FX Options – Risk Model

FXO Risk stream

Agenda

For confidential slides, copy and paste the above text box into the slide.

Pricing

Market Data Inputs

To price an FX Forward, the following market data is required:

- FX Spot Rate – Spot Rate of corresponding currency pair
- Domestic ZC Curve – FX Zero Coupon curve of the domestic (RHS) currency
- Foreign ZC Curve – FX Zero Coupon curve of the foreign (LHS) currency
- Discounting ZC Curve – Discount curve of the VM Currency

To price an FX Options, all of the above plus the following market data is required:

- Implied Volatility Surface – Vol surface for corresponding currency pair

Discounting ZC Curves are sourced from SwapClear.

If either the domestic or foreign currency is USD, the FX Curve is sourced from SwapClear, else it is implied using Spot+Swap points as received from members.

Implied Volatility Surfaces are converted from Market Quotes (ATM, RR10, RR25, FLY10, FLY25) to a volatility surface defined by delta (CALL10, CALL25, ATM, PUT25, PUT10)

FX Trade NPV Calculation

To value an FX Forward Trade, the following inputs are required:

- Relevant FX Spot Rate, *S*
- Domestic (RHS) currency FX ZC Rate between Spot Date and Settlement Date, $r_{domRS,SD}$
- Foreign (LHS) currency FX ZC Rate between Spot Date and Settlement Date, $r_{forRS,SD}$
- Discount Curve ZC Rate between Valuation Date and Settlement Date, $r_{discRS,SD}$

To value an FX Option, all of the above are required as well as the following :

- Implied Volatility, σ

$$V_{FX\_Fwd} = \frac{N_B (F - K) e^{(-r_{discVD,SD}.(SD-VD/365))}}{if\ (domCcy = VMCcy),1,F}$$

$$V_{FXO} = \frac{N_B \left[\Phi F.N(\Phi d_1) - \Phi K.N(\Phi d_2)\right] e^{(-r_{discVD,SD}.(SD-VD/365))}}{if\ (domCcy = VMCcy),1,F}$$

$$d_1 = \frac{\ln(F/K) + 0.5\sigma^2 T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

$$F = e^{(r_{domRS,SD} - r_{forRS,SD}).(SD-RS/365)}$$

Scenario Object

Scenario objects contain all necessary market data to price FX Spot, Forwards and Options.

Scenario object holds the following containers:

- Map<CurrencyPair,SpotRate> SpotRates - a one-one mapping, with a single spot rate for each currency pair
- Map<Currency,ZCCurve> FXCurves - a one-one mapping, with a single FX ZC Curve for each currency
- Map<Currency,ZCCurve> DiscCurves – a one-one mapping, with a single ZC Curve for each VM Currency
- Map<CurrencyPair,VolSurface> volSurfaces – one-one mapping such that there is a volatility surface defined for each currency pair

NPVCalculator Class

Class to calculate value of an FX Spot, Forward, NDF and Option.

Contains the following functions:

- double NPV(Scenario scen, FXTrade *trade) – uses scenario and trade input to deduce relevant NPV calculation and calculate inputs
  - double FXONPV(CcyPair pair, short phi, double S, double K, double domCF, double forCF , double discFactor, double sigma, double timeToExp)
  - double FwdNPV(CcyPair pair, double S, double K, double domCF, double forCF , double discFactor)
- void convertNPV(double K, double S, double foreignNotional) – takes current NPV calculation in *d pips* convention and converts to other conventions

Class contains the following fields (with getters & setter):

- double dpips – NPV in *domestic* per one unit of *foreign*
- double fpips – NPV in *foreign* per one unit of *domestic*
- double d% – NPV in *domestic* per one unit of *domestic*
- double f% – NPV in *foreign* per one unit of *foreign*
- double domestic – NPV in units of *domestic* currency
- double foreign – NPV in units of *foreign* currency

$$\textbf{d pips} \xrightarrow{\times\frac{1}{S_0}} \%\textbf{f} \xrightarrow{\times\frac{S_0}{K}} \%\textbf{d} \xrightarrow{\times\frac{1}{S_0}} \textbf{f pips} \xrightarrow{\times S_0 K} \textbf{d pips}$$

Volatility Surface

Volatility Surface Object

Representation of volatility surface

Volatility Surface object holds the following containers:

- Vector<vector<double>> implied vols – a 2D vector to represent all volatilitys on the surface
- Vector<vector<double>> logMs – a 2D vector to represent all log-moneynesses on the surface
- Vector<double> timeToExp - vector to represent the times to expiry that the volatility surface is defined on
- Vector<double> deltas – vector to represent the deltas that the volatility surface is defined on
- Interpolator* tenorInterpolator – Interpolator strategy class for tenor interpolation
- Interpolator* smileInterpolator – Interpolator strategy class for vol smile interpolation

Volatility Surface Conversion

Market data is received in the following format:

Tenor	ATM	RR10	RR25	FLY10	FLY25
ON	10%	1.5%	3.5%	0.25%	0.25%
…					
2Y	10%	3%	8%	0.5%	1%

And is converted using the definitions of Risk-Reversals and Butterflys:

$$RR_{\partial,t} = \sigma_{c,\partial,t} - \sigma_{p,\partial,t}$$

$$FLY_{\partial,t} = \frac{\sigma_{c,\partial,t} + \sigma_{p,\partial,t} - 2\sigma_{ATM,t}}{2}$$

To the following format:

Tenor	CALL10	CALL25	ATM	PUT25	PUT10
ON	12%	11%	10%	9.5%	8.5%
…					
2Y	15%	12%	10%	9%	7%

Volatility Surface Scenario Generation

Volatility Surfaces defined using a ‘Vol-for-delta’ convention, implied volatility is quoted for a given tenor and delta.

Relative Returns are calculated using this quotation too, ie

$$r_{i,\delta,t} = \frac{\sigma_{i,\delta,t}}{\sigma_{i,\delta,t-HP}} - 1$$

Returns on volatility surfaces are not scaled, therefore given a new base volatility surface, the simulated surface for scenario with time *t* can be defined as:

$$\sigma^{*}_{i,\delta,t} = \sigma_{i,\delta,N}.(1 + r_{i,\delta,t})$$

Volatility Surface Translation

Log-moneyness (*log(S/K)*) of each quote is calculated so that surface can be interpolated using a given trade's strike.

Premium Not Included in Delta

For currency pairs where the premium is not included in the delta quotation (ie AUDUSD, EURUSD, and GBPUSD) – the translation from delta to log-moneyness is a simple analytical formula:

$$M = \ln\left(\frac{S}{F/\exp\{\sigma\sqrt{T}\Phi.N^{-1}(\Delta e^{Z_{base,RS,SD}{}^{\wedge}RS,SD}) - 0.5\sigma^2 T\}}\right)$$

Premium Included in Delta

For currency pairs where the premium is included in the delta quotation (ie USDCHF, USDJPY, EURCHF, EURJPY and EURGBP) – the translation from delta to log-moneyness is the calculated using a root finding algorithm such as Newton-Raphson as no closed-form analytical solution exists.

Volatility Surface Translation

Implied Volatilities

Tenor	CALL10	CALL25	ATM	PUT25	PUT10
ON	9.60%	9.50%	8.93%	9.49%	9.56%
1W	8.55%	8.12%	7.76%	8.05%	8.48%
1M	9.11%	8.70%	8.45%	8.63%	9.01%
3M	9.36%	8.94%	8.68%	8.82%	9.15%
6M	9.51%	9.03%	8.75%	8.83%	9.18%
1Y	10.12%	9.56%	9.18%	9.29%	9.65%
2Y	10.50%	9.76%	9.34%	9.42%	9.89%

Log-Moneyness Axes

Tenor	CALL10	CALL25	ATM	PUT25	PUT10
ON	-0.64%	-0.34%	0.00%	0.33%	0.64%
1W	-1.73%	-0.86%	0.01%	0.85%	1.70%
1M	-2.46%	-1.24%	0.02%	1.21%	2.40%
3M	-3.65%	-1.84%	0.03%	1.76%	3.48%
6M	-5.07%	-2.55%	0.06%	2.37%	4.72%
1Y	-6.70%	-3.37%	0.11%	3.01%	6.02%
2Y	-9.86%	-4.88%	0.22%	4.28%	8.66%

Volatility Surface Interpolation and Extrapolation

For a given trade and volatility surface, an implied volatility quote is calculated using both trade time to expiry, T and trade log-moneyness M.

Interpolation along the volatility surface is performed first along adjacent log-moneyness axes, followed by interpolation along the tenor axis is applied to these points. As follows:

1. Identify volatility smiles with time to expiry either side of T
2. Perform vol smile interpolation on both smiles along the log-moneyness axes, with input log-moneyness M
3. Interpolate along the tenor axis to retrieve output implied volatility quote

Volatility Surface Interpolation and Extrapolation

Log-Moneyness Axis Interpolation

Each volatility smile will have 5 log-moneyness points (derived from vol-for-delta quotation in §2.2) along with 5 corresponding implied volatility quotes. Monotonic interpolation is performed along these points.

Flat extrapolation is applied before/after the first/last point.

Tenor Axis Interpolation

Given two implied volatility quotes and two times to expiry, linear interpolation is applied in variance space using volatility day weighting scheme as below.

Flat extrapolation is applied before/after the first/last tenor.

$$\sigma = T^{-0.5}\left[\sigma_{n-1}^2 T_{n-1} + \frac{\sigma_n^2 T_n - \sigma_{n-1}^2 T_{n-1}}{T_n - T_{n-1}}\left(\alpha^2 C_T + O_T \frac{(T_n - T_{n-1} - \alpha C)}{O}\right)\right]^{0.5}$$

$\sigma_n =$ Implied Volatility at tenor n

$\sigma_{n-1} =$ Implied Volatility at tenor $n-1$

$O =$ Number business days between $n-1$ and n

$O_T =$ Number business days between $n-1$ and T

$C =$ Number non-business days between $n-1$ and n

$C_T =$ Number non-business days between $n-1$ and T

$\alpha =$ Weighting applied to non-business days

Volatility Surface Arbitrage Conditions

1. Calendar Spread Constraint

   A call with a longer expiry should be worth more than a call of shorter expiry having the same strike. Ie:

$$C(K-\Delta,\sigma(K-\Delta,t))-C(K,\sigma(K,t))\geq 0$$

2. Call Spread Constraint

   A call with lower strike should be worth more than a call of higher strike having the same maturity. Ie:

$$C(K,T+\Delta,\sigma(K,T+\Delta))-C(K,T,\sigma(K,T))\geq 0$$

3. Butterfly Spread Constraint

   A call with a certain strike must be worth less than the average of two adjacent calls of equal distance, this produces a constraint on the convexity of the curve. Ie:

$$C(K-\Delta,\sigma(K-\Delta,t))-2C(K,\sigma(K,t))+C(K+\Delta,\sigma(K+\Delta,t))\geq 0$$

Volatility Surface De-Arbitraging

All simulated volatility surfaces are checked for arbitrages.

If an arbitrage exists on a simulated volatility surface, we use a bounded solution to remove the arbitrage.

Volatility Surface De-Arbitraging is performed in the following order:

1. Check for and remove calendar spread arbitrage
2. For each volatility smile, calculate strike at each point and split each smile in h(=100) segments
3. Starting at ATM point, use adjacent points to check for violations of the call and calendar spread conditions locally
   a) If arbitrage exists, adjust implied volatility by the minimum amount necessary to remove arbitrage
4. Move to next point along the smile

Greeks

Spot Delta

1. The sensitivity of an option's price (NPV) to a one unit (or 100% relative) change in the underlying spot rate
2. The delta of an option can be calculated using either a simulation-based or analytical approach.

Simulation Based Calculation

Base Scenario

Tenor	CALL10	CALL25	ATM	PUT25	PUT10
i	10%	10%	10%	10%	10%

S
0.75

R_dom	R_for	R_disc
1%	0.5%	0.5%

NPV
NPV_Base

Simulated Scenario

Tenor	CALL10	CALL25	ATM	PUT25	PUT10
i	10%	10%	10%	10%	10%

S
1.5

R_dom	R_for	R_disc
1%	0.5%	0.5%

NPV
NPV_Sim

$$\Delta = NPV_{sim} - NPV_{after}$$

Gamma

1. The sensitivity of an option's spot delta to a 1% change in the underlying spot rate.
2. The Gamma of an option can be calculated using either a simulation-based or analytical approach.

Simulation Based Calculation

Base Scenario

Tenor	CALL10	CALL25	ATM	PUT25	PUT10
i	10%	10%	10%	10%	10%

S
0.75

R_dom	R_for	R_disc
1%	0.5%	0.5%

NPV
Δ_Base

Simulated Scenario

Tenor	CALL10	CALL25	ATM	PUT25	PUT10
i	10%	10%	10%	10%	10%

S
0.7575

R_dom	R_for	R_disc
1%	0.5%	0.5%

NPV
Δ_Sim

$$\Gamma = \Delta_{sim} - \Delta_{base}$$

Theta

1. The sensitivity of an option's price to a 1 day change in the trade time to expiry/maturity.
2. The theta of an option can be calculated using either a simulation-based or analytical approach.

Simulation Based Calculation

Base Scenario

Tenor	CALL10	CALL25	ATM	PUT25	PUT10
i	10%	10%	10%	10%	10%

S
0.75

R_dom	R_for	R_disc
1%	0.5%	0.5%

NPV
NPV_Base

Simulated Scenario

Tenor	CALL10	CALL25	ATM	PUT25	PUT10
i-δ	10%	10%	10%	10%	10%

S
0.75

R_dom	R_for	R_disc
1%	0.5%	0.5%

NPV
NPV_Sim

$$\Theta = NPV_{sim} - NPV_{base}$$

Vega

1. The sensitivity of an option's price to a 1% absolute increase in the input implied volatility.
2. The Gamma of an option can be calculated using either a simulation-based or analytical approach.

Simulation Based Calculation

Base Scenario

Tenor	CALL10	CALL25	ATM	PUT25	PUT10
i	10%	10%	10%	10%	10%

S
0.75

R_dom	R_for	R_disc
1%	0.5%	0.5%

NPV
NPV_Base

Simulated Scenario

Tenor	CALL10	CALL25	ATM	PUT25	PUT10
i	**11%**	**11%**	**11%**	**11%**	**11%**

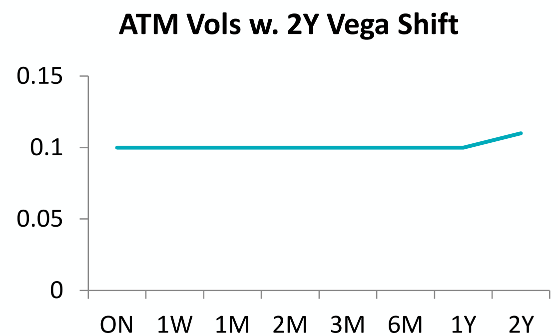
S
0.75

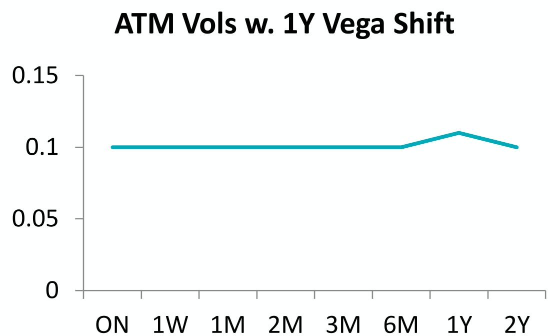
R_dom	R_for	R_disc
1%	0.5%	0.5%

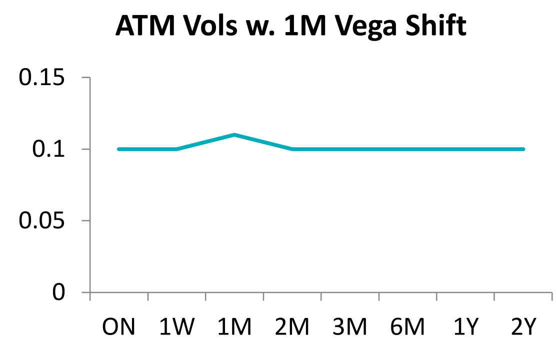
NPV
NPV_Sim

$$v_i = NPV_{sim} - NPV_{after}$$

Vega Bucketing – “Naïve” Approach



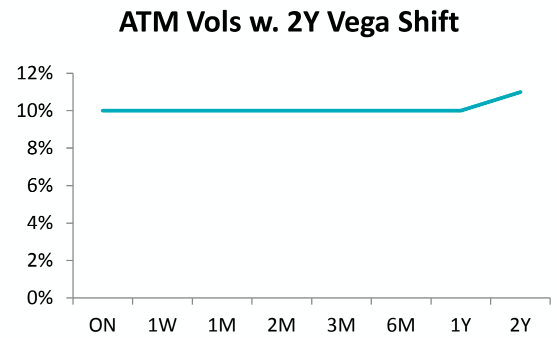


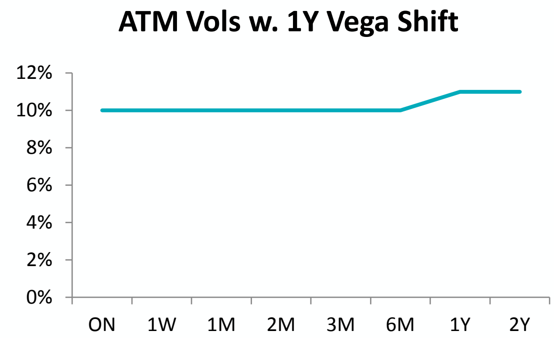


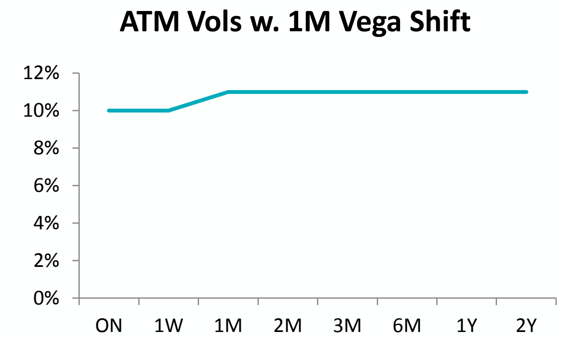
- Calculate the value of the portfolio using unshifted/’base’ market data: NPV_{base}
- To calculate vega at a particular tenor t, increase the volatilities at t by 1%
- Recalculate the value of the portfolio, using the shifted implied volatility surface: NPV_t
- Calculate P&L due to shift of volatility surface at tenor t: $PL_{T=} NPV_{T-} NPV_{base}$
- $v_{t=} PL_t$

Issue with this approach is that there is a possibility that the vega risk is over-estimated

Vega Bucketing – Proposed Approach (backward shift)







- Calculate the value of the portfolio using unshifted/'base' market data: NPV_{base}
- To calculate vega at the last tenor, *t(*=2Y), shift the volatilities at *t* by 1%
- Recalculate the value of the portfolio, using the shifted implied volatility surface: NPV_t
- Calculate P&L due to shift of volatility surface at tenor *t-1*: $PL_{t-1=}\ NPV_{t-}\ NPV_{base}$
- Move to the next tenor *t-1*, increase volatilities by 1% whilst ensuring all previously shifted volatilities remain
- Recalculate the value of the portfolio, using the shifted implied volatility surface: NPV_{t-1}
- Calculate P&L due to shift of volatility surface at tenor *t-1*: $PL_{t-1=}\ NPV_{t-1-}\ NPV_t$
- $v_{t=}\ PL_t$

This approach ensures that the vega due to a 1% parallel shift across the whole volatility surface is equal to the sum of the vega by tenor.

Rega

1. The sensitivity of an option's price to a 10bps absolute increase in the corresponding risk-reversal volatility quote.
2. The Rega of an option can only be calculated using a simulation-based approach.
3. Rega is calculated for each tenor and delta (10,25)

Simulation Based Calculation

Base Scenario

Tenor	CALL10	CALL25	ATM	PUT25	PUT10	S	R_dom	R_for	R_disc	NPV
i	10%	10%	10%	10%	10%	0.75	1%	0.5%	0.5%	NPV_Base

Simulated Scenario

Tenor	CALL10	CALL25	ATM	PUT25	PUT10	S	R_dom	R_for	R_disc	NPV
i	**10.05%**	10%	10%	10%	**9.95%**	0.75	1%	0.5%	0.5%	NPV_Sim

$$rega_{\delta,i} = NPV_{sim} - NPV_{after}$$

Sega

1. The sensitivity of an option's spot delta to a 10bps absolute increase in the corresponding butterfly volatility quote.
2. The Sega of an option can only be calculated using a simulation-based approach.
3. Sega is calculated for each tenor and delta (10,25)

Simulation Based Calculation

Base Scenario

Tenor	CALL10	CALL25	ATM	PUT25	PUT10	S	R_dom	R_for	R_disc		NPV
i	10%	10%	10%	10%	10%	0.75	1%	0.5%	0.5%	→	NPV_Base

Simulated Scenario

Tenor	CALL10	CALL25	ATM	PUT25	PUT10	S	R_dom	R_for	R_disc		NPV
i	10.05%	10%	10%	10%	10.05%	0.75	1%	0.5%	0.5%	→	NPV_Sim

$$sega_{\delta,i} = NPV_{sim} - NPV_{after}$$

Rega/Sega Bucketing

1. Follows the same principle as vega bucketing in that shifts to the implied volatility surface begin at the back-end of the curve and we calculate the incremental P&L of an extra tenor shift.
2. For the delta axes, we use the same approach as the by-tenor calculation.
3. For a volatility surface with delta definitions CALL10, CALL25, ATM, PUT15 and PUT10 we calculate rega/sega by delta by first shifting the 10 Delta points at tenor t.
4. After shifting 10 delta points, we revalue the portfolio to get the 10 Delta Rega/Sega at tenor t.
5. We then calculate the change in portfolio value after shifting the 25 Delta points, this gives us the Rega/Sega for 25 Delta at tenor t.
6. After calculating 10 and 25 Delta Rega/Sega at tenor t we move to the next tenor as per the Vega bucketing.

Initial Margin Calculation

Market Data Refresh/Scenario Generation

1. Consistent with the current NDF service, scenario returns will be calculated at each EOD and kept constant throughout the day.
2. FX Spot and interest rate ZC historical returns are scaled under two models: Mid-Vol (Core) and quantile vol (Floor) scaling. *New*
3. FX Volatility are not scaled. *New*
4. At each Market Data Refresh (MDR), these sets of scenario returns will be applied to the current market data to produce 2x2500 Simulated Scenario objects. *New*
5. Post simulation of scenario objects, the de-arbitraging process will need to be performed to check for and remove any arbitrages created by the scenario generation process. *New*
6. Although we do not scale implied volatility returns, we still must run the de-arbitraging process on both Mid-Vol and Quantile-Vol scaling models independently, as simulated FX Spot and ZC rates will differ which could create arbitrages under one scaling model and not the other. *New*
7. Once volatility surfaces have been successfully de-arbed, we can perform the pre-calculation step of transforming all volatility surfaces to log-moneyness space. *New*

Simulated P&Ls

For each portfolio, two vectors of scenario P&Ls (length 2500) are defined. The first being scenario P&Ls of the Core IM Model. The second being scenario P&Ls based on the IM Floor Model.

Simulated P&L calculated as:

$$PL_{portfolio,t} = V_{portfolio,t} - V_{portfolio,N}$$

Where,

$$\begin{aligned}
PL &= \text{simulated portfolio P\&L in Reporting Ccy at time } t \\
V_{portfolio,t} &= \text{simulated value of portfolio at scenario date } t \text{ in Reporting Ccy} \\
V_{portfolio,N} &= \text{current value of portfolio in Reporting Ccy}
\end{aligned}$$

Final IM Calculation

Initial Margin Estimation

1. For both sets of P&L vectors, the Initial Margin is calculated as the average of the seven largest portfolio losses.
2. This gives two values, the Core IM (based on Mid-Vol) and IM Floor (based on Quantile-Vol) estimates.

Maximum Loss Comparison

1. The final IM is calculated as the maximum loss estimate of the Core IM and IM Floor Estimates:

$$IM_{Final} = Min(IM_{Core}, IM_{Floor})$$

Liquidity Risk Margin Calculation

Liquidity Risk Margin (LRM)

1. LRM simulates the cost of hedging a portfolio's large concentrated exposure during the DMP
2. It assumes proxy hedging on the liquid part of the volatility surface
3. The overall portfolio LRM is the sum of 5 components across all individual currency pairs:
4. LRM is calculated at currency pair level and accounts for the following exposures:
   - outright Spot Delta $\text{LRM\_Delta}_{\text{Ccy Pair}}$
   - Gamma (approximated by Vega <=1 week) $\text{LRM\_Gamma}_{\text{Ccy Pair}}$
   - Vega (>1 week) $\text{LRM\_Vega}_{\text{Ccy Pair}}$
   - Rega $\text{LRM\_Rega}_{\text{Ccy Pair}}$
   - Sega $\text{LRM\_Sega}_{\text{Ccy Pair}}$

$$\text{LRM} = \sum_{\text{Ccy Pair}} \text{LRM\_Delta}_{\text{Ccy Pair}} + \text{LRM\_Gamma}_{\text{Ccy Pair}} + \text{LRM\_Vega}_{\text{Ccy Pair}} + \text{LRM\_Rega}_{\text{Ccy Pair}} + \text{LRM\_Sega}_{\text{Ccy Pair}}$$

LRM – Delta

1. The Delta component of LRM captures the potential cost in hedging excessive outright Delta exposures
2. Calculated by applying a multiplier to the portfolio IM

$$\mathrm{LRM\_Delta}_{\mathtt{Ccy\ Pair}} = \mathrm{IM}_{\mathtt{Portfolio}} \times (\mathrm{DeltaIMM}_{\mathtt{CcyPair}} - 1)$$

3. The multiplier is selected from a Delta IMM matrix given the currency pair portfolio spot Delta and tenor with largest absolute forward Delta exposure.
   - Flat extrapolation is applied below the min and beyond the max Delta threshold, and linear interpolation in-between

Tenor\Spot Delta ($m eq.)	CCY PAIR – Delta IMM Matrix			
	5000	10000	15000	20000
1W	1.00	1.09	1.18	1.26
...	1.00	1.09	1.18	1.26
2Y	1.00	1.09	1.18	1.26

4. DeltaIMM is calibrated based on a quarterly DMG survey that indicates the Delta amount that can be traded in 24h in a stressed market

LRM – Gamma & Volatility

1. LRM is calculated by applying a volatility Bid/Ask spread and position adjustment to the outright exposures
2. The vol spread parameters are derived from member price contributions
3. The position adjustment matrices (based on outright exposure) are calibrated from a quarterly DMG survey
    - Flat extrapolation is applied below the min / beyond the max Vega threshold, and linear interpolation in-between

Vega 1wk (USD mil. Equiv.	EUR /USD	USD /JPY	EUR /JPY
0.25	1.0000	1.0000	1.0000
0.50	1.2500	1.2500	1.3500
1.00	1.5000	1.5000	1.7000

$$LRM\_Gamma_{Ccy\ Pair} = -\left|Vega_{CcyPair,1wk}\right| \text{ x } ATMSpread_{CcyPair,1wk} \text{ x } GammaPosAdj_{CcyPair}$$

4. LRM_Gamma is representing the cost of hedging short-dated Vega (i.e. <=1W) using ATM options

LRM – Gamma & Volatility (cont'd)

1. LRM_Vega represents the cost of hedging longer-dated Vega (i.e. >1W) using ATM options

$$\text{LRM\_Vega}_{\text{Ccy Pair}} = \begin{cases} \sum_{\substack{\text{Vega}>0 \\ \text{Tenor}>1wk}} -\left|\text{Vega}_{\text{CcyPair,Tenor}}\right| \times \text{ATMSpread}_{\text{CcyPair,Tenor}} \times \text{VegaPosAdj}_{\text{CcyPair}}, & \text{if } \text{Vega}_{\text{CcyPair}}^{\text{Tenor}>1wk} > 0 \\ \sum_{\substack{\text{Vega}\le 0 \\ \text{Tenor}>1wk}} -\left|\text{Vega}_{\text{CcyPair,Tenor}}\right| \times \text{ATMSpread}_{\text{CcyPair,Tenor}} \times \text{VegaPosAdj}_{\text{CcyPair}}, & \text{if } \text{Vega}_{\text{CcyPair}}^{\text{tenor}>1wk} \le 0 \end{cases}$$

2. LRM_Rega represents the cost of hedging Rega using 25-delta risk reversals

$$\text{LRM\_Rega}_{\text{Ccy Pair}} = \begin{cases} \sum_{\substack{\text{Rega}>0 \\ \text{Tenor}}} -\left|\text{Rega}_{\text{CcyPair,Tenor}}\right| \times \text{RegaSpread}_{\text{CcyPair,Tenor}} \times \text{RegaPosAdj}_{\text{CcyPair}} \times 10, & \text{if } \text{Rega}_{\text{CcyPair}} > 0 \\ \sum_{\substack{\text{Rega}\le 0 \\ \text{Tenor}}} -\left|\text{Rega}_{\text{CcyPair,Tenor}}\right| \times \text{RegaSpread}_{\text{CcyPair,Tenor}} \times \text{RegaPosAdj}_{\text{CcyPair}} \times 10, & \text{if } \text{Rega}_{\text{CcyPair}} \le 0 \end{cases}$$

3. LRM_Sega represents the cost of hedging Sega using 25-delta butterflies

$$\text{LRM\_Sega}_{\text{Ccy Pair}} = \begin{cases} \sum_{\substack{\text{Sega}>0 \\ \text{Tenor}}} -\left|\text{Sega}_{\text{CcyPair,Tenor}}\right| \times \text{SegaSpread}_{\text{CcyPair,Tenor}} \times \text{SegaPosAdj}_{\text{CcyPair}} \times 10, & \text{if } \text{Sega}_{\text{CcyPair}} > 0 \\ \sum_{\substack{\text{Sega}\le 0 \\ \text{Tenor}}} -\left|\text{Sega}_{\text{CcyPair,Tenor}}\right| \times \text{SegaSpread}_{\text{CcyPair,Tenor}} \times \text{SegaPosAdj}_{\text{CcyPair}} \times 10, & \text{if } \text{Sega}_{\text{CcyPair}} \le 0 \end{cases}$$

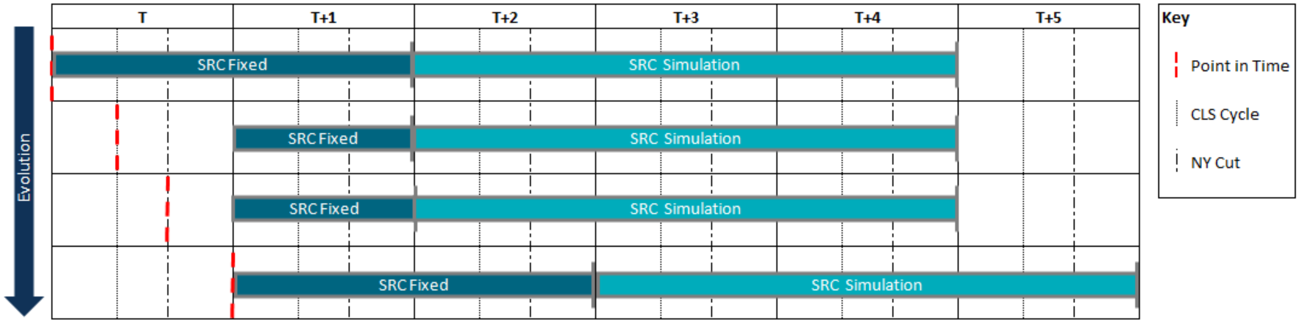
Settlement Management Margin (*SMM*)

1. In the event of settlement failure, ForexClear will need to fulfil their settlement pay in obligations and pay in to CLS on behalf of the member with a settlement failure
2. SMM is considered as the potential cost incurred should ForexClear need to fulfil a members settlement obligations on their behalf

$$SMM = Settlement\ Replacement\ Cost\ (SRC) + Settlement\ Variation\ Margin\ (SVM)$$

- The *SRC* represents the potential cost of executing next-day FX transactions in order to rebalance/replenish the settlement provisions used in the event of a member settlement failure

$$SRC = SRC_{Fix} + SRC_{sim}$$



- The *SVM* accounts for the price changes (MtM) on these positions between EOD SD-2 and their settlement in CLS since their settlement price has been determined

SRC Fixed (SRC_{Fix})

1. Once the settlement limits enforcement process has been executed the settlement obligations are fixed

$$SRC_{Fix} = \sum_{Ccy} SRC_{Ccy}$$

$$= \sum_{Ccy} \frac{SrcSpread_{Ccy}}{10{,}000} \times \min(0, SettObligation_{Ccy,T} + SettObligation_{Ccy,T+1} + Prefunding_{Ccy}) \times FxRate_{Ccy-USD}$$

2. SrcSpreadCcy is the bid-mid spread (in basis points) that would be incurred in executing next-day trades for notional amounts in the table below over a 12 hour period under stress market conditions.

These values are obtained from a quarterly survey of the DMG:

Currency	AUD	CHF	EUR	GBP	JPY	USD
SPA (Local CCY (m))	80	80	160	120	0	360
Spread (bp)	10	20	15	20	20	20

SRC Simulated (SRC_{Sim})

1. In order to simulate what the settlement obligations may be prior to them becoming known the SRCSim will use the Foreign Exchange Settlement Exposure Tolerance (FxSET) model to calculate the worst expected settlement exposure between T+2 and T+4
2. The expected settlement exposure over the 3 days will be capped at the 3 times the Settlement Provision Amounts (SPA) given a forced trade down will occur once obligations are known to ensure members are below the SPA in all currencies
3. Calculate SRC_{Sim} per currency under each scenario (j) in the *FxSET* model

$$SRC_{Ccy,j} = max\left(min\left(\sum_{i=2}^{4} Settlement\ Exp_{Ccy,j,T+i}, 0 \right), -3SPA_{Ccy} \right) \times \frac{SrcSpread_{Ccy}}{10{,}000}$$

4. Calculate a total SRC_{Sim} in USD per scenario

$$SRC_{USD,j} = \sum_{Ccy} SRC_{Ccy,j} \times FxRate_{Ccy-USD,j}$$

5. Take the worst scenario under the *FxSET* model

$$SRC_{Sim} = \min(SRC_{USD,j})\ \forall j$$

Foreign Exchange Settlement Exposure Tolerance (*FxSET*)

1. ForexClear manages settlement risk in the service through defined currency exposure thresholds
2. The FxSET model calculates potential settlement exposures in relation to cleared deliverable FX spot, forward, and option contracts
3. The largest simulated settlement exposure per portfolio is taken from:
   - 10 years (2500 scenarios) of historical spot rate returns and a five-day holding period
   - Simulating scenarios from ForexClear's stress testing suite
4. Simulated Cash Flow Logic:
   - For an FX spot or forward contract, the settlement obligation for a given trade is fixed and certain
   - For an FX option is based on moneyness and on a modified logical exercise/expiry rule that incorporates a bid/ask spread parameter to account for pin risk very close to the given spot rate

Minimum Excess Requirement (MER)

1. MER is a required collateral buffer calculated at each EOD imposed on member accounts for the following day which they can use to register trades against
2. MER is designed to reduce the number of rejected trades and intraday call
   - This is achieved by considering a lookback on the peak relative increase in margin requirements taking a certain confidence rank (x^{th} largest increase over y business days)
3. MER is calculated at member account level at each EOD as a function of:
   - IM – 'Initial margin'
   - LRM – 'Liquidity risk margin'
   - SRM – 'Sovereign risk margin'
   - CRiM – 'Credit risk margin'
   - SMM – 'Settlement management margin'
   - CM – 'Completion margin'
     - CM is defined as the expected increase in margin resulting from the next day fixings/settlements. That is, CM is the difference in margin between the current portfolio and the portfolio excluding next day fixings/settlements, capped at zero (no benefit).
4. For all purposes, IM from here on will be defined as IM + LRM + SRM + CRiM + SMM

Minimum Excess Requirement (MER) cont'd...

1. MER calculated at EOD t (effective ITD t+1) is defined as follows:

$$\mathrm{MER_t} = \mathrm{MAX}(\mathrm{CM_t} + 50\% * \text{MER buffer}, \text{MER buffer}, \text{Floor})$$

where

$$\text{MER buffer}_\mathrm{t} = \mathrm{MIN}\ (\text{MER perentage}_\mathrm{t}, 30\%) * \text{EOD IM}_\mathrm{t}$$

$$\text{MER percentage}_\mathrm{t} = \text{Percentile}_{0.8,21}\left\{\frac{\text{ITD peak IM}_\mathrm{t}}{\text{EOD IM}_{\mathrm{t}-1}} - 1, \dots, \frac{\text{ITD peak IM}_{\mathrm{t}-20}}{\text{EOD IM}_{\mathrm{t}-21}} - 1\right\}$$

$$CM_t = MIN(0, IM_{Excl} - IM_{Incl})$$

MER Model Parameter	Inter-Dealer Model	FCM Client Model
MER Percentile	80	80
MER Lookback Period	21 days	21 days
Relative MER Cap	30%	30%
Absolute MER Floor	USD 2.5m	Nil
Absolute CM Floor	Nil	Nil