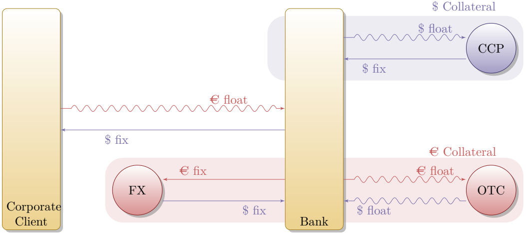
Funding in Foreign Currencies: Market dislocations and price adjustments



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Talk Outline

1. Frictions and Dislocations in the FX Market
2. Collateralization and Funding Costs in Derivative Pricing
3. Basis Curve Bootstrapping and Practical Approximations

Reference Papers

- Moreni, N., Pallavicini, A. (2017)
  ⟶ "Derivative Pricing with Collateralization and FX Market Dislocations". *IJTAF* 20.
- Shabani, M., Stenfors, A. and Toporowski, J. (2016)
  ⟶ "Bank Risk Premia and Abenomics: The Return of the Japan Premium in the Cross-Currency Swap Market". *LSE Financial Markets Group Paper Series*.
- Fujii, M., Takahashi, A. (2016)
  ⟶ "A General Framework for the Benchmark Pricing in a Fully Collateralized Market". *IJFE*, 3 (3).
- Baba, N. and Packer, F. and Nagano, T. (2008)
  ⟶ "The Spillover of Money Market Turbulence to FX Swap and Cross-Currency Swap Markets". *BIS Quarterly Review* 1.

Talk Outline

1. Frictions and Dislocations in the FX Market
2. Collateralization and Funding Costs in Derivative Pricing
3. Basis Curve Bootstrapping and Practical Approximations

Covered Interest Parity – I

- Interest-rate differentials between two currencies should be perfectly reflected in the foreign-exchange (FX) swap prices, otherwise arbitrages would be possible.
- Investors cannot earn profits by

  $\longrightarrow$ borrowing in a country with a lower interest rate,

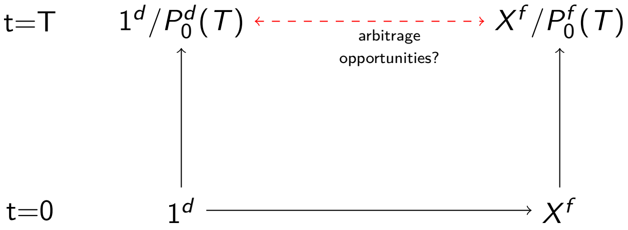
  $\longrightarrow$ exchanging for foreign currency, and

  $\longrightarrow$ investing in a foreign country with a higher interest rate.

  due to gains or losses from exchanging back to their domestic currency at maturity.
- The equivalence in this two strategies is known as covered interest parity (CIP).

Covered Interest Parity – II

- The CIP may fail during period of financial crisis reflecting funding difficulties of financial institutions.
  - ⟶ The Japanese banking crisis of late '90s.
  - ⟶ The credit crunch occurred since 2007.



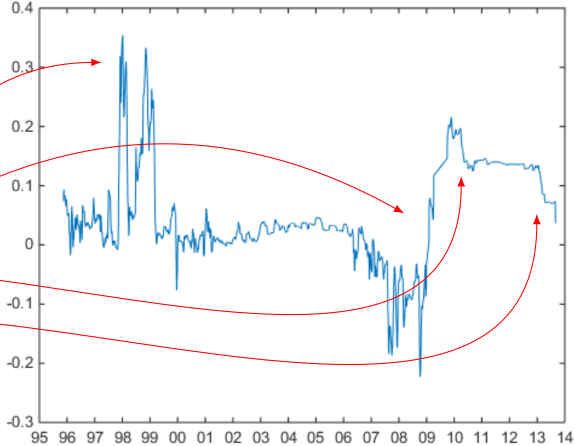
The Japanese Banking Crisis – I

- As disussed in Covrig et al. (2004) and in Shabani et al. (2016), in the aftermath of the 1989 stock market crash, the Japanese economy slowed down entering a prolonged slump.
- The soundness of the Japanese banking system weakened culminating with several highly important financial institutions defaulting in 1997.
- Insolvency in the banking sector highlighted the increasing inability of Japanese banks to access unsecured funds in foreign currencies, and to a lesser degree also in Yen.
- The failure of the CIP led to the emergence of the so-called *Japan Premium*, namely

  $\longrightarrow$ a premium on borrowing costs for Japanese banks in the international financial markets.

The Japanese Banking Crisis – II

- ⟶ Banking crisis
- ⟶ Credit crunch
- ⟶ Tsunami
- ⟶ Abenomics



Japan premium. Difference in % between the 3m JBA Tibor rate minus the 3m ICE (ex BBA) JPY Libor rate.

Market Dislocations after the Credit Crunch – I

- Since the financial crisis of 2007 banks and financial institutions, which were so far considered as non-defaultable corporations, started being suspicious about the liquidity availability and credit worthiness of their counterparties.
- Borrowing money, even for short maturities (under one year), became more expensive, as banks charged their counterparties higher rates for unsecured lending.
- The shortage of funding sources forced central banks to adopt a number of non-standard measures to support financing conditions and credit flows both in domestic and foreign currencies.
- Despite these efforts market frictions and dislocations in single-currency and FX markets strengthened.

Market Dislocations after the Credit Crunch – II

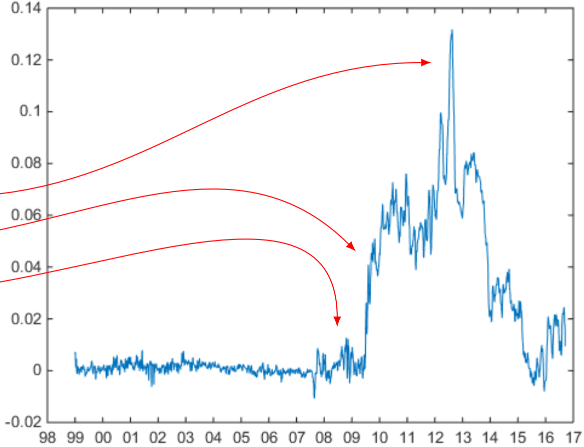
- The failure of CIP between USD and EUR, GBP and JPY as discussed in Baba et al. (2008) can be ascribed to several facts.
  - ⟶ The market perceives EU financial institutions riskier than US ones.
  - ⟶ The shortage in USD of EU financial institutions leads to one-sided order flows concentrated on USD borrowing.
  - ⟶ It is difficult to size the borrowing costs in the money market by means of Libor rates.
  - ⟶ Liquidity peaks in the USD market do not correspond to the time frame during which EU financial institutions are obliged to fulfill USD payments (mismatching market opening times).
- We can name *US Premium* the additional costs faced by non-US institutions to fund in USD.

Market Dislocations after the Credit Crunch – III

→ Rating downgrade

→ Greek crisis

→ Credit crunch



US premium for EUR. Difference in % between the 3m EMMI (ex EBF) Euribor rate minus the 3m ICE (ex BBA) EUR Libor rate.

Market Dislocations after the Credit Crunch – IV

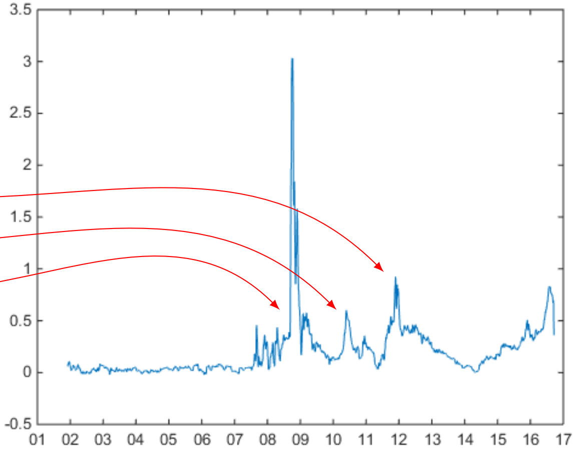
- The failure of the CIP has direct consequences also in derivative option prices.
- Dislocations may produce additional costs in funding and hedging, possibly leading to severe liquidity shortages.
  - ⟶ See the IMF working paper by Barkbu and Ong (2010).
- Funding costs depend on the funding strategies adopted by investors.
  - ⟶ Funding policies are a collection of different strategies, driven not only by financial factors.
- The dislocations we are dealing with are not counterparty-specific but systemic.
  - ⟶ We focus on a domestic investor who can fund in foreign currencies only by means of FX spot, forward, and cross-currency swap contracts.
  - ⟶ In Fujii and Takahashi (2016) the authors suggest to treat funding costs coming from market dislocations as additional FVA terms.

Talk Outline

Collateral Funding in the FX Market – I

- Liquid market derivatives are usually collateralized with collateral assets remunerated at overnight rate (OIS curve).
- If we assume that our foreign funding policy is implemented by trading in the FX market, we can calculate a cross-currency spread by comparing:
  - $\longrightarrow$ foreign collateral rates implied by the CIP relationship (off-shore rates), and
  - $\longrightarrow$ foreign collateral rates quoted in the foreign money markets (on-shore rates).
- We expect to spot again the market dislocations described by the previous analyses, although the impact of macro-economic events may be quantitatively different.

Collateral Funding in the FX Market – II



- → Rating downgrade
- → Greek crisis
- → Credit crunch

Cross-currency spread. Difference in % between the rate implied via CPI from the 3m EUR OIS rate minus the 3m USD OIS rate.

Derivative Pricing – I

- Market dislocations and collateral funding costs have an impact on hedging and funding strategies and, in turn, on derivative pricing when foreign currencies are involved.
- How can we price a derivative contract whose cash flows or collateral assets are expressed in a foreign currency ?
- We restrict our analysis with the following assumptions, see Moreni and Pallavicini (2015).
  - ⟶ We consider that foreign cash can be funded only by trading in the FX market.
  - ⟶ Derivative contracts are perfectly collateralized, namely the collateralization procedure is able to prevent any loss in case of default of one of the two counterparties.
  - ⟶ Collateral assets may be re-hypothecated, see Brigo et al. (2011).

Derivative Pricing – II

- Market dislocations prevent us to follow the classical approach where the domestic risk-neutral measure is equivalent to the foreign risk-neutral measure.
- According to Piterbarg (2010) we can price perfectly collateralized contract, such as FX swaps, by discounting at the collateral rate.

$$V_t^{\mathrm{FXswap}} := \mathbb{E}_t\left[\left(\frac{\chi_T}{X_t(T;e)} - 1\right) D(t,T;e)\right]$$

where $D(t,T;e)$ is the domestic EUR OIS discount factor, χ_T the FX spot rate, and $X_t(T;e)$ the FX forward rate.

- The above expectation is taken under the domestic risk-neutral measure.

Basis Curves – I

- The FX forward rate is quoted by the market so that the FX swap is at par, namely

$$X_t(T;e) = \frac{\mathbb{E}_t[\,\chi_T D(t,T;e)\,]}{\mathbb{E}_t[\,D(t,T;e)\,]} = \mathbb{E}_t^{T;e}[\,\chi_T\,]$$

where the last expectation is taken under the collateralized forward measure $\mathbb{Q}^{T;e}$ defined by the Radon-Nikodym derivative

$$\left.\frac{d\mathbb{Q}^{T;e}}{d\mathbb{Q}}\right|_t := \frac{D(0,t;e)P_t(T;e)}{P_0(T;e)}\,, \quad P_t(T;e) := \mathbb{E}_t[\,D(t,T;e)\,]$$

Basis Curves – II

- By following Moreni and Pallavicini (2015) we can use FX forward rates to define a new pricing measure: the collateralized basis measure $\mathbb{Q}^b$.

$$\left.\frac{d\mathbb{Q}^b}{d\mathbb{Q}}\right|_t := \frac{\chi_t}{\chi_0} D(0,t;e - b^f(e)) \,, \quad b^f_t(e)\,dt := e_t\,dt - \mathbb{E}_t\left[\frac{d\chi_t}{\chi_t}\right]$$

- If we use the above measure in the definition of FX forward rate, we can define the effective foreign funding curve (or basis curve) as

$$P^f_t(T;e) = \frac{X_t(T;e)}{\chi_t} P_t(T;e) \,, \quad P^f_t(T;e) := \mathbb{E}^b_t\left[\, D(t,T;b^f(e)) \,\right]$$

- We can also define the corresponding basis forward measure $\mathbb{Q}^{T;b}$.

Master Pricing Equations – I

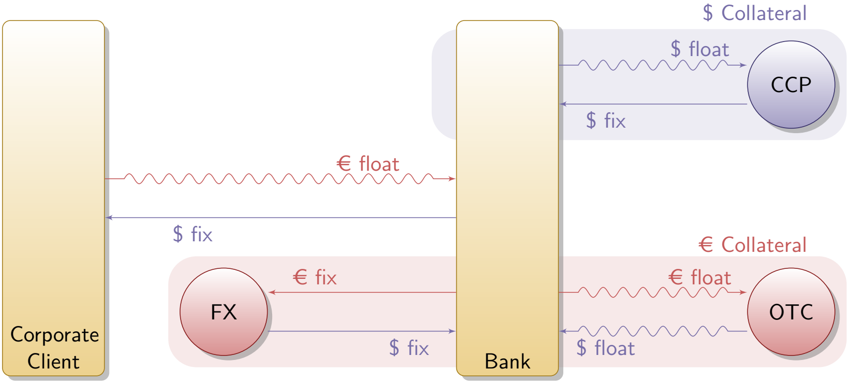
- We can reformulate the classical pricing theory to derivative contracts according to the currency of contractual cash flows and collateral accounts (always in case of perfect collateralization).

π_t	C_t	Pricing Formula
d	d	$V_t = \int_t^T \mathbb{E}_t[\, D(t,u;c)\, d\pi_u\,]$
d	f	$V_t = \int_t^T \mathbb{E}_t\left[\, D(t,u;c^f - b^f(e) + e)\, d\pi_u\,\right]$
f	d	$V_t^f = \int_t^T \mathbb{E}_t^b\left[\, D(t,u;c + b^f(e) - e)\, d\pi_u^f\,\right]$
f	f'	$V_t^f = \int_t^T \mathbb{E}_t^b\left[\, D(t,u;c^{f'} - b^{f'}(e) + b^f(e))\, d\pi_u^f\,\right]$

Master Pricing Equations – II

- Foreign market risks are usually quoted in foreign markets.
  - ⟶ In particular, accrual rates for foreign collateral accounts are quoted in foreign money markets.
- Market quotes of foreign contracts are mainly traded by players which can access foreign money markets without restrictions.
- Thus, an investor, which can fund in a foreign currency only via FX swaps, cannot calibrate foreign risk dynamics to such market quotes.
- We do not have a unique price because of market incompleteness.
  - ⟶ Pricing techniques developed for incomplete markets should be used to price foreign contracts.

An Example of a Cross-Currency Trade – I



A EUR-based bank borrows USD to a corporate client by hedging market risks both with bilateral and cleared products. Additional hedging in the FX market is required to match the collateral flows.

An Example of a Cross-Currency Trade – II

- We simplify the example by considering only interest-rate swaps of one period. We focus on the USD floating leg.
- We can write the price of the leg within the bilateral contract as

$$V_t^{f,\mathrm{OTC}} := \alpha\,\mathbb{E}_t^b\big[\,D(t,T_1;b^f(e))L_{T_0}^f(T_1)\,\big]$$

while the same leg in the cleared contract is given by

$$\begin{aligned} V_t^{f,\mathrm{CCP}} &:= \alpha\,\mathbb{E}_t^b\big[\,D(t,T_1;e^f)L_{T_0}^f(T_1)\,\big] \\ &= V_t^{f,\mathrm{OTC}} + \frac{\alpha}{\chi_t}\int_t^{T_1} du\,\mathbb{E}_t\big[\,D(t,u;e)\,\chi_u V_u^{f,\mathrm{CCP}}\left(e_u^f - b_u^f(e)\right)\big] \end{aligned}$$

where α is the year-fraction, and L^f is the USD Libor rate.

- The second term on the right-hand side represents the additional exposure to FX market risks due to foreign collateralization.

An Example of a Cross-Currency Trade – III

- The additional contribution depends on the spread $s_t^f(e) := e_t^f - b_t^f(e)$.
  - $\longrightarrow$ Such spread represents the funding costs due to market dislocations of a EUR-based institution to fund in USD via FX swaps.

$$V_t^{f,\mathrm{CCP}} - V_t^{f,\mathrm{OTC}} = \frac{\alpha}{\chi_t} \int_t^{T_1} du \, \mathbb{E}_t \left[D(t,u;e) \, \chi_u \, s_u^f(e) V_u^{f,\mathrm{CCP}} \right]$$

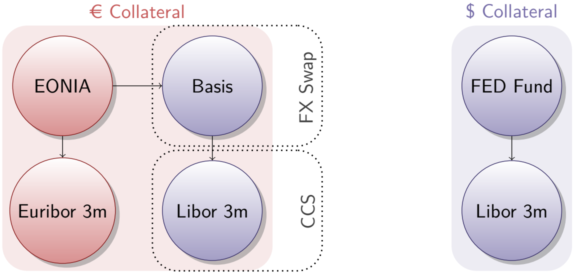
- We do not have enough market quotes to calibrate the dynamics of s_t^f under $\mathbb{Q}^b$, and so under $\mathbb{Q}$.
  - $\longrightarrow$ The practical choice of using quotes from the USD money market may lead to mis-price funding costs.
  - $\longrightarrow$ We notice that funding initial margins required by the CCP introduces additional funding costs.
- Moreover, cross-currency trades in practice usually span over long maturities and include renotioning. Both these features lead to price uncertainties due to market incompleteness.

Talk Outline

Basis Curve Bootstrapping – I

- In the FX market we can find two categories of liquid instruments used to fund in foreign currencies:
  - $\longrightarrow$ FX spot, forward and swap contracts;
  - $\longrightarrow$ constant-notional and marked-to-market cross-currency swaps (hereafter CN-CCS and MtM-CCS)
- CCS contracts usually consists in two legs of payments: a leg paying a floating domestic rate plus a spread vs. a leg paying a floating foreign rate.
  - $\longrightarrow$ The CCS spread might be paid by the domestic leg in some contracts.
  - $\longrightarrow$ Fixed rate payments are less common.
  - $\longrightarrow$ CN and MtM features describe how the notional amounts are exchanged on contract payment dates.
- Cross-currency swaps allow us to obtain information on forward Libor rates once the basis curve is known.
  - $\longrightarrow$ We take the point of view of a Euro-based bank trading EUR and USD.

Basis Curve Bootstrapping – II

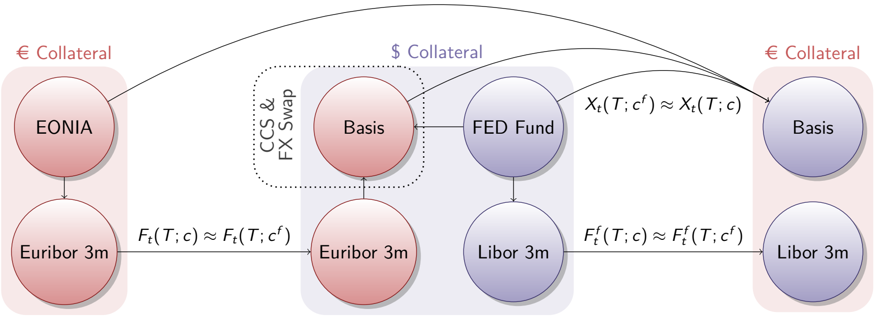


EUR and USD term structures. Red circles refer to EUR curves, blues circles to USD curves. Collateralization currency is shown in background shading. EONIA and FED fund rates are used as collateral rates respectively in EUR and USD markets.

Basis Curve Bootstrapping – III

- A first problem in this bootstrapping strategy is given by liquid FX market quotes.
  - $\longrightarrow$ FX swaps are usually quoted only up to two-three years.
  - $\longrightarrow$ We could use CCS to complete these quotes if we are able to approximate forward Libor curves.
- Cash instruments are used to implement funding strategies in foreign currencies, so that we consider only collateral agreements expressed in domestic currency.
  - $\longrightarrow$ We recall that at present providers do not differentiate FX market quotes per collateralization currency.
  - $\longrightarrow$ Such uncertainty is reflected by bid/ask spreads of market quotes.
- On the other hand, it seems more reasonable to consider market quotes from the point of view of investors whose domestic currency is the major currency in the contract.

Basis Curve Bootstrapping – IV

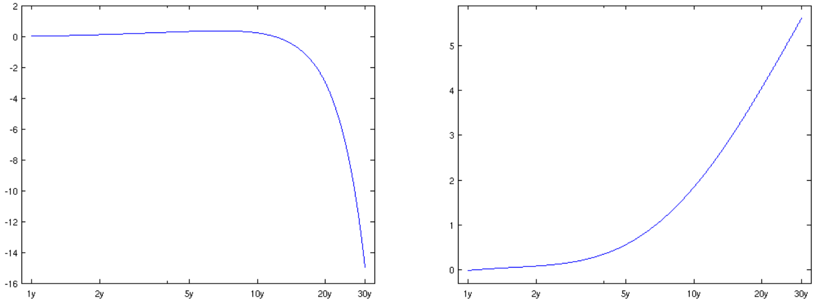


EUR and USD term structures. Uncertainties in collateral currency used in market quotes can be handled by approximating only FX forward rates.

Changing the Funding Currency – I

- We can size the approximations we made in the bootstrapping procedure by comparing quotes of cross-currency products from the point of view of investors with different funding policies.
- As a first example we consider the currency pair EUR/USD.
  - ⟶ We bootstrap implied foreign discount curves from marked-to-market cross-currency swaps (MtM-CCS) with renotioning on the USD leg.
  - ⟶ We price constant-notional cross-currency swaps (CN-CCS), which are not usually quoted by the market.
- We repeat the calculations starting from the same set of market quotes, by adopting first the point of view of a EUR investor, then of a USD investor.

Changing the Funding Currency – II



Left panel: differences in basis points between EUR/USD forward FX rates bootstrapped by a EUR investor and by a USD investor.

Righ panel: differences in basis points between EUR/USD CN-CCS par rates bootstrapped by a EUR investor and by a USD investor.

Assessing Convexity Adjustments – I

- We proceed with a second test of approximations usually found in the practice.
  - ⟶ Other tests can be found in Moreni and Pallavicini (2017).
- Net present values of FX products used in curve bootstrapping algorithms depend on the volatilities and correlations of underlying FX and interest rates.
  - ⟶ These dependencies are usually treated as convexity corrections statically included in basis curve definitions.
- We analyze the price of a leg with notional resetting of a EUR/USD MtM-CCS with collateralization in EUR.
  - ⟶ Here, USD plays the role of the foreign currency.
  - ⟶ We analyze the cases of a leg paying either a floating or a fixed rate.
- This analysis depened on the particular dynamical model we adopt for underlying risk factors.

Assessing Convexity Adjustments – II

$\rho^{F^f,X}$	USD Libor 3M		fwd USD Libor 3M	
	CN	MtM	CN	MtM
+50%	-25,116	-26,998	-25,116	-12,788
+10%	-25,116	-27,337	-25,116	-24,438
0%	-25,116	-27,350	-25,116	-27,350
-10%	-25,116	-27,333	-25,116	-30,261
-50%	-25,116	-26,965	-25,116	-41,905

- Premia in USD for a notional of 1M and a maturity of 10Y for cross-currency swaps.
- Only floating MtM-CCS are liquid on the market for EUR/USD.
- Exotic CCS may show an impact when varying the correlation between foreign Libor rates and FX rates.

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