Internet Appendix

Credit Migration and Covered Interest Rate Parity

Gordon Y. Liao[1]

August 2019

1 Data description

I create a merged data set of 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 ISINs and CUSIPs 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 maturities of less than one year and of less than ten percent of the original maturity are excluded since the liquidity for these bonds are poor and pricing is 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 from 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

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 a Moody's rating of single A or better. This split allows for a roughly equal

[1] The views in this paper are solely the responsibility of the author and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or any other person associated with the Federal Reserve System.

number of high-grade vs. low-grade. When the sample is restricted to only low-grade bonds, 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 differentials are also larger.

Non-mechanical comovement A possible concern is that the high comovement between the two deviations is driven mechanically since the funding rate (swap rate) appears in the calculation of both the 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 the 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 investors reaching-for-yield, a motive that has been studied by Becker and Ivashina (2015) and Choi and Kronlund (2017), among others. However, the reach-for-yield effect occurs gradually and is far from mechanical. I consider such an effect to be a source of credit demand shock ε_κ.

It would also appear that the CIP basis, defined as the actual non-dollar funding rate minus the FX-implied non-dollar funding rate, $x_{EUR} \equiv r_{EUR}^{actual} - r_{EUR}^{FX-implied}$, is mechanically affected by changes in r_{EUR}^{actual}. However, event studies using intraday data around ECB policy announcements by Du, Tepper, and Verdelhan (2018) suggest that x_{EUR} decreases when there is a positive shock to the two-year German bund yield. This evidence goes against a mechanical effect that would result in the correlation of κ and x.

Non-USD currency bases In the main text, we analyzed both credit spread differentials and CIP violations for six major currencies against the U.S. dollar. These deviations can also be analyzed against other currencies. Fig. 3 and 4 graph the credit spread differentials and CIP violations against EUR and GBP. These graphs also show a 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. 3 shows that all credit spreads against EUR have widened since 2014. With the exception of JPY, the euro credit spread is tighter than all other credit spreads. This is perhaps indicative of a euro-specific factor.

3 Cross-currency basis as CIP deviation

The cross-currency basis B is defined as the fair exchange of \$LIBOR for foreign LIBOR $+B$. Alternatively, the OIS rate can be used instead of LIBOR. The following derivation establishes the relation between cross-currency basis swaps and CIP deviation. Fig. 5 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 x in the following equation

$$F = S\frac{1+r}{1+r^*-x}.$$

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

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

Consider the following replicating portfolio for a cross-currency basis swap
Positive=Receive, Negative=Pay

Transaction	t0 ($)	Interim ($)	T ($)	t0 (F)	Interim (F)	T (F)
Rec. Euribor + B vs pay $LIBOR cross-currency swap	$+S_0$	$-S_0L_t$	$-S_0$	-1	L_t^*+B	$+1$
Spot FX	$-S_0$			$+1$		
Foreign: Pay fixed/rec. floating par swap in amount $\frac{B}{R^*}$					$B/R^*\,[L_t^*-R^*]$	
Foreign: Pay floating zero coupon swap (ZCS) in amount $\left(1+\frac{B}{R^*}\right)$					$-L_t^*\left(1+\frac{B}{R^*}\right)$	$\left(1+\frac{B}{R^*}\right)\left[(1+Z^*)^T-1\right]$
Dollar: Rec. floating ZCS in amount S_0		S_0L_t	$-S_0\left[(1+Z)^T-1\right]$			
Sell foreign fwd. of in amount $\frac{S_0(1+Z)^T}{F}$			$\frac{S_0(1+Z)^T}{F}F$			$-\frac{S_0(1+Z)^T}{F}$
	0	0	0	0	0	

Setting the foreign cash flow of time T equal to 0, we get

$$\begin{aligned}
\left(1+\frac{B}{R^*}\right)\left[\left(1+Z^*\right)^T-1\right]+1 &= \frac{S_0\left(1+Z\right)^T}{F} \\
\left(1+Z^*\right)^T+\frac{B\left[\left(1+Z^*\right)^T-1\right]}{R^*} &= \frac{S_0\left(1+Z\right)^T}{F} \\
1+\frac{B\left[\left(1+Z^*\right)^T-1\right]}{R^*\left(1+Z^*\right)^T} &= \frac{S_0\left(1+Z\right)^T}{F\left(1+Z^*\right)^T} \\
F &= \frac{S_0\left(1+Z\right)^T}{\left(1+Z^*\right)^T}\left(1+B\frac{\left[\left(1+Z^*\right)^T-1\right]}{R^*\left(1+Z^*\right)^T}\right)^{-1} \\
F_{d/f} &= S_{d/f}\frac{\left(1+Z\right)^T}{\left(1+Z^*\right)^T}\left(1+PV^*\left[B\right]\right)^{-1}
\end{aligned}$$

Now relating this to the simplified definition

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

We set the two relations equal to each other and obtain

$$\begin{aligned}
\frac{1}{\left(1+Z^*-x\right)^T} &= \frac{1}{\left(1+Z^*\right)^T}\left[1+B\frac{\left(1+Z^*\right)^T-1}{R^*\left(1+Z^*\right)^T}\right]^{-1} \\
\left(1+Z^*-x\right)^T &= \left[1+B\frac{\left(1+Z^*\right)^T-1}{R^*\left(1+Z^*\right)^T}\right]\left(1+Z^*\right)^T
\end{aligned}$$

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

$$\begin{aligned}
\left(1+Z^*\right)^T+T\left(1+Z^*\right)^{T-1}x &\approx \left[1+X\frac{\left(1+Z^*\right)^T-1}{R^*\left(1+Z^*\right)^T}\right]\left(1+Z^*\right)^T \\
\frac{Tx}{1+Z^*} &\approx -B\frac{\left(1+Z^*\right)^T-1}{R^*\left(1+Z^*\right)^T} \\
x &\approx -B\left[\frac{\left(1+Z^*\right)^T-1}{R^*\left(1+Z^*\right)^T}\right]\frac{1+Z^*}{T}
\end{aligned}$$

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

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

Suppose zero rates for different maturities are constant, $Z_{0,t}=Z_{0,T}=z$, i.e. the zero curve is flat (this also implies a flat swap curve). Generally, zero coupon curves are upward sloping. Assuming a flat curve

biases the discount factor to be smaller, making for a more conservative estimation. Then the PV becomes

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

and x becomes

$$\begin{aligned} x &\approx -PV\frac{1+z^*}{T}B \\ &\approx \left[\frac{(z^*+1)^{-T}-1}{z^*T}(1+z^*)\right]B \\ &\approx -\left[1+\frac{1}{2}(1-T)z^*+1/6(T^2-1)(z^*)^2\right]B \end{aligned}$$

where the last line applies a third-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 the LIBOR-OIS swap or the Fixed-for-Floating LIBORswap 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. 6 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 reflects 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 motives. 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 issuance. The main model predictions, along with additional implications, emerge in the extended model. Fig. 7 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 π, 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[2]. Investors have a mean-variance preference with risk tolerance τ_i and choose investment amount X_U to solve the following

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

which has the solution

$$X_U = \tau_i \frac{(1-\pi) Y_U - \pi L - r_U}{V_C}. \tag{2}$$

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[3]. European credit investors have a demand of

$$X_E = \tau_i \frac{(1-\pi) Y_E - \pi L - r_E}{V_C}. \tag{3}$$

Exogenous credit demand shocks In addition, I introduce idiosyncratic demand shocks of ε_U in dollar bonds and ε_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 μ of the debt to be issued in dollars at a cost of Y_U. The remainder $1-\mu$ of the debt is issued in euros, 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

$$X_U + \varepsilon_U = \mu D \tag{4}$$

$$X_E + \varepsilon_E = (1-\mu) D. \tag{5}$$

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

$$Y_E - Y_U = \underbrace{\frac{V_C}{\tau_i} \left((1-2\mu) D - \varepsilon_\kappa \right)}_{\kappa} + \underbrace{\left(r_E - r_U \right)}_{\rho}. \tag{6}$$

$$\equiv \kappa + \rho \tag{7}$$

where $\varepsilon_\kappa \equiv \varepsilon_E - \varepsilon_U$ is the relative idiosyncratic euro credit demand. The credit spread differential, κ, is a function of dollar issuance share μ, local investor risk preference τ_i, payoff variance V_C and relative credit

[2] A Bernoulli default distribution with probability π, 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.

[3] Given common default probability π 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.

demand shock. κ represents the 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 euros instead of dollars, i.e. $\mu = 0$, then the relative credit spread in euros 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 an amount of capital to devote to either CIP deviations, denoted as x, or to an alternate 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 $\max_s xs + f(W - \gamma|s|)$. The solution, $x = sign[s]\gamma f'(W - \gamma|s|)$, provides the intuition that the expected gain from conducting an additional unit of 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.

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 a euro funding ratio of $1 - m$. This target could represent the firm's operational exposures in different currencies. For instance, AT&T would have $m = 1$ since its operations are entirely in the U.S. The issuer thus has an exchange rate exposure of $(m - \mu)$ given its choice of dollar issuance share μ. 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 dollars in the spot market for conversion of euro issuance proceeds into dollars and sells dollars in the forward market for future repayment of debt. The currency swap trader must hold the opposite position, that is, lending dollars to AT&T by selling dollars in the spot market and buying dollars in the forward market.

Exogenous FX swap demand In addition, there is a source of exogenous shock ε_x that represents other non-issuance-related use of FX-swaps. The sources of exogenous shocks are discussed in Section 5.

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

$$x = \gamma^2 \phi \left(D \left(m - \mu \right) h + \varepsilon_x \right) \tag{8}$$

Equation 8 provides several intuitive comparative statics. First, the CIP deviation x is proportional to the total amount of hedging demand $D\left(m-\mu\right)h+\varepsilon_F$. x is positive when there is a net hedging demand for borrowing dollars/lending euros, that is when $D\left(m-\mu\right)h+\varepsilon_x > 0$. This can occur if the issuer has a dollar funding shortfall, $m > \mu$, e.g. if AT&T issues a fraction of its bonds in euros but has its entire funding needs in U.S. dollars and therefore needs to borrow dollars/lend euros via the FX market. On the other hand, x is negative when the net hedging demand is for borrowing euros/lending dollars. Second, more stringent haircut requirements γ intensify 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 $D\left(m-\mu\right)h$ does not have to have the same sign as other exogenous hedging demand, ε_x. In the case $sign[\varepsilon_x] \neq sign[D(m-\mu)]$ and $|\varepsilon_x| > |D\left(m-\mu\right)|$, the issuer provides (rather than demands) liquidity in the FX swap market and incurs 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 a fraction μ of the debt to be issued in dollars and a hedging ratio h to minimize the total financing cost. Dollar debt carries a promised yield of Y_U, and the remaining debt is issued in euros at a yield of $Y_E \equiv Y_U + \kappa + \rho$. The unhedged cost difference is $\kappa + \rho$, where ρ the interest rate differential is the gain from FX carry trade. FX-unhedged issuance that deviates 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[4]. Since $D\left(m-\mu\right)$ is the currency mismatch and $1-h$ fraction of this mismatch is unhedged, the cost due to FX volatility is $\frac{1}{2\tau_F} D^2 \left(m-\mu\right)^2 \left(1-h\right)^2 V_F$. FX hedging imposes an adjustment to debt servicing cost equal to the amount of hedging need $\left(m-\mu\right)h$ multiplied by the per-unit price of hedging x, which is the deviation from CIP.

Given the above setup, the firm solves

$$\min_{\mu,h} D \left[\underbrace{\mu Y_U}_{\text{USD funding cost}} + \underbrace{\left(1-\mu\right)\left(Y_U+\kappa\right)}_{\text{EUR funding cost}} + \underbrace{\left(m-\mu\right)hx}_{\text{hedging cost}} + \underbrace{\frac{1}{2\tau_F} D \left(m-\mu\right)^2 \left(1-h\right)^2 V_F}_{\text{distaste for FX volatility}} \right]. \tag{9}$$

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

[4]The incentive to hedge volatile cash flows can be rationalized in the framework of costly external finance and a firm's incentive to keep sufficient internal funds available to take advantage of attractive investment opportunities (Froot, Scharfstein, and Stein 1992).

take the equilibrium prices as given when solving their optimization 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

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

and

$$h^* = 1 + \frac{\tau_F x}{(m - \mu^*)\, DV_F}. \tag{11}$$

Equation 10 says that the issuer has a natural inclination to issue a fraction m of the total debt in dollars to obtain the optimal capital structure. With credit market frictions, dollar issuance share increases in the relative euro credit spread κ. That is, if AT&T's euro credit spread were wide relative to that of the dollar, it is more incentivized to issue in dollars. Similarly, segmentation in the FX market also affects the equilibrium share of issuance in dollar. When the cost of borrowing dollars in the FX market is large, AT&T is reluctant to issue in euros and engage in the swapping of proceeds to dollars–therefore the dollar issuance ratio μ^* 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 dollars via the FX market ($x > 0$) . Similarly, when there is a euro financing shortfall $m < \mu^*$, hedging is incomplete if it is costly to borrow euros via the FX market ($x < 0$). Furthermore, hedging ratio approaches unity when the firm has zero risk tolerance τ_F, a 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), (8), (10), and (11), we have four equilibrium conditions and four endogenous variables (x, κ, μ, h) summarized again below:

- Credit spread difference (euro minus dollar credit spreads)

$$\kappa = \frac{V_C}{\tau_i} \left((1 - 2\mu)\, D + \varepsilon_\kappa \right) \tag{6}$$

- CIP violation (FX-implied minus actual euro funding rate)

$$x = \gamma^2 \phi \left(D\,(m - \mu)\, h + \varepsilon_x \right) \tag{8}$$

- Issuance share in dollar

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

- Hedging ratio

$$h = 1 + \frac{\tau_F x}{(m - \mu)\, DV_F} \tag{11}$$

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 ε_κ (positive indicates relative demand for euro credit) and FX swap demand shock ε_x (positive indicates dollar-borrowing demand).

We can solve the model and obtain the general equilibrium solutions for κ, x, μ, and h. We analyze the solution for κ and x, and especially focus on the shock terms.

The solutions can be written in matrix form as

$$\begin{bmatrix} \kappa \\ x \\ \mu \end{bmatrix} = \Lambda \left(\begin{bmatrix} -\left(\tau_F V_C + \tau_s V_C V_F\right) - \tau_\chi V_C V_F D & -2\tau_\chi V_C V_F D \\ \tau_\chi V_C V_F D & \tau_i V_F + 2\tau_\chi V_C V_F D \\ -\tau_\chi \left(\tau_F V_C + \tau_s V_C V_F\right) & \tau_\chi \tau_i V_F \end{bmatrix} \begin{bmatrix} \varepsilon_\kappa & \varepsilon_x \end{bmatrix}^T + \text{const.} \right) \tag{12}$$

where

$$\Lambda = \left[D\tau_\chi \left(2V_C \left(\tau_F + V_F \tau_s \right) + V_F \tau_i \right) + \tau_i \left(\tau_F + V_F \tau_s \right) \right]^{-1}.$$

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

While comparative statics with respect to the terms that appear in Λ cannot be seen easily in the above expression, it is informative to examine the direction and relative magnitude of the impact of ε_κ and ε_x shocks on κ, x and μ. A positive ε_κ shock (more demand for euro credit) compresses the relative euro credit spread κ as well as increases the hedging cost x. The credit shock's effect on CIP deviation x, indicated by the term $\tau_\chi V_C V_F D \Lambda$, is from the issuer's conversion of its euro bond issuance proceeds into dollar. Given limited FX swap arbitrageur capital, the demand to borrow dollars and lend euros exerts a price pressure on FX forwards relative to spot exchange rates, creating the deviation in CIP as a result. The credit shock's impact on the corporate basis $\kappa + x$ is $-\left(\tau_F V_C + \tau_s V_C V_F\right) \Lambda$. This impact motivates the firm to shift the currency of issuance to lean against the shock. Therefore, μ, the share of issuance denominated in dollars, declines proportionally to this impact.

Similarly, a ε_x shock to the FX swap market also has multitudinous effects on the two LOOP violations and issuance currency choice. A positive ε_x shock represents demand for borrowing dollars/lending euros (buy dollar spot/sell dollar forward) via the FX market. Therefore, the ε_x shock raises x, making it more costly to swap euros into dollars. Facing this higher cost of conversion, the firm has less incentives to issue in euros, and its share of dollar issuance increases by $\tau_\chi \tau_i V_F \Lambda$. With an inward shift in the supply of euro credit, the price of euro credit increases as well, or equivalently κ falls. Similar to the impact of ε_k shocks, the impact of ε_x shocks on the equilibrium issuance share in dollars is $\tau_\chi \tau_i V_F \Lambda$; this is directly proportional to the shock's impact on the corporate basis $\kappa + x$.

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

4.5 Imperfect alignment of deviations

In the previous 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 is imperfect alignment. Since the firm integrates the two deviations, there must be some frictions that prevent the firms from completely aligning the two deviations.

$$\min_{\mu,h}\left[\underbrace{-\mu\kappa}_{\text{credit spread diff.}}+\underbrace{\frac{1}{\tau_\chi}(m-\mu)^2}_{\text{optimal capital structure deviation}}+\underbrace{(m-\mu)hx}_{\text{hedging cost}}+\underbrace{\frac{1}{2\tau_F}D(m-\mu)^2(1-h)^2V_F}_{\text{distaste for FX volatility}}\right]. \tag{13}$$

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

Partial equilibrium; FOC condition for μ^*

$$\mu^* = m + \tau_\chi(\kappa + x) \tag{14}$$

h^* is the same as before.

The solution can be written in matrix form,

$$\begin{bmatrix}\kappa\\ x\\ \kappa+x\\ \mu\end{bmatrix} = \Lambda\left(\begin{bmatrix}-\left(\tau_\chi\gamma^2\phi V_F D+\gamma^2\phi\tau_F+V_F\right)V_C & -2\gamma^2\phi\tau_\chi V_C V_F D\\ \tau_\chi\gamma^2\phi V_F D V_C & \gamma^2\phi\left(2\tau_\chi V_C D+\tau_i\right)V_F\\ -\left(\gamma^2\phi\tau_F+V_F\right)V_C & \gamma^2\phi\tau_i V_F\\ -\tau_\chi\left(\gamma^2\phi\tau_F+V_F\right)V_C & \tau_\chi\gamma^2\phi\tau_i V_F\end{bmatrix}\begin{bmatrix}\varepsilon_\kappa & \varepsilon_x\end{bmatrix}^T + const.\right) \tag{15}$$

where

$$\Lambda = \left[\gamma^2\phi\left(\tau_F\left(2DV_C\tau_\chi+\tau_i\right)+DV_F\tau_i\tau_\chi\right)+V_F\left(2DV_C\tau_\chi+\tau_i\right)\right]^{-1}$$

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 to shocks to either credit or FX swap demand directly opposite of each other, $\frac{\partial\kappa}{\partial\varepsilon_\kappa} \approx -\frac{\partial x}{\partial\varepsilon_\kappa}$ and $\frac{\partial\kappa}{\partial\varepsilon_x} \approx -\frac{\partial x}{\partial\varepsilon_x}$. The two deviations also have similar magnitude, $|\kappa| \approx |x|$. When firms are completely unconstrained in capital structure, $\lim_{\tau_\chi\to\infty}\kappa = -\lim_{\tau_\chi\to\infty}x$.

As we have already seen in Equation 15, the two violations share common loadings on ε_x and ε_κ shocks. Rewriting the comparative statics of the violations with respect to the shocks, we have

$$\frac{1}{\tau_\chi}\frac{\partial\mu}{\partial\varepsilon_\kappa} = \frac{\partial x}{\partial\varepsilon_\kappa}+\frac{\partial\kappa}{\partial\varepsilon_\kappa}$$

and

$$\frac{1}{\tau_\chi}\frac{\partial\mu}{\partial\varepsilon_x} = \frac{\partial x}{\partial\varepsilon_x}+\frac{\partial\kappa}{\partial\varepsilon_x}.$$

When the issuer is completely unrestricted in the choice of issuance currency, the two deviations are perfectly

offseting in response to shocks, i.e. $\lim_{\tau_\chi \to \infty} \frac{\partial \kappa}{\partial \varepsilon_\kappa} = -\lim_{\tau_\chi \to \infty} \frac{\partial x}{\partial \varepsilon_\kappa}$ and $\lim_{\tau_\chi \to \infty} \frac{\partial \kappa}{\partial \varepsilon_x} = -\lim_{\tau_\chi \to \infty} \frac{\partial x}{\partial \varepsilon_x}$. Empirically, the two time series have a high level of negative correlation but are not perfectly negatively correlated. This indicates that issuers have a τ_χ that is high but not infinite.

Proposition 2. *(The comovement of cross-currency issuance with the corporate basis)* $Sign\left[\frac{\partial \mu}{\partial \varepsilon}\right] = Sign\left[\frac{\partial(\kappa+x)}{\partial \varepsilon}\right]$ *and* $Sign\left[\frac{\partial \mu}{\partial m}\right] = -Sign\left[\frac{\partial(\kappa+x)}{\partial m}\right]$. Dollar issuance ratio μ is positively correlated to the corporate basis $\kappa + x$ when shocks originate from the demand for credit or FX forwards. μ is negatively correlated to $\kappa + x$ when shocks originate from exogenous changes in the desired issuance currency mix m (supply shocks)[5].

Proposition 3. *(The cross-section of issuance-based arbitrage)* $\frac{\partial^2 \mu}{\partial \varepsilon_\kappa \partial \tau_X} < 0$, $\frac{\partial^2 \mu}{\partial \varepsilon_x \partial \tau_X} > 0$, $\frac{\partial^2(\kappa+x)}{\partial \varepsilon_\kappa \partial \tau_X} > 0$, and $\frac{\partial^2(\kappa+x)}{\partial \varepsilon_x \partial \tau_X} < 0$,. Firms with stronger balance sheets (higher τ_χ) respond more aggressively to demand shocks in credit and FX, and their firm-specific corporate basis is less responsive to shocks.

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

Proposition 5. *(The amount of capital available for arbitrage use)* $\frac{\partial(\kappa+x)}{\partial \varepsilon_\kappa \partial D} > 0$, $\frac{\partial(\kappa+x)}{\partial \varepsilon_x \partial D} < 0$. The impact of shocks on the corporate basis 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)* $\frac{\partial \kappa}{\partial \varepsilon \partial V} < 0, \frac{\partial x}{\partial \varepsilon \partial V} > 0$, $\frac{\partial \kappa}{\partial \varepsilon \partial \tau} > 0$, *and* $\frac{\partial x}{\partial \varepsilon \partial \tau} < 0$. With higher payoff variance V_C, exchange rate variance V_F or lower risk tolerances τ_F and τ_i, the impact of demand shocks on credit spread differential and CIP violations is amplified.

This is because when the credit markets have perfectly elastic supply curves, credit demand shocks have smaller impacts on the relative price of credit; therefore, the corporate basis is also impacted. Similarly, the FX shock term $\frac{1}{\tau_\chi}\frac{\partial \mu}{\partial \varepsilon_x}$ converges to zero as either the FX arbitrageur's risk tolerance or the issuer's tolerance for exchange rate volatility approaches infinity. That is, when the FX arbitrageur or issuer provides a perfectly elastic supply of FX swaps, ε_x shocks would not have an impact on the CIP deviation and the corporate basis.

5 Source of ε_κ and ε_x shocks

In this section, I discuss the possible sources of shocks to the credit spread and FX basis in detail. For a graphical illustration of the frictions in the two markets, see Fig. 8.

[5]

$$\frac{\partial(\kappa + x)}{\partial m} = -2\gamma^2 \phi \tau_F B V_C - 2 B V_C V_F$$
$$\frac{\partial \mu}{\partial m} = \gamma^2 \phi \tau_\chi \tau_i V_F B + \tau_i V_F + \tau_i \gamma^2 \phi \tau_F$$

5.1 ε_κ 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 credit in Europe and the U.S., resulting in changes in ε_κ.

- **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, reduced its domestic bond holdings in October 2014 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, 2017; Bordalo, Gennaioli, and Shleifer, 2018; Greenwood, Hanson, and Jin, 2019; Greenwood and Hanson, 2013). 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 ε_x 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[6]. 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 ε_x 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, 2016).

- **Structured note issuers** also utilize currency swaps in the hedging of ultra long-dated structured products whose payoff depends on the 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.

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

- **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 the foreign currency exposure of insurance firm asset holdings[7]. 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[8].

  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[9].

- **Hedging demand from investors** I do not consider this an ε_x 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[10].

6 Additional analyses

6.1 Structural VAR

I test the spillover of deviations through the channel of debt issuance by analyzing the impulse responses of credit spread differential κ, CIP violation x, and issuance flow μ to ε_κ and ε_x shocks. Additionally, I show that large issuances have a price impact on the FX basis.

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

Fig. 9 presents the orthogonalized impulse response functions with shocks to the credit and CIP deviations. I apply Cholesky Decomposition following a partial identification approach that restricts μ to respond

[7] Previously, insurance firms partially hedged using rolling short-dated FX forwards

[8] Foreign banks have a total excess reserve at the Fed totaling $766 billion as of September 2016, of which $429 billion are funded through fed fund and repo agreements as a part of the IOER-fed fund arbitrage (Flow of Funds Table L.112).

[9] ECB's Security Market Program that started in 2010 and the Outright Monetary Transaction program that started in 2012 both were initially sterilized purchasing programs. Sterilization encouraged the use of ECB excess reserves and provided a way for banks to obtain HQLAs needed to fulfill liquidity coverage ratio requirements. The end of ECB sterilization in 2014 meant that European banks needed to look for other HQLA to replace around $200 billion of ECB excess reserves. Therefore, these banks had to either invest in EUR assets or swap into other currencies and park their cash at the Fed or other central banks.

[10] 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.

with a lag to κ and x but allows κ and x to have contemporaneous effects on each other. This specification is the following:

$$\begin{bmatrix} 1 & & \\ a_{\kappa\mu} & 1 & a_{\kappa x} \\ a_{x\mu} & a_{x\kappa} & 1 \end{bmatrix} \begin{bmatrix} \mu_t \\ \kappa_t \\ x_t \end{bmatrix} = B \begin{bmatrix} \mu_{t-1} \\ \kappa_{t-1} \\ x_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{\mu,t} \\ \varepsilon_{\kappa,t} \\ \varepsilon_{x,t} \end{bmatrix}.$$

The first row of the figure confirms model prediction 1. A ε_κ shock that increases the euro credit spread relative to the dollar also increases dollar issuance fraction μ (top middle) and reduces dollar hedging cost x (top right). Credit spread differential then gradually normalizes over the next few months after the initial shock, as do μ and x. The bottom row shows the impulse responses with an exogenous shock in ε_x that signals an increase in the cost of swapping to USD from the other currencies. As predicted by Proposition 1, a higher cost of swapping from EUR to USD increases dollar issuance share μ (bottom middle). Euro credit spread relative to USD credit spread also decreases as EUR issuance supply shifts inward (bottom right). The persistence of response in issuance flow μ to ε_κ and ε_x shocks suggests that corporate financing decisions are slow-moving. The price under-reactions in the market not directly impacted by the shocks conforms with model predictions for slow-moving, partially segmented markets (Greenwood, Hanson, and Liao, 2018).

6.2 Limits to arbitrage spillover

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

The empirical measures of these two types of limits to arbitrage are difficult to assess. The FX collateral haircut for a derivative transaction is specific to the trade and depends on the currency, maturity, and counterparty. The indirect costs of holding arbitrage positions to maturity are also challenging to quantify. As a suggestive test, I analyze the impact of broker-dealer leverage, proxying for γ, and the VIX index, proxying for $\frac{V}{\tau}$, on the absolute level of credit spread differential and CIP deviation. The results, presented in table 2, are suggestive of the models on the spillover of constraints. Column 1 and 3 shows that a positive innovation to broker-dealer leverage factor is associated with reductions in the absolute level of the CIP basis and credit spread differential. Column 2 and 4 shows that a positive increase in the VIX index is associated with increases in the absolute level of the two deviations.

7 Appendix Tables

Table 1 Bond data summary

		All bonds		June 2016 outstanding	
		Number	Notional $bil	Number	Notional $bil
currency	all	34,945	23,217	18,746	11,970
	USD	12,530	9,732	6,273	5,053
	EUR	8,608	9,257	4,776	4,572
	JPY	8,152	1,969	4,814	1,049
	GBP	1,492	945	848	637
	CAD	1,124	516	542	246
	CHF	2,017	478	1,015	241
	AUD	1,022	319	478	171
rating	AA- or higher	11,937	10,780	5,561	4,614
	A+ to BBB-	13,633	9,367	7,736	5,564
	HY (BB+ or lower)	1,898	1,119	975	676
	NA	7,477	1,951	4,474	1,117
maturity	1-3yrs	1,259	967	131	86
	3-7 yrs	14,704	10,480	4,898	3,146
	7-10 yrs	4,736	2,941	3,030	1,909
	10yr+	14,246	8,829	10,687	6,828

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 which summarize 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 which summarize debt outstanding on June 2016, maturity is categorized based on the remaining maturity of each bond.

Table 2 Broker-dealer leverage and risk tolerance

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

	CIP basis $\|x\|$		credit diff. $\|\kappa\|$	
levfac γ^{-1}	-1.755		-4.916	
	[-2.26]		[-3.40]	
vix $\tau^{-1}V$		0.499		0.932
		[3.25]		[4.15]
_cons	18.37	9.589	17.83	0.947
	[8.09]	[2.40]	[8.70]	[0.21]
N	288	906	288	906

8 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 specification in the main text. The dotted blue line is estimated with cross-sectional regressions that control 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.

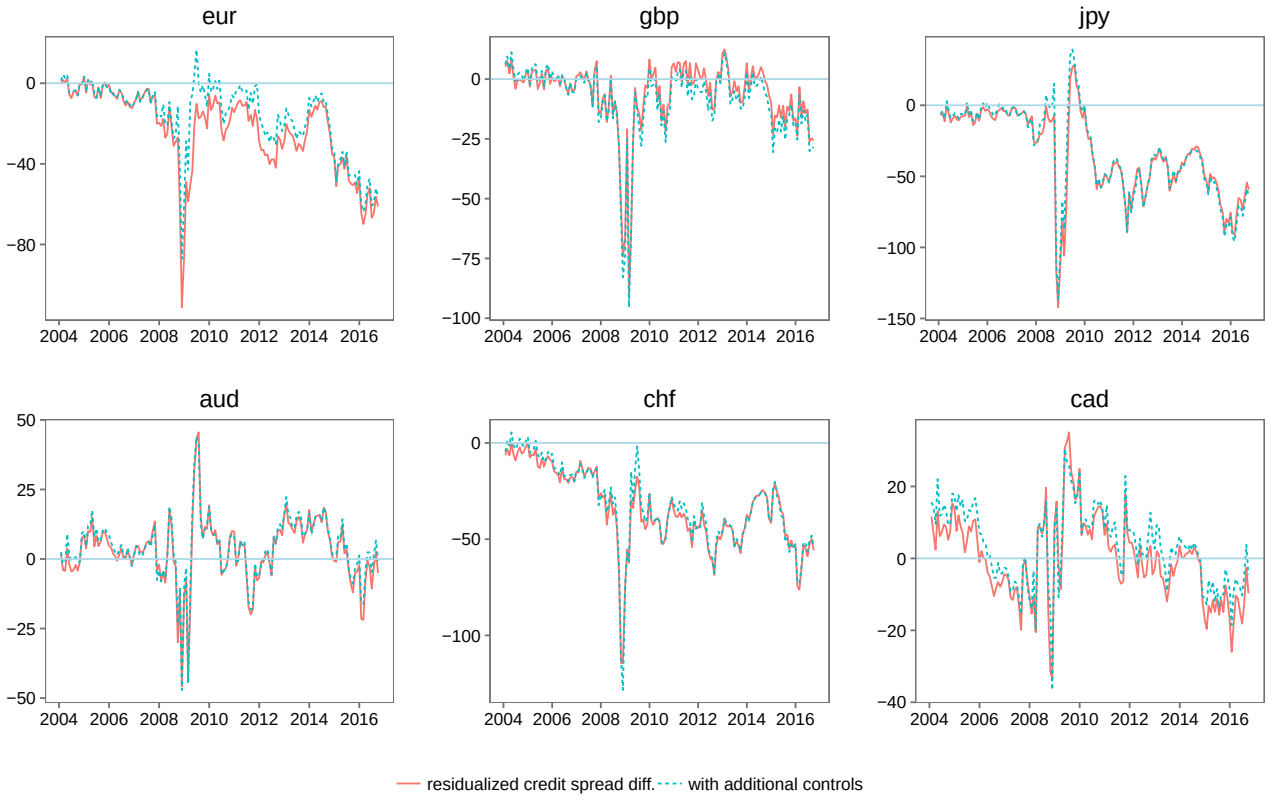


Figure 2 Low-grade vs high-grade credit spread differential in other currencies

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 κ, by firm f, and with maturity m. The residualized credit spread of currency κ relative to dollar is defined as $\hat{\alpha}_{c,t} - \hat{\alpha}_{usd,t}$.

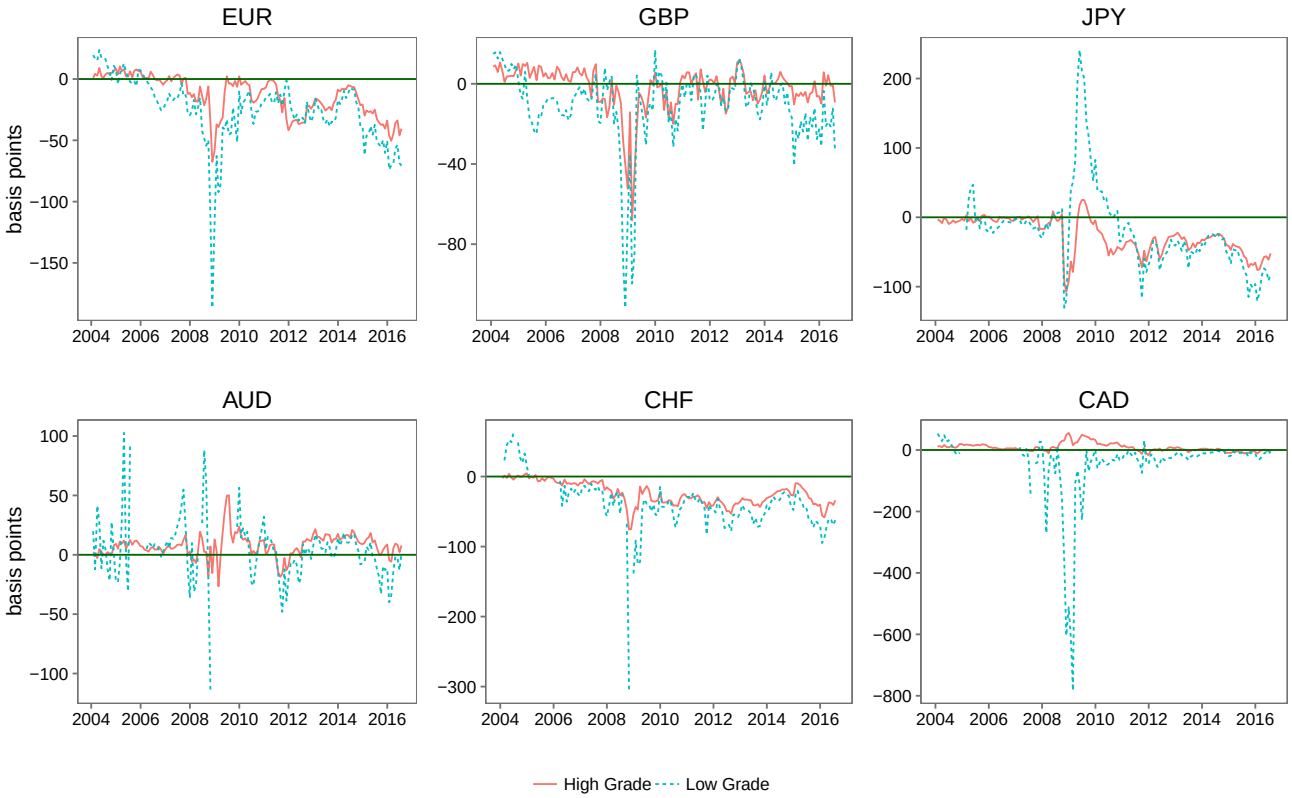


Figure 3 Credit spread differential and CIP violation relative to EUR

This figure presents credit spread differentials ($\kappa_{c,t}$) and CIP deviations ($x_{c,t}$) 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.

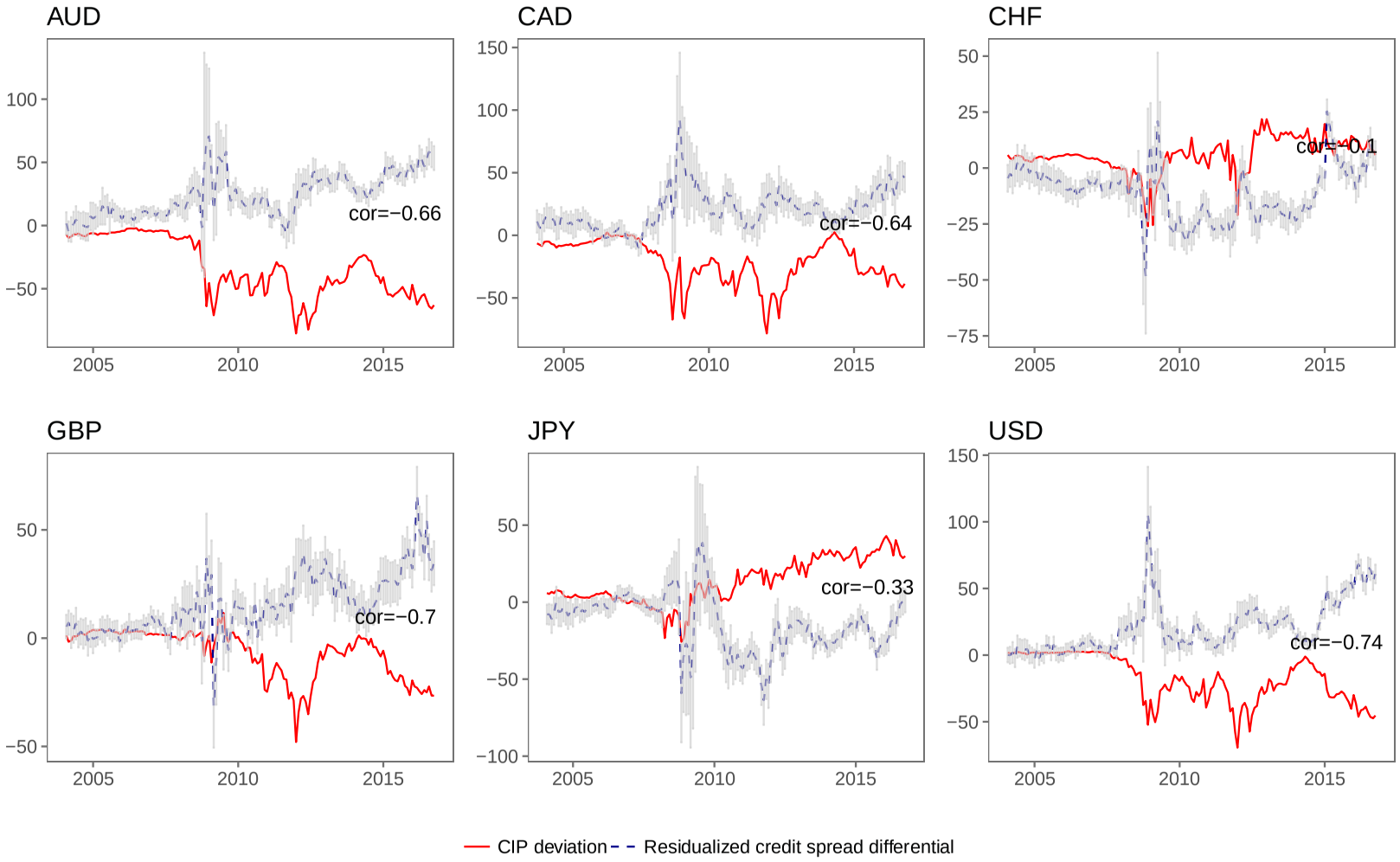


Figure 4 Credit spread differential and CIP violation relative to GBP

This figure presents credit spread differentials ($\kappa_{c,t}$) and CIP deviations ($x_{c,t}$) relative to GBP for six major funding currencies (c = 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.

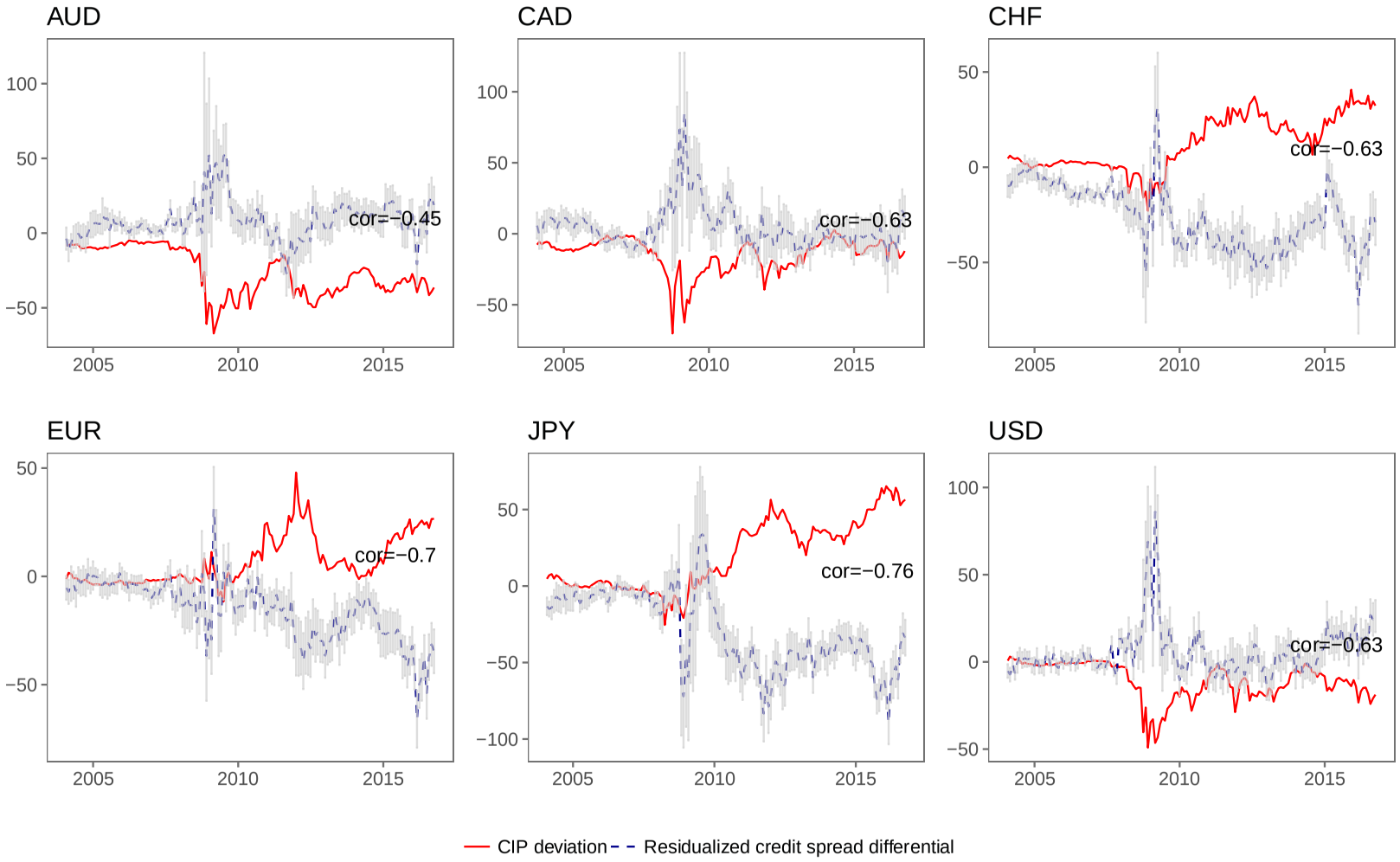


Figure 5 Cross-currency basis swap cash flows

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.

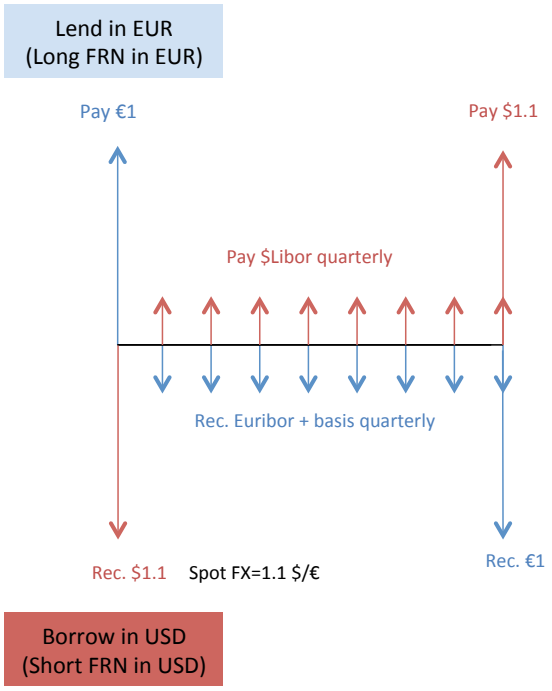
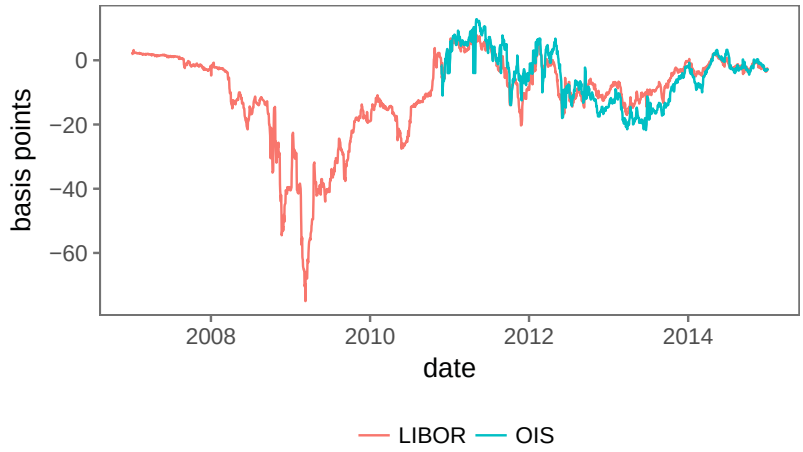


Figure 6 Cross-currency basis swap with OIS rates

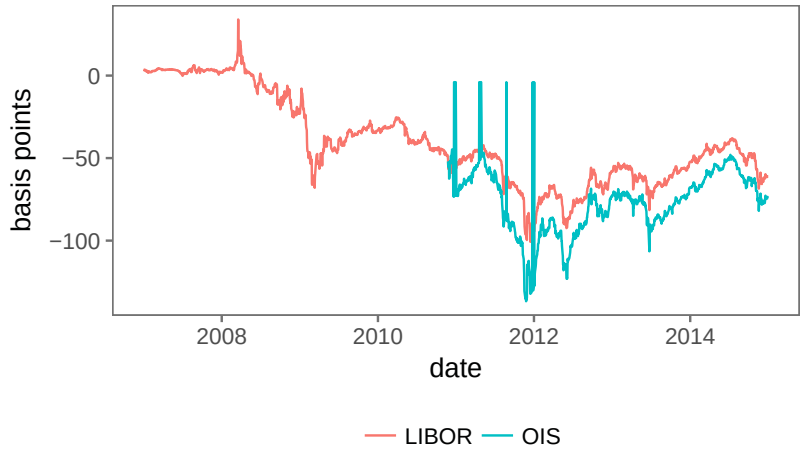
This figure presents a comparison of cross-currency basis swaps ($-x_t$) with short-term reference rates as LIBOR (Red) and OIS rate (Blue) for EUR, GBP, and JPY at the five year maturity. The OIS-based cross-currency bases swap rates are from ICAP.

Panel A: EUR

Panel B: GBP



Panel C: JPY



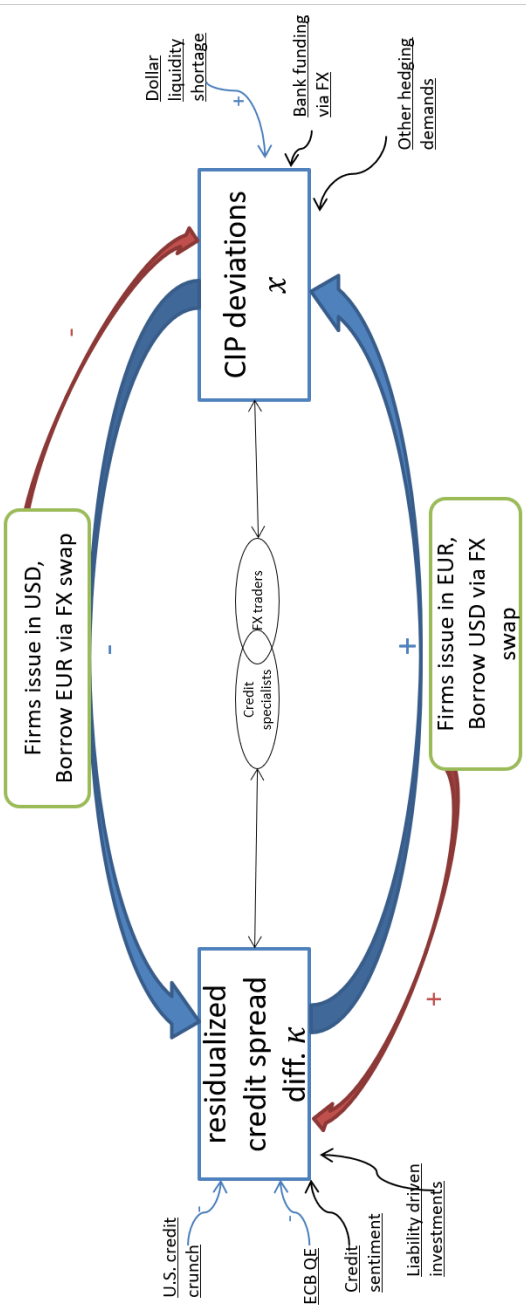


Figure 7 Model schematics

Figure 8 Sources of shocks and institutional details

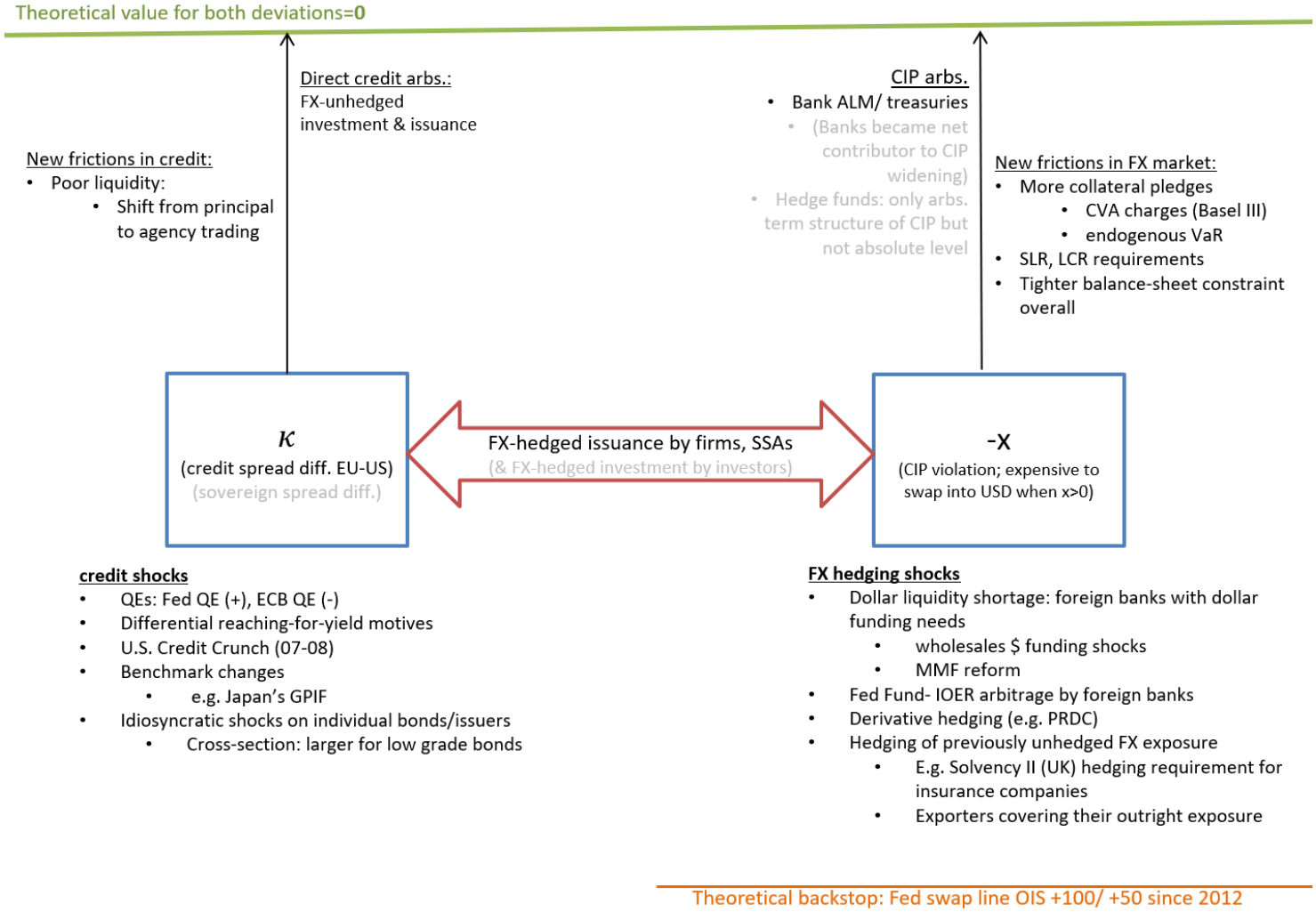
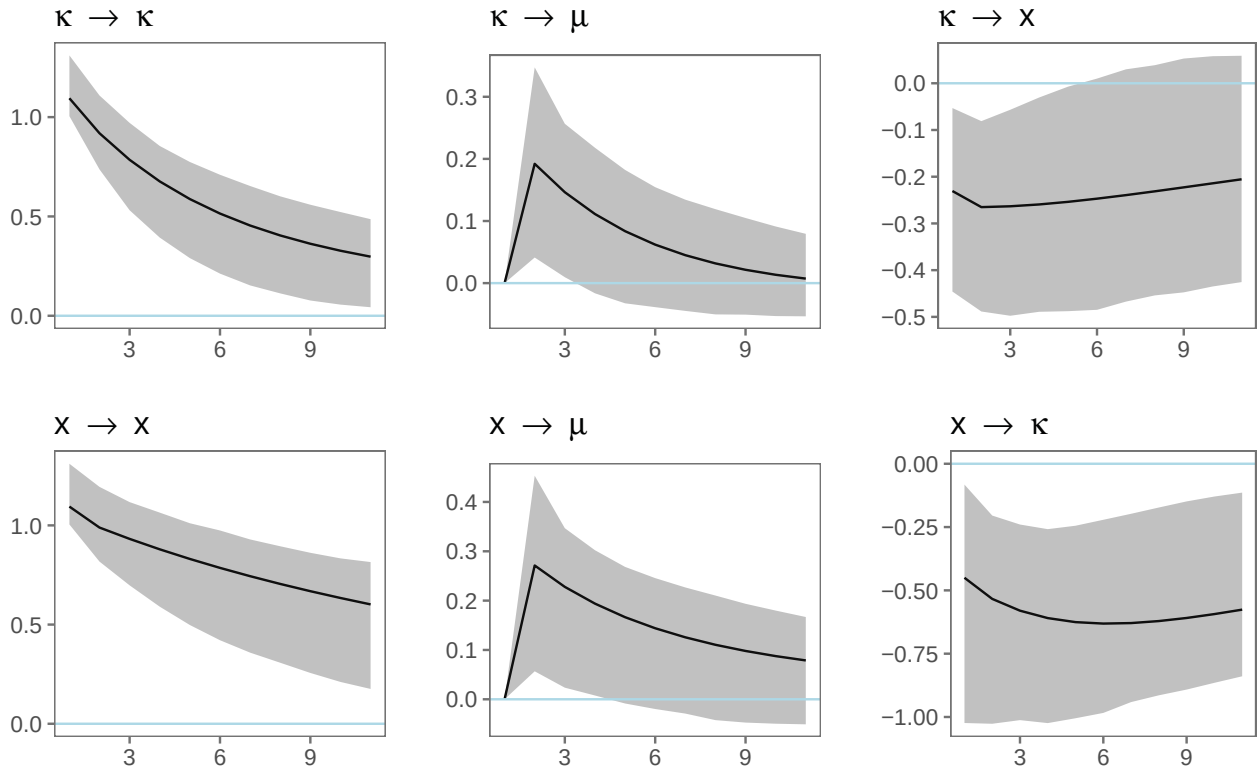


Figure 9 Spillover of deviations: partially identified impulse responses of deviations and issuance flow for EURUSD

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

$$\begin{bmatrix} 1 & & \\ a_{\kappa\mu} & 1 & a_{\kappa x} \\ a_{x\mu} & a_{x\kappa} & 1 \end{bmatrix} \begin{bmatrix} \mu_t \\ \kappa_t \\ x_t \end{bmatrix} = B \begin{bmatrix} \mu_{t-1} \\ \kappa_{t-1} \\ x_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{\mu,t} \\ \varepsilon_{\kappa,t} \\ \varepsilon_{x,t} \end{bmatrix}$$

I apply a partial identification method by assuming that issuance flow responds with a lag to both ε_κ and ε_x shocks, but x and κ has no ordering with respect to each other. The orthogonalized impulse responses to ε_κ and ε_x 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.



References

Becker, B. and Ivashina, V. (2015). Reaching for yield in the bond market. *The Journal of Finance*, 70(5):1863–1902.

Boermans, M. A., Frost, J., and Bisschop, S. S. (2016). European bond markets: Do illiquidity and concentration aggravate price shocks? *Economics Letters*, 141:143–146.

Bordalo, P., Gennaioli, N., and Shleifer, A. (2018). Diagnostic expectations and credit cycles. *The Journal of Finance*, 73(1):199–227.

Choi, J. and Kronlund, M. (2017). Reaching for yield in corporate bond mutual funds. *The Review of Financial Studies*, 31(5):1930–1965.

Du, W., Tepper, A., and Verdelhan, A. (2018). Deviations from covered interest rate parity. *The Journal of Finance*, 73(3):915–957.

Duffie, D. (2010). Presidential address: Asset price dynamics with slow-moving capital. *The Journal of finance*, 65(4):1237–1267.

Froot, K. A., Scharfstein, D. S., and Stein, J. C. (1993). Risk management: Coordinating corporate investment and financing policies. *the Journal of Finance*, 48(5):1629–1658.

Greenwood, R. and Hanson, S. G. (2013). Issuer quality and corporate bond returns. *Review of Financial Studies*, 26(6):1483–1525.

Greenwood, R., Hanson, S. G., and Jin, L. J. (2019). Reflexivity in credit markets. *National Bureau of Economic Research*.

Greenwood, R. and Vayanos, D. (2010). Price pressure in the government bond market. *The American Economic Review*, 100(2):585–590.

Ivashina, V., Scharfstein, D. S., and Stein, J. C. (2015). Dollar funding and the lending behavior of global banks. *The Quarterly Journal of Economics*, 1241:1281.

López-Salido, D., Stein, J. C., and Zakrajšek, E. (2017). Credit-market sentiment and the business cycle. *The Quarterly Journal of Economics*, 132(3):1373–1426.

Mitchell, M., Pedersen, L. H., and Pulvino, T. (2007). Slow moving capital. *American Economic Review*, 97(2):215–220.

Pozsar, Z. (2016). Global money notes. *Credit Suisse*.

Rampini, A. A. and Viswanathan, S. (2010). Collateral, risk management, and the distribution of debt capacity. *The Journal of Finance*, 65(6):2293–2322.

Tuckman, B. and Porfirio, P. (2003). Interest rate parity, money market basis swaps, and cross-currency basis swaps. *Fixed income liquid markets research, Lehman Brothers*.