FINASTRA

**TREASURY AND CAPITAL MARKETS:
PRICING AND RISK METRICS GUIDE**

LINEAR INTEREST RATE SERIES

Part 2: Multicurrencies Curve Construction

THE FUTURE OF
FINANCE IS OPEN

CONTENTS

EXECUTIVE SUMMARY

Prior to the financial crisis, organizations used varying measurement practices when pricing different financial instruments. After the crisis, due to new regulation and the growing demand for transparency, firms are now expected to show and explain how they hedge and manage risk.

The purpose of this paper is to explore and build a non-USD discount curve which accounts for the cross-currency basis between two currencies. When building a cross-currency basis curve, it is often the case that the underlying transaction cashflows and the collateral currency are not in the same denomination.

For example, USD cashflows in the underlying transaction could be collateralized with GBP cash. The calibration routine generally proceeds by evaluating the foreign leg (usually USD) to par, and then calibrating the domestic leg (usually non-USD) discount curve to the market cross-currency basis swap spreads. The value of the domestic leg requires the discount curves fit to domestic market instruments as explained in the preceding Finastra paper, "Single Yield Curve Construction".

We hope you find this guide on how to calculate multicurrencies curves useful. For more information on how we can help with your risk management, please contact us at capitalmarkets@finastra.com or visit us at finastra.com.

Understanding non-USD discount curves which account for the cross-currency basis between two currencies

> “Since the financial crisis, regulatory mandates and structural reform within the derivatives market has fundamentally changed how derivatives are priced.”

Pedro Porfirio
Global Head of Treasury and Capital Markets, Finastra

In the preceding Finastra paper, “Single Yield Curve Construction”, we describe the typical single yield curve calibration instruments, the mathematics of the calibration of single currency yield curves and the construction of the ultimate single currency yield curve. In this paper, we discuss the following:

- The calibration instruments for building a cross-currency basis curve between two currencies
- The mathematics of the calibration of the cross-currency basis curve
- The construction of the ultimate cross-currency basis curve
- The construction of the non-USD single currency discount curves using the derived cross-currency basis curves

Model Inputs:
In addition to the inputs needed for “Single Yield Curve Construction”, the following additional inputs are needed for cross-currency basis curve construction:

A. Mid-Market FX Forwards (which are typically used for the short end <1Y)

B. Mid-Market Cross Currency Basis Swap Spreads for Float/Float Cross Currency Swaps (this is typically the case for developed market currency vs. USD cross-currency swap market quotes)

C. Mid-Market Cross Currency Swap Fixed Rates for Fix/Float Cross Currency Swaps (this is typically the case for emerging market currency vs USD cross-currency swap market quotes)

D. Mid-Market Cross Currency Basis Swap Spreads for Resettable Float/Float Cross Currency Swaps (which are liquid and prevalent in both emerging markets/developed markets quotes)

FX Forwards used to build cross-currency basis curve for the short end

FX forwards are an obligation to buy one currency/sell another currency at a pre-agreed future date and at a pre-agreed exchange rate (the "FX forward rate"). These instruments are typically used to build a cross-currency basis curve for the short end (<1Y). For ease of exposition, let us consider the example of a long USD/short GBP FX Forward for forward delivery at time T which is assumed to be GBP cash collateralized.

The calibration constraints for FX forwards are explained below. In the discussion below, note the domestic leg is USD denominated and the foreign leg is GBP denominated:

1. **NPV of USD leg expressed in USD** = NPV of the GBP leg expressed in USD
2. **The calibration constraint** follows from the fact that we are using mid-market FX forward rates as calibration instruments which have an NPV of zero. The NPVs of the USD and GBP legs can be calculated as follows:

NPV of the USD leg in USD = $Not^{USD} \times USD\ DF(T)$

NPV of the GBP leg in USD = $FX_{t_0} \times Not^{GBP} \times GBP\ DF^{*}(T)$

where:

$\mathrm{Not}^{\mathrm{USD}}$ = USD Notional

$\mathrm{Not}^{\mathrm{GBP}}$ = GBP Notional

FX_{t_0} = USD/GBP FX Spot rate at inception t_0 (where 1 unit of GBP = FX_{t_0} units of USD) which is assumed to take delivery two business days from inception

$USD\ DF(T)$ = USD discount curve (with USD cash collateral) to payment date T ,which is explained in the Finastra paper "Single Currency Curve Construction"

$GBP\ DF(T)$ = GBP discount curve (with GBP cash collateral) to payment date T_{i+1},which is explained in the Finastra paper "Single Currency Curve Construction"

$GBP\ DF^{*}(T)$ = USD/GBP cross-currency basis adjusted GBP discount curve to payment date T_{i+1}

$$GBP\ DF^{*}(T) = GBP\ DF(T) x exp(-\int_{s=0}^{s=T} XCCY\ Spread(s) ds)$$

In practice, the function $XCCY$ Spread(s) is calibrated to USD/GBP mid-market FX forwards from the short maturities to the longer maturities (for just the short end <1Y).

Calibration constraints of Cross Currency Basis Swaps

Cross Currency Basis Swaps:
For ease of exposition, let us consider the example of a USD/GBP cross currency swap which is collateralized by USD cash. A USD/GBP cross currency swap is a floating vs floating swap. One leg pays/receives USD Libor flat and the other leg receives/pays GBP Libor + USD/GBP cross basis swap spread. The market convention is to quote the cross-basis spread for a given tenor and also to quote it as a spread to the non-USD LIBOR leg.

The implication of the existence of a cross-currency basis swap spread in the market is that both the USD and GBP floating legs cannot have a present value of par when valued from the pure USD and GBP discount curves (which have been calibrated on single-currency yield curve instruments) and hence, the GBP discount leg needs an adjustment for the GBP/USD cross currency basis swap spread.

3. **The calibration constraints for cross-currency swaps are explained below.** In the discussion below, note the domestic leg is USD denominated and the foreign leg is GBP denominated:

NPV of USD leg expressed in USD = NPV of GBP leg expressed in USD.

This calibration constraint follows from the fact that we are using mid-market cross-currency basis swap spreads as calibration instruments which have an NPV of zero. The NPVs of the USD and GBP legs can be calculated as follows:

4. **NPV of the USD leg in USD =**

$$\sum_{i=1}^{N} Not^{USD} \times USD\ Libor(t_i) x USD\ DF(t_{i+1})$$

where:

$t_0, t_2 \ldots.. t_{N-1}$ = USD Libor fixing dates at the start of each coupon period

$t_1, t_2 \ldots.. t_N$ = USD Libor payment dates at the end of each coupon period

Not^{USD} = USD Notional

$USD\ Libor(t_i)$ = USD Libor forward from t_i which is inferred from the USD projection curve derived in the Finastra paper "Single Currency Curve Construction"

$USD\ DF(t_{i+1})$ = USD discount curve (collateralized with GBP cash) to payment date t_{i+1},which is explained in the Finastra paper "Single Currency Curve Construction"

5. **NPV of the GBP leg in USD =**

$$FX_{t_0} \sum_{i=1}^{N} Not^{GBP} \times (GBP\ Libor(t_i) + XCCY\ Spread) x GBP\ DF^{*}(t_{i+1})$$

where:

$t_0, t_2 \ldots.. t_{N-1}$ = GBP Libor fixing dates at the start of each coupon period

$t_1, t_2 \ldots.. t_N$ = GBP Libor payment dates at the end of each coupon period

Not^{GBP} = GBP Notional

$GBP\ Libor(t_i)$ = GBP Libor forward from t_i which is inferred from the GBP projection curve derived in the Finastra paper "Single Currency Curve Construction"

$GBP\ DF(t_{i+1})$ = GBP discount curve (with GBP cash collateral) to payment date t_{i+1},which is explained in the Finastra paper "Single Currency Curve Construction"

FX_{t_0} = USD/GBP FX Spot rate at inception t_0 (where 1 unit of USD = FX_{t_0})units of GBP) which is assumed to take delivery 2 business days from inception date t_0 .

XCCY Spread = GBP/USD Cross-Currency Basis Mid-Market Spread for the maturity of the swap

$GBP\ DF^{*}(t_{i+1})$ = USD/GBP Cross-Currency Basis Adjusted GBP discount curve to payment date t_{i+1}

$$GBP\ DF^{*}(t_{i+1}) = GBP\ DF(t_{i+1}) x exp(-\int_{s=0}^{s=t_{i+1}} XCCY\ Spread(s) ds)$$

Calibration constraints of Cross Currency Basis Swaps Cont'd

$XCCY\ Spread(s)$ = piecewise constant function of instantaneous USD/GBP cross-currency basis swap spreads

In practice, the function $XCCY\ Spread(s)$ is calibrated to USD/GBP mid-market cross- currency spreads from the short maturities to the long maturities in an iterative fashion. This process is known as "bootstrapping" the cross-currency basis curve.

It is assumed that the USD and GBP Libor forwards are adjusted for any required tenor basis corrections. For instance, the most liquid GBP interest rate swap is fixed vs 6m GBP Libor in the GBP interest rate swap market.

Hence, if a 3m GBP forward Libor projection is required then the 6m GBP Libor forward projection curve would need to be adjusted by the mid-market 6s/3s GBP forward tenor basis swap spreads.

Resettable Cross Currency Basis Swaps – Resettable Leg vs. Constant Leg

Resettable Cross Currency Basis Swaps:
For ease of exposition, let us consider the example of a USD/GBP resettable cross currency basis swap. A USD/GBP resettable cross currency basis swap is a floating/floating swap with a variable notional on one leg. One leg paying/receiving USD Libor flat on a variable notional (known as the "Resettable leg") and the other leg receiving/paying GBP Libor + USD/GBP Cross Currency Basis Swap Spread on the constant notional (known as the "Constant Leg").

The market convention is to quote the cross-basis spread for a given tenor and also to quote it as a spread to non-USD LIBOR. The notional on the Resettable leg is adjusted on each reset date as per the then prevailing USD/GBP FX spot at the time and there is a notional exchange reflecting the FX spot changes from the last reset date to the current reset date.

The market history of these contracts was that they were initiated to reduce counterparty credit risk on cross-currency swaps by aiming to reset the MTM of the cross-currency swap to close to par at each reset date.

The calibration constraints for a resettable cross-currency swaps are explained below:

6. NPV of Resettable leg = NPV of Constant Leg

In the discussion below, note the domestic leg is USD denominated and the foreign leg is GBP denominated.
The net present values of the Resettable and Constant legs can be calculated as follows (assuming we receive the receiving the Resettable leg and paying the Constant leg):

7. Resettable Leg: On the Resettable leg, the notional is exchanged on each reset date based on the prevailing FX spot rate on that date and there is a notional exchange on that reset date reflecting the change in FX spot from the last reset date to the current date. The NPV of the resettable leg is given by the following:

NPV of Resettable Leg in Resettable Leg Currency =

$$\sum_{i=0}^{N-1} N_{Const} \times FX(t_i) \times$$
$$DCF(t_i, t_{i+1}) \times F_{Reset}(t_i, t_{i+1}) \times DF_{Reset}(0, t_{i+1})$$
$$-N_{Const} \times FX(t_0) - \sum_{i=1}^{N-1} N_{Const} \times (FX_i - FX_{i-1}) \times DF^*{}_{Const}(0, t_i)$$
$$+N_{Const} \times FX(t_N) \times DF^*{}_{Const}(0, t_N)$$

where:

$t_0, t_2 \ldots.. t_{N-1}$ = Libor fixing dates at the start of each coupon period

$t_1, t_2 \ldots.. t_N$ = Libor payment dates at the end of each coupon period

N_{Const} = Fixed Notional of the Constant Leg

$FX(t_i)$ = FX spot rate at time t_i for 1 unit of Constant Leg Currency against Resettable Leg currency (which is USD/GBP in out example)

$DCF(t_i, t_{i+1})$ = daycount faction from t_i to t_{i+1}

$F_{Reset}(t_i, t_{i+1})$ = forward interest rate from t_i to t_{i+1} in the Resettable leg currency (which is USD in our example), which is inferred from the USD projection curve as derived in Finastra paper "Single Currency Curve Construction". The forward interest rate may need to be adjusted by the appropriate tenor basis spread if the target forward underlying is different to the default LIBOR length in the USD projection curve.

$DF_{Reset}(0, t_{i+1})$ = discount factor from t_{i+1} to time 0 in the Resettable leg currency (which is USD in our illustrative example)

$DF^*_{Const}(0, t_i)$ = discount factor from t_{i+1} to time 0 in the Constant leg currency (which is GBP in our illustrative example)

Resettable Cross Currency Basis Swaps – Resettable Leg vs. Constant Leg, Cont'd

8. Constant Leg: The constant leg is simply the NPV of a floating cashflow on a deterministic notional. The NPV of the Constant Leg is given by the following:

NPV Constant Leg in Constant Leg Currency =
$(-Not_{Constant} + Not_{Constant} x DF^{*}_{Const}(0, t_n))$

$+\sum_{i=0}^{N-1} Not_{Const} \times DCF(t_i, t_{i+1}) \times (F_{Const}(t_i, t_{i+1})$
$+ XCCY\ Spread) \times DF^{*}_{Const}(0, t_{i+1})$

where:

$Not_{Constant}$ = Notional of the Constant Leg (which is pre-agreed at outset and unchanged over deal life and is a GBP notional in the case of our example)

$DF^{*}_{Const}(0, t_i)$ = discount factor from t_i to time 0 in the constant leg currency (which is GBP in the case of our example)

$DF^{*}_{Const}(t_{i+1})$ = $DF_{Const}(t_{i+1}) x exp(-\int_{s=0}^{s=t_{i+1}} XCCY\ Spread(s) ds)$

$DCF(t_i, t_{i+1})$ = daycount faction from t_i to t_{i+1}

$F_{Const}(t_i, t_{i+1})$ = forward interest rate from t_i to t_{i+1} in the Constant leg currency (which is GBP in our example), which is inferred from the GBP projection curve as derived in the Finastra paper "Single Currency Curve Construction". The forward interest rate may need to be adjusted by the appropriate tenor basis spread if the target forward underlying is different to the default LIBOR length in the GBP projection curve.

In practice, the function $XCCY\ Spread(s)$ is calibrated to market USD/GBP mid-market resettable cross currency spreads from the short maturities to the long maturities in an iterative fashion. This process is known as "bootstrapping" the cross-currency basis curve.

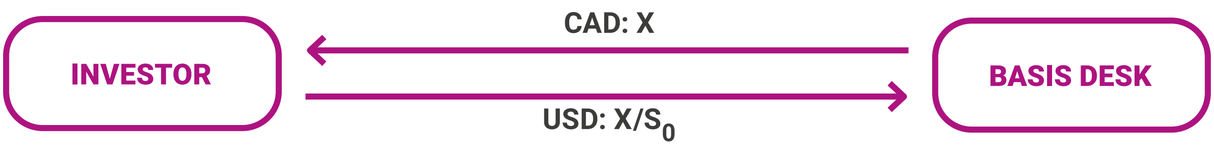
Exploring how to build a non-USD discount curve that accounts for a cross currency basis allows for a better understanding of how the derivatives market operates. Post crisis, this is important for financial institutions to consider due to the changes in how derivatives are fundamentally priced, with collateral choices having an impact on the discounting curves used in derivative valuations.

Mechanics of a mark-to-market USDCAD basis swap (with principal adjustments at quarterly payment dates)

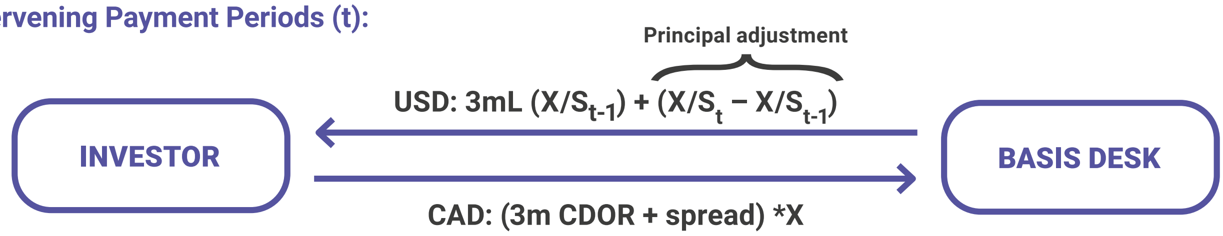
S_a: Spot exchange rate at period "a"

X: Notional principal of basis swap on non-USD leg

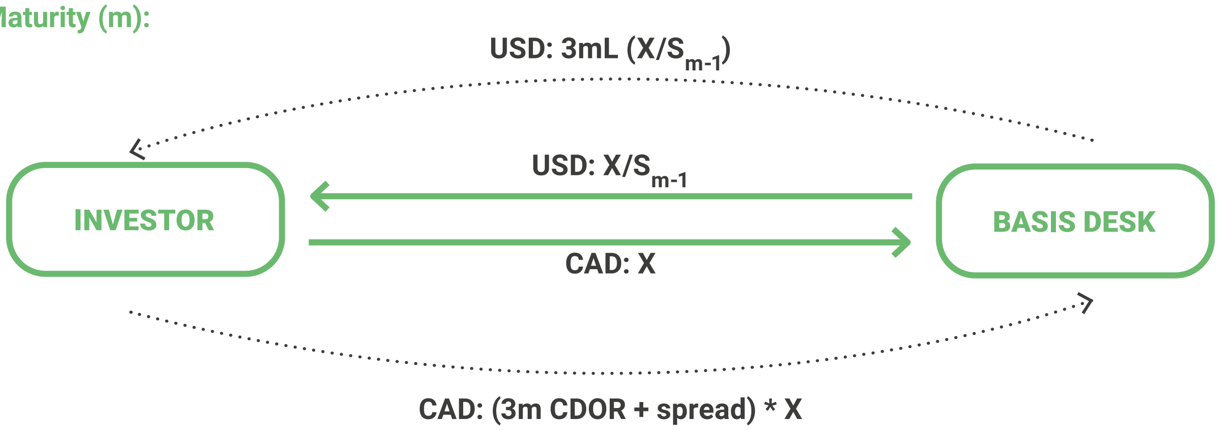
At Inception of Swap (0):



Intervening Payment Periods (t):



At Maturity (m):



Source:
Credit Suisse, Fixed Income Reseach, Cross-Currency Basis Swaps, 2013.

Improve System Performance and Profitability

> "Finastra Services can help you to improve the pricing quality of your front office system and ensure alignment with market best practice."

Fusion Kondor is the ultimate system for markets trading. With Curves Checking, we can help you improve your pricing valuation capabilities, leading to enhanced performance and improving pricing quality.

Maintaining Fusion Kondor's system performance at optimal level benefits the entire organization from the front office to the back office, and helps you achieve better pricing, which could result in better maintained capital reserves, and cash payments related to collateral agreements.

If your Yield and Volatility curves are not properly configured, this can cause discrepancies in asset pricing and the profit and loss calculations. Our experts can help you optimize the Fusion Kondor configuration to ensure you are aligned with market best practice, improving pricing and risk management across all instruments.

Approach

In a three-stage process, our expert consultants analyze your curve structure to determine instrument valuation and adherence to market best practice. This reveals whether curves need to be updated, replaced or deleted.

1. **Review Stage**
   We analyze the system in terms of structure, instrument definition, assignment and overall usage to determine what improvements could be made
2. **Business investigation**
   We discuss potential pricing issues with different business departments
3. **Detailed analysis**
   Our report outlines possible problems and suggests options to improve pricing accuracy and adherence to market best practices.

Once the three-stage process is completed we will provide you with a document detailing the client environment analysis and suggested actions. You can choose to follow the suggestions independently, or we will be happy to support any changes necessary.

Finastra Services can unlock the potential of our software, leveraging best practice to reduce costs and improve client profitability.

About Finastra Services
Finastra Services comprise specialized teams across consulting, delivery, training and support. Together, they enable Finastra to consistently deliver great customer outcomes with our solutions.

Leveraging our people, ecosystem and a wide range of enablement tools and approaches, Finastra Services help you to optimize the time to market, user experience and return on your investment in Fusion solutions, making them better, faster and safer.

To find how to improve your system performance, contact your Finastra Services representative now and benefit from a customized service at a fixed price.

Benefits

- Improved portfolio evaluation
- The ability to adapt to market changes such as level of liquidity or economic events
- Opportunities to trade new offshore currencies
- Avoidance of pricing discrepancies
- Compliance with regulatory requirements
- Improved Kondor performance speeds:
  - Reduce Kondor Curves Server (KCS) loads
  - Speed up batch process

The Finastra services team has several years' experience of effectively managing curves in Kondor.

We can help you find an effective solution for your potential pricing issues or help identify any problem with amendment of curves.

To see how we can help you, contact us today at services@finastra.com

About the author

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Pedro Porfirio leads the global field and customer engagement with capital markets customers and prospects. Based in London, Pedro drives the growth of the company's entire capital markets business line spanning treasury, capital markets, and investment management. Pedro joined Finastra from Calypso Technology where he worked as Chief Product Officer, and brings over 25 years' experience in banking and technology. Pedro holds an aerospace engineering degree from ITA in Brazil and an MBA from University of Michigan.

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About Finastra

Finastra is building an open platform that accelerates collaboration and innovation in financial services, creating better experiences for people, businesses and communities. Supported by the broadest and deepest portfolio of financial services software, Finastra delivers this vitally important technology to financial institutions of all sizes across the globe, including 90 of the world's top100 banks. Our open architecture approach brings together a number of partners and innovators. Together we are leading the way in which applications are written, deployed and consumed in financial services to evolve with the changing needs of customers. Learn more at **finastra.com**

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