau_X} < 0, \frac{\partial^2 \mu}{\partial \varepsilon_F \partial \tau_X} > 0, \frac{\partial^2 (\kappa - b)}{\partial \varepsilon_X \partial \tau_X} > 0, \) and \( \frac{\partial^2 (\kappa - b)}{\partial \varepsilon_F \partial \tau_X} < 0 \). Firms with stronger balance sheet (higher \( \tau_X \)) respond more aggressively to demand shocks in credit and FX, and their firm-specific net deviation is less responsive to shocks.

**Proposition 4. (The balance sheet of financial intermediary)** \( \frac{\partial \gamma}{\partial \varepsilon} < 0, \frac{\partial \mu}{\partial \varepsilon} < 0 \). When haircut for swap traders \( \gamma \) is high, both deviations are more responsive to demand shocks. The effect on net deviation is ambiguous, depending on the source of the shock.

\[
\frac{\partial (\kappa - b)}{\partial m} = -2\gamma^2 \phi \tau F BV C + 2BV C V F
\]

\[
\frac{\partial \mu}{\partial m} = \gamma^2 \phi \tau X \tau F V B + \tau V F + \tau_1 \gamma^2 \phi \tau F
\]
Proposition 5. (The amount of capital available for arbitrage use) \( \frac{\partial (\kappa - b)}{\partial \varepsilon} \) > 0, \( \frac{\partial (\kappa - b)}{\partial \varepsilon} < 0 \). The impact of shocks on the net deviation is smaller when total amount of debt issuance is high.

This follows the intuition that when issuers are able to provide enough cross-market arbitrage capital, the FX funding and credit markets become more integrated.

Proposition 6. (Risk and risk tolerance) \( \frac{\partial \kappa}{\partial \varepsilon} \frac{\partial V}{\partial \varepsilon} < 0 \), \( \frac{\partial b}{\partial \varepsilon} \frac{\partial V}{\partial \varepsilon} < 0 \), \( \frac{\partial \kappa}{\partial \varepsilon} \frac{\partial \tau}{\partial \varepsilon} > 0 \), and \( \frac{\partial b}{\partial \varepsilon} \frac{\partial \tau}{\partial \varepsilon} > 0 \). With higher payoff variance \( V_C \), exchange rate variance \( V_F \) or lower risk tolerances \( \tau_F \) and \( \tau_i \), the impact of demand shocks on credit spread differential and CIP violations are amplified.

This is because when the credit markets have perfectly elastic supply curves, credit demand shocks are unable to make a dent in the relative price of credit in the first place; therefore, no misalignment is created. Similarly, the FX shock misalignment term \( \frac{1}{\tau_F} \frac{\partial \mu}{\partial \varepsilon_F} \) converges to zero as either FX arbitrageur’s risk tolerance or issuer’s tolerance for exchange rate volatility approach infinity. That is, when FX arbitrageur or issuer provides perfectly elastic supply of FX swaps, \( \varepsilon_F \) shocks would not make an impact on CIP, thus, no misalignment between \( \kappa \) and \( b \) is created.

5 Source of \( \varepsilon_K \) and \( \varepsilon_b \) shocks

In this section, I discuss the possible sources of shocks to credit spread and FX basis in detail. For a graphical illustration of the frictions in the two markets, see Fig. 2.

5.1 \( \varepsilon_K \) shocks

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

- **Passive investor portfolio changes** Shifts in passive institutional investor’s benchmarks and portfolios can bring large changes to the demand for assets. For instance, Japan’s Government Pension Investment Fund, which holds US$1.2 trillion in assets and serves as the most frequently used portfolio benchmark for other Japanese-based asset managers, in October 2014 reduced its domestic bond holding from 60 percent to 35 percent and increased its allocations to stocks and foreign assets. This large, one-time portfolio shift differs from that of active credit specialists who decide on bond investments based on credit risks at higher frequencies.

- **Regulatory-driven demand shocks** Portfolio shifts can also be driven by regulatory reforms. One such regulatory change occurred in the United Kingdom, when the 2005 Pension Reform Act forced pension funds to mark their liabilities to market by discounting them at the yield on long-term bonds. This reform significantly increased the demand for long-term securities (Greenwood and Vayanos 2010).

- **Credit-market sentiments** Many papers have analyzed the role of credit sentiment on asset prices and the real economy (López-Salido, Zakrajšek and Stein, 2015; Bordalo, Gennaioli, and Shleifer, 2016; Greenwood, Hanson, and Jin, 2016; Greenwood and Hanson, 2014). A shock to the relative credit demand between bond markets can arise if credit sentiments differentially impact different markets. One
such episode occurred around the time of the Bear Stearns collapse, when the residualized USD credit spread widened relative to the EUR credit spread as fears of US credit market meltdown heightened.

5.2 $\varepsilon_b$ shocks

- **Dollar liquidity shortage** Since the crisis, non-U.S. banks, in need of short-term USD funding for their U.S. operations, have become active borrowers of USD through FX swaps. A particularly striking episode of demand shock for FX swaps into USD is the 2011-12 Eurozone Sovereign Crisis. Dollar money market funds stopped lending to European banks out of fear of fallouts from the sovereign crisis. This episode is detailed in Ivashina, Scharfstein, and Stein (2015). Acute $\varepsilon_b$ shocks typically affect short-term CIP more than long-term CIP.

- **Money market reform** in the U.S. that took effect in October 2016 has reduced the availability of wholesale USD funding to foreign banks and increased their reliance on funding via currency swaps (Pozsar and Smith, 2016).

- **Structured note issuers** also utilize currency swaps in the hedging of ultra long-dated structured products whose payoff depends on exchange rate at a future date. The hedging of Power Reverse Dual Currency Notes by issuers had been an important driver of currency basis in the AUD, JPY, and other Asian currencies.

- **Regulatory-driven hedging demands** New regulatory requirements for the hedging of previously under-hedged exposures have also driven the CIP basis. Solvency II Directives on EU and U.K. insurance companies demanded greater usage of longer-dated cross-currency basis swaps to reduce foreign currency exposure of insurance firm asset holdings. The Solvency II rules started with initial discussions in 2009 and finally took effect in 2016.

- **Central bank policies** European banks with excess EUR liquidity have been able to take advantage of the higher interest on excess reserve (IOER) rate offered by the Fed through conversion via FX swaps. As of September 2016, foreign bank offices in the U.S. have $377 billion in currency-swapped deposits at the Fed.

The policies at other central banks also affected CIP violations. For example, the termination of the ECB’s sterilization programs reduced the amount of High Quality Liquid Assets (HQLA) for European banks and was a contributing factor to the widening of the CIP violation in 2014.

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

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

## Table 1 Bond data summary

<table>
<thead>
<tr>
<th>currency</th>
<th>All bonds</th>
<th>June 2016 outstanding</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Notional $bil</td>
</tr>
<tr>
<td>USD</td>
<td>12,530</td>
<td>9,732</td>
</tr>
<tr>
<td>EUR</td>
<td>8,608</td>
<td>9,257</td>
</tr>
<tr>
<td>JPY</td>
<td>8,152</td>
<td>1,969</td>
</tr>
<tr>
<td>GBP</td>
<td>1,492</td>
<td>945</td>
</tr>
<tr>
<td>CAD</td>
<td>1,124</td>
<td>516</td>
</tr>
<tr>
<td>CHF</td>
<td>2,017</td>
<td>478</td>
</tr>
<tr>
<td>AUD</td>
<td>1,022</td>
<td>319</td>
</tr>
<tr>
<td>rating</td>
<td>AA- or higher</td>
<td>11,937</td>
</tr>
<tr>
<td></td>
<td>A+ to BBB-</td>
<td>13,633</td>
</tr>
<tr>
<td></td>
<td>HY (BB+ or lower)</td>
<td>1,898</td>
</tr>
<tr>
<td></td>
<td>NA</td>
<td>7,477</td>
</tr>
<tr>
<td>maturity</td>
<td>1-3yrs</td>
<td>1,250</td>
</tr>
<tr>
<td></td>
<td>3-7 yrs</td>
<td>14,704</td>
</tr>
<tr>
<td></td>
<td>7-10 yrs</td>
<td>4,736</td>
</tr>
<tr>
<td></td>
<td>10yr+</td>
<td>14,246</td>
</tr>
</tbody>
</table>

This table presents the summary of the merged data set for all bonds (including matured bonds) and outstanding bonds in June 2016. For the first two columns that summarizes all bonds, maturity and rating are categorized based on the first occurrence of each bond in the data set (typically at issuance). For the last two columns that summarizes debt outstanding on June 2016, maturity is categorized based on the remaining maturity of each bond.
7 Appendix Figures

Figure 1 Additional Controls

This figure presents the credit spread differential between bonds denominated in different currencies relative to US dollar. The solid red line is the residualized credit spread differential constructed based on the procedure in the main text. The dotted blue line is estimated with cross-sectional regressions that controls for the amount outstanding, the age of the bond relative to maturity, governance law and the seniority of the bond in addition to maturity bucket, rating, and firm.
Figure 2 Low-grade vs high-grade credit spread differential in other currencies

This figure presents the credit spread differential between bonds denominated in different currencies relative to US dollar for low-grade and high-grade bonds. High grade bonds are defined as bonds with single-A or higher rating by Moody. I estimate the following cross-sectional regression at each date $t$ for low-grade and high-grade bonds separately

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

where $S_{it}$ is the yield spread over the swap curve for bond $i$ that is issued in currency $\kappa$, by firm $f$, and with maturity $m$. The residualized credit spread of currency $\kappa$ relative to dollar is defined as $\hat{\alpha}_{c,t} - \hat{\alpha}_{usd,t}$. 

---

**EUR**

**GBP**

**JPY**

**AUD**

**CHF**

**CAD**
Figure 3 Residualized credit spread differential, CIP deviations, and interest rate differential

This figure presents the residualized credit spread differential (euro minus dollar) and CIP deviations for EURUSD in the top panel and interest rate differential (5-year euro minus dollar interest rate swap differential) in the bottom panel.
Figure 4 Credit spread differential and CIP violation relative to EUR

This figure presents credit spread differentials ($\alpha_c - \alpha_{EUR}$) and CIP deviations ($r_{FX \text{ implied}}^c - r_c$) relative to EUR for six major funding currencies ($c = AUD, CAD, CHF, GBP, JPY, USD$). Vertical bars represent the 95% confidence interval for the estimated credit spread differentials constructed using robust standard errors clustered at the firm level.
Figure 5: Credit spread differential and CIP violation relative to GBP

This figure presents credit spread differentials ($\alpha_c - \alpha_{GBP}$) and CIP deviations ($r_{FX\text{ implied}}^c - r_c$) relative to GBP for six major funding currencies ($c = \text{AUD, CAD, CHF, EUR, JPY, USD}$). Vertical bars represent the 95% confidence interval for the estimated credit spread differentials constructed using robust standard errors clustered at the firm level.
Figure 6 Cross-currency basis swap cash flows

This figure decomposes the cash flows of a lend EUR/borrow USD (receive Euribor + basis versus pay $Libor) cross-currency basis swap into two floating-rate notes (FRNs) in EUR and USD. The euro lending cash flows are shown in blue and the dollar borrowing cash flows are shown in red. Upward arrows represent payments and downward arrows represent receivables. An initial exchange of €1 for $1.1 (at the spot FX rate) is made at the swap initiation date. Floating rate coupons based on the Euribor and $Libor reference rates are exchanged every quarter in the interim. A final exchange of the original principal amount (at the initial FX rate) is made at the maturity date. The other counterparty of this swap holds a borrow EUR/lend USD position and the reverse of the cash flows shown below.
Figure 7 Cross-currency basis swap with OIS rates

This figure presents a comparison of cross-currency basis swaps with short-term reference rates as LIBOR (Red) and OIS rate (Blue) for EUR, GBP, and JPY at the five year maturity. The OIS-based cross-currency bases swap rates are from ICAP.

Panel A: EUR

Panel B: GBP

Panel C: JPY
Figure 8 Model schematics

EU-US residualized credit spread

Firms issue in USD, Borrow EUR via FX swap

Firms issue in EUR, Borrow USD via FX swap

Credit specialists
FX traders

U.S. credit crunch
ECB QE
Credit sentiment
Liability driven investments

Dollar liquidity shortage
Bank funding via FX
Other hedging demands
Figure 9 Sources of shocks and institutional details

**Theoretical value for both deviations = 0**

**New frictions in credit:**
- Poor liquidity:
  - Shift from principal to agency trading

**Direct credit arbs:**
- FX-unhedged investment & issuance

**CIP arbs:**
- Bank ALM/treasury
  - (banks became net contributor to CIP widening)
- Hedge funds; only arbs.
  - Term structure of CIP but not absolute level

**New frictions in FX market:**
- More collateral pledges
  - CVA charges (Basel III)
  - Endogenous VaR
- SLR, LCR requirements
  - Tighter balance-sheet constraint overall

**K**
- (credit spread diff. EU-US)
- (sovereign spread diff.)

**FX-hedged Issuance by firms, SSAs**

**b**
- (CIP violation; expensive to swap into USD when b<0)

**Credit shocks**
- CIES: Fed QE (+), ECB QE (-)
- Differential reaching-for-yield motives
- U.S. Credit Crunch (07-08)
- Benchmark changes
  - E.g. Japan’s GPIF
- Idiosyncratic shocks on individual bonds/issuers
  - Cross-section: larger for low grade bonds

**b shocks**
- Dollar liquidity shortage: foreign banks with dollar funding needs
  - Wholesales $ funding shocks
  - MMF reform
- Fed Fund IOER arbitrage by foreign banks
- Derivative hedging (e.g. PRDC)
- Hedging of previously unhedged FX exposure
  - E.g. Solvency II (UK) hedging requirement for insurance companies
  - Exporters covering their outright exposure

*Theoretical backstop: Fed swap line QE +100/+50 since 2012*
I estimate a first order vector autoregression (VAR) of the form

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

I apply Cholesky Decomposition by ordering the variables as \(\mu, b, \text{ and } \kappa\). This ordering assumes that issuance responds with a lag to both \(\varepsilon_\kappa\) and \(\varepsilon_b\) shocks, and credit deviation respond with a lag to CIP shocks. The orthogonalized impulse responses to \(\varepsilon_\kappa\) and \(\varepsilon_b\) shocks are graphed below. The choice of lag 1 is selected by Bayesian Information Criteria. 95\% confidence intervals are shown in gray.

Figure 10 Spillover of deviations: orthogonalized impulse responses of deviations and issuance flow for EURUSD
I estimate a first order vector autoregression (VAR) of the form

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

I apply a partial identification method by assuming that issuance flow responds with a lag to both $\varepsilon_{\kappa}$ and $\varepsilon_{b}$ shocks, but $b$ and $\kappa$ has no ordering with respect to each other. That is, $\varepsilon_{b}$ and $\varepsilon_{\kappa}$ can have contemporaneous effects on both $b$ and $\kappa$. The orthogonalized impulse responses to $\varepsilon_{\kappa}$ and $\varepsilon_{b}$ shocks are graphed below. The choice of lag 1 is selected by Bayesian Information Criteria. Confidence intervals at the 95% level using bootstrapped standard errors are shown in gray.

Figure 11 Spillover of deviations: partially identified impulse responses of deviations and issuance flow for EURUSD
References


