Adenza

Model Validation Report

Calypso FX Barrier Option Using FXOTheoratical Pricer

Version 1.1

November 21,2023

Adenza Proprietary and Confidential

Report Summary

Testing of FX Single Barrier Option Valuation using FXOTheoratical Pricer.

Reference

[1] Calypso, Calib FXO Pricers, Version 17.0, February 2022

[2] Calypso, FX Volatility Surface Interpolation, October 2023

Document History

Revision History

Version Number	Revision Date	Author	Summary of Changes
1.0	6/14/2018	Chang-Cheng Yang	Initial Version
1.1	11/21/2023	Chang-Cheng Yang	Reformatted

Distribution

Name	Title	Date	Version Number

Contents

Section 1. The FX Option Single Barrier Trade

In this document we use GBP/USD currency pair as an example. One creates an Up-In Barrier Option using VannaVolga Pricer and comparing with the FXOTheoretical Pricer on the same trade, and also comparing with the corresponding Vanilla Option Trade

Market Data

Default Rate Sides	Choice
GBP/USD Spot	1.38000
GBP SONIA 1D Curve	GBP.Sonia.Vanilla
GBP/USD Vol	GBP.USD.FXOption
USD FEDFUNDS 1D Curve	USD.FF.1D

Pricing

Valuation Date	03/01/2018
Valuation Time	10:00:00 AM
Pricing Env	OFFICIAL
Output 1 or 2 way	1-way

Strip Generator

Generate F11 Apply Clear

Legs to strip	None

Leg 1 Details

FX Spot	1.38000
Fwd Points	9.983
FX Fwd	1.3809983
Volatility	
Ccy 1 Rate	0.407491
Ccy 2 Rate	0.466145
Valuation FX Date	03/01/2018
Valuation Spot Date	03/05/2018
Pricing Model	FXOVannaVolga
FX_POINTS	false
INCLUDE_FEES	true
NPV_INCLUDE_CASH	false
TV_ASIAN_ARITH_PROXY	Log Normal
TV_ATM_TYPE	Market Concordant
TV_USE_FLAT_TERM_STR...	false
USE_SMILE_VOL	true
VV_ACCRUAL_RESETTAB...	
VV_CONSISTENCY_ENFO...	Basic
VV_EXPIRY_BARRIER_MO...	Market
VV_HEDGE_EXPIRY	Barrier End Date
VV_HEDGE_POLICY	Synthetic

Find Property...	Totals	1	2	3
Strategy Name		Barrier	Barrier	Vanilla
Price		Price	Price	Price
Save		Save	Save	Save
Solve		Don't Solve	Don't Solve	Don't Solve
Status		NONE	NONE	NONE
Action		NEW	NEW	NEW
Sales Person		Salesperson 1	Salesperson 1	Salesperson 1
Trader		TraderSeniorNYC	TraderSeniorNYC	TraderSeniorNYC
Book		RATES_FLOW_N...	RATES_FLOW_N...	RATES_FLOW_...
Counterpart Role		CounterParty	CounterParty	CounterParty
Counterparty		NONE	NONE	NONE
Internal Book				
Broker				
Ccy Pair		GBP/USD	GBP/USD	GBP/USD
Buy/Sell		Buy	Buy	Buy
Put/Call		GBP Put	GBP Put	GBP Put
Strike		1.41000	1.41000	1.41000
Notional		10,000,000.00	10,000,000.00	10,000,000.00
Notional Ccy		GBP	GBP	GBP
Ccy1 Amount		10,000,000.00	10,000,000.00	10,000,000.00
Ccy2 Amount		14,100,000.00	14,100,000.00	14,100,000.00
Expiry Date		04/12/2019	04/12/2019	04/12/2019
Expiry		FRI 291d 9M+16	FRI 291d 9M+16	FRI 291d 9M+16
Expiry Cut		NYC 10:00	NYC 10:00	NYC 10:00
Delivery Date		04/16/2019	04/16/2019	04/16/2019
Expiry Delivery Link		On	On	On
Exercise Type		European	European	European
Barrier Duration		FULL	FULL	
Barrier Type		UI	UI	
Barrier		1.39000	1.39000	
Volatility			12.26549	12.00826
FX Spot		1.38000	1.38000	1.38000
Fwd Points		9.983	9.983	9.983
FX Fwd		1.3809983	1.3809983	1.3809983
Ccy 1 Rate		0.407491	0.407491	0.407491
Ccy 2 Rate		0.466145	0.466145	0.466145
Pricing Model		FXOVannaVolga	FXOTheoretical	FXOMarket
Settle Type		Physical	Physical	Physical
Settle Ccy				
PV USD	2,367,785.93	750,325.16	762,067.58	855,393.18
PV GBP	1,715,734.53	543,697.29	552,206.03	619,831.21

Section 2. Analysis

2.1 The Vanilla Option

The Vanilla European Option Premium $Euro = Euro(F, K, \sigma, T, \phi)$ is calculated with the closed-form formulae from the Black model as shown below:

$$Euro(F, K, \sigma, T, \phi) = \phi Df_2 \left[FN\left(\phi \frac{\ln(F/K) + 0.5\sigma^2 T}{\sigma\sqrt{T}} \right) - KN\left(\phi \frac{\ln(F/K) - 0.5\sigma^2 T}{\sigma\sqrt{T}} \right) \right]$$

where,

$$\phi = \begin{cases} 1, & if \quad Call \\ -1, & if \quad Put \end{cases},$$

$$Df_2 = Df^{USD}(DeliveryDate)$$

$$F = spotFX \times \frac{Df^{GBP}}{Df^{USD}}$$

$$Df^{GBP} = \frac{Df^{GBP}(DeliveryDate)}{Df^{GBP}(SpotDate)},$$

$$Df^{USD} = \frac{Df^{USD}(DeliveryDate)}{Df^{USD}(SpotDate)}$$

$$\sigma = \sigma_{VolatilitySurface}(valDateTimeStamp, volSurfaceTimeStamp, spotFX, T, K)$$

$$Option\ NPV = Notional * Euro(F, K, \sigma, T, \phi)$$

2.2 The Single Barrier FX Options with Theoretical Pricer

We denote H as the barrier level, $S = spotFX$. In the first four sections, we describe the standard barrier options implemented in Calypso which is so-called the FXOTheoretical Price. We first check the following simple cases:

2.2.1 Spot and Barrier

If it is Up-In and $S \geq H$ then Barrier Option = European Vanilla Option

If it is Down-In and $S \leq H$ then Barrier Option = European Vanilla Option

Note the barrier parities:

$$Knock\text{-}in + Knock\text{-}out = Vanilla$$

Thus,

If it is Up-Out and $S > H$ then Barrier Option = 0

If it is Down-Out and $S < H$ then Barrier Option = 0

2.2.2 Strike and Barrier

If it is Up-In and $K \geq H$ then Barrier Call Option = Vanilla Call Option

If it is Down-In and $K \leq H$ then Barrier Put Option = Vanilla Put Option

Corresponding,

If it is Up-Out and $K > H$ then Barrier Call Option = 0

If it is Down-Out and $K < H$ then Barrier Put Option = 0

2.2.3 Regular Cases – Knock-Out Barrier

We now consider the remaining cases. We denote:

$$\lambda = \frac{\ln(S/F) + 0.5\sigma^2 T}{\sigma^2 T}$$

$$a = \ln Df_2 - \frac{1}{2}\frac{\left(\ln(F/S) - 0.5\sigma^2 T\right)^2}{\sigma^2 T} = \ln Df_2 - \frac{1}{2}\lambda^2\sigma^2 T$$

$$b = \frac{\ln(F/S) - 0.5\sigma^2 T}{\sigma\sqrt{T}} = -\lambda\sigma\sqrt{T}$$

$$l = \begin{cases} \dfrac{\ln(K/S)}{\sigma\sqrt{T}}, & if \quad UpBarrier \,\&\, Call \\ \dfrac{\ln(max(H,K)/S)}{\sigma\sqrt{T}}, & if \quad DownBarrier \,\&\, Call \\ \dfrac{\ln(H/S)}{\sigma\sqrt{T}}, & if \quad DownBarrier \,\&\, Put \\ -\infty, & Otherwise \end{cases},$$

$$u = \begin{cases} \dfrac{\ln(H/S)}{\sigma\sqrt{T}}, & if \quad UpBarrier \,\&\, Call \\ \dfrac{\ln(\min(H,K)/S)}{\sigma\sqrt{T}}, & if \quad UpBarrier \,\&\, Put \\ \dfrac{\ln(K/S)}{\sigma\sqrt{T}}, & if \quad DownBarrier \,\&\, Put \\ \infty, & Otherwise \end{cases}$$

Note that $N(\infty) = 1, \quad N(-\infty) = 0$, and $N(-x) = 1 - N(x)$

$$
\begin{aligned}
&SingleBarrierPremium = B(S,K,H,\sigma_{ATM},T,\phi) \\
&= \phi\left[N\left(u-b-\sigma\sqrt{T}\right)-N\left(l-b-\sigma\sqrt{T}\right)\right]e^{a+\ln S+0.5(b+\sigma\sqrt{T})^2} \\
&-\phi K\left[N\left(u-b\right)-N\left(l-b\right)\right]e^{a+0.5b^2} \\
&-\phi\left[N\left(u-b-2\frac{\ln(H/S)}{\sigma\sqrt{T}}-\sigma\sqrt{T}\right)-N\left(l-b-2\frac{\ln(H/S)}{\sigma\sqrt{T}}-\sigma\sqrt{T}\right)\right]e^{a-2\frac{\ln^2(H/S)}{\sigma^2 T}+\ln S+0.5\left(b+2\frac{\ln(H/S)}{\sigma\sqrt{T}}+\sigma\sqrt{T}\right)^2} \\
&+\phi K\left[N\left(u-b-2\frac{\ln(H/S)}{\sigma\sqrt{T}}\right)-N\left(l-b-2\frac{\ln(H/S)}{\sigma\sqrt{T}}\right)\right]e^{a-2\frac{\ln^2(H/S)}{\sigma^2 T}+\ln S+0.5\left(b+2\frac{\ln(H/S)}{\sigma\sqrt{T}}\right)^2} \\
&= \phi Df_2 F\left[N\left(u+(\lambda-1)\sigma\sqrt{T}\right)-N\left(l+(\lambda-1)\sigma\sqrt{T}\right)\right] \\
&-\phi Df_2 K\left[N\left(u+\lambda\sigma\sqrt{T}\right)-N\left(l+\lambda\sigma\sqrt{T}\right)\right] \\
&-\phi Df_2 F\left(\frac{H}{S}\right)^{2(1-\lambda)}\left[N\left(u+(\lambda-1)\sigma\sqrt{T}-2\frac{\ln(H/S)}{\sigma\sqrt{T}}\right)-N\left(l+(\lambda-1)\sigma\sqrt{T}-2\frac{\ln(H/S)}{\sigma\sqrt{T}}\right)\right] \\
&+\phi Df_2 K\left(\frac{H}{S}\right)^{-2\lambda}\left[N\left(u+\lambda\sigma\sqrt{T}-2\frac{\ln(H/S)}{\sigma\sqrt{T}}\right)-N\left(l+\lambda\sigma\sqrt{T}-2\frac{\ln(H/S)}{\sigma\sqrt{T}}\right)\right]
\end{aligned}
$$

2.2.4 Regular Cases – Knock-In Barrier

Knock-In Barrier is derived by the following relationship:

$$Knock\text{-}in + Knock\text{-}out = Vanilla$$

Thus:

$$
\begin{aligned}
Up\text{-}in &= Vanilla - Up\text{-}out \\
Down\text{-}in &= Vanilla - Down\text{-}out
\end{aligned}
$$

Remark: Note that in Theoretical Pricer the ATM volatility interpolated from FX Option Volatility Surface is applied.

2.2.5 Rebate Formulae

We let H be the barrier level and use the same notations as in the previous sections. We re-define:

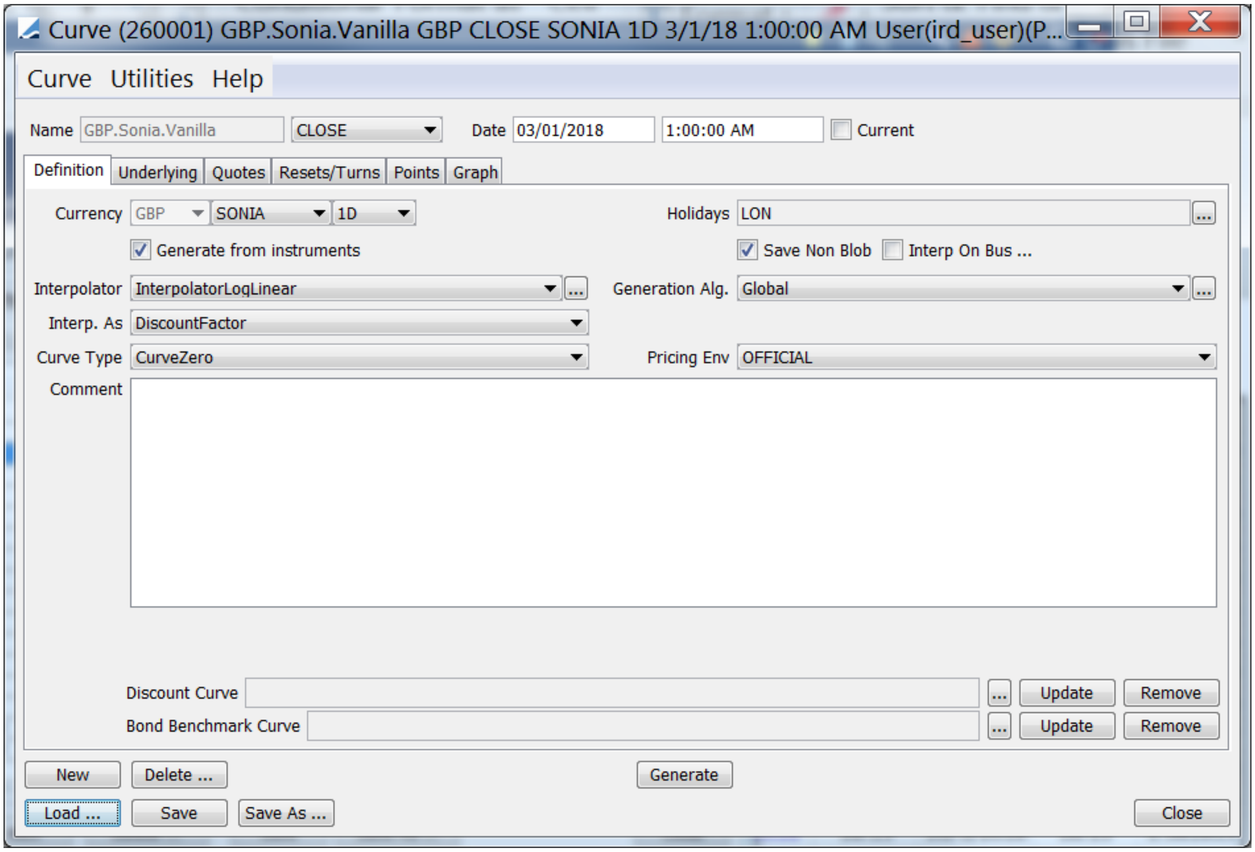
$$l = \begin{cases} \dfrac{\ln(H/S)}{\sigma\sqrt{T}}, & \textit{if } H \textit{ is the Lower Barrier Level} \\ -\infty, & \textit{Otherwise} \end{cases}$$

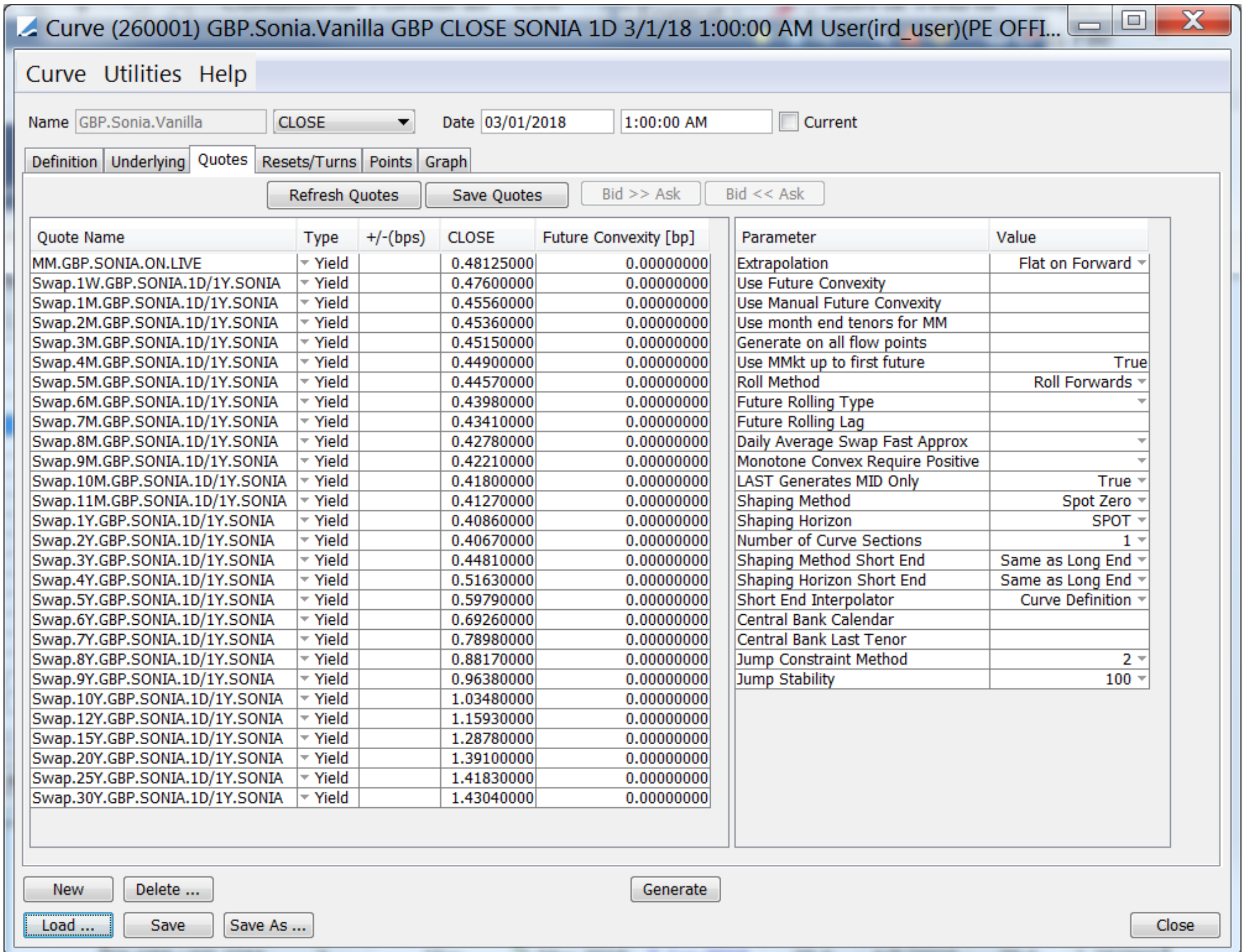
$$u = \begin{cases} \dfrac{\ln(H/S)}{\sigma\sqrt{T}}, & \textit{if } H \textit{ is the Up Barrier Level} \\ \infty, & \textit{Otherwise} \end{cases}$$

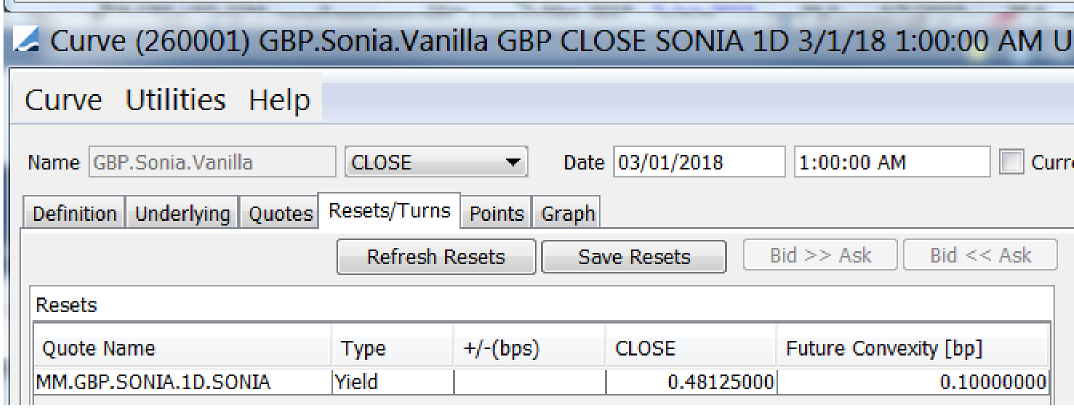
$$\begin{aligned} BarrierRebatePremium &= \left[N\left(u-b-\sigma\sqrt{T}\right) - N\left(l-b-\sigma\sqrt{T}\right)\right] e^{a+\ln S+0.5(b+\sigma\sqrt{T})^2} \\ &- \left[N\left(u-b-2\frac{\ln(H/S)}{\sigma\sqrt{T}}-\sigma\sqrt{T}\right) - N\left(l-b-2\frac{\ln(H/S)}{\sigma\sqrt{T}}-\sigma\sqrt{T}\right)\right] e^{a-2\frac{\ln^2(H/S)}{\sigma^2 T}+\ln S+0.5\left(b+2\frac{\ln(H/S)}{\sigma\sqrt{T}}+\sigma\sqrt{T}\right)^2} \\ &= Df_2 F\left[N\left(u+(\lambda-1)\sigma\sqrt{T}\right) - N\left(l+(\lambda-1)\sigma\sqrt{T}\right)\right] \\ &- Df_2 F\left(\frac{H}{S}\right)^{2(1-\lambda)} \left[N\left(u+(\lambda-1)\sigma\sqrt{T}-2\frac{\ln(H/S)}{\sigma\sqrt{T}}\right) - N\left(l+(\lambda-1)\sigma\sqrt{T}-2\frac{\ln(H/S)}{\sigma\sqrt{T}}\right)\right] \end{aligned}$$

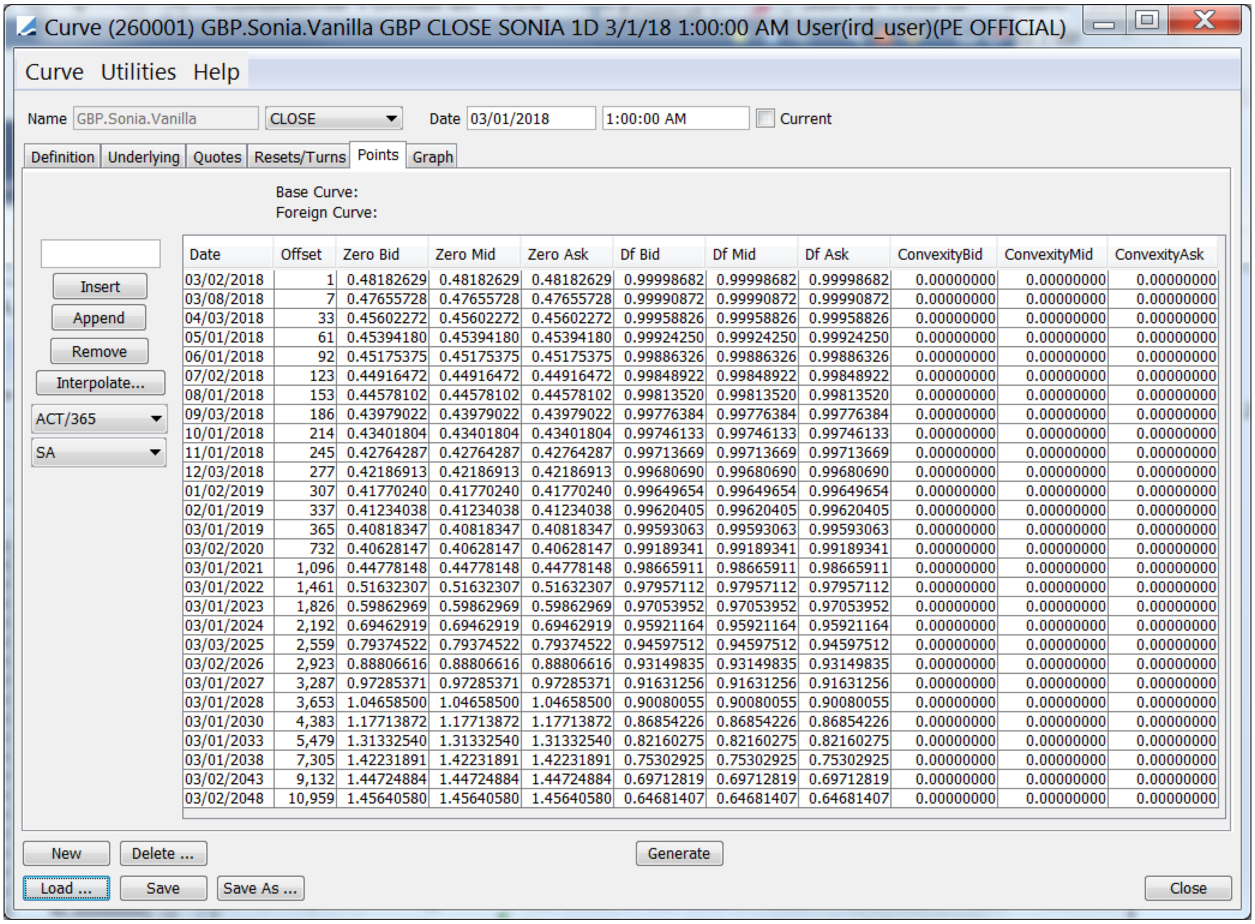
Section 3. Appendix A: Market Data Setup

3.1 The Primary Currency Discount Curve



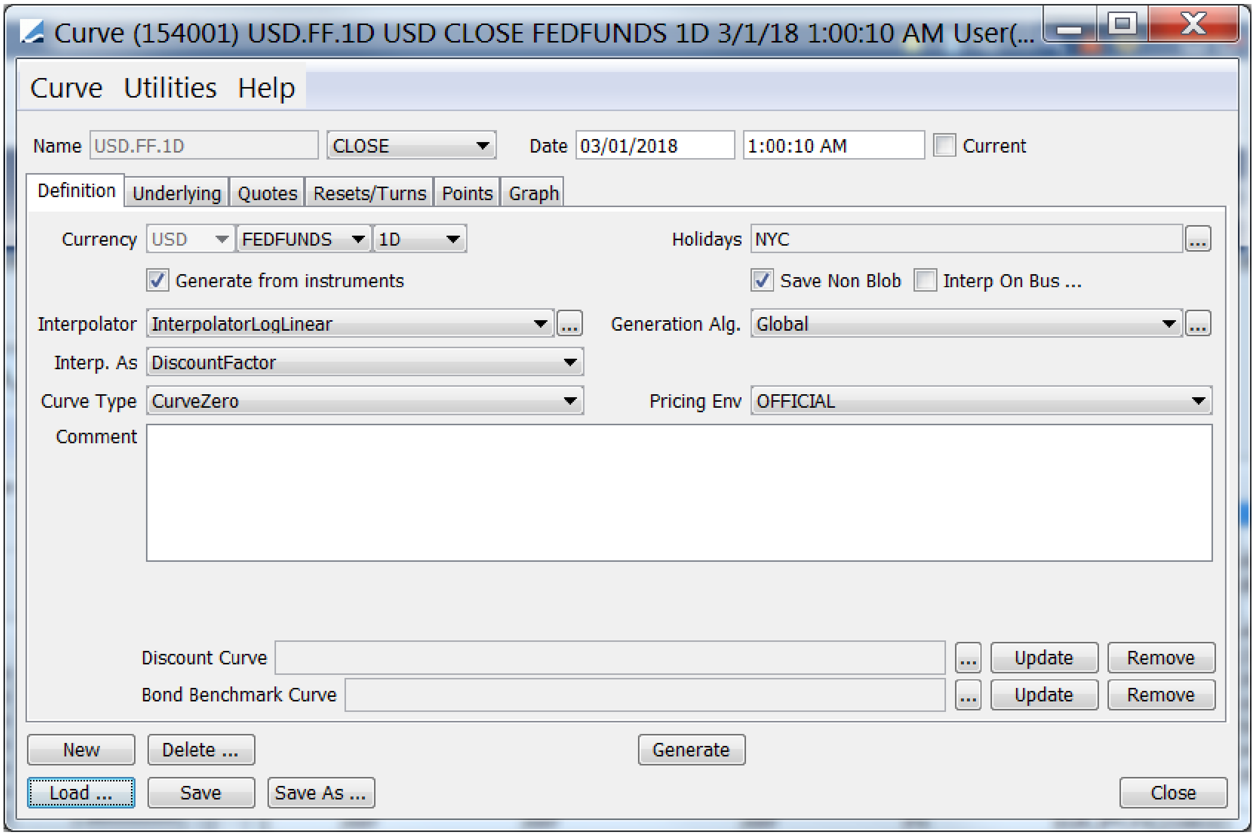

Curve (260001) GBP.Sonia.Vanilla GBP CLOSE SONIA 1D 3/1/18 1:00:00 AM User(ird_user)(PE OFFI...
Curve Utilities Help
Name GBP.Sonia.Vanilla CLOSE Date 03/01/2018 1:00:00 AM Current
Definition Underlying Quotes Resets/Turns Points Graph
Refresh Quotes Save Quotes Bid >> Ask Bid << Ask
Quote Name Type +/-(bps) CLOSE Future Convexity [bp]
MM.GBP.SONIA.ON.LIVE Yield 0.48125000 0.00000000
Swap.1W.GBP.SONIA.1D/1Y.SONIA Yield 0.47600000 0.00000000
Swap.1M.GBP.SONIA.1D/1Y.SONIA Yield 0.45560000 0.00000000
Swap.2M.GBP.SONIA.1D/1Y.SONIA Yield 0.45360000 0.00000000
Swap.3M.GBP.SONIA.1D/1Y.SONIA Yield 0.45150000 0.00000000
Swap.4M.GBP.SONIA.1D/1Y.SONIA Yield 0.44900000 0.00000000
Swap.5M.GBP.SONIA.1D/1Y.SONIA Yield 0.44570000 0.00000000
Swap.6M.GBP.SONIA.1D/1Y.SONIA Yield 0.43980000 0.00000000
Swap.7M.GBP.SONIA.1D/1Y.SONIA Yield 0.43410000 0.00000000
Swap.8M.GBP.SONIA.1D/1Y.SONIA Yield 0.42780000 0.00000000
Swap.9M.GBP.SONIA.1D/1Y.SONIA Yield 0.42210000 0.00000000
Swap.10M.GBP.SONIA.1D/1Y.SONIA Yield 0.41800000 0.00000000
Swap.11M.GBP.SONIA.1D/1Y.SONIA Yield 0.41270000 0.00000000
Swap.1Y.GBP.SONIA.1D/1Y.SONIA Yield 0.40860000 0.00000000
Swap.2Y.GBP.SONIA.1D/1Y.SONIA Yield 0.40670000 0.00000000
Swap.3Y.GBP.SONIA.1D/1Y.SONIA Yield 0.44810000 0.00000000
Swap.4Y.GBP.SONIA.1D/1Y.SONIA Yield 0.51630000 0.00000000
Swap.5Y.GBP.SONIA.1D/1Y.SONIA Yield 0.59790000 0.00000000
Swap.6Y.GBP.SONIA.1D/1Y.SONIA Yield 0.69260000 0.00000000
Swap.7Y.GBP.SONIA.1D/1Y.SONIA Yield 0.78980000 0.00000000
Swap.8Y.GBP.SONIA.1D/1Y.SONIA Yield 0.88170000 0.00000000
Swap.9Y.GBP.SONIA.1D/1Y.SONIA Yield 0.96380000 0.00000000
Swap.10Y.GBP.SONIA.1D/1Y.SONIA Yield 1.03480000 0.00000000
Swap.12Y.GBP.SONIA.1D/1Y.SONIA Yield 1.15930000 0.00000000
Swap.15Y.GBP.SONIA.1D/1Y.SONIA Yield 1.28780000 0.00000000
Swap.20Y.GBP.SONIA.1D/1Y.SONIA Yield 1.39100000 0.00000000
Swap.25Y.GBP.SONIA.1D/1Y.SONIA Yield 1.41830000 0.00000000
Swap.30Y.GBP.SONIA.1D/1Y.SONIA Yield 1.43040000 0.00000000
Parameter Value
Extrapolation Flat on Forward
Use Future Convexity
Use Manual Future Convexity
Use month end tenors for MM
Generate on all flow points
Use MMkt up to first future True
Roll Method Roll Forwards
Future Rolling Type
Future Rolling Lag
Daily Average Swap Fast Approx
Monotone Convex Require Positive
LAST Generates MID Only True
Shaping Method Spot Zero
Shaping Horizon SPOT
Number of Curve Sections 1
Shaping Method Short End Same as Long End
Shaping Horizon Short End Same as Long End
Short End Interpolator Curve Definition
Central Bank Calendar
Central Bank Last Tenor
Jump Constraint Method 2
Jump Stability 100
New Delete ... Generate
Load ... Save Save As ... Close

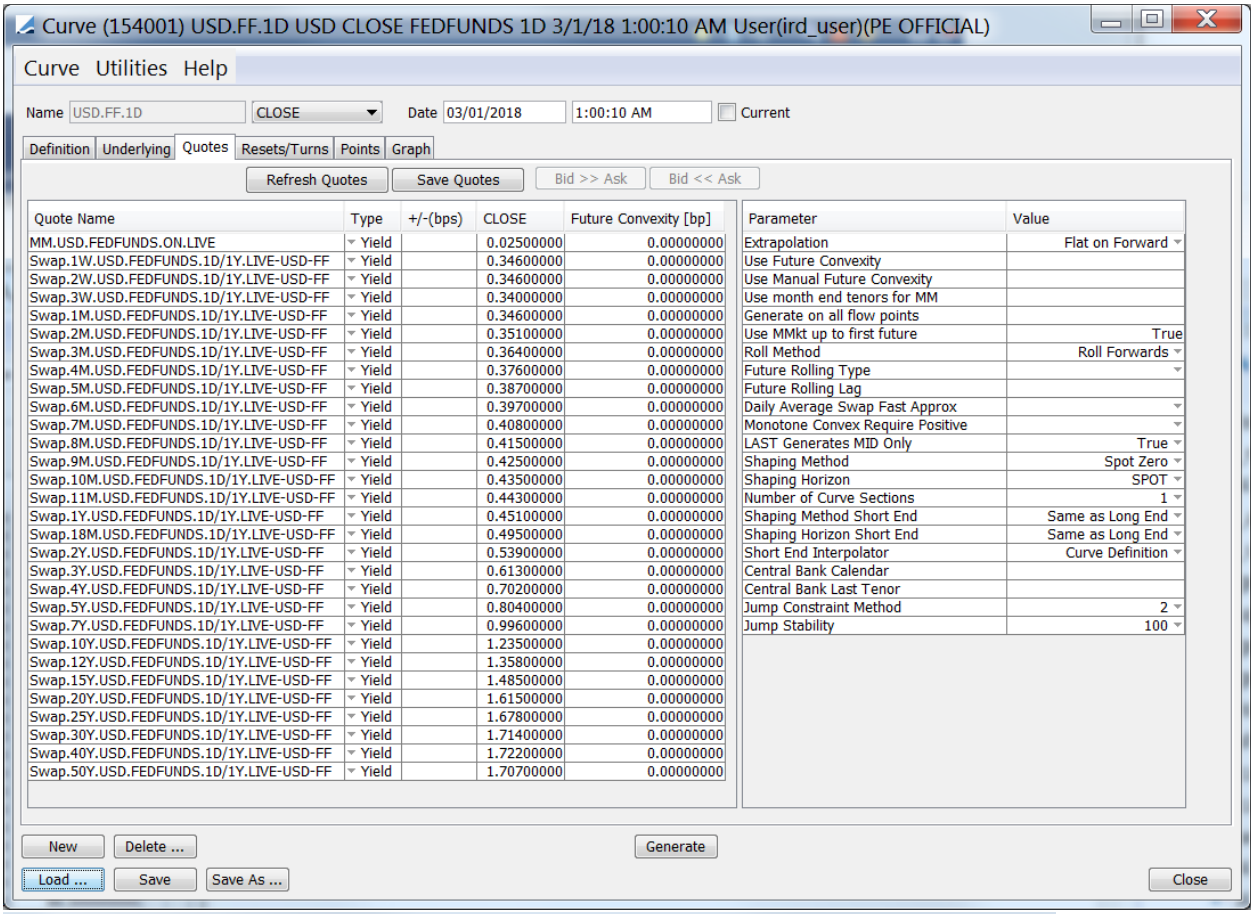

Curve (260001) GBP.Sonia.Vanilla GBP CLOSE SONIA 1D 3/1/18 1:00:00 AM Us
Curve Utilities Help
Name GBP.Sonia.Vanilla CLOSE Date 03/01/2018 1:00:00 AM Curre
Definition Underlying Quotes Resets/Turns Points Graph
Refresh Resets Save Resets Bid >> Ask Bid << Ask
Resets
Quote Name Type +/-(bps) CLOSE Future Convexity [bp]
MM.GBP.SONIA.1D.SONIA Yield 0.48125000 0.10000000

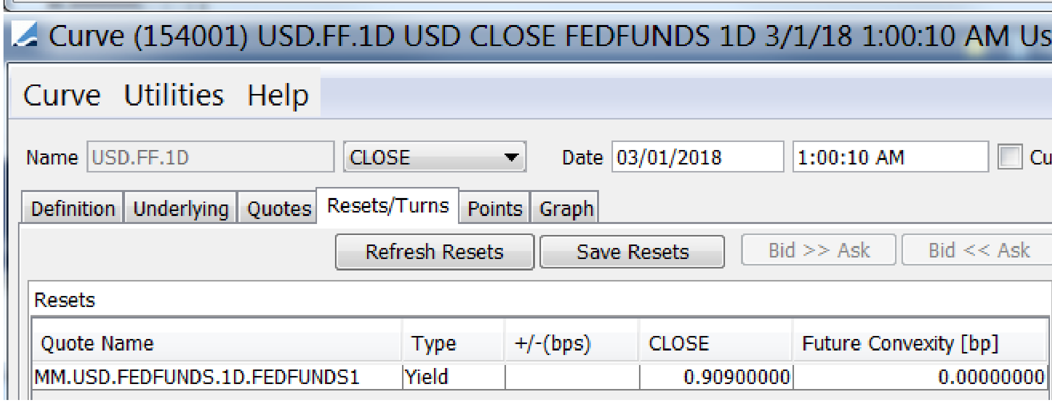


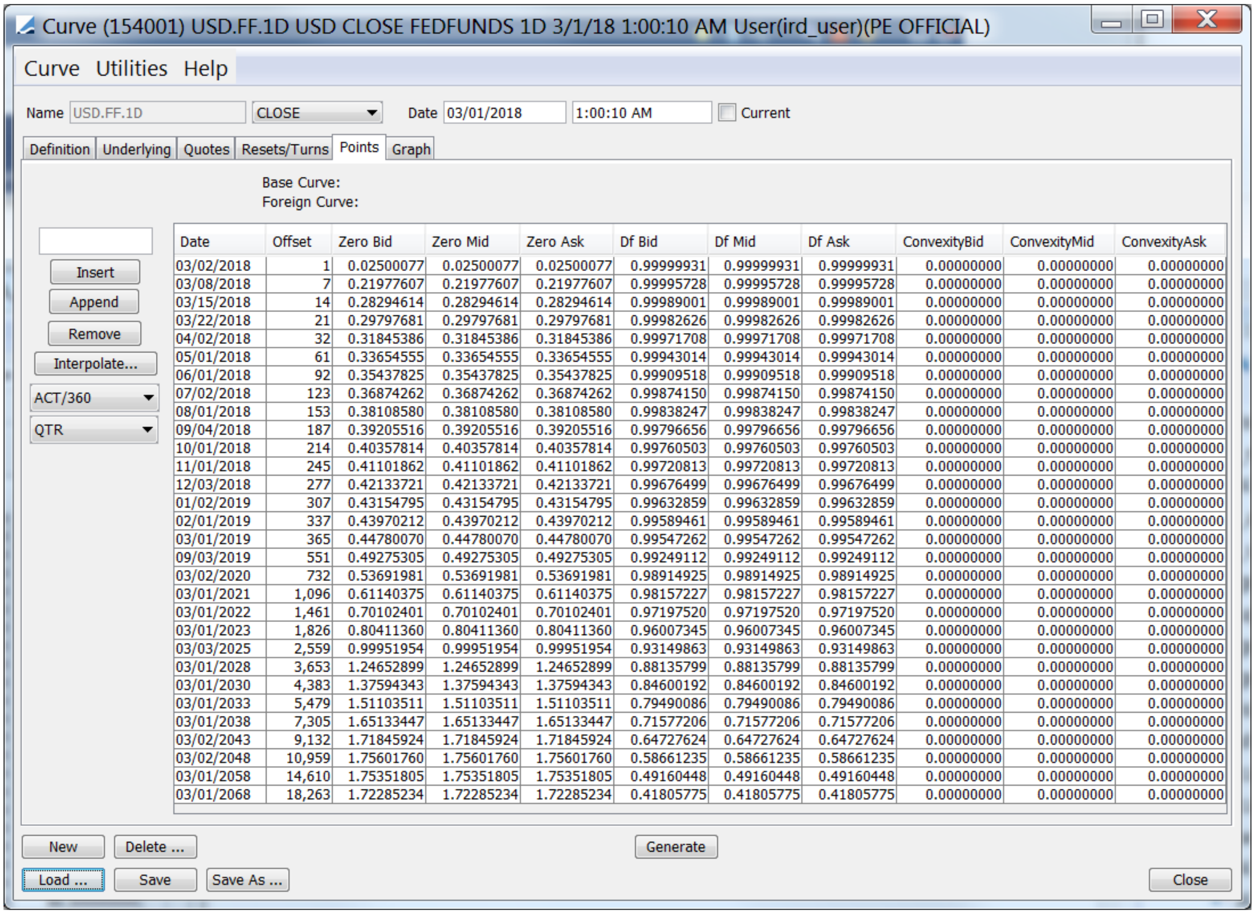
Date	Offset	Zero Bid	Zero Mid	Zero Ask	Df Bid	Df Mid	Df Ask	ConvexityBid	ConvexityMid	ConvexityAsk
03/02/2018	1	0.48182629	0.48182629	0.48182629	0.99998682	0.99998682	0.99998682	0.00000000	0.00000000	0.00000000
03/08/2018	7	0.47655728	0.47655728	0.47655728	0.99990872	0.99990872	0.99990872	0.00000000	0.00000000	0.00000000
04/03/2018	33	0.45602272	0.45602272	0.45602272	0.99958826	0.99958826	0.99958826	0.00000000	0.00000000	0.00000000
05/01/2018	61	0.45394180	0.45394180	0.45394180	0.99924250	0.99924250	0.99924250	0.00000000	0.00000000	0.00000000
06/01/2018	92	0.45175375	0.45175375	0.45175375	0.99886326	0.99886326	0.99886326	0.00000000	0.00000000	0.00000000
07/02/2018	123	0.44916472	0.44916472	0.44916472	0.99848922	0.99848922	0.99848922	0.00000000	0.00000000	0.00000000
08/01/2018	153	0.44578102	0.44578102	0.44578102	0.99813520	0.99813520	0.99813520	0.00000000	0.00000000	0.00000000
09/03/2018	186	0.43979022	0.43979022	0.43979022	0.99776384	0.99776384	0.99776384	0.00000000	0.00000000	0.00000000
10/01/2018	214	0.43401804	0.43401804	0.43401804	0.99746133	0.99746133	0.99746133	0.00000000	0.00000000	0.00000000
11/01/2018	245	0.42764287	0.42764287	0.42764287	0.99713669	0.99713669	0.99713669	0.00000000	0.00000000	0.00000000
12/03/2018	277	0.42186913	0.42186913	0.42186913	0.99680690	0.99680690	0.99680690	0.00000000	0.00000000	0.00000000
01/02/2019	307	0.41770240	0.41770240	0.41770240	0.99649654	0.99649654	0.99649654	0.00000000	0.00000000	0.00000000
02/01/2019	337	0.41234038	0.41234038	0.41234038	0.99620405	0.99620405	0.99620405	0.00000000	0.00000000	0.00000000
03/01/2019	365	0.40818347	0.40818347	0.40818347	0.99593063	0.99593063	0.99593063	0.00000000	0.00000000	0.00000000
03/02/2020	732	0.40628147	0.40628147	0.40628147	0.99189341	0.99189341	0.99189341	0.00000000	0.00000000	0.00000000
03/01/2021	1,096	0.44778148	0.44778148	0.44778148	0.98665911	0.98665911	0.98665911	0.00000000	0.00000000	0.00000000
03/01/2022	1,461	0.51632307	0.51632307	0.51632307	0.97957112	0.97957112	0.97957112	0.00000000	0.00000000	0.00000000
03/01/2023	1,826	0.59862969	0.59862969	0.59862969	0.97053952	0.97053952	0.97053952	0.00000000	0.00000000	0.00000000
03/01/2024	2,192	0.69462919	0.69462919	0.69462919	0.95921164	0.95921164	0.95921164	0.00000000	0.00000000	0.00000000
03/03/2025	2,559	0.79374522	0.79374522	0.79374522	0.94597512	0.94597512	0.94597512	0.00000000	0.00000000	0.00000000
03/02/2026	2,923	0.88806616	0.88806616	0.88806616	0.93149835	0.93149835	0.93149835	0.00000000	0.00000000	0.00000000
03/01/2027	3,287	0.97285371	0.97285371	0.97285371	0.91631256	0.91631256	0.91631256	0.00000000	0.00000000	0.00000000
03/01/2028	3,653	1.04658500	1.04658500	1.04658500	0.90080055	0.90080055	0.90080055	0.00000000	0.00000000	0.00000000
03/01/2030	4,383	1.17713872	1.17713872	1.17713872	0.86854226	0.86854226	0.86854226	0.00000000	0.00000000	0.00000000
03/01/2033	5,479	1.31332540	1.31332540	1.31332540	0.82160275	0.82160275	0.82160275	0.00000000	0.00000000	0.00000000
03/01/2038	7,305	1.42231891	1.42231891	1.42231891	0.75302925	0.75302925	0.75302925	0.00000000	0.00000000	0.00000000
03/02/2043	9,132	1.44724884	1.44724884	1.44724884	0.69712819	0.69712819	0.69712819	0.00000000	0.00000000	0.00000000
03/02/2048	10,959	1.45640580	1.45640580	1.45640580	0.64681407	0.64681407	0.64681407	0.00000000	0.00000000	0.00000000

3.2 The Quoting Currency Discounting Curve



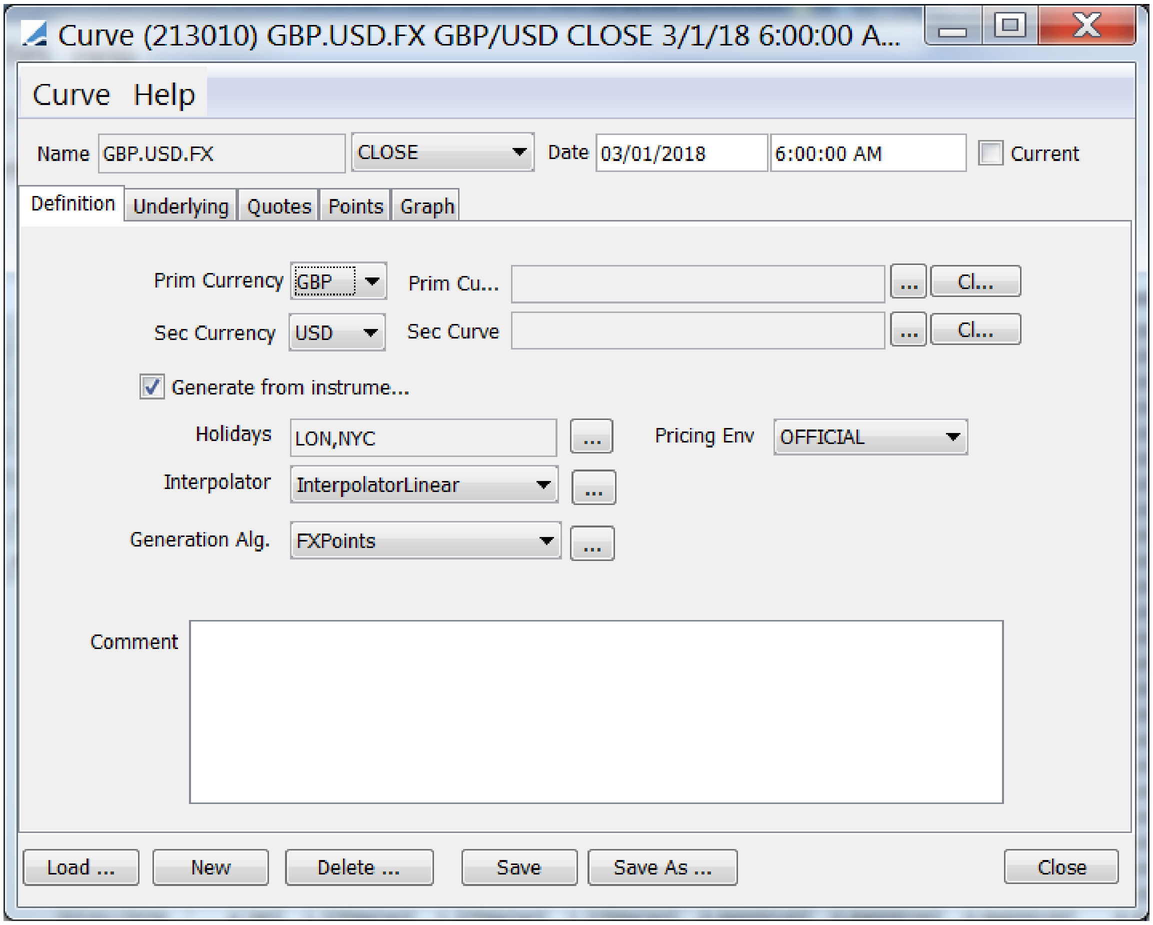

Curve (154001) USD.FF.1D USD CLOSE FEDFUNDS 1D 3/1/18 1:00:10 AM User(ird_user)(PE OFFICIAL)
Curve Utilities Help
Name USD.FF.1D CLOSE Date 03/01/2018 1:00:10 AM Current
Definition Underlying Quotes Resets/Turns Points Graph
Refresh Quotes Save Quotes Bid >> Ask Bid << Ask
Quote Name Type +/-(bps) CLOSE Future Convexity [bp]
MM.USD.FEDFUNDS.ON.LIVE Yield 0.02500000 0.00000000
Swap.1W.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.34600000 0.00000000
Swap.2W.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.34600000 0.00000000
Swap.3W.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.34000000 0.00000000
Swap.1M.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.34600000 0.00000000
Swap.2M.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.35100000 0.00000000
Swap.3M.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.36400000 0.00000000
Swap.4M.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.37600000 0.00000000
Swap.5M.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.38700000 0.00000000
Swap.6M.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.39700000 0.00000000
Swap.7M.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.40800000 0.00000000
Swap.8M.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.41500000 0.00000000
Swap.9M.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.42500000 0.00000000
Swap.10M.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.43500000 0.00000000
Swap.11M.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.44300000 0.00000000
Swap.1Y.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.45100000 0.00000000
Swap.18M.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.49500000 0.00000000
Swap.2Y.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.53900000 0.00000000
Swap.3Y.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.61300000 0.00000000
Swap.4Y.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.70200000 0.00000000
Swap.5Y.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.80400000 0.00000000
Swap.7Y.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 0.99600000 0.00000000
Swap.10Y.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 1.23500000 0.00000000
Swap.12Y.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 1.35800000 0.00000000
Swap.15Y.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 1.48500000 0.00000000
Swap.20Y.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 1.61500000 0.00000000
Swap.25Y.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 1.67800000 0.00000000
Swap.30Y.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 1.71400000 0.00000000
Swap.40Y.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 1.72200000 0.00000000
Swap.50Y.USD.FEDFUNDS.1D/1Y.LIVE-USD-FF Yield 1.70700000 0.00000000
Parameter Value
Extrapolation Flat on Forward
Use Future Convexity
Use Manual Future Convexity
Use month end tenors for MM
Generate on all flow points
Use MMkt up to first future True
Roll Method Roll Forwards
Future Rolling Type
Future Rolling Lag
Daily Average Swap Fast Approx
Monotone Convex Require Positive
LAST Generates MID Only True
Shaping Method Spot Zero
Shaping Horizon SPOT
Number of Curve Sections 1
Shaping Method Short End Same as Long End
Shaping Horizon Short End Same as Long End
Short End Interpolator Curve Definition
Central Bank Calendar
Central Bank Last Tenor
Jump Constraint Method 2
Jump Stability 100
New Delete ... Generate
Load ... Save Save As ... Close

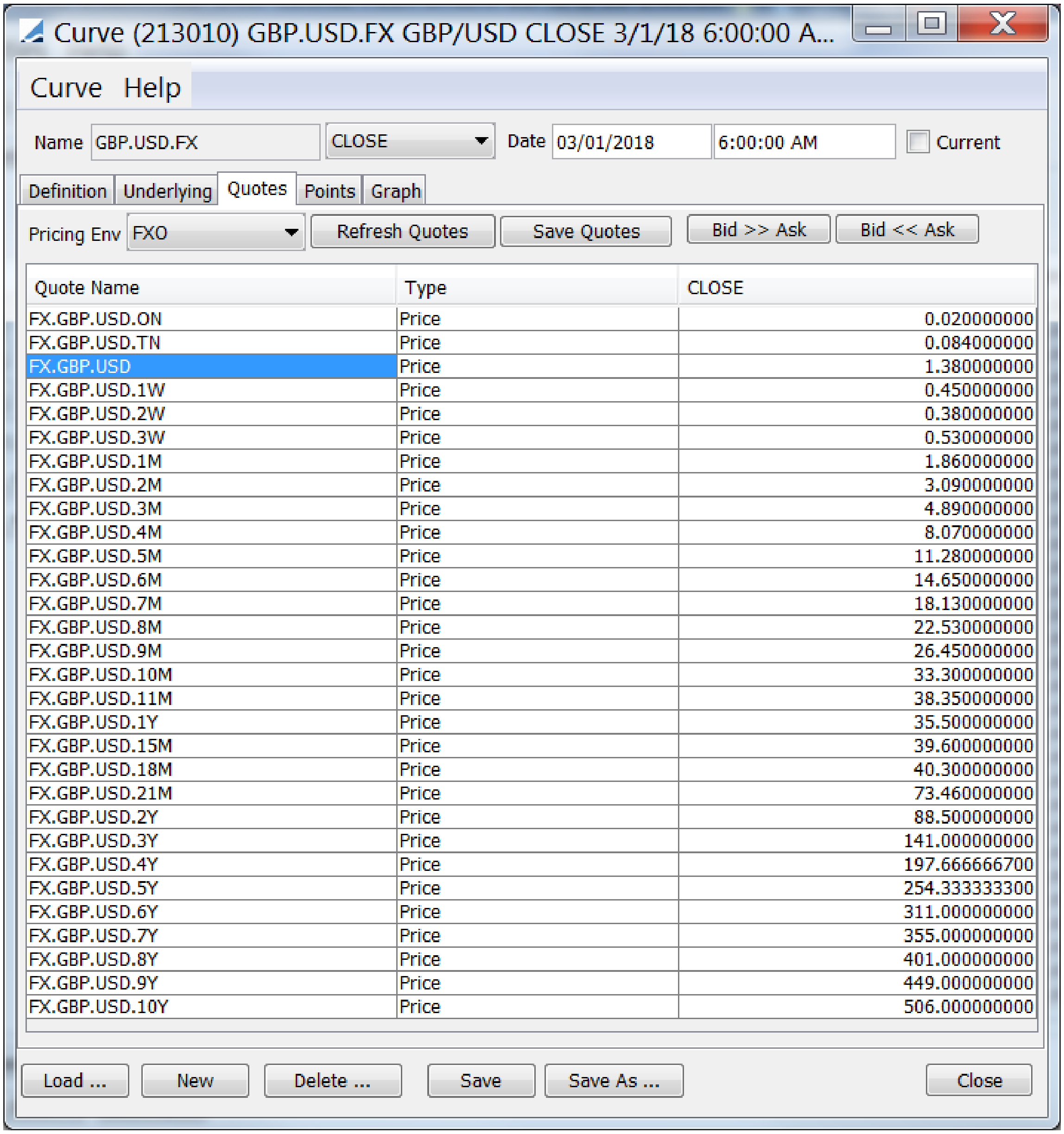

Curve (154001) USD.FF.1D USD CLOSE FEDFUNDS 1D 3/1/18 1:00:10 AM Us
Curve Utilities Help
Name USD.FF.1D CLOSE Date 03/01/2018 1:00:10 AM Cu
Definition Underlying Quotes Resets/Turns Points Graph
Refresh Resets Save Resets Bid >> Ask Bid << Ask
Resets
Quote Name Type +/-(bps) CLOSE Future Convexity [bp]
MM.USD.FEDFUNDS.1D.FEDFUNDS1 Yield 0.90900000 0.00000000



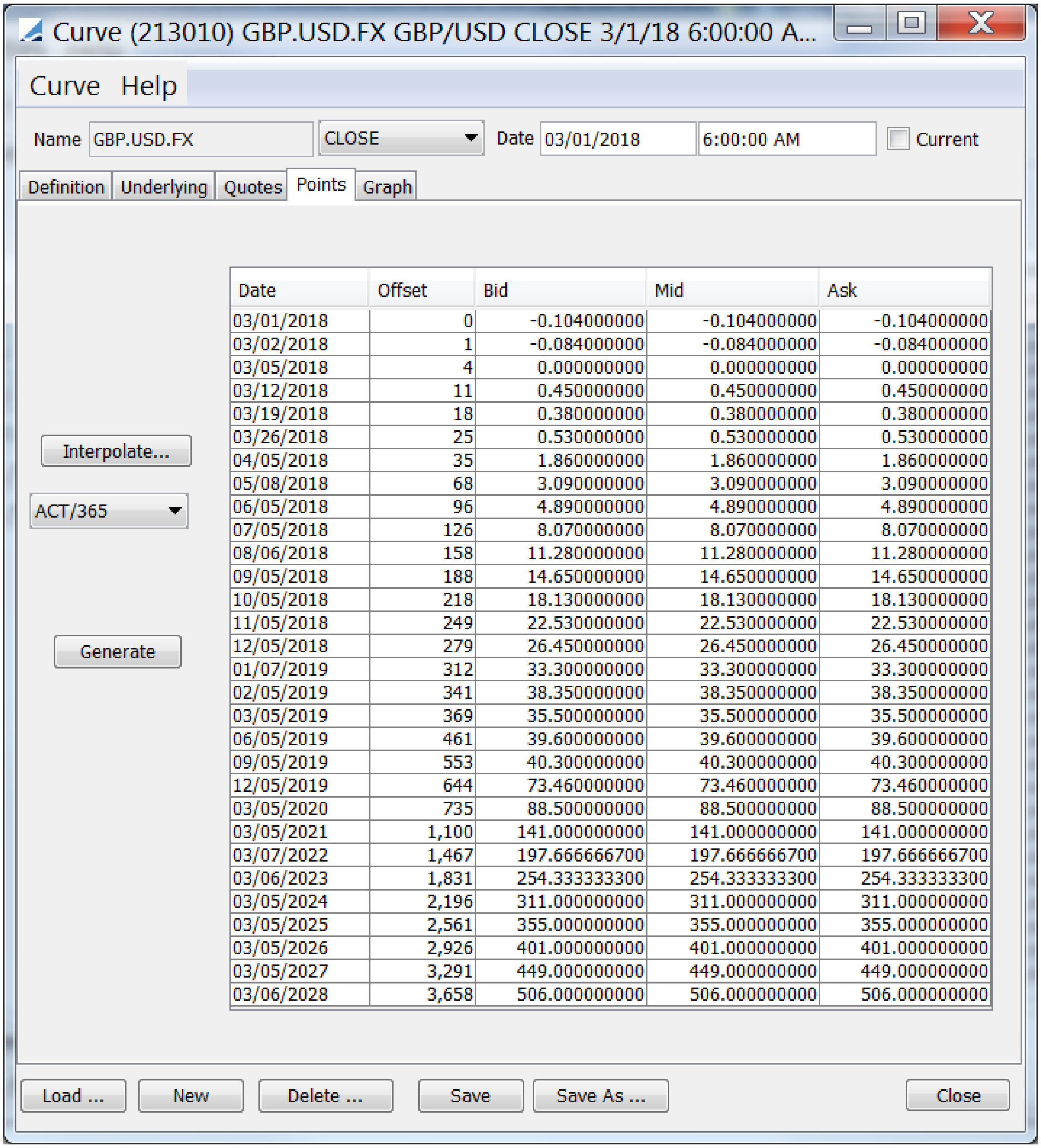
Date	Offset	Zero Bid	Zero Mid	Zero Ask	Df Bid	Df Mid	Df Ask	ConvexityBid	ConvexityMid	ConvexityAsk
03/02/2018	1	0.02500077	0.02500077	0.02500077	0.99999931	0.99999931	0.99999931	0.00000000	0.00000000	0.00000000
03/08/2018	7	0.21977607	0.21977607	0.21977607	0.99995728	0.99995728	0.99995728	0.00000000	0.00000000	0.00000000
03/15/2018	14	0.28294614	0.28294614	0.28294614	0.99989001	0.99989001	0.99989001	0.00000000	0.00000000	0.00000000
03/22/2018	21	0.29797681	0.29797681	0.29797681	0.99982626	0.99982626	0.99982626	0.00000000	0.00000000	0.00000000
04/02/2018	32	0.31845386	0.31845386	0.31845386	0.99971708	0.99971708	0.99971708	0.00000000	0.00000000	0.00000000
05/01/2018	61	0.33654555	0.33654555	0.33654555	0.99943014	0.99943014	0.99943014	0.00000000	0.00000000	0.00000000
06/01/2018	92	0.35437825	0.35437825	0.35437825	0.99909518	0.99909518	0.99909518	0.00000000	0.00000000	0.00000000
07/02/2018	123	0.36874262	0.36874262	0.36874262	0.99874150	0.99874150	0.99874150	0.00000000	0.00000000	0.00000000
08/01/2018	153	0.38108580	0.38108580	0.38108580	0.99838247	0.99838247	0.99838247	0.00000000	0.00000000	0.00000000
09/04/2018	187	0.39205516	0.39205516	0.39205516	0.99796656	0.99796656	0.99796656	0.00000000	0.00000000	0.00000000
10/01/2018	214	0.40357814	0.40357814	0.40357814	0.99760503	0.99760503	0.99760503	0.00000000	0.00000000	0.00000000
11/01/2018	245	0.41101862	0.41101862	0.41101862	0.99720813	0.99720813	0.99720813	0.00000000	0.00000000	0.00000000
12/03/2018	277	0.42133721	0.42133721	0.42133721	0.99676499	0.99676499	0.99676499	0.00000000	0.00000000	0.00000000
01/02/2019	307	0.43154795	0.43154795	0.43154795	0.99632859	0.99632859	0.99632859	0.00000000	0.00000000	0.00000000
02/01/2019	337	0.43970212	0.43970212	0.43970212	0.99589461	0.99589461	0.99589461	0.00000000	0.00000000	0.00000000
03/01/2019	365	0.44780070	0.44780070	0.44780070	0.99547262	0.99547262	0.99547262	0.00000000	0.00000000	0.00000000
09/03/2019	551	0.49275305	0.49275305	0.49275305	0.99249112	0.99249112	0.99249112	0.00000000	0.00000000	0.00000000
03/02/2020	732	0.53691981	0.53691981	0.53691981	0.98914925	0.98914925	0.98914925	0.00000000	0.00000000	0.00000000
03/01/2021	1,096	0.61140375	0.61140375	0.61140375	0.98157227	0.98157227	0.98157227	0.00000000	0.00000000	0.00000000
03/01/2022	1,461	0.70102401	0.70102401	0.70102401	0.97197520	0.97197520	0.97197520	0.00000000	0.00000000	0.00000000
03/01/2023	1,826	0.80411360	0.80411360	0.80411360	0.96007345	0.96007345	0.96007345	0.00000000	0.00000000	0.00000000
03/03/2025	2,559	0.99951954	0.99951954	0.99951954	0.93149863	0.93149863	0.93149863	0.00000000	0.00000000	0.00000000
03/01/2028	3,653	1.24652899	1.24652899	1.24652899	0.88135799	0.88135799	0.88135799	0.00000000	0.00000000	0.00000000
03/01/2030	4,383	1.37594343	1.37594343	1.37594343	0.84600192	0.84600192	0.84600192	0.00000000	0.00000000	0.00000000
03/01/2033	5,479	1.51103511	1.51103511	1.51103511	0.79490086	0.79490086	0.79490086	0.00000000	0.00000000	0.00000000
03/01/2038	7,305	1.65133447	1.65133447	1.65133447	0.71577206	0.71577206	0.71577206	0.00000000	0.00000000	0.00000000
03/02/2043	9,132	1.71845924	1.71845924	1.71845924	0.64727624	0.64727624	0.64727624	0.00000000	0.00000000	0.00000000
03/02/2048	10,959	1.75601760	1.75601760	1.75601760	0.58661235	0.58661235	0.58661235	0.00000000	0.00000000	0.00000000
03/01/2058	14,610	1.75351805	1.75351805	1.75351805	0.49160448	0.49160448	0.49160448	0.00000000	0.00000000	0.00000000
03/01/2068	18,263	1.72285234	1.72285234	1.72285234	0.41805775	0.41805775	0.41805775	0.00000000	0.00000000	0.00000000

3.3 The FX Curve



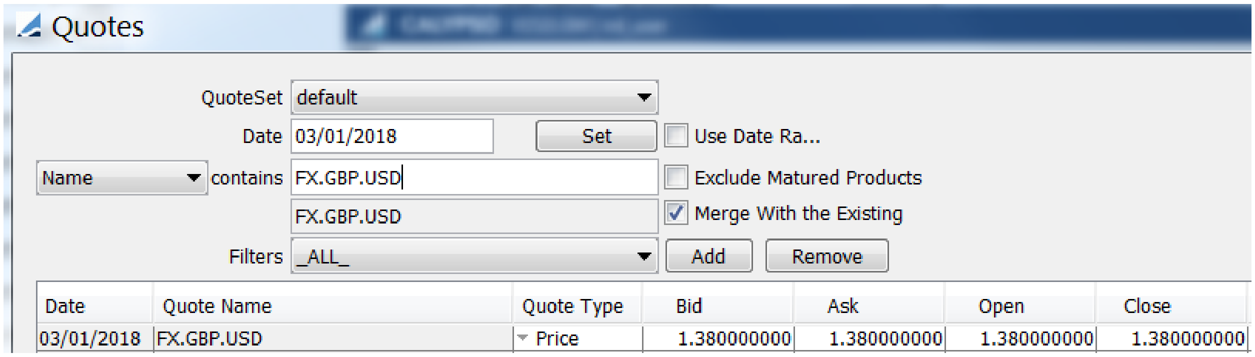


Quote Name	Type	CLOSE
FX.GBP.USD.ON	Price	0.020000000
FX.GBP.USD.TN	Price	0.084000000
FX.GBP.USD	Price	1.380000000
FX.GBP.USD.1W	Price	0.450000000
FX.GBP.USD.2W	Price	0.380000000
FX.GBP.USD.3W	Price	0.530000000
FX.GBP.USD.1M	Price	1.860000000
FX.GBP.USD.2M	Price	3.090000000
FX.GBP.USD.3M	Price	4.890000000
FX.GBP.USD.4M	Price	8.070000000
FX.GBP.USD.5M	Price	11.280000000
FX.GBP.USD.6M	Price	14.650000000
FX.GBP.USD.7M	Price	18.130000000
FX.GBP.USD.8M	Price	22.530000000
FX.GBP.USD.9M	Price	26.450000000
FX.GBP.USD.10M	Price	33.300000000
FX.GBP.USD.11M	Price	38.350000000
FX.GBP.USD.1Y	Price	35.500000000
FX.GBP.USD.15M	Price	39.600000000
FX.GBP.USD.18M	Price	40.300000000
FX.GBP.USD.21M	Price	73.460000000
FX.GBP.USD.2Y	Price	88.500000000
FX.GBP.USD.3Y	Price	141.000000000
FX.GBP.USD.4Y	Price	197.666666700
FX.GBP.USD.5Y	Price	254.333333300
FX.GBP.USD.6Y	Price	311.000000000
FX.GBP.USD.7Y	Price	355.000000000
FX.GBP.USD.8Y	Price	401.000000000
FX.GBP.USD.9Y	Price	449.000000000
FX.GBP.USD.10Y	Price	506.000000000

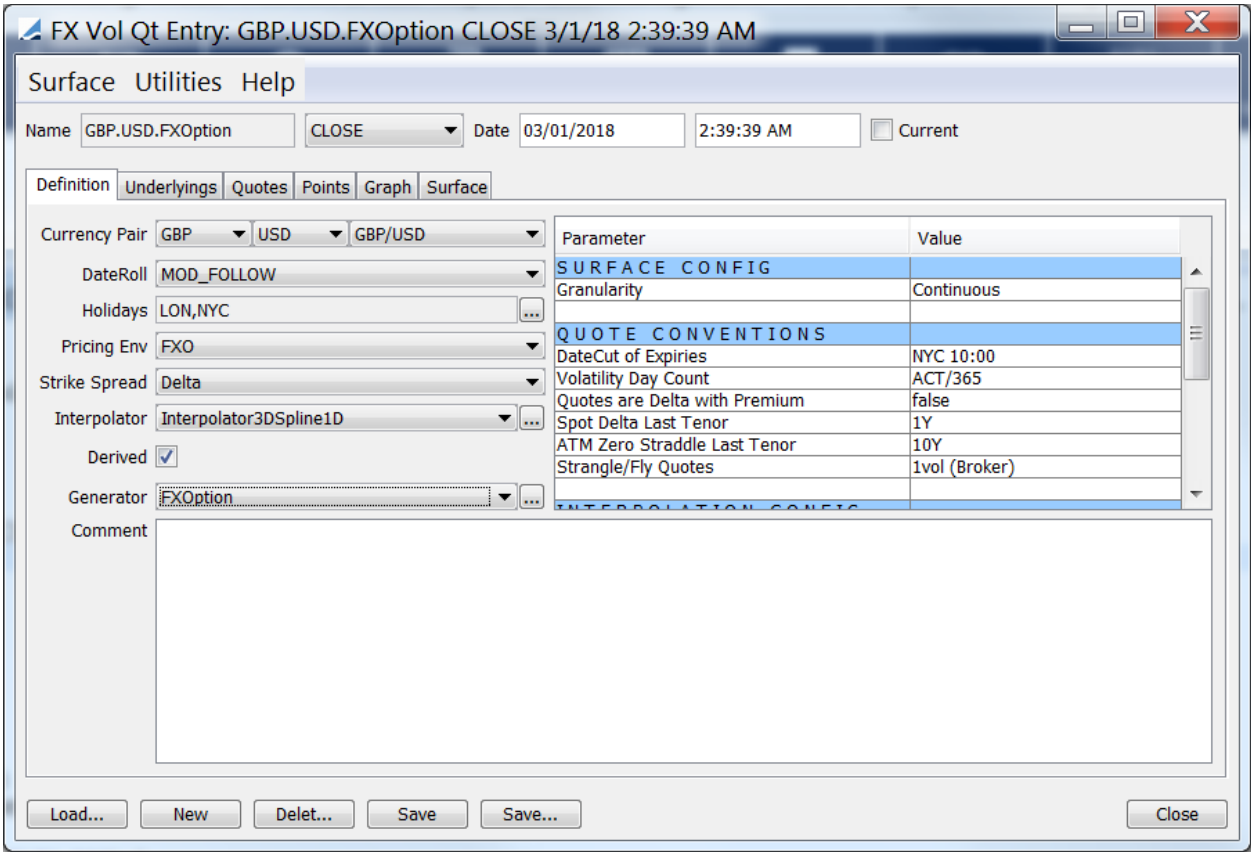


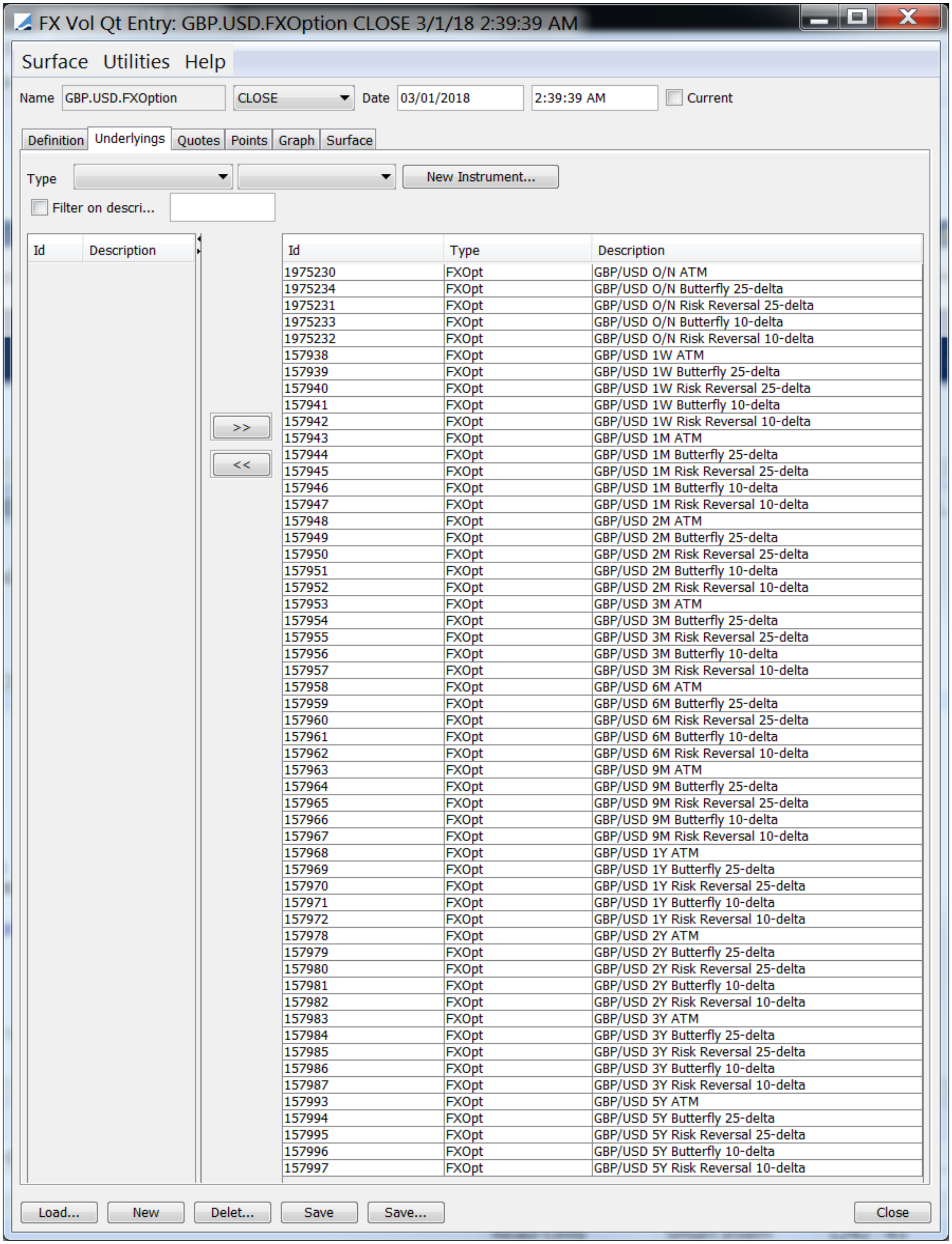
Date	Offset	Bid	Mid	Ask
03/01/2018	0	-0.104000000	-0.104000000	-0.104000000
03/02/2018	1	-0.084000000	-0.084000000	-0.084000000
03/05/2018	4	0.000000000	0.000000000	0.000000000
03/12/2018	11	0.450000000	0.450000000	0.450000000
03/19/2018	18	0.380000000	0.380000000	0.380000000
03/26/2018	25	0.530000000	0.530000000	0.530000000
04/05/2018	35	1.860000000	1.860000000	1.860000000
05/08/2018	68	3.090000000	3.090000000	3.090000000
06/05/2018	96	4.890000000	4.890000000	4.890000000
07/05/2018	126	8.070000000	8.070000000	8.070000000
08/06/2018	158	11.280000000	11.280000000	11.280000000
09/05/2018	188	14.650000000	14.650000000	14.650000000
10/05/2018	218	18.130000000	18.130000000	18.130000000
11/05/2018	249	22.530000000	22.530000000	22.530000000
12/05/2018	279	26.450000000	26.450000000	26.450000000
01/07/2019	312	33.300000000	33.300000000	33.300000000
02/05/2019	341	38.350000000	38.350000000	38.350000000
03/05/2019	369	35.500000000	35.500000000	35.500000000
06/05/2019	461	39.600000000	39.600000000	39.600000000
09/05/2019	553	40.300000000	40.300000000	40.300000000
12/05/2019	644	73.460000000	73.460000000	73.460000000
03/05/2020	735	88.500000000	88.500000000	88.500000000
03/05/2021	1,100	141.000000000	141.000000000	141.000000000
03/07/2022	1,467	197.666666700	197.666666700	197.666666700
03/06/2023	1,831	254.333333300	254.333333300	254.333333300
03/05/2024	2,196	311.000000000	311.000000000	311.000000000
03/05/2025	2,561	355.000000000	355.000000000	355.000000000
03/05/2026	2,926	401.000000000	401.000000000	401.000000000
03/05/2027	3,291	449.000000000	449.000000000	449.000000000
03/06/2028	3,658	506.000000000	506.000000000	506.000000000

3.4 Spot FX Quote

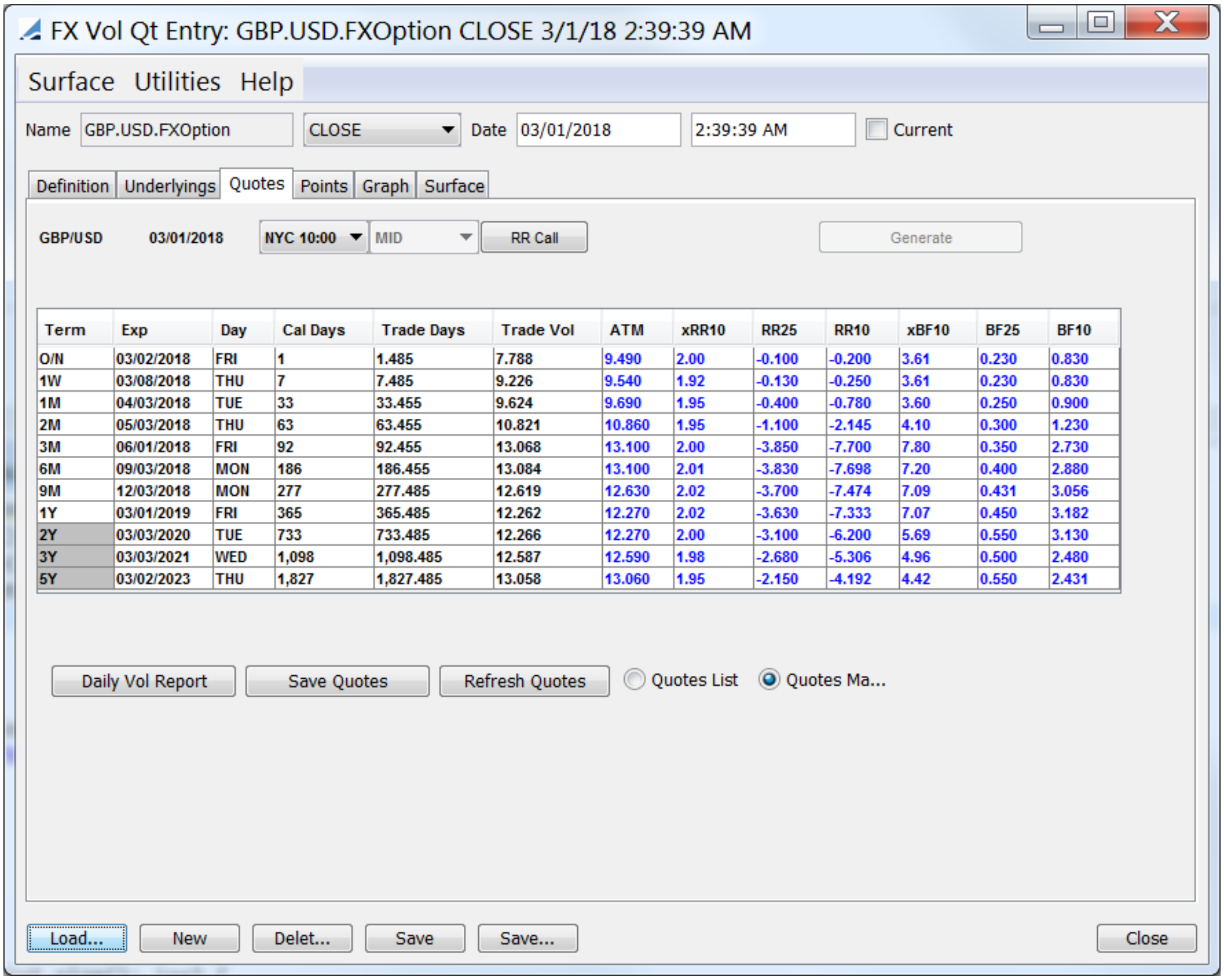


3.5 FX Option Volatility Surface

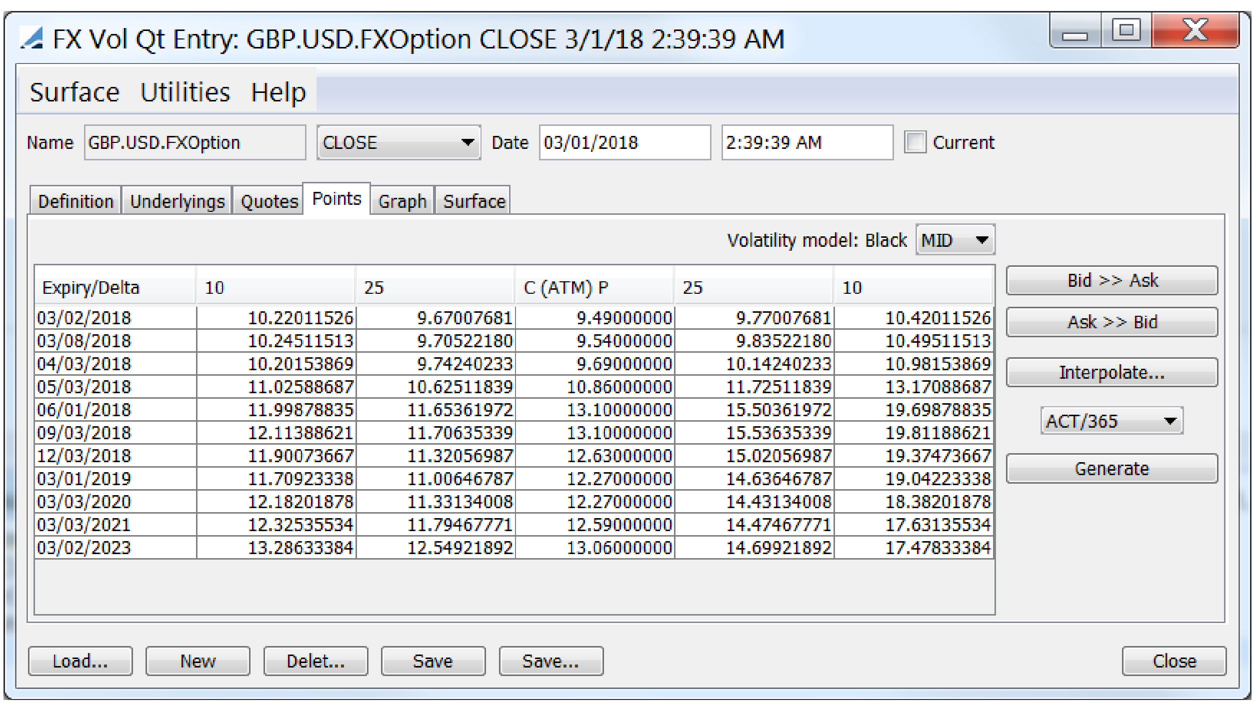




Id	Type	Description
1975230	FXOpt	GBP/USD O/N ATM
1975234	FXOpt	GBP/USD O/N Butterfly 25-delta
1975231	FXOpt	GBP/USD O/N Risk Reversal 25-delta
1975233	FXOpt	GBP/USD O/N Butterfly 10-delta
1975232	FXOpt	GBP/USD O/N Risk Reversal 10-delta
157938	FXOpt	GBP/USD 1W ATM
157939	FXOpt	GBP/USD 1W Butterfly 25-delta
157940	FXOpt	GBP/USD 1W Risk Reversal 25-delta
157941	FXOpt	GBP/USD 1W Butterfly 10-delta
157942	FXOpt	GBP/USD 1W Risk Reversal 10-delta
157943	FXOpt	GBP/USD 1M ATM
157944	FXOpt	GBP/USD 1M Butterfly 25-delta
157945	FXOpt	GBP/USD 1M Risk Reversal 25-delta
157946	FXOpt	GBP/USD 1M Butterfly 10-delta
157947	FXOpt	GBP/USD 1M Risk Reversal 10-delta
157948	FXOpt	GBP/USD 2M ATM
157949	FXOpt	GBP/USD 2M Butterfly 25-delta
157950	FXOpt	GBP/USD 2M Risk Reversal 25-delta
157951	FXOpt	GBP/USD 2M Butterfly 10-delta
157952	FXOpt	GBP/USD 2M Risk Reversal 10-delta
157953	FXOpt	GBP/USD 3M ATM
157954	FXOpt	GBP/USD 3M Butterfly 25-delta
157955	FXOpt	GBP/USD 3M Risk Reversal 25-delta
157956	FXOpt	GBP/USD 3M Butterfly 10-delta
157957	FXOpt	GBP/USD 3M Risk Reversal 10-delta
157958	FXOpt	GBP/USD 6M ATM
157959	FXOpt	GBP/USD 6M Butterfly 25-delta
157960	FXOpt	GBP/USD 6M Risk Reversal 25-delta
157961	FXOpt	GBP/USD 6M Butterfly 10-delta
157962	FXOpt	GBP/USD 6M Risk Reversal 10-delta
157963	FXOpt	GBP/USD 9M ATM
157964	FXOpt	GBP/USD 9M Butterfly 25-delta
157965	FXOpt	GBP/USD 9M Risk Reversal 25-delta
157966	FXOpt	GBP/USD 9M Butterfly 10-delta
157967	FXOpt	GBP/USD 9M Risk Reversal 10-delta
157968	FXOpt	GBP/USD 1Y ATM
157969	FXOpt	GBP/USD 1Y Butterfly 25-delta
157970	FXOpt	GBP/USD 1Y Risk Reversal 25-delta
157971	FXOpt	GBP/USD 1Y Butterfly 10-delta
157972	FXOpt	GBP/USD 1Y Risk Reversal 10-delta
157978	FXOpt	GBP/USD 2Y ATM
157979	FXOpt	GBP/USD 2Y Butterfly 25-delta
157980	FXOpt	GBP/USD 2Y Risk Reversal 25-delta
157981	FXOpt	GBP/USD 2Y Butterfly 10-delta
157982	FXOpt	GBP/USD 2Y Risk Reversal 10-delta
157983	FXOpt	GBP/USD 3Y ATM
157984	FXOpt	GBP/USD 3Y Butterfly 25-delta
157985	FXOpt	GBP/USD 3Y Risk Reversal 25-delta
157986	FXOpt	GBP/USD 3Y Butterfly 10-delta
157987	FXOpt	GBP/USD 3Y Risk Reversal 10-delta
157993	FXOpt	GBP/USD 5Y ATM
157994	FXOpt	GBP/USD 5Y Butterfly 25-delta
157995	FXOpt	GBP/USD 5Y Risk Reversal 25-delta
157996	FXOpt	GBP/USD 5Y Butterfly 10-delta
157997	FXOpt	GBP/USD 5Y Risk Reversal 10-delta



Term	Exp	Day	Cal Days	Trade Days	Trade Vol	ATM	xRR10	RR25	RR10	xBF10	BF25	BF10
O/N	03/02/2018	FRI	1	1.485	7.788	9.490	2.00	-0.100	-0.200	3.61	0.230	0.830
1W	03/08/2018	THU	7	7.485	9.226	9.540	1.92	-0.130	-0.250	3.61	0.230	0.830
1M	04/03/2018	TUE	33	33.455	9.624	9.690	1.95	-0.400	-0.780	3.60	0.250	0.900
2M	05/03/2018	THU	63	63.455	10.821	10.860	1.95	-1.100	-2.145	4.10	0.300	1.230
3M	06/01/2018	FRI	92	92.455	13.068	13.100	2.00	-3.850	-7.700	7.80	0.350	2.730
6M	09/03/2018	MON	186	186.455	13.084	13.100	2.01	-3.830	-7.698	7.20	0.400	2.880
9M	12/03/2018	MON	277	277.485	12.619	12.630	2.02	-3.700	-7.474	7.09	0.431	3.056
1Y	03/01/2019	FRI	365	365.485	12.262	12.270	2.02	-3.630	-7.333	7.07	0.450	3.182
2Y	03/03/2020	TUE	733	733.485	12.266	12.270	2.00	-3.100	-6.200	5.69	0.550	3.130
3Y	03/03/2021	WED	1,098	1,098.485	12.587	12.590	1.98	-2.680	-5.306	4.96	0.500	2.480
5Y	03/02/2023	THU	1,827	1,827.485	13.058	13.060	1.95	-2.150	-4.192	4.42	0.550	2.431



Expiry/Delta	10	25	C (ATM) P	25	10
03/02/2018	10.22011526	9.67007681	9.49000000	9.77007681	10.42011526
03/08/2018	10.24511513	9.70522180	9.54000000	9.83522180	10.49511513
04/03/2018	10.20153869	9.74240233	9.69000000	10.14240233	10.98153869
05/03/2018	11.02588687	10.62511839	10.86000000	11.72511839	13.17088687
06/01/2018	11.99878835	11.65361972	13.10000000	15.50361972	19.69878835
09/03/2018	12.11388621	11.70635339	13.10000000	15.53635339	19.81188621
12/03/2018	11.90073667	11.32056987	12.63000000	15.02056987	19.37473667
03/01/2019	11.70923338	11.00646787	12.27000000	14.63646787	19.04223338
03/03/2020	12.18201878	11.33134008	12.27000000	14.43134008	18.38201878
03/03/2021	12.32535534	11.79467771	12.59000000	14.47467771	17.63135534
03/02/2023	13.28633384	12.54921892	13.06000000	14.69921892	17.47833384

3.6 FX Option Pricing Parameters Setting

Product Type	Name	Value
FXOption	USE_FX_MID	false
FXOption	ROLL_VALUE_DT_B	true
FXOption	QuoteUsage	CLOSE
FXOption	INSTANCE_TYPE	CLOSE
FXOption	FX_POINTS	true
FXOption	USE_VOLATILITY_ADJ	false
FXOption	ZD_PRICING	true
FXOption	VV_REFERENCE_DELTA_TYPE	Market Concordant
FXOption	NPV_INCLUDE_COST	true
FXOption	VV_EXPIRY_BARRIER_MODEL	Market
FXOption	USE_RT_FX_FWD_PTS	false
FXOption	VV_SPARE_TERMINAL_ADJUSTMENT	true
FXOption	VV_WEIGHT_POLICY	Expected Life Fraction
FXOption	MKT_ASIAN_CASH_IN_PRIMARY_MODEL	Theoretical
FXOption	CURVE_USAGE	MID
FXOption	FXOPT_VEGA_DBL_SIDE	true
FXOption	INCLUDE_FEES	true
FXOption	USE_ATM_VOL	false
FXOption	VALUE_SETTLED_TRADE	false
FXOption	ROLL_ATM_VOL	false
FXOption	USE_BUY_SELL_CURVE_SIDE	false
FXOption	TV_USE_FLAT_TERM_STRUCTURE	false
FXOption	NPV_INCLUDE_CASH	false
FXOption	VV_WEIGHT_USE_SYMMETRIC_PROB	true
FXOption	VV_CONSISTENCY_ENFORCEMENT	Basic
FXOption	VV_TERMINAL_REF_MODEL	Market
FXOption	ADJUST_FOR_SPOT_MISMATCH	true
FXOption	VALUE_INTRADAY_OPTIONS	true
FXOption	VV_HEDGE_EXPIRY	Barrier End Date
FXOption	TV_ASIAN_ARITH_PROXY	Log Normal
FXOption	VV_HEDGE_POLICY	Synthetic
FXOption	TV_ATM_TYPE	Market Concordant
FXOption	RHO_SHIFT_UNDERLYINGS	false
FXOption	ADJUST_FX_RATE	true
FXOption	USE_DELTA_TERM_B	false
FXOption	VV_REFERENCE_DELTA	25

3.7 Tested Version