Nasdaq Calypso Analytics Library

Version 16.1 / Version 17 / Version 18

This document guides the user through the installation, configuration and functionality of the Calypso Analytics Library.

Contents

Section 1. Overview of Calypso Analytics

The Calypso analytics library allows the user to gain access to the latest analytics developed by the Financial Engineering team at Calypso. The module will allow the user to price various structures including interest rate derivatives (IRD) (e.g. callable inverse floating swaps, TaRNs and Snowballs), equity derivatives (e.g. variance swaps and basket options) and inflation products (e.g. YoY and LPI swaps). It also includes tools to provide market data generation, e.g. ATM cap stripping and a local volatility surface generator.

The use of separate analytics jars creates the benefit of efficient installation and configuration of the latest analytics without the need in many cases for upgrade of the core Calypso platform.

The Calypso analytics Library (CALIB) is compatible with Calypso version 10.0 onwards. The table below provides a summary of the functionality available:

Analytics Description	**Product Coverage – Trade valuation**					
	IRD	**Bonds**	**Equity**	**Inflation**	**FX**	**Commodity**
PricerLGMM1FBackward	X	X				
PricerLGMM1FForward	X	X				
PricerSwaptionLGMM1F	X					
PricerLGMM1FSaliTree		X				
PricerSwapLGMM1F	X					
PricerLiborMarketModel	X					
PricerCarrLeeVolatilityDerivative			X			
PricerBlackNFMonteCarloExotic			X		X	X
PricerLocalVolatilityNFMonteCarloExotic			X		X	
PricerSVJMonteCarloExotic			X			
PricerCappedSwapLPI				X		
PricerCapFloorInflationBlack				X		
PricerSwapInflation				X		
PricerJYAnalytic				X		
PricerVarianceSwapReplicationFX					X	
PricerIDIAnalytic	X					
PricerIDIAnalyticBarrier	X					

Table 1. Summary of the Pricing analytics contained in the Calypso analytics Library (CALIB)

Analytics Description	Product Coverage – Market Data Generation		
	IRD	Equity	Inflation
Generator CapATM	X		
Generator CapBlack	X		
Generator Spline and SplineSimple		X	
Generator SVI and SVISimple		X	
Generator SVJ and HestonSimple		X	
Generator DividendImplied		X	
Generator InflationKerkhof			X

Table 2. Summary of the market data generators contained in the Calypso analytics Library (CALIB)

The IRD and bond pricers are based on the Linear Gauss Markov model (LGMM) which is a one factor model equivalent to the Hull-White approach. Two versions of the pricer are available allowing the user to price a number of different trade types. Example transactions and test cases can be found in separate documentation.

The equity variance swap pricer provides valuation of variance swaps using the replication methodology introduced in a Goldman's paper, further details are documented in section 4.1. A general Monte Carlo based pricer has also been developed to support the pricing of structured equity basket options see section 4.2.

Within CALIB there is also support for pricing of some common inflation products, Y-on-Y (or period on period) swaps, Inflation Caps and floors and LPI swaps. Y-on-Y swaps are supported via the Jarrow Yildirim model see section 5.1.

The following files are required to be deployed to gain access to the analytics, the module is designed so that upon request it can be made available on earlier version of Calypso without effort. These files can be requested through Calypso support desk:

CALIB.jar – Calypso analytics Library

CALIBINTEGRATION.jar – Integration layer to allow the analytics module and the functionality contained to be compatible with any version of Calypso from v10.0 onwards.*

Calypso-pricingscript.jar - PricerBlackNFMonteCarloExotic has a dependency on the pricing script functionality therefore requires to be included on the class path.

*Note some of the functionality available in the Calypso analytics library cannot be back ported to earlier versions of Calypso because the user interface is not available. E.g. (see section 3.2.4) the user defined calibration framework is only available for Calypso v10.

Section 2. Installation

2.1 Basic Setup

Place the Calypso Analytics JAR files (*CALIB.jar*, *CALIBINTEGRATION.jar and Calypso-pricingscript.jar*) onto the *Calypso* class path in runjava.bat.

2.2 Configuration of Functionality - Execute SQL

The Calypso environment is required to be configured for the functionality in the analytics jars. For the LGM pricers this can be automated by running the Execute SQL functionality from the AppStarter with SchemaDataLGMM.xml. If this is performed successfully the following settings will be configured within the specified Calypso environment:

Configuration for PricerLGMM1FForward, PricerLGMM1FBackward and PricerSwaptionLGMM1F:

- Add the supported pricers to applicable product types
- Add the required pricing parameters for the pricers
- Add the required pricing measures for the pricers
- Add the required domain values for user defined calibration framework

Note the SchemaDataLGMM.xml file can be requested from the Calypso support desk and are also contained within CALIBINTEGRATION.jar.

Manual configuration of the LGM pricers can also be performed. Details of the configuration steps contained in SchemaDataLGMM.xml can be found in Appendix 1: Registering Functionality - CALIB

Configuration of the other analytics offered in CALIB is required to be performed manually; this process will be described later in the documentation.

Section 3. IRD / Bond Pricing

3.1 Pricers for Callable IRD Options

3.1.1 PricerSwaptionLGMM1F

Overview

PricerSwaptionLGMM1F supports the valuation of non-vanilla swaptions, either fixed end date or fixed tenor, using the so-called LGM model, a term coined by P.Hagan in an unpublished, but widely known, working paper[1]. PricerSwaptionLGMM1F is different in nature to alternative implementations of the LGM models in Calypso i.e. backward and forward LGM model described in this document or SwaptionLGMM (core Calypso). It is designed as dedicated and optimized pricer for specific product payoffs, listed below. PricerLGMM1FBackward and PricerLGMM1FForward are designed to be more generic in nature and provide increased flexibility and product coverage i.e. support of eXSP.

The primary function of PricerSwaptionLGMM1F is to support the following trade types:

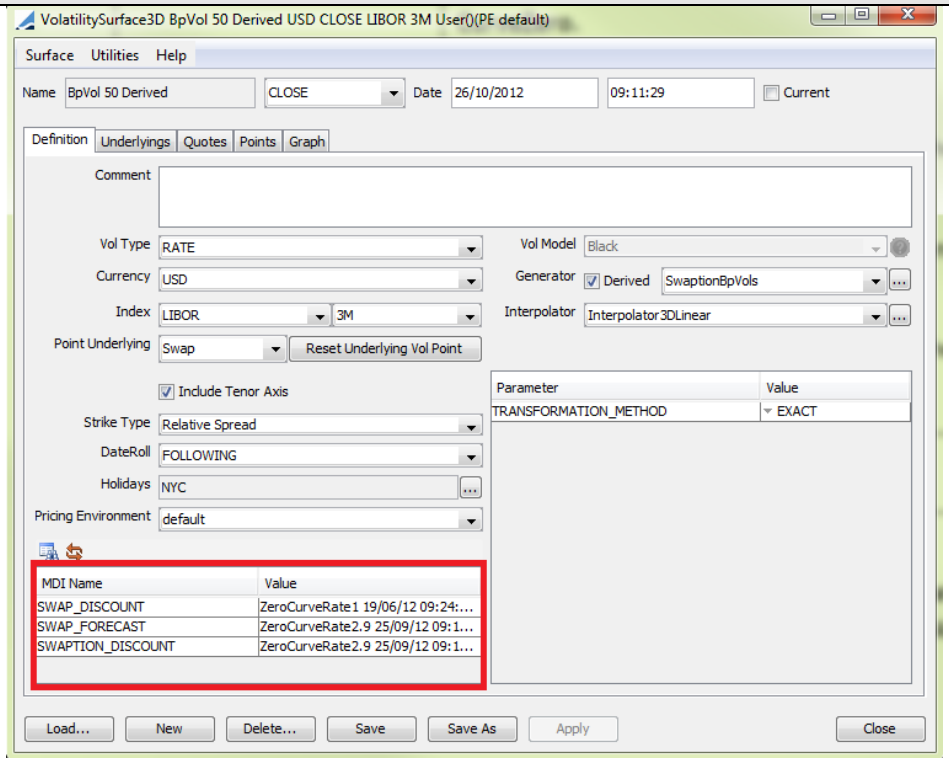
- Fixed Tenor – the underlying swaps corresponding to the exercise dates all have the same relative maturity
- Fixed End Date – the underlying swaps corresponding to the exercise dates all shared the same end-date
- Zero Coupon Swaptions
- American Swaptions
- Bermudan Amortising Swaptions
- Options on swaps with non-matching schedules (mid-period exercise dates)
- Compounding swaps
- Averaging Swaps

Note there is also an implementation of the LGMM1F pricer for cancellable swaps (PricerSwapLGMM1F), this uses exactly the same methodology as PricerSwaptionLGMM1F.

Market Data Configuration

Market Data	Description
Discount Curve	This curve will be used for both vanilla and trade discounting if no overrides on the volatility surface. N.B. This curve may not be used at all if both discount curves are set in the surface.
Forecast Curve	This curve will be used for both vanilla and trade forecasting if no overrides on the volatility surface.
Swaption Volatility	Using the same generator and surface underlyings as before. In the MDI parameter area, you will see the below three new items, all of kind CurveZero. SWAP_DISCOUNT – this MDI will be used as the vanilla discount curve. SWAP_FORECAST – this MDI will be used as the vanilla forecast curve. SWAPTION_DISCOUNT – this MDI will be used as the trade funding curve.

[1] The paper is "Methodology for callable swaps and Bermudan 'exercise into' swaptions", P.S.Hagan circulated and discussed on the Wilmott forums (www.wilmott.com).

Market Data	Description
	
LGMM Mean Reversion Matrix	Mean reversion matrix can be constant or a time dependent mean reversion. Configuration for constant mean reversion same as PricerLGMM1FBackward
	Description of time dependent mean reversion

Pricing Parameters

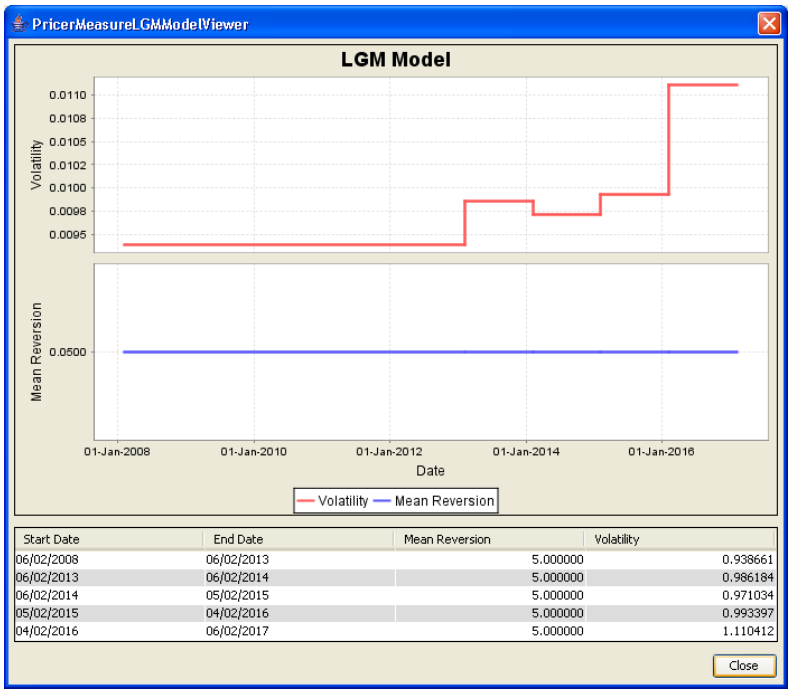
Pricing Parameter	Type	Description	Typical Value
LGMM_MEAN_REV	Rate	Same as PricerLGMM1Fbackward	
LGMM_MODEL_VOL	Rate	Same as PricerLGMM1Fbackward	
LGMM_IR_RATE	Rate	Same as PricerLGMM1Fbackward	
LGMM_CALIBRATION_INSTRUMENTS	Choice	Same as PricerLGMM1Fbackward – Calibration for PricerSwaptionLGMM1F is controlled via pricing parameters only, it does not use the calibration framework	
LGMM_CALIBRATION_SCHEME	Choice	Same as PricerLGMM1Fbackward - Calibration for PricerSwaptionLGMM1F is controlled via pricing parameters only, it does not use the calibration framework	
LGMM_CONTROL_VARIATE	Boolean	When pricing the Bermudan, also price the first European numerically and use it as a control variate.	FALSE
LGMM_LATTICE_NODES	Integer	The number of nodes in the discretisation of the state space of the Markov process.	35
LGMM_QUAD_ORDER	Integer	The number of point in the local quadrature rule used in the roll-back routine.	20
LGMM_LATTICE_CUTOFF	Double	The number of deviations to the outer model node in the state space discretisation.	6
LGMM_RISK_OPTIMISE	Boolean	Controls whether or not optimization techniques are used within scenario analysis, in particular for shift and re-values of the volatility surface.	TRUE
LGMM_MIN_MEAN_REVERSION	Rate	When using CALIBRATION_SCHEME=BEST_FIT_LM the user can control the minimum level of mean reversion permitted within the calibration.	-1%
LGMM_MAX_MEAN_REVERSION	Rate	When using CALIBRATION_SCHEME=BEST_FIT_LM the user can control the maximum level of mean reversion permitted within the calibration.	5%
LGMM_MIN_SIGMA	Rate	When using CALIBRATION_SCHEME=BEST_FIT_LM the user can control the minimum level of model volatility permitted within the calibration.	0.01%

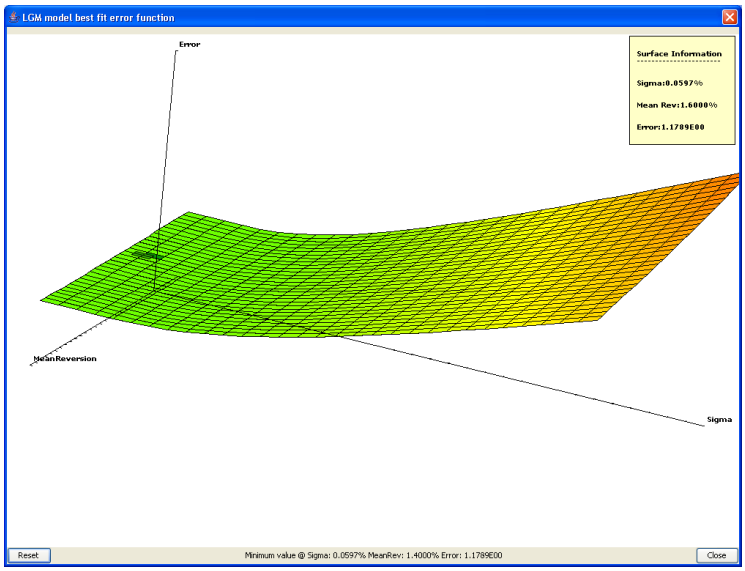
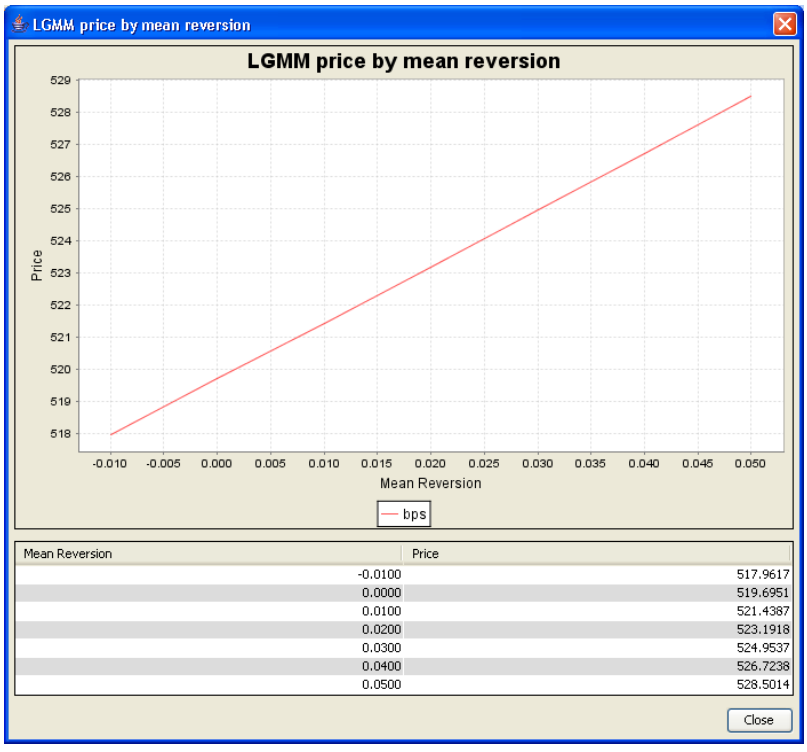
Pricing Parameter	Type	Description	Typical Value
LGMM_MAX_SIGMA	Rate	When using CALIBRATION_SCHEME=BEST_FIT_LM the user can control the maximum level of model volatility permitted within the calibration.	2%
LGMM_BEST_FIT_GRAPH_MESH_SIZE	Integer	When the Pricer Measure LGMM_BEST_FIT_ERR is used, this parameter controls how fine the mesh used in the brute force search is.	30
***MAX_DAYS_SPACING** (*Implemented and applicable for American fixed tenor swaptions only)	Integer	Maximum number of days between time splices in the lattice to be used when pricing American Fixed tenor swaptions. User enters an integer related to the number of days to approximate exercise schedule used in pricing e.g. 30 days	30
LGMM_CALIB_SPACING	Integer	For American swaptions a flag pertaining to the minimum number of days between successive exercise dates becomes visible. Ensure that this spacing is less than or equal to the frequency of the exercise schedule	7
LGMM_CALIB_MIN_CALENDAR_DAYS	Integer	Parameter to control the construction of the calibration instruments, the aim is to remove instruments with short dated expiries from the calibration process. If >0, the lag between the value date and the next exercise date will be at least the number of days assigned to the parameter.	7
LGMM_CALIBRATE_TO_OTM_OPTIONS	Boolean	If set to true it will calibrate to OTM options when valuing regular (with no variation in the notional or coupon) bermudan options.	False
LGMM_ADJUST_FOR_MIDFLOW_EXERCISE	Boolean	If set to true, a flat forward approximation is used in γ(Tex, Te) * (F(Tex, Tex, Te) + [F(t, Ts, Te) - F(t, Tex, Te)])	True
LGMM_CALIBRATE_TO_STD_OPTIONS	Boolean	if set to true, it calibrates to vanilla swaptions as specified by the point underlying swap on the volatility surface used. Note that Bermudan options on irregular swaps (i.e. with amortising notional, fixed coupon schedule, zero coupon payment) use standard swaption calibration always.	True

Pricing Parameter	Type	Description	Typical Value
CALIBRATION_VOL_TYPE	Choice	BLACK_VOL, BP_VOL The volatility model used when calibrating the model.	BLACK_VOL
SWAP_REPLICATION_METHOD	Choice	swap_rate_offset, overlap_negative_weights pv_ratio Defines swap replication method – methodology described below.	swap_rate_offset
DATES_TO_TENOR_THRESHOLD	Integer	The number of days within which a whole year is preserved	7

Pricer Measures

The standard Calypso pricing outputs are available for PricerSwaptionLGMM1F, described below are the additional outputs specific to PricerSwaptionLGMM1F:

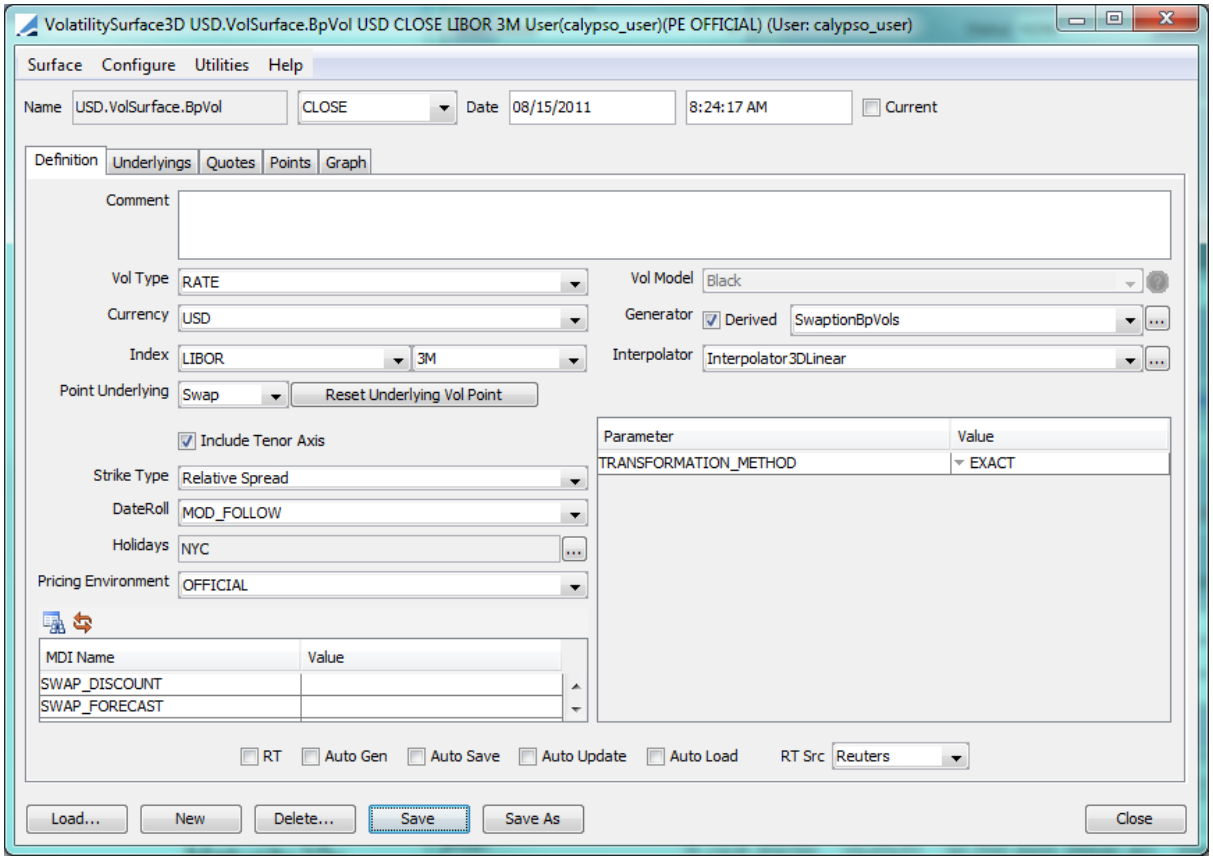
Pricer Measures	Description
LGM Model	When one selects the pricer measure LGM_MODEL the pricer will show the LGM model with values used when computing the NPV. 
LGMM Bestfit Err	When one selects the pricer measure LGMM_BESTFIT_ERR the pricer will do an additional calculation, and search in a brute force fashion over a range of mean reversion and sigma values, and display the best-fit error function. Note: The calibration scheme BEST_FIT_LM does not use this brute-force method, the brute-

Pricer Measures	Description
	force method is simply for the user to get a feel for the error function and double check the BEST_FIT_LM calibration. 
LGMM Mean Reversion Scenario	When one selects the pricer measure LGMM_MEANREV_SCEN, the pricer will do additional valuation, specifically, will vary the constant mean reversion parameter and re-compute the NPV. The purpose is to give the user a sense of how the Bermudan price varies with the mean reversion parameter.  Mean Reversion / Price -0.0100 517.9617 0.0000 519.6951 0.0100 521.4387 0.0200 523.1918 0.0300 524.9537 0.0400 526.7238 0.0500 528.5014

Valuing Callable Zero Coupon Swaptions in Calypso

Below is a description of how the LGMM1F pricer supports two types of callable zero coupon swaptions.

Calibration is performed to standard European swaptions, with characteristics specified in the volatility surface Point Underlying. **This feature is only available on volatility surface in Calypso v12.0 onwards.**



Type 1: Zero Coupon Accrual Swaptions (or cancel swap)

In this variant the swap is cancellable and has a zero coupon fixed leg and standard floating leg with the zero coupon leg compounding up to the maturity of the trade.

An example trade:

Payers Swaption

Maturity 10y

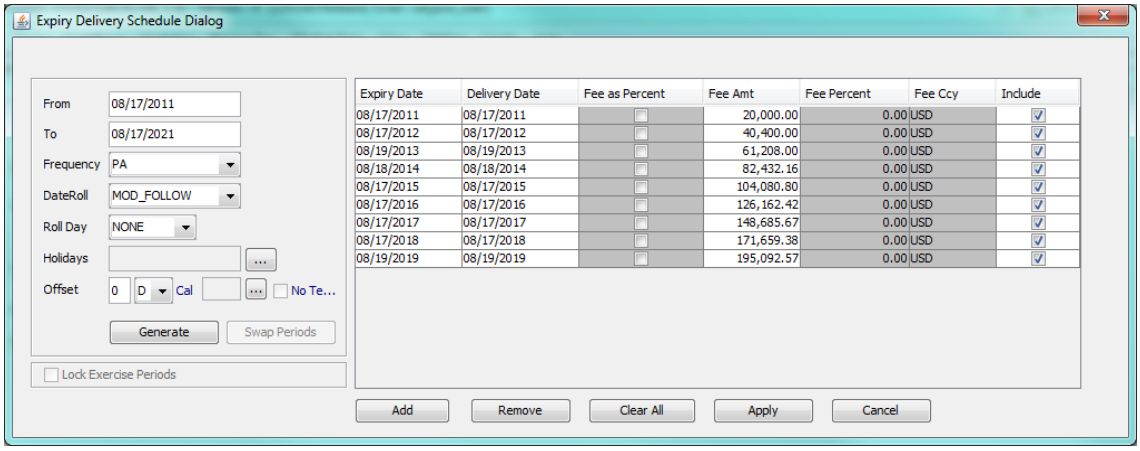
Notional USD 1mm

Fixed Leg: 2% compounded to the trade maturity

Floating Leg: 3m LIBOR, Act/360

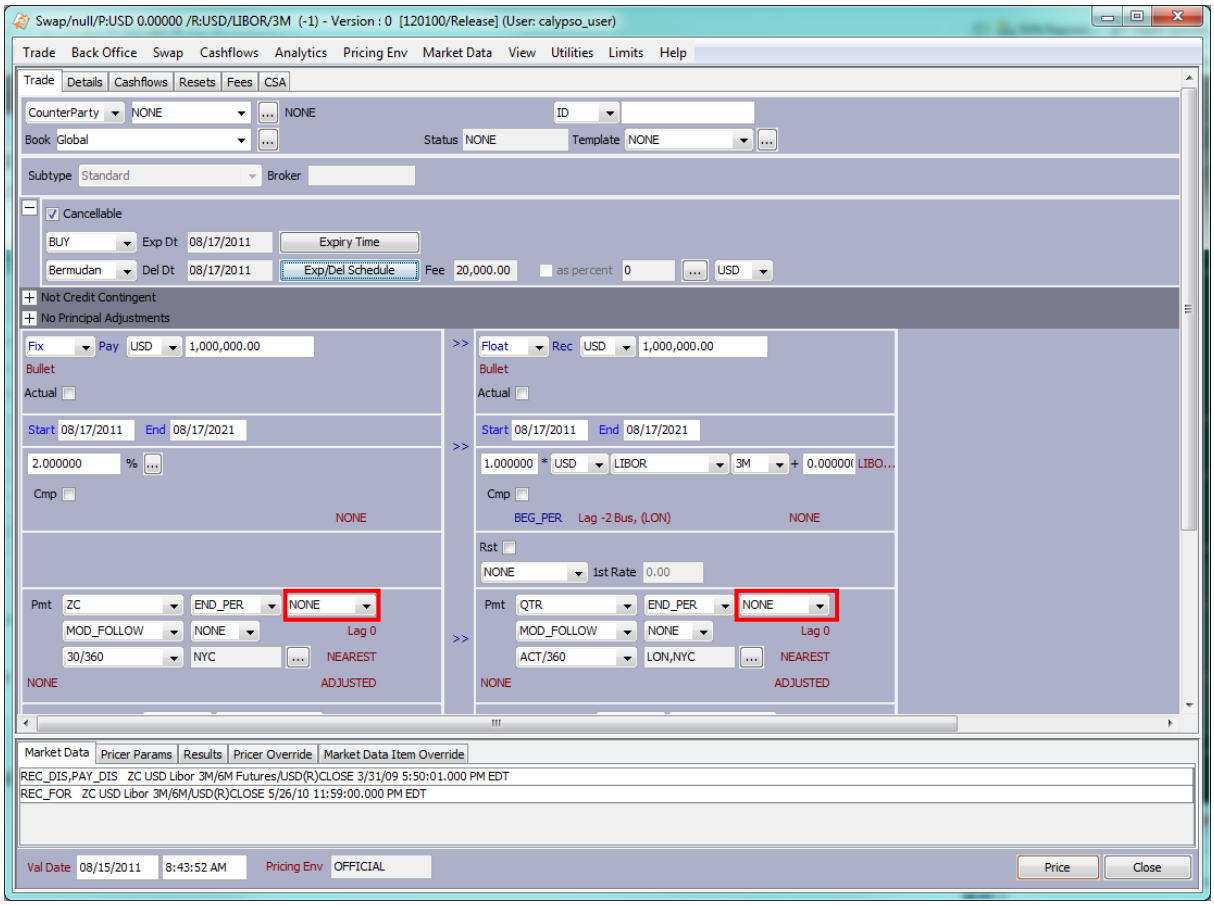
If the swap is not cancelled before the maturity the fixed leg will pay out USD 1m * ((1+2%)^10-1). If, however, it's called on the i-th exercise date the fixed leg will pay out the thus far accumulated coupon of USD 1m * ((1+2%)^i-1). Note that this calculation is hard-coded, regardless of the discount method being used.

This trade is booked as a cancellable swap that has annual exercise dates with exercise fee at each exercise date being the coupon paid/received if the swap gets cancelled. For the above payers swaption the exercise schedule and associated exercise fees are as follows



As an example, the 'fee' for the 5 year expiry date (8/17/2015) is computed as 1e06 * [(1+2%)^5-1]=104,080.80.

The swap is booked as usual with the Cancellable section being populated with the cancellability details



Note that to price a swaption using SwaptionLGMM1F pricer, only discount method NONE is supported.

A zero coupon swaption is an 'irregular' swaption and, therefore, the SWAP_REPLICATION_METHOD needs to be specified - the currently supported method is swap_rate_offset.

Type 2: Zero Coupon Accrual Swaptions

In this variant, the fixed leg pays a regular coupon against a standard floating funding leg but the notional of both legs accretes at the fixed coupon rate. An example trade would be

Payers Swaption

Maturity 5y

Notional USD 1mm

Fixed Leg: 2% paid annually, 30/360

Floating Leg: 3m LIBOR, Act/360

Then the notional of the two legs would change every year according to the following schedule

Year1: 1,000,000

Year2: 1,020,000

Year3: 1,040,400

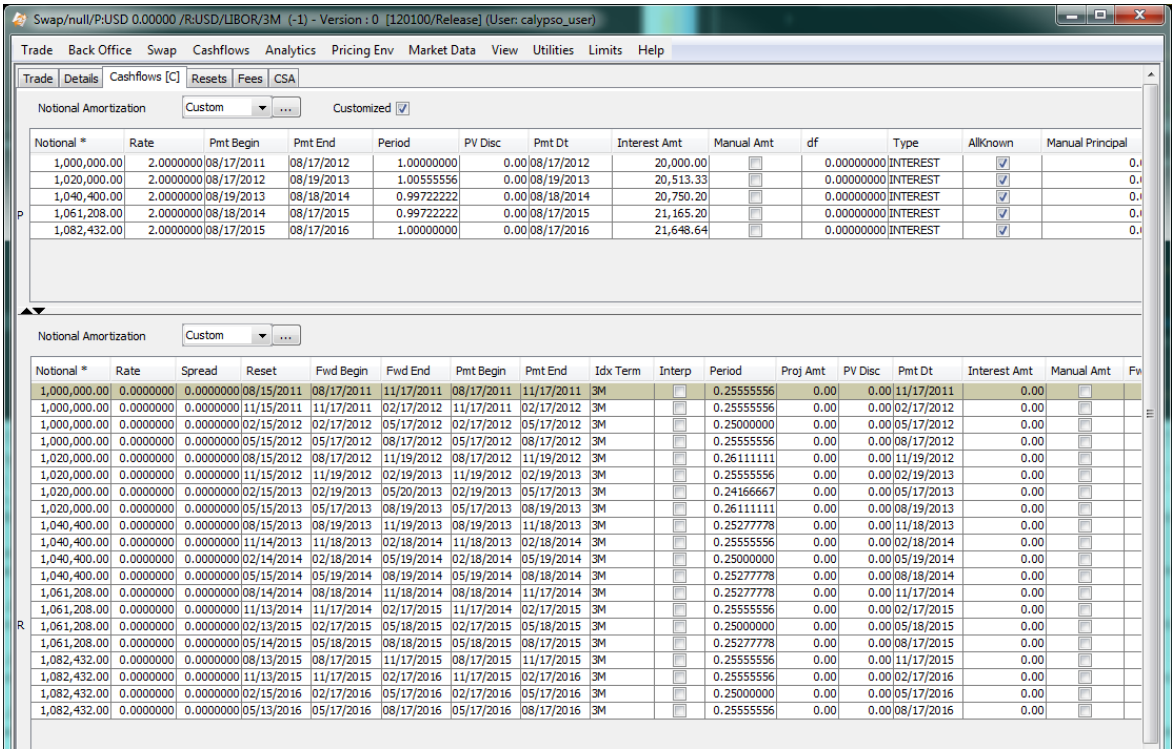
Year4: 1,061,208

Year5: 1,082,432

This is essentially an accreting swaption and can be booked as such using the Swap window, typing in the notional corresponding to each period and locking all the modified columns.

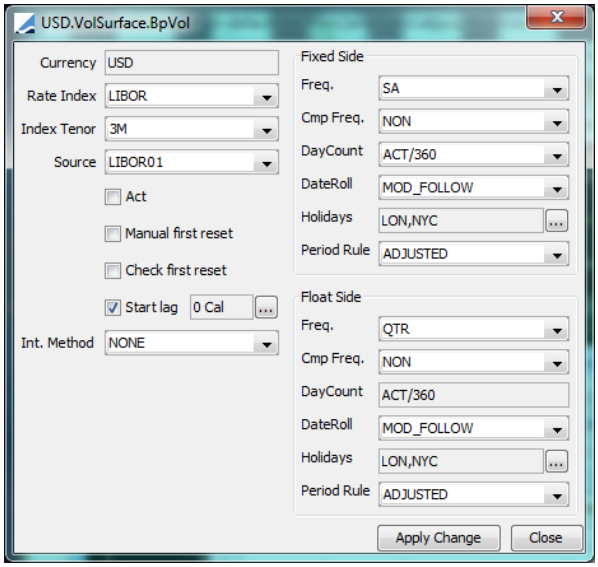
As before, this is a Bermudan option on an irregular swap and the method used to map each of the forward irregular swaps to the vanilla swaption market is specified through the SWAP_REPLICATION_METHOD pricing parameter. The methods currently supported are swap_rate_offset and overlap_negative_weights.

Note that the index factor on the LIBOR leg is not supported.



Calibration to Standard Swaptions

When using PricerLGMM1F any callable trade can be valued by calibrating to the *standard swaptions* of the reference swaption market. The conventions used to define the standard swaptions are set on the Point Underlying of the volatility surface. **This feature is only available on volatility surface in Calypso v12.0 onwards.**



The pricing parameter that controls the use of the standard swaptions is

LGMM_CALIBRATE_TO_STD_OPTIONS

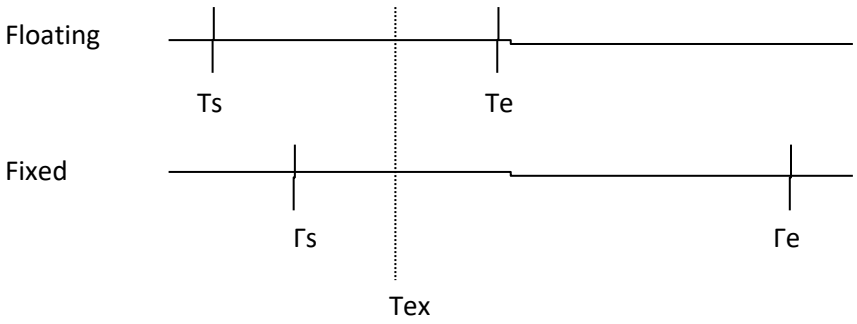
When calibration to standard swaptions is chosen, the swap underlying the option is taken to be irregular and an irregular swaption method needs to be selected.

Note that when manufacturing the standard swaptions, a fast date generation method is employed which produces index start and end dates that may be slightly different to what they should be. The resulting pricing difference is very small.

Options on swaps with non-matching schedules - dealing with mid-period exercise dates

Valuing options on swaps with non-matching schedules requires solving the problem of how to represent and value a fixed or floating flow as of an exercise date that is in the middle of the flow period.

In general, the fixed and floating flows will look as follows



Where Tex is the exercise date

Fixed Flow:

The clean value of the fixed flow as of the exercise date will be

(A) $\delta(Tex, \Gamma e) * C$

With $\delta(Tex, \Gamma e)$ being the coverage (in the fixed leg day count convention) between the exercise date and the payment date of the fixed coupon C.

Floating Flow:

The clean value of the floating flow as of the exercise date will be

(B) $\gamma(Tex, Te) * F(Ts, Ts, Te)$

With $\gamma(Tex, Te)$ being the coverage (in the floating leg day count convention) between the exercise date and the payment date and $F(Ts, Ts, Te)$ is the simple forward rate between Ts and Te, as of Ts.

As this forward rate resets before the exercise date it will not be known at Te in the backward induction algorithm and needs to be approximated.

A reasonable approximation that makes the value of the flow measurable at Tex is to assume that the slope of the curve remains constant at the forward level, thus

(B1) $F(Ts, Ts, Te) = F(Ts, Ts, Te) + F(Tex, Tex, Te) - F(Tex, Tex, Te)$

$\approx F(Tex, Tex, Te) + [F(t, Ts, Te) - F(t, Tex, Te)]$

Making the value of the floating flow

(B2) $\gamma(Tex, Te) * (F(Tex, Tex, Te) + [F(t, Ts, Te) - F(t, Tex, Te)])$

To allow this approximation to be made in Calypso the following pricing parameter needs to be set to true otherwise a flat forward approximation is used in (B2) above:

LGMM_ADJUST_FOR_MIDFLOW_EXERCISE

References

- Hagan, P.S. and Woodward, D.E. (1999), "Markov Interest Rate Models", Applied Mathematical Finance, 6:233-260
- Calypso Technology, "Linear Gauss Markov Model".

3.1.2 PricerSwapLGMM1F

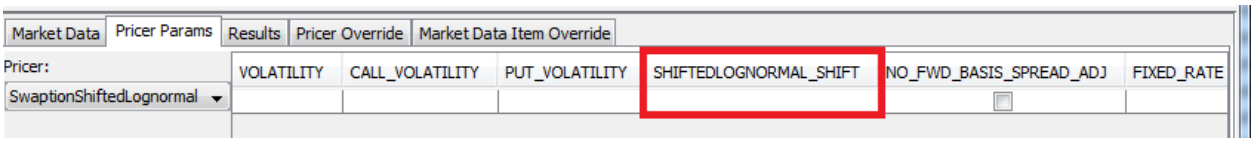
PricerSwapLGMM1F is exactly equivalent to PricerSwaptionLGMM1F but supports cancellable swaps of a similar structure. The methodology implemented is consistent with that discussed above.

3.1.3 PricerSwaptionShiftedLognormal

The purpose of this pricer is to allow for the valuation of swaptions when interest rates are negative. It supersedes the PricerSwaption, and as of version 15.1 it should replace it.

The pricer supports an additive shift to the interest rates, and prices the swaption using a Black-Scholes formula with the shifted forward and the strike.

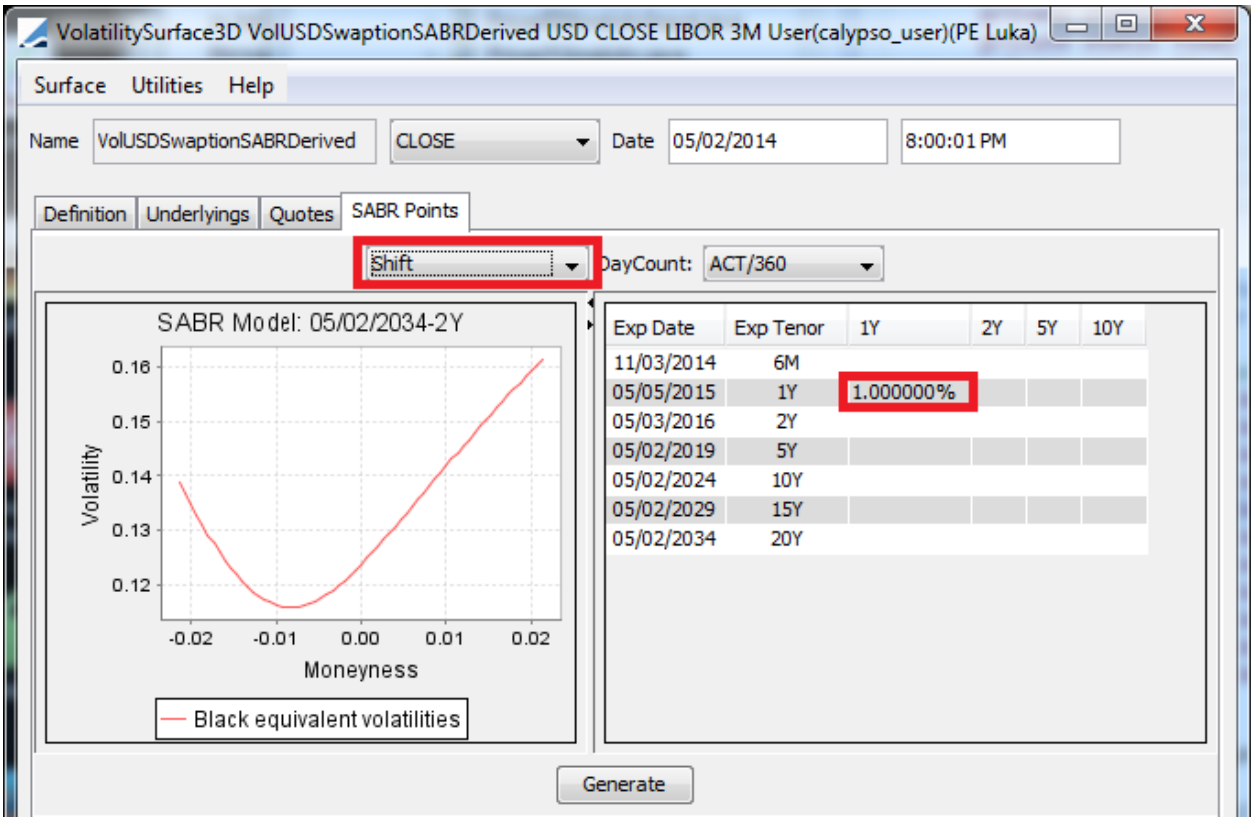
The shift is retrieved from the volatility surface used for pricing the swaption, or it can be passed in as the transient parameter SHIFTEDLOGNORMAL_SHIFT:



The shift in the underlying rates is supported by the generator SwaptionSABRDerived.

If the pricer is used without specifying a value for the SHIFTEDLOGNORMAL_SHIFT or with a volatility surface generated with an older generator, which does not support a shift of the rates, in which case the shift will be simply set to zero.

The volatility and Vega computed by the pricer are expressed in units of the daycount included in the volatility surface. If the volatility is passed to the pricer as a transient parameter, the daycount will default to ACT/365.



3.1.4 PricerSwaptionIRVanillaNormal

This pricer is available as of CALIB-400-2 and is meant to replace PricerSwaptionBpVol for vanilla swaptions.

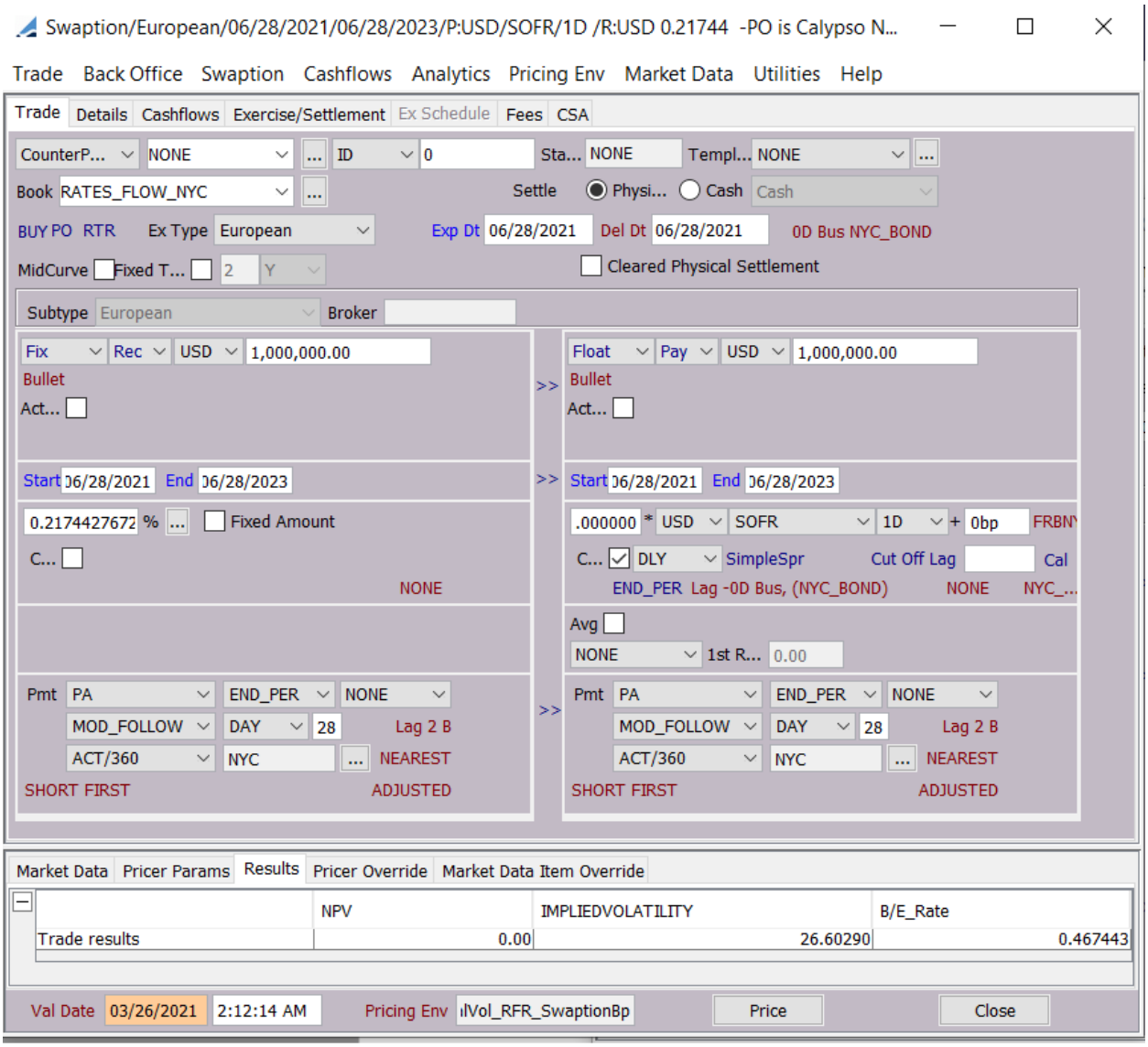
It is optimized for and supports only single-currency European-style options; further, options on swaps with any of the below features are not supported:

- Convexity-adjusted flows (cms-linked, diff-swap, NDS/NDF, reset-in-arrears, pay-early)
- Principal exchange flows
- Compounding swaps
- Basis swaps (a.k.a. floating-for-floating, e.g., 3M LIBOR vs. 6M LIBOR)

However, this pricer does provide analytics for irregular swaptions (a.k.a., options on amortising/roller-coaster/accreting swaps) subject to there being no principal flows.

This pricer also supports RFR daily compounded (but NOT averaged) swaptions. Definition of RFR rate index is the same as described in PricerCapShiftedLognormal, the DailyIndexCalculator of the rate index must be set to DailyCompound2.

A RFR Swaption needs to be defined as below. It must be paid in arrears with daily compounded method SimpleSpr.



3.1.5 PricerSwaptionIRVanillaSLN

This pricer is like PricerSwaptionShiftedLognormal but lacks support for options involving multiple currencies plus the list mentioned in Sec. PricerSwaptionIRVanillaNormal above.

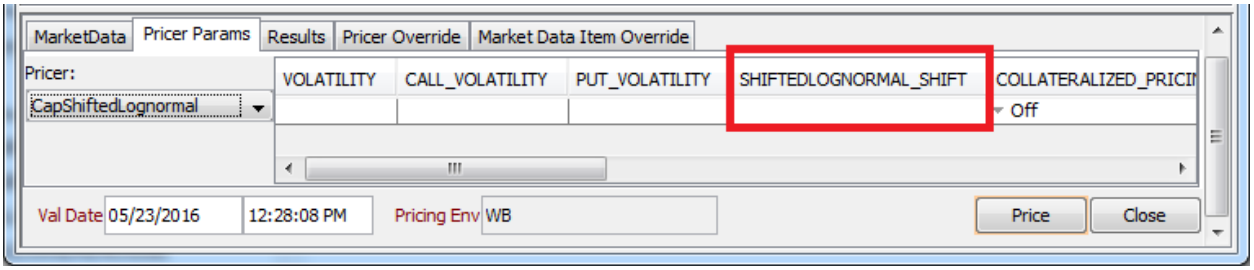
It does not handle irregular swaptions either.

Similar as PricerSwaptionIRVanillaNormal above, it also supports RFR Daily Compounded (but NOT averaged) Swaptions.

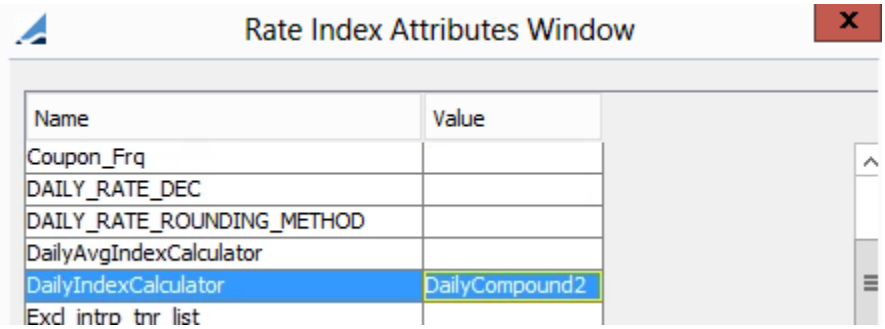
3.1.6 PricerCapShiftedLognormal

This pricer supports an additive shift for the underlying interest rates, so it can be used when the interest rates are negative. When a shift is present the individual caplets are priced using a Black-Sholes formula in which the forward and the strike are modified by adding the shift.

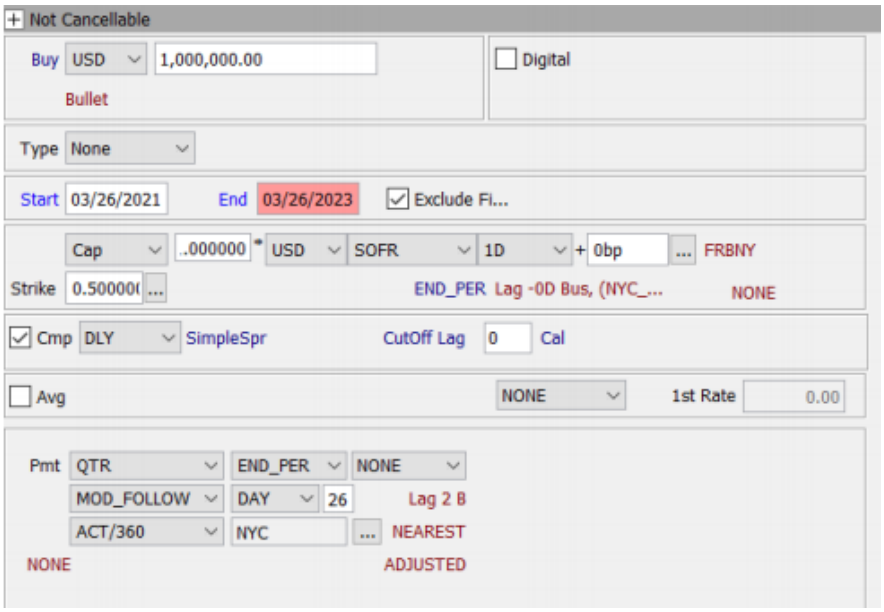
The shift can be read from the caplet volatility surface, (generated with the CapShiftedLognormal generator), or it can be passed in as the SHIFTEDLOGNORMAL_SHIFT transient parameter.



We currently support RFR daily compounded Caps and Floors only, the DailyIndexCalculator of the rate index must be set to DailyCompound2.



An RFR Cap/Floor needs to be defined as below. It must be paid in arrears with daily compounded method SimpleSpr.



3.1.7 PricerCapFloorNormal

Similar functionality to PricerCapShiftedLognormal, except we use a normal as opposed to lognormal model. The volatility used is often referred to as basis point point volatility, or just BpVol. This pricer inherits from the same base class as PricerCapShiftedLognormal and it allows for risk computed via bump-and-re-price to be computed instead using the Jacobian method.

PricerCapFloorNormal also supports RFR Daily compounded (but NOT averaged) Caps and Floors, same as PricerCapShiftedLognormal.

When this pricer is used, one can use IMPLIEDVOLATILITY measure to calculate implied normal vol and BLACK_EQUIV_VOL measure to calculate the equivalent black vol.

3.1.8 PricerCapFloorBpVol

This pricer is due to be replaced by PricerCapFloorNormal after v17.

This pricer supports the valuation of caps using a Normal or BpVol model for each of the underlying caplets, see also the discussion in the SwaptionBpVol pricer. The input to the pricer needs to be a surface, simple or derived, that can provide Normal / Bp vols for the tenor of the underlying caplets. The main pricer measures are defined as follows

Pricer Measure	Description
DELTA	The change in the option value predicted by the option delta: $\Delta V = \Delta \bullet \Delta F$ with ΔF of 1 basis point. The option delta is the theoretical (Bachelier) delta.
GAMMA	The change in the option value predicted by the option gamma: $\Delta V = \Gamma \bullet \Delta F^2$ with ΔF of 1 basis point. The option gamma is the theoretical (Bachelier) gamma.
VEGA	The change in the option value predicted by the option vega: $\Delta V = Vega \bullet \Delta\sigma$ with $\Delta\sigma$ of 1 basis point (0.01%). The option Vega is the theoretical (Bachelier) vega.
THETA	The change in the option value predicted by the option theta: $\Delta V = \Theta \bullet \Delta t$ with Δt of minus one day (= -1/365)

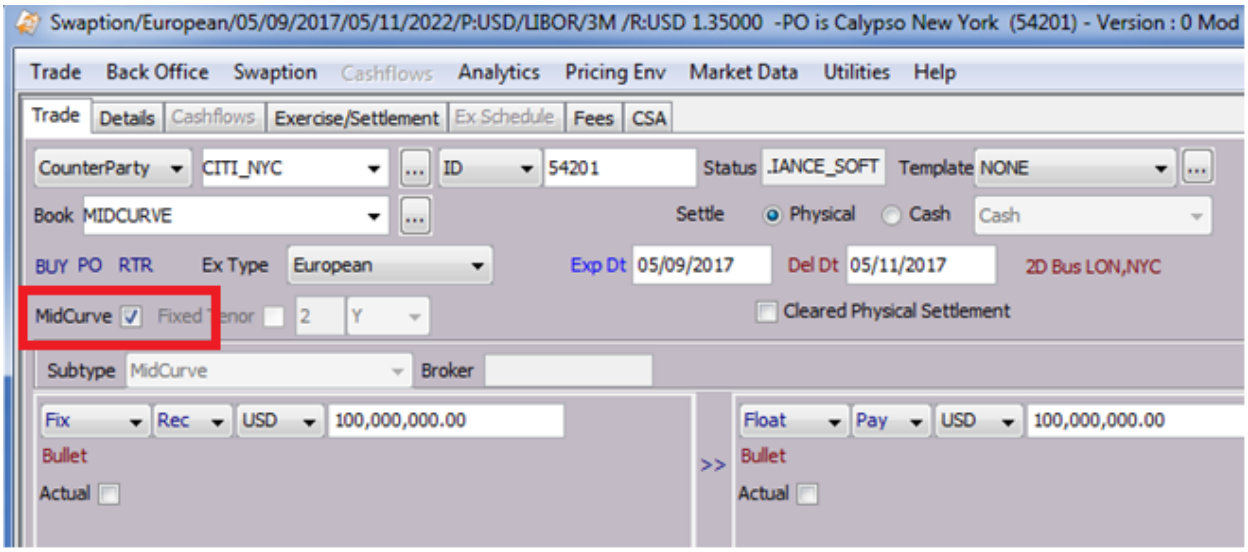
3.1.9 PricerSwaptionMidCurve (*)

(* : scheduled for Calypso version 15.1)

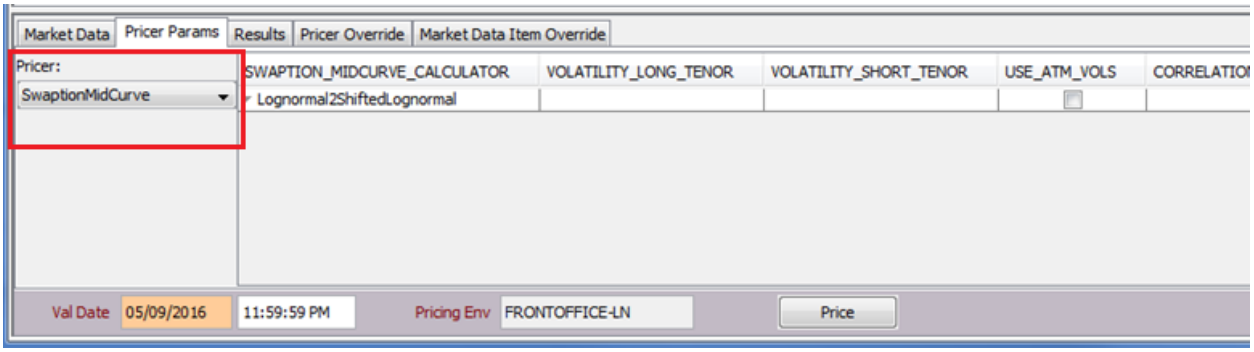
Overview

Mid-curve swaptions are characterised by an option expiry date and two tenors (T1, T2) (or equivalently, three dates). T2 is the maturity tenor of the swap underlying the option, while T1 specifies the delivery lag, i.e., the period between swaption delivery date and underlying swap start date. E.g., a 1Y x 2Y x 5Y mid-curve swaption expires in one year and it was written on the swap starting in three years and ending in eight years. In the case of vanishing T1, the mid-curve swaption collapses into a vanilla swaption.

To price a mid-curve swaption in a Trade window, tick the MidCurve box as below:



and select PricerSwaptionMidCurve:



Models

The available models replicate the forward-starting-swap in a 'nY x mY x pY' by a spread basket of co-initial swaps starting at nY: a long position in an (m+p)Y swap combined with a short position in an mY swap.

The corresponding marginal distributions can be either normal or lognormal. (Shifted-lognormal marginals are not supported).

Likewise, the effective terminal distribution of the forward-starting-swap rate is either of normal or shifted-lognormal type.

Model name	Description
Normal2Normal	Normal marginals + normal effective distributions.
Lognormal2Normal	Lognormal marginals + normal effective distributions.
Lognormal2ShiftedLognormal	Lognormal marginals + shifted-lognormal effective distributions.

Choose a model from the drop-down in SWAPTION_MIDCURVE_CALCULATOR input parameter field.

Pricing Parameters

Pricing Parameter	Type	Description
VOLATILITY_LONG_TENOR	Rate	A transient override for the marginal volatility of the long replicating swap. A value of '1.2' means 1.2 bp vol for normal marginals, while it is 1.2% for lognormals. Use to numerically calculate corresponding marginal vega.
VOLATILITY_SHORT_TENOR	Rate	A transient override for the marginal volatility of the short replicating swap. Same unit conventions as VOLATILITY_LONG_TENOR. Use to numerically calculate corresponding marginal vega.
USE_ATM_VOLS	Rate	Adjust for marginal volatility smiles if FALSE; Currently, only TRUE is supported.
CORRELATION	Rate	A transient override for the correlation between the replicating-swap rates. The correlation is of the 'same' type as the marginals. A value of '0.87' means: 87%. Use to numerically calculate corresponding CORRELATION_01.
SHIFTEDLOGNORMAL_SHIFT	Rate	A transient to pass in the shift of the effective shifted-lognormal distribution. If missing, a default value of '0.0' is assumed. Ignored unless VOLATILITY is passed in. Not applicable to Normal2Normal / Lognormal2Normal models.
VOLATILITY	Rate	A transient override for the effective volatility of the underlying swap. Same unit conventions as VOLATILITY_LONG_TENOR. Use to numerically calculate corresponding vega.

N.B.: Volatility and vega inherit daycount conventions from the swaption volatility surface. If no surface is specified, transient volatilities adopt default ACT/365.

Pricer Measures

Beside the standard PricerSwaptionShiftedLognormal outputs, some additional diagnostics and measures are provided:

Pricer Measure	Description
IMPLIEDVOLATILITY	Effective normal resp. lognormal volatility. Units follow same conventions as input parameters.
IMPLIED_CORRELATION	Correlation between marginal driving processes. (see also: CORRELATION input parameter).
CORRELATION_01	Sensitivity. PV change for +1% change in correlation.
SHIFTEDLOGNORMAL_SHIFT	Swap rate (and strike-) shift in Lognormal2ShiftedLognormal model. '0.34' means: 34bp.
PROB_OF_EXERCISE	Risk-neutral probability (in %) that the swaption expires in-the-money.

3.2 Pricers for Exotic IRD (eXSP)

3.2.1 PricerLGMM1FBackward

Overview

PricerLGMM1FBackward is predominantly designed to support the valuation of American, Bermudan and European swaptions or cancellable swaps using the so-called LGM model. The LGM model was first described by P.Hagan in an unpublished, but widely known, working paper[2]. The LGM model is precisely the Hull-White one factor model expressed as a HJM model. Further details on the Calypso LGM model are found in the dedicated Calypso analytics document, "Linear Gauss Markov model".

PricerLGMM1FBackward can also price the following trade types: Bonds, Single leg swaps and Caps and Floors.

PricerLGMM1FBackward is named with relation to the direction of pricing, i.e. backwards direction; therefore a lattice is constructed for pricing. The lattice is based on a Sali-tree construction and is again documented in detail in the dedicated Calypso analytics document.

PricerLGMM1FBackward provides increased flexibility over PricerSwaptionLGMM and PricerSwapLGM, allowing the user to analyse exotic transactions which incorporate formulaic payoff structures that have been developed through the eXSP framework, e.g. range accruals and inverse floating structures.

Swaptions

A swaption is an option on a swap that can be exercised at predetermined exercise dates. American, Bermudan and European exercise schedules can be specified. PricerLGMM1FBackward is able to price trades with the following underlying swap structures;

- Fixed Vs Float
- Fixed Vs Exotic (eXSP)
- Float Vs Exotic (eXSP)
- Fixed End Date – the underlying swaps corresponding to the exercise dates all share the same end-date

Swaptions can be priced with respect to both sides of the transaction i.e. Right To Pay (RTP), Right To Receive (RTR) and straddles.

[2] The paper is "Methodology for callable swaps and Bermudan 'exercise into' swaptions", P.S.Hagan circulated and discussed on the Wilmott forums (www.wilmott.com).

American fixed tenor swaptions, i.e. the underlying swaps, corresponding to the exercise dates, all have the same relative maturity/tenor are not supported – This trade type is supported with the latest version of PricerSwaptionLGMM1F (available separately on request).

Cancellable Swaps

A cancellable swap is a swap which can be exercised or cancelled at predetermined exercise dates. PricerLGMM1FBackward is able to price trades with the following underlying swap structures;

- Fixed Vs Float
- Float Vs Float
- Fixed Vs Exotic (eXSP)
- Float Vs Exotic (eXSP)

American, Bermudan and European exercise schedules can be supported for cancellable swaps.

Single leg swaps and Caps and Floors using the eXSP framework are also supported.

Callable Bonds – Fixed Rate

A callable bond is debt instrument issued with the purpose of raising capital by borrowing and can be exersiced on predtermined dates. American, Bermudan and European exercise schedules can be supported for callable bonds.

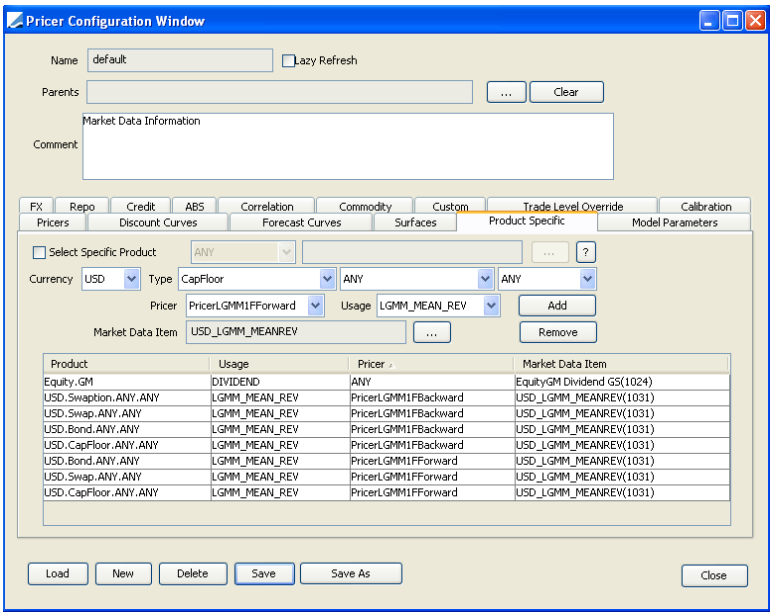
PricerLGMM1FBackward supports pricing of transactions with fixed coupon rates only.

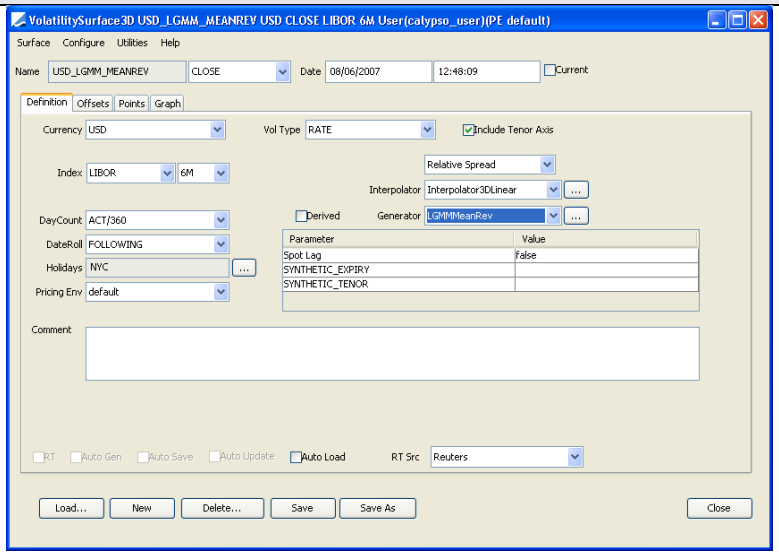
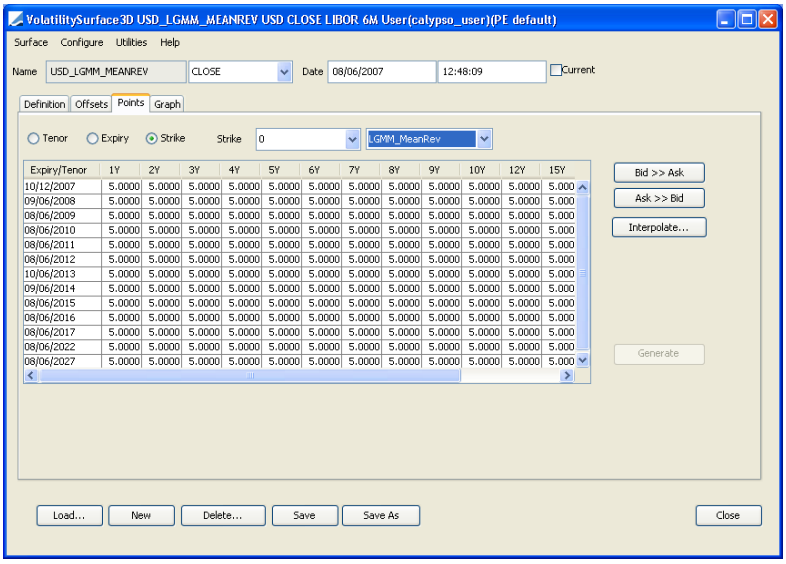
Workflow for Pricing with PricerLGMM1FBackward

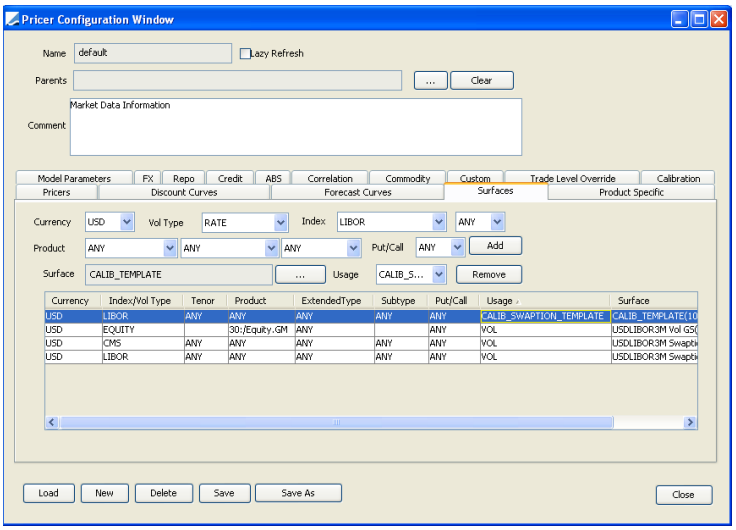
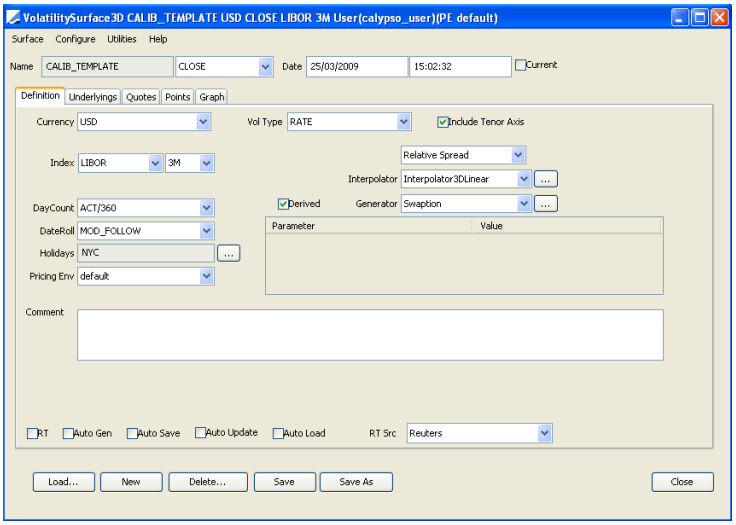
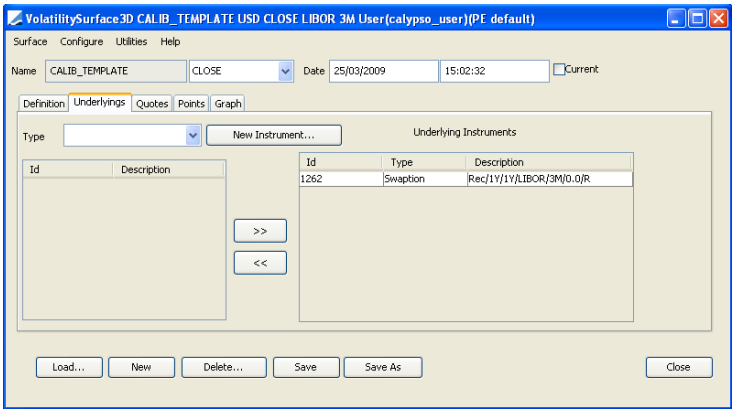
Below is a description of the necessary steps for pricing a trade using the PricerLGMM1FBackward:

- Set up trade (see trade examples documentation for further information)
- Setup / configure required market data (including pricer config settings)
- Setup / configure pricing parameters
- If the user requires to use Auto-Calibration of model (LGMM_AUTO_CALIBRATE = True)
    - Setup / configure calibration pricing parameters
    - Price trade
- If the user requires to use customized calibration (LGMM_AUTO_CALIBRATE = False)
    - Save trade
    - Setup / configure calibration instrument (see Model Calibration section))
    - Price trade

Market Data Configuration

Market Data	Description
Discount Curve	Same as PricerSwaption - Standard Configuration
Forecast Curve	Same as PricerSwaption - Standard Configuration
Swaption Volatility	Same as PricerSwaption - Standard Configuration
LGMM Mean Reversion Matrix	The pricer expects a mean reversion matrix to be configured within the pricer config. In respect of the product specific tab one must have a volatility surface whose generator is LGMMMeanRev, and assign it the PricerLGMM1FBackward where the Usage=LGMM_MEAN_REV Note the usage LGMM_MEAN_REV in the pricer config should appear when the pricer is registered. It is not required to be added in the domain values. Pricer Config Example:  Mean Reversion matrix (Volatility surface) Example: The example below shows the input of a flat 5% mean reversion surface. A simple surface including the tenor axis should be used. Expiries and tenors should be defined on the offsets tab then one should click generate.

Market Data	Description
	 The drop down menu on the points tab should be changed to the LGMM_MEANRev and the values entered. 
CALIB_SWAPTION_TEMPLATE	The pricer expects a CALIB_SWAPTION_TEMPLATE to be configured within the pricer config. Specifically, in the Surfaces tab one must add a volatility surface whose generator is Swaption, and assign it the PricerLGMM1FBackward where the Usage= CALIB_SWAPTION_TEMPLATE. The volatility surface must contain a single underlying swaption; the quote for the swaption is not used in pricing. The template is a definition of the terms and conditions of a swaption in the regular swaption surface, in particular important characteristics such as pmt frequency and day count of the fixed leg. This additional information is essential for model calibration

Market Data	Description
	Pricer Config Example:  Volatility surface example:  

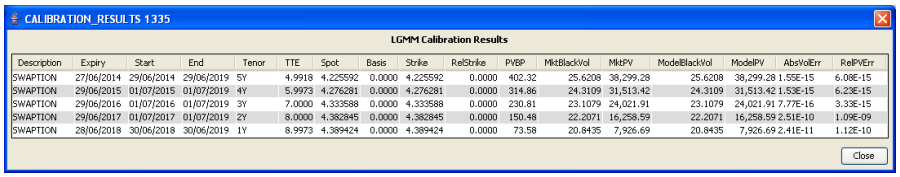
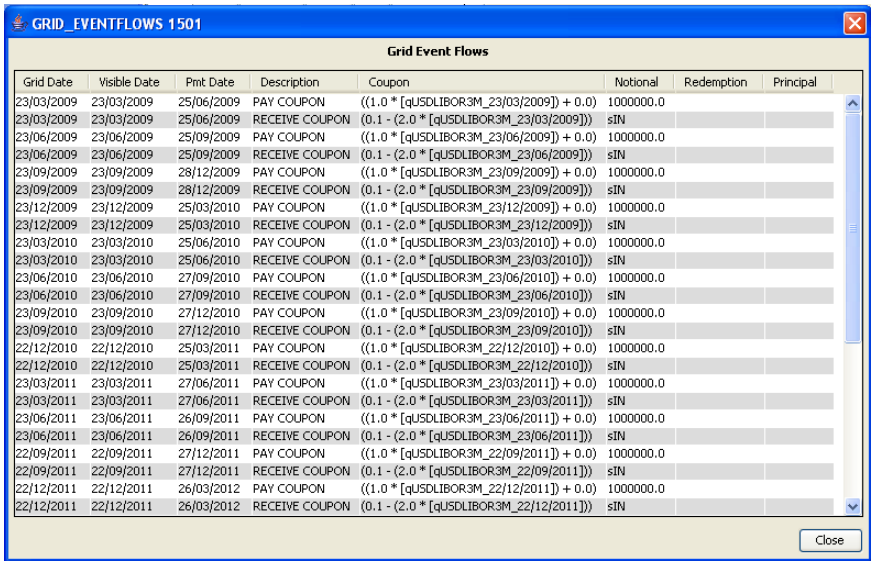
Pricing Parameters

Pricing Parameter	Type	Description	Typical Value
LGMM_MEAN_REV	Rate	A transient override for the mean reversion parameter described in the market data section above.	-1% to 5%
LGMM_MODEL_VOL	Rate	A transient override for the model's volatility parameter described in the market data section above.	~1%
LGMM_IR_RATE	Rate	A transient override for the yield curve described in the market data section above.	0.5%-6%
LGMM_CALIBRATION_INSTRUMENTS	Choice	CORE_SWAPTION – the calibration instruments are European swaptions defined by the exercise dates and the swap related to the exercise date. On a typical 10Y NC 5Y, the core swaption are 5Yx5Y, 6Yx4Y, 7Yx3Y, 8Yx2Y, 9Yx1Y. On fixed-tenor (or trombone) swaption, the core swaptions would be 5Yx5Y, 6Yx5Y, 7Yx5Y, 8Yx5Y, 9Yx5Y Also the strikes are at the strike of the current Bermudan swaption. CORE_AND_SHORT_SWAPTION – the calibration instruments are the core swaptions described above and one additional swaption, defined by the first (alive) exercise date of a maturity the same length as the fixed coupon length. In the previous example of a 10Y NC 5Y it would correspond to a 5Yx1Y swaption. CORE_SWAPTION_ATM – Same as CORE_SWAPTION except the strikes are chosen to be at the money, rather than the same as the trade. CORE_AND_SHORT_SWAPTION_ATM - Same as CORE_AND_SHORT_SWAPTION except the swaptions are at the money.	CORE_SWAPTION
LGMM_CALIBRATION_SCHEME	Choice	EXACT_STEP_SIGMA – the model volatility function is a step function, chosen so as to match the calibration instruments exactly BEST_FIT_LM – the model mean reversion and volatility are constant and chosen by a Levenberg-Marquardt best fit routine applied to the calibration instruments. APPROX_STEP_SIGMA – same as EXACT_STEP_SIGMA except and using a faster but approximate method.	EXACT_STEP_SIGMA

Pricing Parameter	Type	Description	Typical Value
RISK_OPTIMISE	Boolean	Controls whether or not optimization techniques are used within scenario analysis, in particular for shift and revalue of the volatility surface.	True
ACCURACY_LEVEL	Integer	Accuracy of pricing, range from 0-11, 0 being the least accurate (fastest) and 11 being the most accurate (slowest)	5
LGMM_AUTO_CALIBRATE	Boolean	The parameter is designed to increase the flexibility of the calibration process and remove the dependency on creating a customized calibration set when pricing with the two LGM pricers, 1FBackward and 1FForward. If set to true a custom calibration set is not used, instead predefined rules are used to select the instruments i.e. for swaptions and callable trades the calibration instruments are selected to be the core diagonals for non callable trades the calibrations instruments are selected with expiries to be in sync with the cashflow dates. If LGMM_AUTO_CALIBRATE is set to false the custom calibration set is used.	True
LGMM_CALIBRATE_TO_OTM_OPTIONS	Boolean	Flag to switch the calibration to be performed on OTM swaptions. An additional column has also been added to the CALIBRATION_RESULTS pricer measure to highlight the option type used in calibration.	True
INCLUDE_FEES	Boolean		True
NPV_ INCLUDE_FEES	Boolean		True
RESET_FROM_CURVE	Boolean		False
NPV_INCLUDE_COST	Boolean		False
MULTIPLE_CURVES	Boolean	Flag to set to true to recognize different forecast/discount curves. False if only take discount curve.	False

Pricer Measures

The standard Calypso pricing outputs are available for PricerLGMM1FBackward, described below are the additional outputs specific to the PricerLGMM1FBackward:

Pricer Measure	Description
Calibration results	When one selects (drill down) the pricer measure CALIBRATION_RESULTS the pricer will show details of the intermediate steps in the calibration. 
Grid Event Flows	When one selects the pricer measure GRID_EVENTFLOWS the salient points in the grid / lattice will be displayed. It also provides information on the coupon, (outstanding) notional, redemption (termination payment) and principal payments found at each point in the grid. Cashflows are ordered chronologically and are described as 'Pay coupon' or 'Receive coupon' which relate to the pay or receive legs of the transaction. 

References

- Hagan, P.S. and Woodward, D.E. (1999), "Markov Interest Rate Models", Applied Mathematical Finance, 6:233-260
- Calypso Technology, "Linear Gauss Markov Model".

3.2.2 PricerLGMM1FForward

Overview

As with the PricerLGMM1FBackward, the PricerLGMM1FForward is based on the so-called LGM model, which is precisely the Hull-White one factor model expressed as an HJM model. The numerical scheme used is Monte-Carlo based, and so is designed to support products that can be priced in the forward direction, for example path dependent trades.

PricerLGMM1FForward can price the following trade types: Swaps, Bonds, Single leg swaps and Caps and Floors. It also supports the pricing of many formulaic based payoff structures in eXSP, e.g. TaRN's or Snowballs.

The pricer supports non-callable transactions only.

Workflow for Pricing with PricerLGMM1FForward

Below is a description of the necessary steps for pricing a trade using the PricerLGMM1FForward:

- Set up trade (see trade example documentation for further information)
- Setup / configure required market data (including pricer config settings)
- Setup / configure pricing parameters
- If the user requires to use Auto-Calibration of model (LGMM_AUTO_CALIBRATE = True)
    - Setup / configure calibration pricing parameters
    - Price trade
- If the user requires to use customized calibration (LGMM_AUTO_CALIBRATE = False)
    - Save trade
    - Setup / configure calibration instrument (see Model Calibration section)
    - Price trade

Market Data Configuration

Market Data	Description
Discount Curve	Same as PricerSwaption - Standard Configuration
Forecast Curve	Same as PricerSwaption - Standard Configuration
Swaption Volatility	Same as PricerSwaption - Standard Configuration
LGMM Mean Reversion Matrix	The pricer expects a mean reversion matrix to be configured within the pricer config. In respect of the product specific tab one must create a volatility surface whose generator is LGMMMeanRev, and assign it the PricerLGMM1FForward where the Usage=LGMM_MEAN_REV (Configuration same as PricerLGMM1FBackward)
CALIB_SWAPTION_TEMPLATE	The pricer expects a CALIB_SWAPTION_TEMPLATE to be configured within the pricer config. Specifically, in the Surfaces tab one must add a volatility surface whose generator is Swaption, and assign it the PricerLGMM1FForward where the Usage= CALIB_SWAPTION_TEMPLATE. The volatility surface must contain a single underlying swaption; the quote for the swaption is not used in pricing.

Market Data	Description
	The template is a definition of the terms and conditions of a swaption in the regular swaption surface, in particular important characteristics such as pmt frequency and day count of the fixed leg. This additional information is essential for model calibration (Configuration same as PricerLGMM1FBackward)

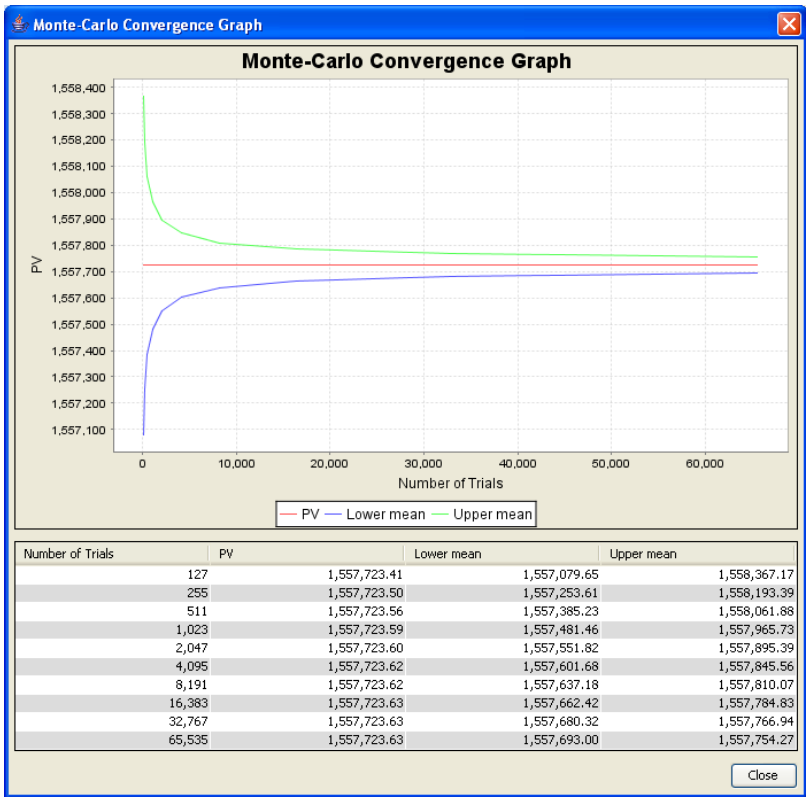
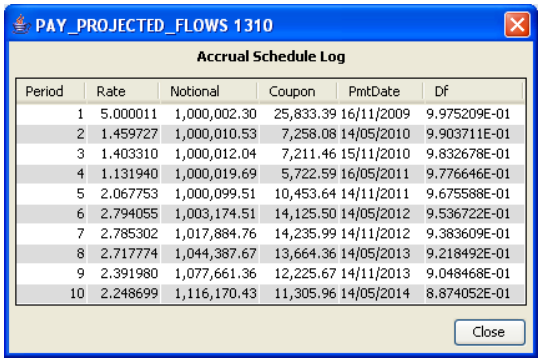
Pricing Parameters

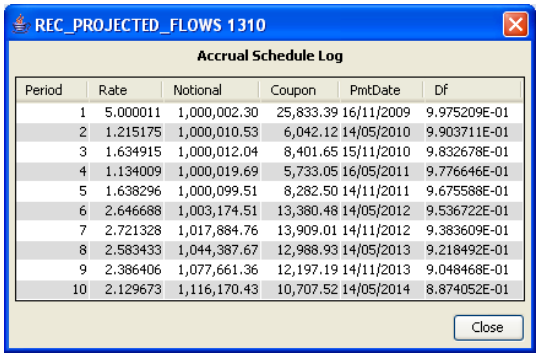
Pricing Parameter	Type	Description	Typical Value
LGMM_CALIBRATION_INSTRUMENTS	Choice	CORE_SWAPTION – the calibration instruments are European swaptions defined by the exercise dates and the swap related to the exercise date. On a typical 10Y NC 5Y, the core swaption are 5Yx5Y, 6Yx4Y, 7Yx3Y, 8Yx2Y, 9Yx1Y. On fixed-tenor (or trombone) swaption, the core swaptions would be 5Yx5Y, 6Yx5Y, 7Yx5Y, 8Yx5Y, 9Yx5Y Also the strikes are at the strike of the current Bermudan swaption. CORE_AND_SHORT_SWAPTION – the calibration instruments are the core swaptions described above and one additional swaption, defined by the first (alive) exercise date of a maturity the same length as the fixed coupon length. In the previous example of a 10Y NC 5Y it would correspond to a 5Yx1Y swaption. CORE_SWAPTION_ATM – Same as CORE_SWAPTION except the strikes are chosen to be at the money, rather than the same as the trade. CORE_AND_SHORT_SWAPTION_ATM- Same as CORE_AND_SHORT_SWAPTION except the swaptions are at the money.	CORE_SWAPTION
LGMM_CALIBRATION_SCHEME	Choice	EXACT_STEP_SIGMA – the model volatility function is a step function, chosen so as to match the calibration instruments exactly BEST_FIT_LM – the model mean reversion and volatility are constant and chosen by a Levenberg-Marquardt best fit routine applied to the calibration instruments. APPROX_STEP_SIGMA – same as EXACT_STEP_SIGMA except and	EXACT_STEP_SIGMA

Pricing Parameter	Type	Description	Typical Value
		using a faster but approximate method.	
LGMM_MODEL_VOL	Rate	A transient override for the model's volatility parameter.	~1%
IR_RATE	Rate	A transient override for the yield curve.	0.5%-6%
LGMM_MEAN_REV	Rate	A transient override for the mean reversion parameter.	-1% to 5%
RISK_OPTIMISE	Boolean	Controls whether or not optimization techniques are used within scenario analysis, in particular for shift and revalue of the volatility surface.	True
ACCURACY_LEVEL	Integer	Accuracy of pricing, range from 0-11, 0 being the least accurate (fastest) and 11 being the most accurate (slowest)	5
LGMM_AUTO_CALIBRATE	Boolean	The parameter is designed to increase the flexibility of the calibration process and remove the dependency on creating a customized calibration set when pricing with the two LGM pricers, 1FBackward and 1FForward. If set to true a custom calibration set is not used, instead predefined rules are used to select the instruments i.e. For swaptions and callable trades the calibration instruments are selected to be the core diagonals for non-callable trades the calibrations instruments are selected with expiries to be in sync with the cash flow dates. If LGMM_AUTO_CALIBRATE is set to false the custom calibration set is used.	True
LGMM_CALIBRATE_TO_OTM_OPTIONS	Boolean	Flag to switch the calibration to be performed on OTM swaptions. An additional column has also been added to the CALIBRATION_RESULTS pricer measure to highlight the option type used in calibration.	True
INCLUDE_FEES	Boolean		True
NPV_ INCLUDE_FEES	Boolean		True
RESET_FROM_CURVE	Boolean		False
NPV_INCLUDE_COST	Boolean		False

Pricer Measures

The standard Calypso pricing outputs are available for PricerLGMM1FForward, described below are the additional outputs specific to the PricerLGMM1FForward:

Pricer Measures	Description
MC Graph	Graph to show convergence of simulations performed.  Number of Trials | PV | Lower mean | Upper mean 127 | 1,557,723.41 | 1,557,079.65 | 1,558,367.17 255 | 1,557,723.50 | 1,557,253.61 | 1,558,193.39 511 | 1,557,723.56 | 1,557,385.23 | 1,558,061.88 1,023 | 1,557,723.59 | 1,557,481.46 | 1,557,965.73 2,047 | 1,557,723.60 | 1,557,551.82 | 1,557,895.39 4,095 | 1,557,723.62 | 1,557,601.68 | 1,557,845.56 8,191 | 1,557,723.62 | 1,557,637.18 | 1,557,810.07 16,383 | 1,557,723.63 | 1,557,662.42 | 1,557,784.83 32,767 | 1,557,723.63 | 1,557,680.32 | 1,557,766.94 65,535 | 1,557,723.63 | 1,557,693.00 | 1,557,754.27 Close
Calibration results	Same as PricerLGMM1Fbackward
Grid Event Flows	Same as PricerLGMM1Fbackward
Pay Projected Flows	When one selects the pricer measure PAY_PROJECTED_FLOWS, the pricer will display projected coupons and discount factors found in pricing the pay leg. 

Pricer Measures	Description
Receive Projected Flows	When one selects the pricer measure RECEIVE_PROJECTED_FLOWS, the pricer will display projected coupons and discount factors found in pricing the receive leg. 

REC_PROJECTED_FLOWS 1310

Accrual Schedule Log

Period	Rate	Notional	Coupon	PmtDate	Df
1	5.000011	1,000,002.30	25,833.39	16/11/2009	9.975209E-01
2	1.215175	1,000,010.53	6,042.12	14/05/2010	9.903711E-01
3	1.634915	1,000,012.04	8,401.65	15/11/2010	9.832678E-01
4	1.134009	1,000,019.69	5,733.05	16/05/2011	9.776646E-01
5	1.638296	1,000,099.51	8,282.50	14/11/2011	9.675588E-01
6	2.646688	1,003,174.51	13,380.48	14/05/2012	9.536722E-01
7	2.721328	1,017,884.76	13,909.01	14/11/2012	9.383609E-01
8	2.583433	1,044,387.67	12,988.93	14/05/2013	9.218492E-01
9	2.386406	1,077,661.36	12,197.19	14/11/2013	9.048468E-01
10	2.129673	1,116,170.43	10,707.52	14/05/2014	8.874052E-01

Close

References

- Hagan, P.S. and Woodward, D.E. (1999), "Markov Interest Rate Models", Applied Mathematical Finance, 6:233-260
- Calypso Technology, "Linear Gauss Markov Model".

3.2.3 eXSP Support – PricerLGMM1FBackward and PricerLGMM1FForward

Overview

The Exotic Structure window (eXSP) is a separate framework which provides the flexibility to define exotic formulas / payoffs for interest and principal payments for either leg on a trade. The eXSP framework is accessible through the 'Structured Window' when an Exotic leg is selected. This functionality allows the user to capture a variety of transaction types when standard trade windows do not facilitate the trade entry, IRD examples include: TaRN, Snowballs and Range Accruals.

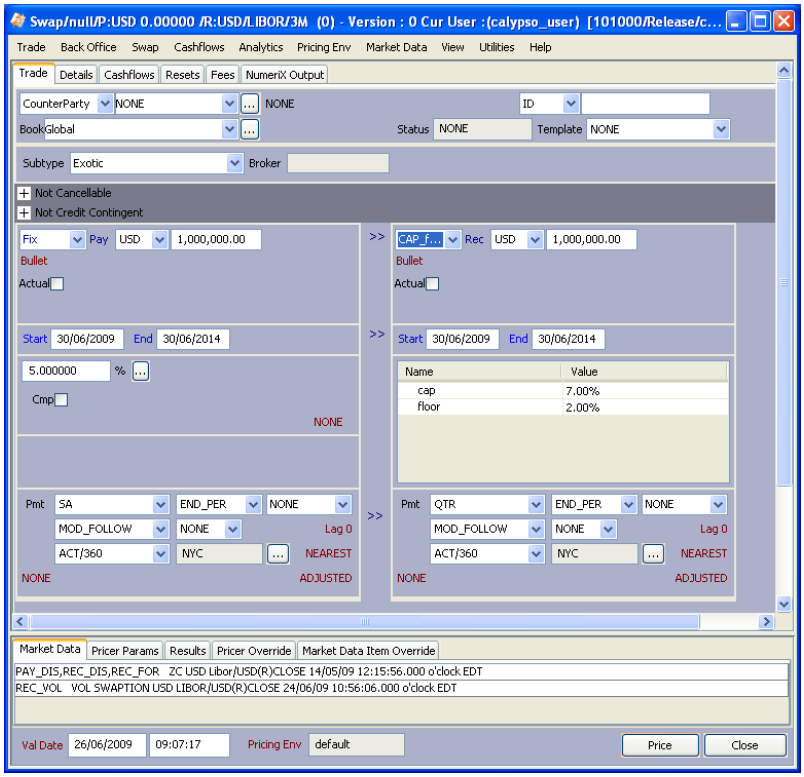
PricerLGMM1FBackward and PricerLGMM1FForward provide pricing support of eXSP structures within the following products: Swaps, Bonds, Single leg swaps and Caps and Floors. PricerLGMM1FBackward also supports swaptions.

For more general information on the use of eXSP please refer to the following Calypso documentation: *Calypso Help - Exotic Structure Window*.

eXSP quotables

All user defined quotables are supported by both pricers provided that they reference information that is applicable to the pricer. Array variables are also supported by both pricers provided they contain valid quotable references, eXSP system variables or functions. Array variables that change with time are also supported. Time series variables are supported by PricerLGMM1FBackward allowing range accrual transactions to be captured.

Trades which incorporate a saved eXSP type or template can be priced with the PricerLGMM1FBackward and PricerLGMM1FForward. eXSP features relating to the structure can be exposed on the trade window, if these are modified, the user must go to cash flows drop down menu and click 'Generate (F8)' before pricing the transaction, this enables the trade structure to be refreshed.



Example of exotic swap using saved eXSP type – Cap / Floor levels exposed in trade window

eXSP System Variables

The table below describes the support of eXSP system variables in each of the pricers; PricerLGMM1FBackward and PricerLGMM1FForward. An error message will be generated if the user attempts to price a transaction containing any of the eXSP variables not supported.

eXSP Variable	Usage	Support in Forward pricer	Support in Backward pricer
sAC	Accumulated coupon payments	YES	NO
sACI	Accumulated coupon payments including current coupon	YES	NO
sCN	Current notional	NO	NO
sCP	Period number	YES	YES
sIN	Initial notional	YES	YES
sPN	Notional in previous period	YES	NO
sPR	Coupon in previous period	YES	NO
sCALCN	Calculated Notional for a given period	YES	NO
sCALCR	Calculated Coupon Rate for a given period	YES	NO

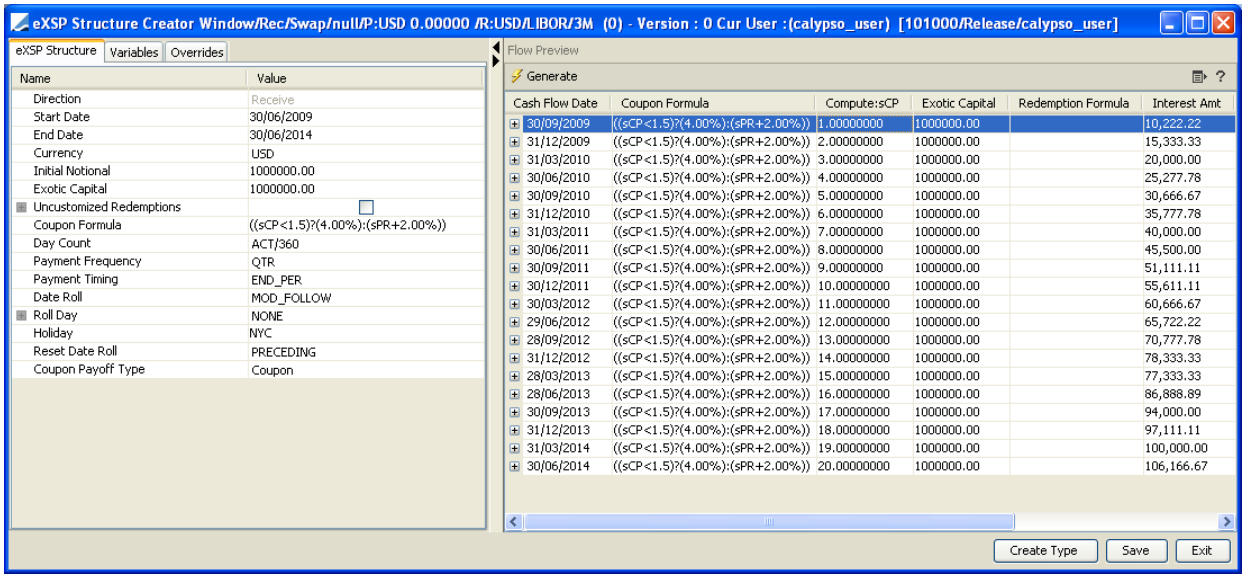
Note: The variables sAC, sACI, sPN, sPR, sCALCN and sCALCR are not supported in the PricerLGMM1FBackward due the likelihood of these variables creating a structure which is path dependent in nature.

For PricerLGMM1FForward if the sPN or sPR variables are used in the first period of the transaction an error message will be generated, however if they are a part of a formula which is not evaluated no error message would be generated:

E.g. Coupon for Snowball structure

(sCP<1.5)?4%:sPR + 2%

when sCP<1.5 no error generated.



Example of eXSP structure when sPR does not create an error message with PricerLGMM1FForward

eXSP Functions

The table below describes the support of eXSP functions in each of the pricers; PricerLGMM1FBackward and PricerLGMM1FForward. An error message will be generated if the user attempts to price a transaction containing any of the functions not supported.

Function	Purpose	Support		Function	Purpose	Support
+	addition of numbers	YES		&&	Boolean AND	YES
-	subtraction	YES		||	Boolean OR	YES
*	multiplication	YES		()?():()	Conditional	YES
/	division	YES		Max	Finds maximum of two values	YES
>	greater than	YES		Min	Finds minimum of two values	YES
>=	greater than or equal to	YES		<=	less than or equal to	YES
<	less than	YES				

eXSP Time Series Functions

Currently PricerLGMM1FBackward provides support of the xwavg function, enabling IRD range accrual transactions to be modelled. An error message will be generated if the user attempts to price a transaction containing any of the other variables described below.

Time Series Variables	Purpose	Support in Forward pricer	Support in Backward pricer
xwavg	Finds the average of a time series variable format is (xwavg, period begin, period end)	NO	YES

eXSP Redemption Formulas

The table below describes the support of eXSP redemption formulas in each of the pricers; PricerLGMM1FBackward and PricerLGMM1FForward. An error message will be generated if the user attempts to price a transaction containing any of the redemption formulas not supported.

Redemption Formulas	Purpose	Support in Forward pricer	Support in Backward pricer
xcoupon	Creates a final coupon upon redemption	YES	NO
xprincipal	Creates a final notional/principal amount upon redemption	YES	NO

3.2.4 Model Calibration - PricerLGMM1FBackward and PricerLGMM1FForward

Calibration of the model parameters for PricerLGMM1FBackward and PricerLGMM1FForward can be performed by a number of different methods, described below:

Auto-Calibration –This calibration method uses predefined rules, refined by the use of pricing parameters, to control the selection of the calibration instruments and behavior of the calibration process. This is the default behavior of the model when LGMM_AUTO_CALIBRATE in the pricing parameter set is set to true (Main entry> Market Data > Pricing Environment > Pricing Parameter Set).

User Defined Calibration Framework - If LGMM_AUTO_CALIBRATE in the pricing parameter set is False, auto calibration is not performed and a custom calibration should be defined. The customized calibration is controlled by a separate framework which allows instruments and calibration to be saved against an individual trade or selection trades.

The user can also enter fixed values the model parameters; model volatility, mean reversion and interest rate via the following transient pricing parameters: MODEL_VOL, MEAN_REV and IR_RATE. These parameters are designed for testing and allow an individual trade to be priced on the fly; they will not be used in risk or portfolio level reports. This method of supplying the model parameters takes precedence over other calibration techniques.

Auto-Calibration

By default the calibration of the PricerLGMM1FBackward and PricerLGMM1FForward models is automated by using the pricing parameter CALIBRATION_INSTRUMENTS and the user does not select specific calibration instruments. For swaption trades the calibration is performed with instruments selected from the exercise schedule of the transaction and the underlying swap details. E.g. for a typical Bermudan Swaption 10Y NC 5Y the calibration instruments would be European swaptions selected to be the core diagonals i.e. 5Yx5Y, 6Yx4Y, 7Yx3Y, 8Yx2Y, 9Yx1Y. On a Fixed Tenor swaption the core swaptions would be 5Yx5Y, 6Yx5Y, 7Yx5Y, 8Yx5Y, 9Yx5Y.

For transaction types which are callable, including exotic callable swaps, the calibration instruments are selected to be in line with the call schedule of the trade with a tenor relating to the structure of the underlying.

For non-exercisable / non-callable trades the calibration instruments are selected to be in line with the start dates of the cashflow on the most frequently paying leg. I.e. the system will create the calibration instruments based on the grid event dates that have been constructed for the trade.

In all of the above cases the strikes of the calibration instruments are set at the fixed strike of the trade or ATM levels, The CALIBRATION_INSTRUMENTS drop down allows the users to control the strike level: CORE_SWAPTIONS selects the fixed rate of the trade and CORE_SWAPTIONS_ATM selects ATM strikes.

As described previously the calibration scheme is controlled by LGMM_CALIBRATION_SCHEME pricing parameter. There are a choice of three settings; EXACT_STEP_SIGMA, BEST_FIT_LM and APPROX_STEP_SIGMA.

User Defined Calibration Framework

Configuration of Calibration Framework

When using PricerLGMM1FBackward and PricerLGMM1FForward the user is able to define the calibration instruments to be used with the model; this requires the use of the Calibration framework.

Out-of-the-box, PricerLGMM1FBackward and PricerLGMM1FForward is designed to calibrate AnalyticsCalibratibleLGMModel using LGMCalibrationFromTemplate. Refer to the Javadoc for information on creating custom models that can be calibrated, and calibrators.

The section below describes the configuration steps of the calibration framework for PricerLGMM1FBackward and PricerLGMM1FForward. Please note this functionality is only available for v10.0 of Calypso and beyond.

- Install Java 3D
- Configure Jars
- Add domain values
- Modify pricer configuration file

Install Java 3D

The hyper surface and calibration applications require the installation of Java 3D. Java 3D can be obtained at the following link: https://java3d.dev.java.net/binary-builds.html

The user has two options when using Java3D with Web Start:

- Option 1 - Have Java 3D installed locally on the client machine. Web Start will pick up the jars from the local JRE.
- Option 2 - The jnlp can use the following line to download the Web Start libraries from Sun - it will ask a security question but installation of Java 3D on the client is not required: <extension href="http://download.java.net/media/java3d/webstart/release/java3d-latest.jnlp"/>

Configure Jars

Add the following jars to the Calypso CLASSPATH:

- j3dcore.jar
- j3dutils.jar
- vecmath.jar

By default, the use of 3D graphics is turned off. It should only be turn it on only if Java 3D is installed. To turn the use of 3D graphics on, set the environment property CAN_HANDLE_JAVA_3D to true. CAN_RENDER_IMAGE_FROM_3D_RENDERER can also be set to true to allow snapshots of 3D graphs to be taken.

[NOTE: This should only be turned on if CAN_HANDEL_JAVA_3D is set to true, AND the current hardware supports GLVERSON > 1.2. If the hardware does not support GLVERSION > 1.2 an exception will be generated and the entire Java session will end.]

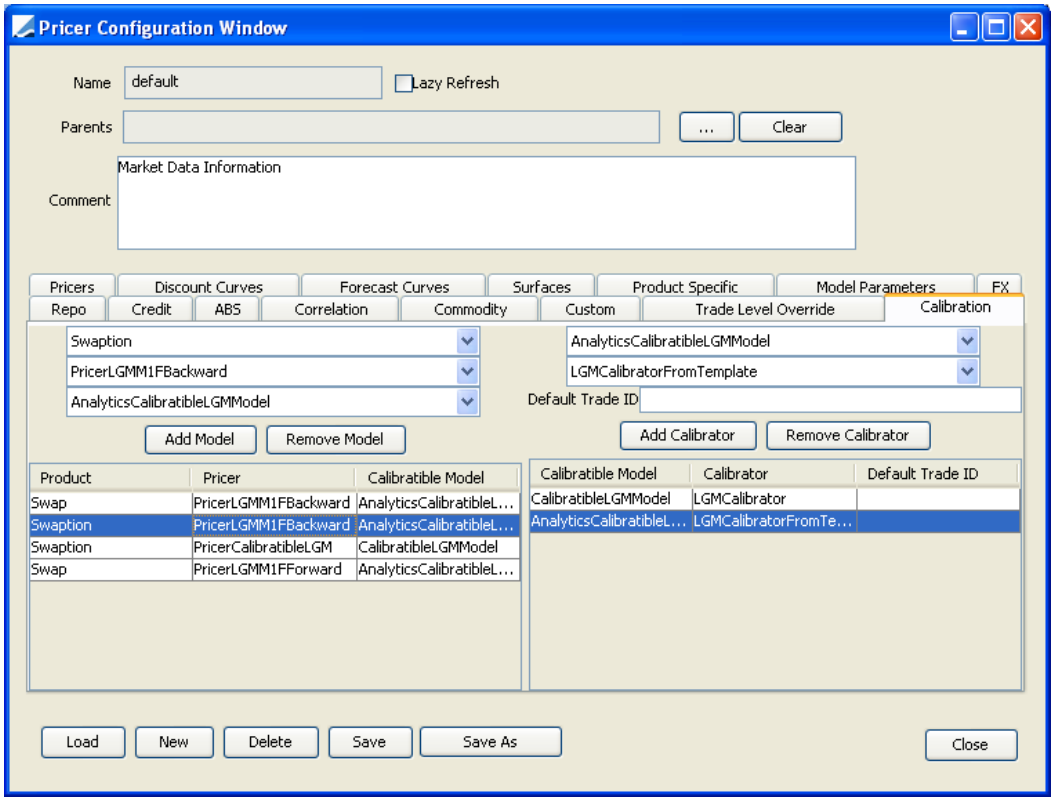
Domain value changes

Go to Main Entry > Configuration > System > Domain Values, make the following additions then click Save All Domains. This configuration will also be performed via the Execute SQL process described in section 2.2.

Domain Name	Value
CustomCalibrationFrameConfig	AnalyticsFrameConfig
CustomCalibrationMeasureConfig	AnalyticsCalibrationMeasureConfig
calibratibleModels	AnalyticsCalibratibleLGMModel
Calibrators	LGMCalibratorFromTemplate

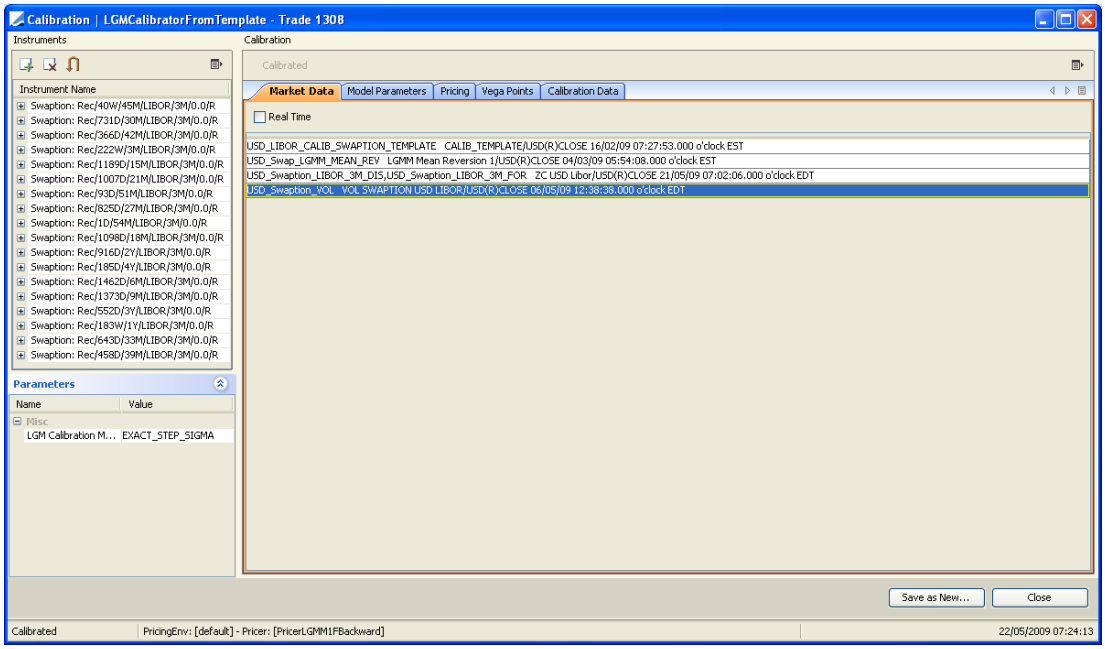
Pricer Configuration changes

For each product type to be priced with the PricerLGMM1FBackward or PricerLGMM1fForward add the calibration model and calibrator as per the example in the below screenshot.



General Description of Calibration Framework

From the trade window choose Utilities > Calibration to perform on-the-fly calibration. The calibration window shown below will be displayed. This framework is used to save a set of calibration instruments against an individual trade or a selection of trades. Once a calibration scheme is saved, the trade will use these instruments to price the transaction even if the trade window or Calypso is closed. The calibration set can be modified and re-saved to a trade if required.



Template

On the left-hand side pane, the template represents the list of instruments used to calibrate the model. By default, the instruments are European swaptions that make up the exercise schedule. If the trade is not exercisable or callable the calibration instruments are selected to be European swaptions that are in schedule with the start date of the cash flow period of the most frequent paying leg.

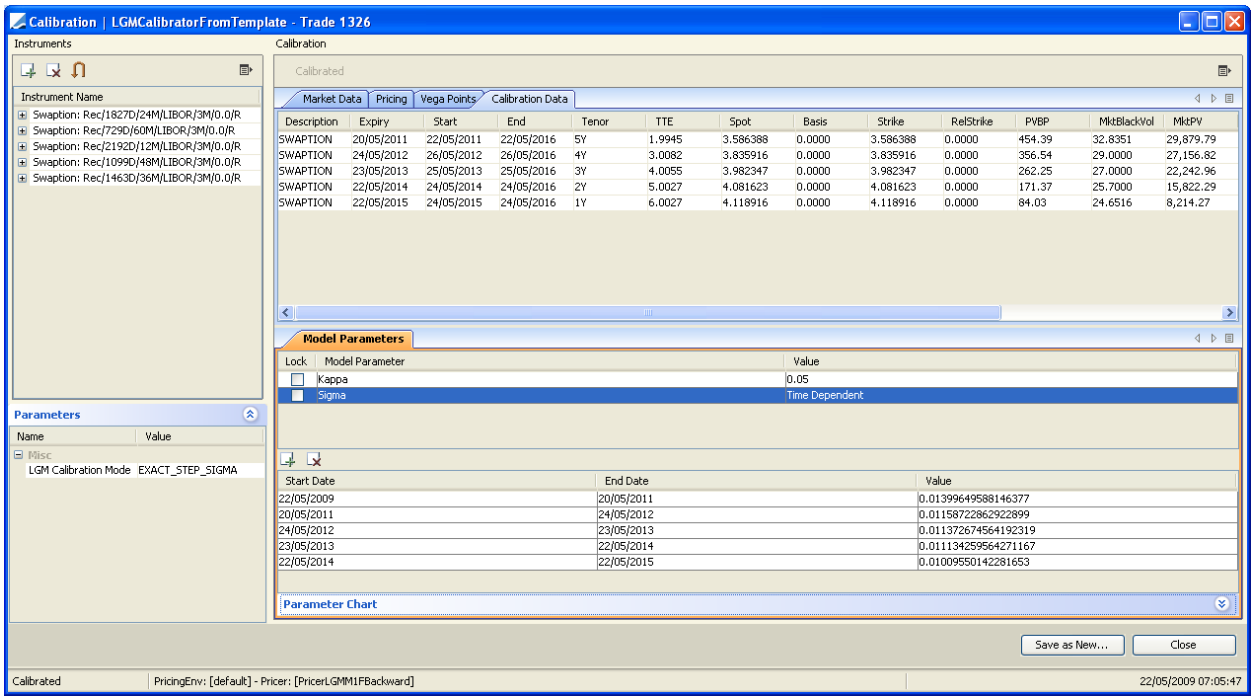
The user can add and remove instruments from that list using the and icons. The default calibration set can be reloaded by using the icon. Additional columns can be displayed for more information using the icon.

Once a set of calibration instruments is defined the user can drill down to the details and modify the parameters as required.

Results

All the panels on the right-hand side display the results of the calibration.

The user can select which panels they wish to display from the View field. Each panel operates independently and can be moved around, or rearranged according to ones needs.



Click a panel heading, and select whether to view it as a new horizontal panel, or as a new vertical panel.

Calibration Process

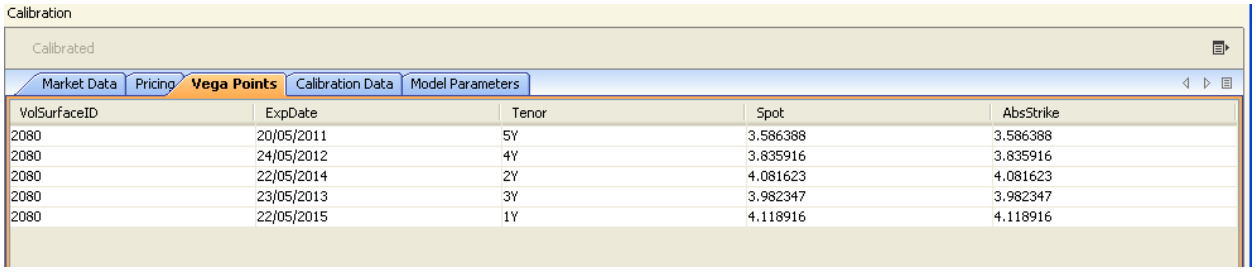
Add calibration instruments on the left-hand side and modify their parameters as required, then click Calibrate. The system will compute Kappa aka LGM mean reversion, and Sigma the LGM model volatility.

If a fixed value for the LGMM_MEAN_REV pricing parameter is configured in the trade, only Sigma will be computed.

If a fixed value for the LGMM_MODEL_VOL pricing parameter is configured in the trade, only Kappa (mean reversion) will be computed.

Vega Points

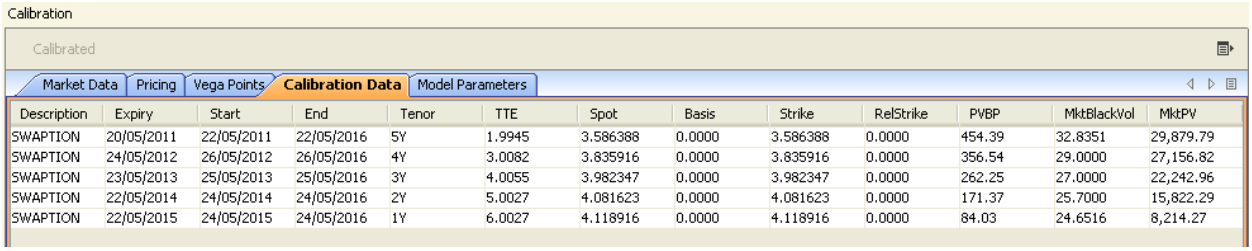
The Vega points tab shows the points on the volatility surface to which the trade will be sensitive to.



The order of the columns can be changed by drag and drop

Calibration Data

The calibration data tab shows the model volatility against the Black volatilities.

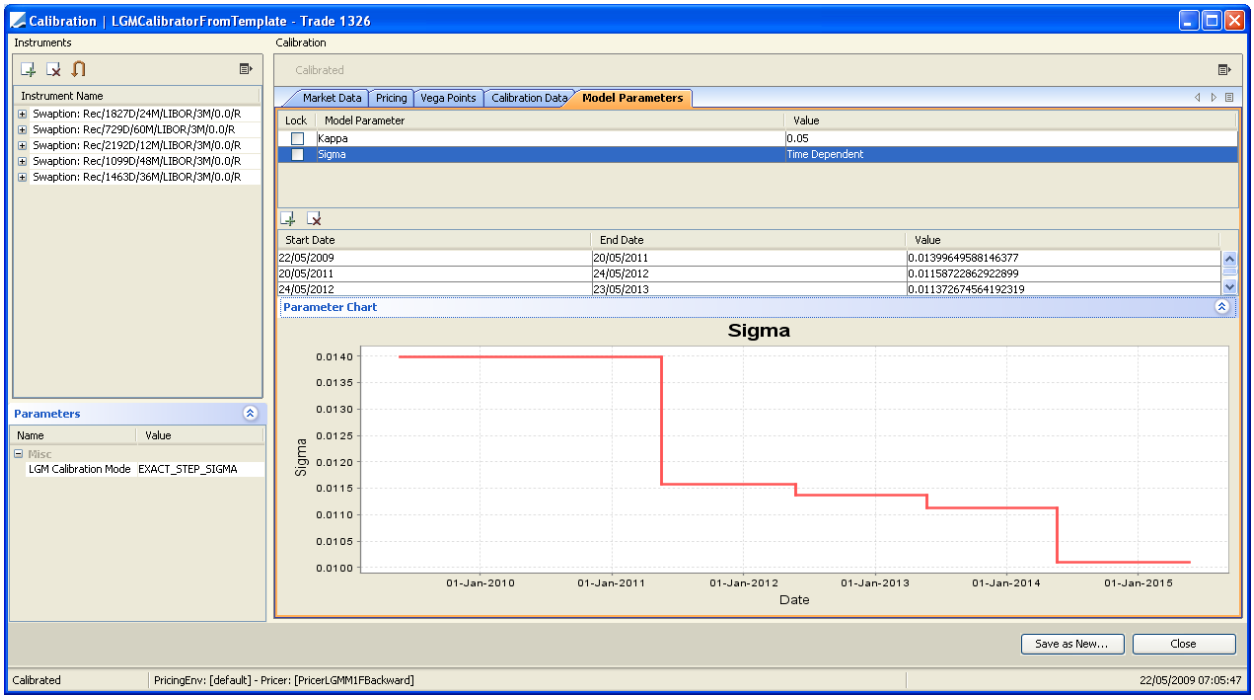


Description	Expiry	Start	End	Tenor	TTE	Spot	Basis	Strike	RelStrike	PVBP	MktBlackVol	MktPV
SWAPTION	20/05/2011	22/05/2011	22/05/2016	5Y	1.9945	3.586388	0.0000	3.586388	0.0000	454.39	32.8351	29,879.79
SWAPTION	24/05/2012	26/05/2012	26/05/2016	4Y	3.0082	3.835916	0.0000	3.835916	0.0000	356.54	29.0000	27,156.82
SWAPTION	23/05/2013	25/05/2013	25/05/2016	3Y	4.0055	3.982347	0.0000	3.982347	0.0000	262.25	27.0000	22,242.96
SWAPTION	22/05/2014	24/05/2014	24/05/2016	2Y	5.0027	4.081623	0.0000	4.081623	0.0000	171.37	25.7000	15,822.29
SWAPTION	22/05/2015	24/05/2015	24/05/2016	1Y	6.0027	4.118916	0.0000	4.118916	0.0000	84.03	24.6516	8,214.27

The order of the columns can be changed by drag and drop

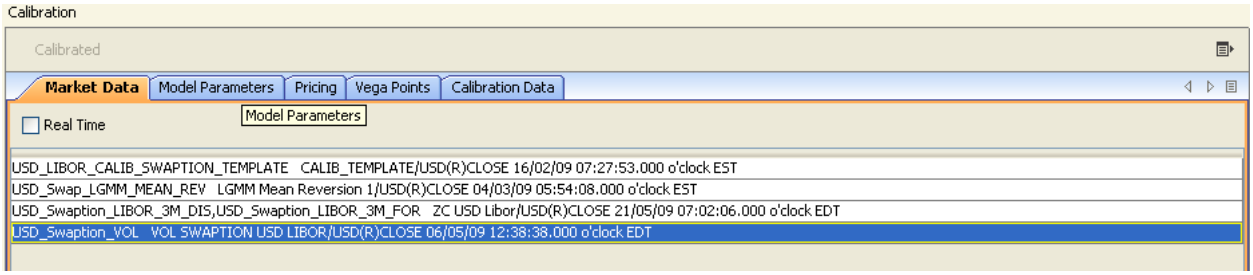
Model Parameters

The model parameters tab displays the computed Sigma and Kappa – The user can drill down to view the details.



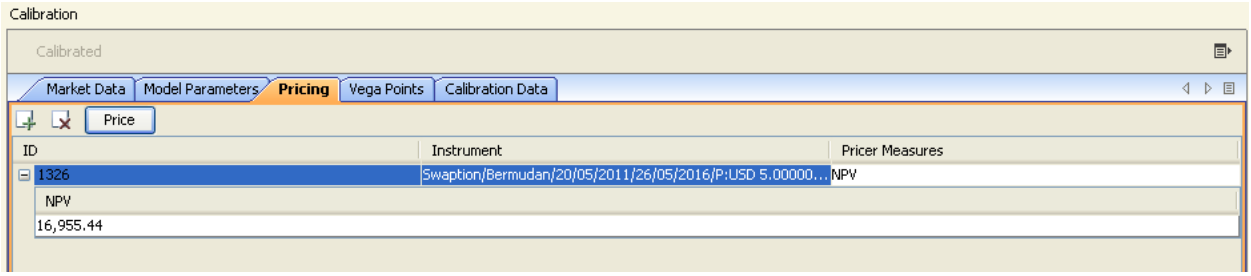
Market Data

The market data tab displays the data used to calibrate the trade.



Pricing

Trades priced using the same calibration set can be added to the pricing tab. This sample implementation currently supports NPV.



Click Price to compute the selected pricer measures.

Click to add a trade. One can add a trade or an underlying instrument from the volatility surface.

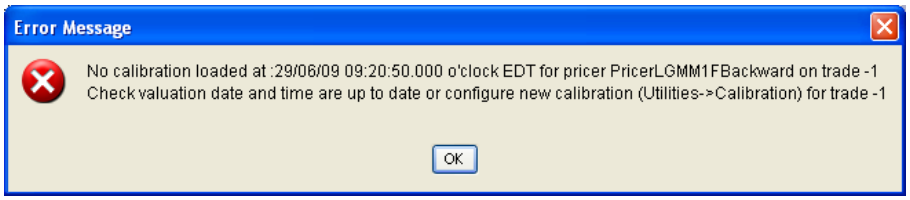
Calibration Scheme

The calibration scheme is controlled by LGMM_CALIBRATION_SCHEME pricing parameter (see drop down menu, bottom left corner of calibration window). There are a choice of three settings; EXACT_STEP_SIGMA, BEST_FIT_LM and APPROX_STEP_SIGMA.

Workflow for using the User Defined Calibration Framework

Below is a description of the necessary steps for calibrating and pricing a trade using the PricerLGMM1FBackward and PricerLGMM1FForward with the customized calibration framework:

- Set up trade (see trade example documentation for further information)
- Save trade
- Set up and save calibration instruments (see description of the calibration framework). If this configuration step is not performed the following error message will be generated:



- Move valuation date/time forwards (double click Val date)
- Price trade

3.2.5 PricerLiborMarketModel

Single Currency

The Libor Market Model (Also known as BGM in reference to the quants that first developed the model: Brace Gatarek Musiela) is a financial model used for the pricing of exotic interest rate derivatives. The Calypso implementation; PricerLiborMarketModel supports the pricing of exotic swap and swaption products.

A Libor market model describes the evolution of a set of spanning, discrete forward LIBOR rates. Each of the forward rates {f0, f1, ..., fn} represents the forward, as seen today, cost of borrowing over its reference period. All the other quantities needed for valuation purposes (discount factors, swap rates etc.) can be derived from the forward rates.

In the spirit of the original Black model, each of the forward IBOR rates evolves according to a displaced diffusion stochastic differential equation

$$\frac{d(f_i(t) + s_i)}{(f_i(t) + s_i)} = \mu_i(t)dt + \sigma_i(t)dW(t)$$

With the drift term being a function of the forward rates and their volatilities and determined by no-arbitrage arguments, see references [1] and [2] for a more detailed discussion.

The volatility of each forward IBOR rate can be specified according to the requirements of the product to be priced so that a set of vanilla swaptions can be replicated while the cap market skew is reproduced.

Different volatility parameterizations are used in the market, the approach currently used in Calypso is the so-called *abcd* parametric form

$$\sigma_i(t) = \kappa_i\left[\left(a + b(T_i - t)\right)e^{-c(T_i - t)} + d\right]$$

with the parameters (a, b, c, d) calibrated to user-selected swaptions and $\mathbf{\backslash mathbit\backslash kappa\backslash mathbiti}$either set to 1 or calibrated to the cap volatilities.

The instantaneous correlation between two forward LIBOR rates is determined by the reset time distance

$$\rho_{ij}(t) = e^{-\beta(T_i - T_j)}$$

with beta being a user input and usually calibrated to historical data.

Calibration

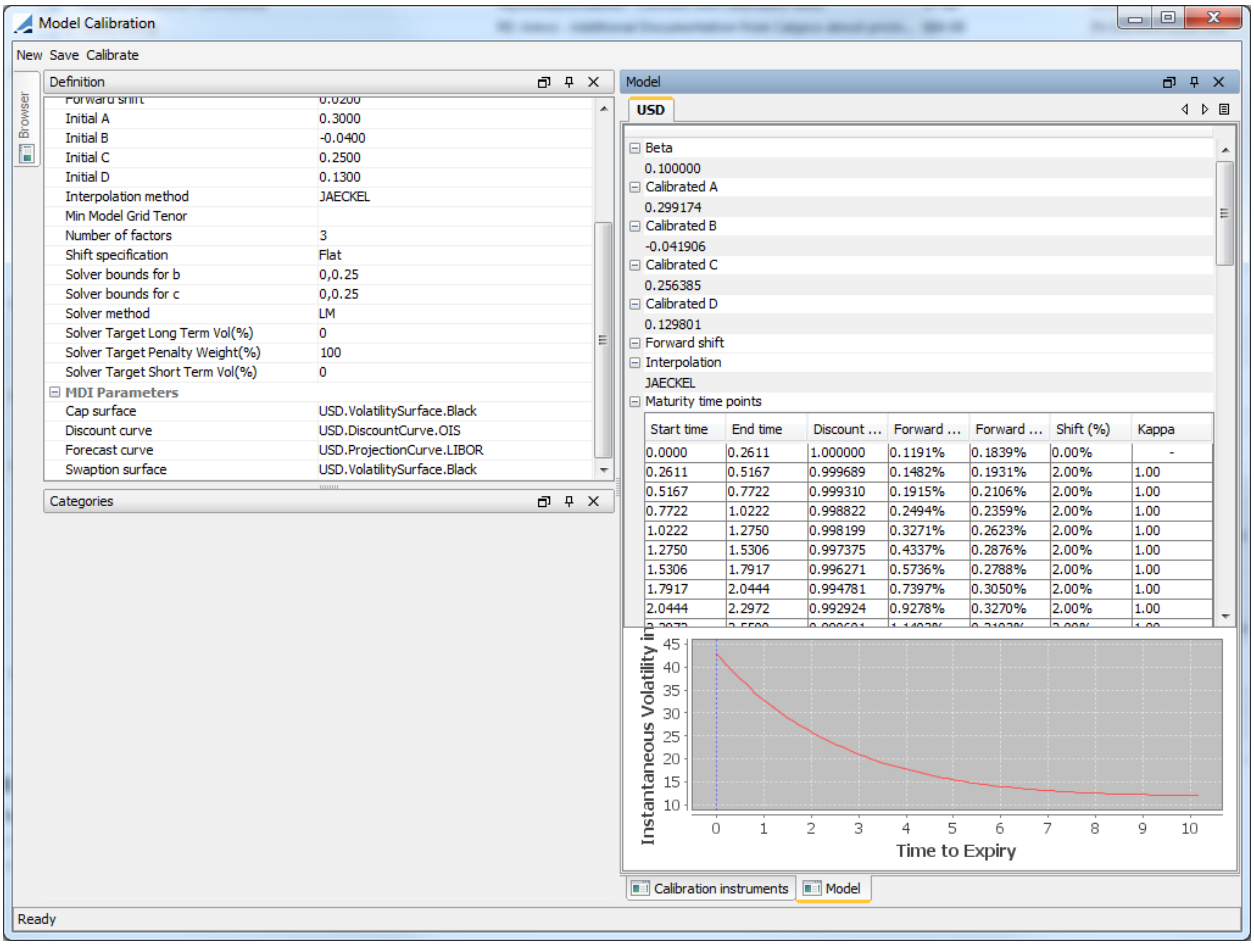
The calibration can be accessed from Main Entry -> Market Data -> Model Calibration. Specify the Calibrator to be LMM, the relevant Pricing Environment and the date/time of the calibration.

Calibration of the parametric abcd specification

The following need to be specified on the model calibration screen

- the name of the model calibration, to be used when accessing it through the Pricer Config
- the correlation **Beta** (as per the model exposition above). This will normally be calibrated by the model user using historical data.

- how the forward rate shift (s_i) will be specified. Setting 'Shift Specification' to
    - **Flat** will set the shift of the forward rates to the shift specified in **Forward Shift**
    - **Calibrated To Caplets** will calibrate the shift to the caplet volatility surface provided as the **Cap Surface** (this is in Beta version)
- the **Number of factors** in the model, should be at least 1
- the **Solver Bounds for b** whose format is lowerBound,upperBound e.g. 0,0.25.
- the **Solver Bounds for c** whose format is again lowerBound,upperBound
- the **Solver Target Long Term Vol** which is a target value of the model a
- the **Solver Target Short Term Vol** which is a target value of the model a+d
- the **Solver Target Penalty Weight** which is the weight applied to the target constraints (recommended default value when specifying the constraints is 100)
- Specify the **Interpolation method** to be, the recommended one being JAECKEL with FLAT_FORWARD being deprecated
- Specify the **Solver method**, if a quick local fit is required use **LM** (for Levenberg-Marquardt), otherwise use the slower global **DE** (for Differential Evolution) fit. The latter may take a few minutes, depending on the number of calibration instruments.
- If the Solver method specified is LM, also specify the initial guess for the volatility parameters {a, b, c, d}
- Specify the **Discount/Forecast curves** and **Cap/Swaption surfaces**. Note that the Cap market is not currently used so it can be the same as the swaption surface. The swaption surface must have a Swap underlying set as it is used to manufacture swaptions during the calibration process.
- Specify the Swaption underlyings in the **Calibration instruments** tab. Note that, since the calibrator optimizes the 4 model volatility parameters {a, b, c, d}, a minimum of 4 calibration swaptions must be specified.
- Hit **Calibrate**, this will calibrate the model and return the calibrated model parameters and model detail on the Model tab. Check that the calibrated model parameters are different to the initial guesses, if they are the same this is an indication that the calibration did not work well.



FAQ - parametric abcd calibration

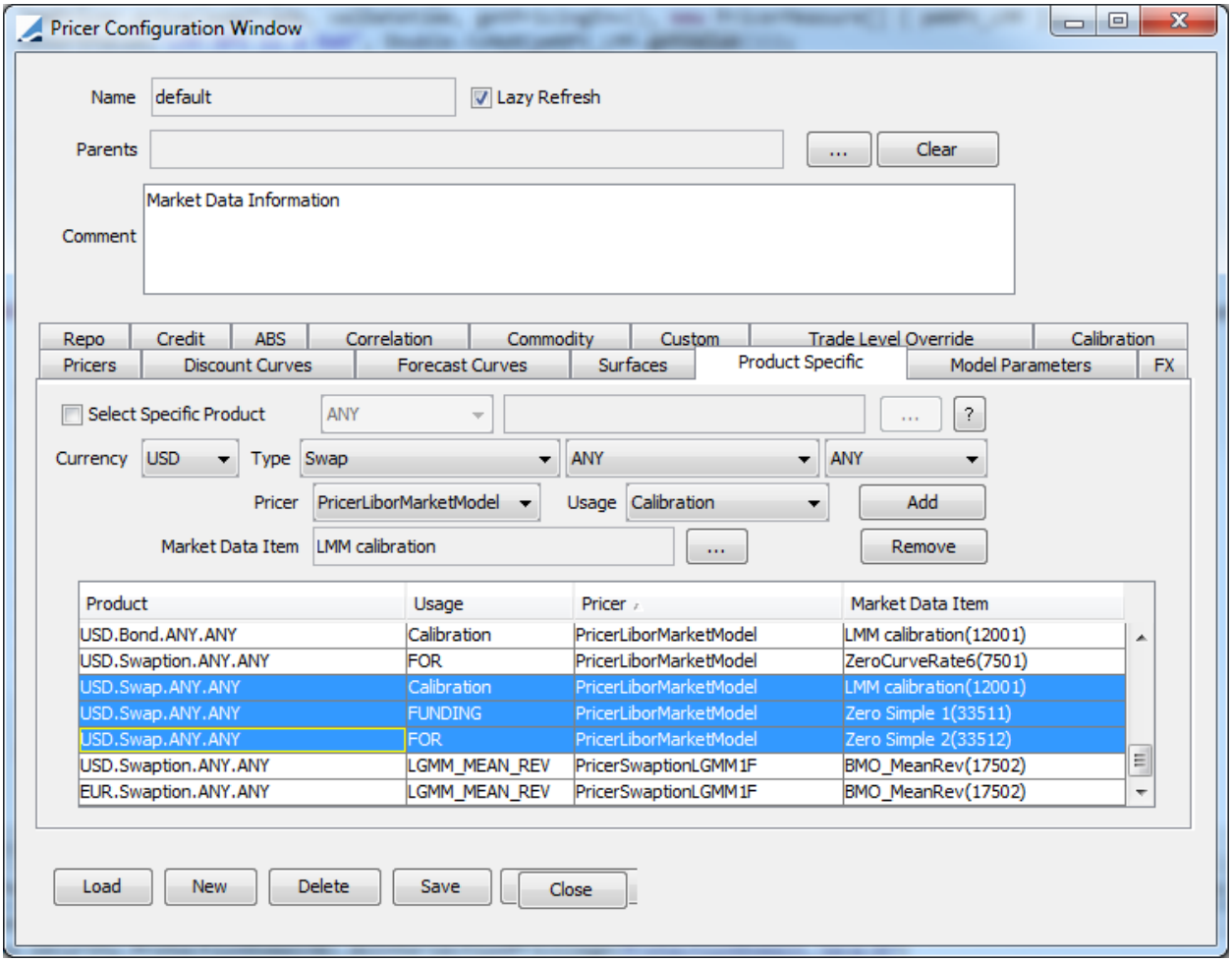
- **If you get an error message about wrong lambdas in the next step**: this is usually observed when using the local optimizer LM and the initial guess is not good enough. Either change the initial guess or switch to the global optimizer - DE.
- **Which Solver to use, LM or DE.** This will depend on the quality of the initial guess for {a,b,c,d}. If the guess is reasonably good then probably use LM as it's a local optimizer and, thus, quick. Otherwise use DE but it will be slower. The best approach might to use DE once in a while to establish the neighborhood of the solution then use LM with the DE solution as the initial guess.

Pricer Config setup

Main Entry -> Pricing Environment -> Pricer Configuration

Under the Product Specific tab associate the type of the trade to be valued (e.g. *Swap*) with the Pricer (*PricerLiborMarketModel*) and the model calibration object under the usage **Calibration**

Under the same tab we can also set up (trade) discount and forecast curves for discounting and forecasting, usage FUNDING and FOR respectively.



Valuation of American Swaptions

The valuation of American swaptions is also supported through the use of an implementation of the Longstaff-Schwartz algorithm. At each exercise date the algorithm computes the estimated exercise and continuation value based on a training set of paths and, based on that, computes a *lower bound* on the value of the option for that path.

When valuing an American option from the Swaption window there are 2 ways to specify the proxy exercise schedule:

1. Specify the exercise schedule on the Exercise Schedule tab
2. Clear the default exercise schedule on the Exercise Schedule tab, thus using a default monthly proxy schedule.

When valuing an American swaption as part of a cancellable swap the default monthly exercise proxy is used.

Cancellable Swaps

The valuation of cancellable swaps is currently supported by the LMM, however all of the legs have to be either Fixed or Float.

Market Data Configuration

Market Data	Description
LMM Calibration	The calibration of the Libor market model is stored on a ModelCalibration object that can be setup from Market Data ->Model Calibration.

Pricing Parameters

Pricing Parameter	Type	Description	Typical Value
ACCURACY_LEVEL	Integer	An integer (1 to 11) specifying the accuracy of the Monte Carlo simulation with 11 being the most accurate and slowest.	5

Pricer Measures

Pricer Measures	Description
NPV	Net Present Value
WAL	The Weighted Average Life of the underlying swap
MC_GRAPH	A graph displaying the convergence of the simulated NPV

Cross Currency

The cross currency model builds on the single currency model, adding a dynamic equation for the FX rate of each currency pair in the model. Although the volatility of any FX rate will in general be stochastic, an approximation of its volatility is employed during calibration that seems to be effective, see the Calypso LMM white paper.

Calibration of the FX volatility

As with the single-currency calibration you access the Cross-Currency calibration window through **Main Entry -> Market Data -> ModelCalibration**

There is a main section where the user specifies

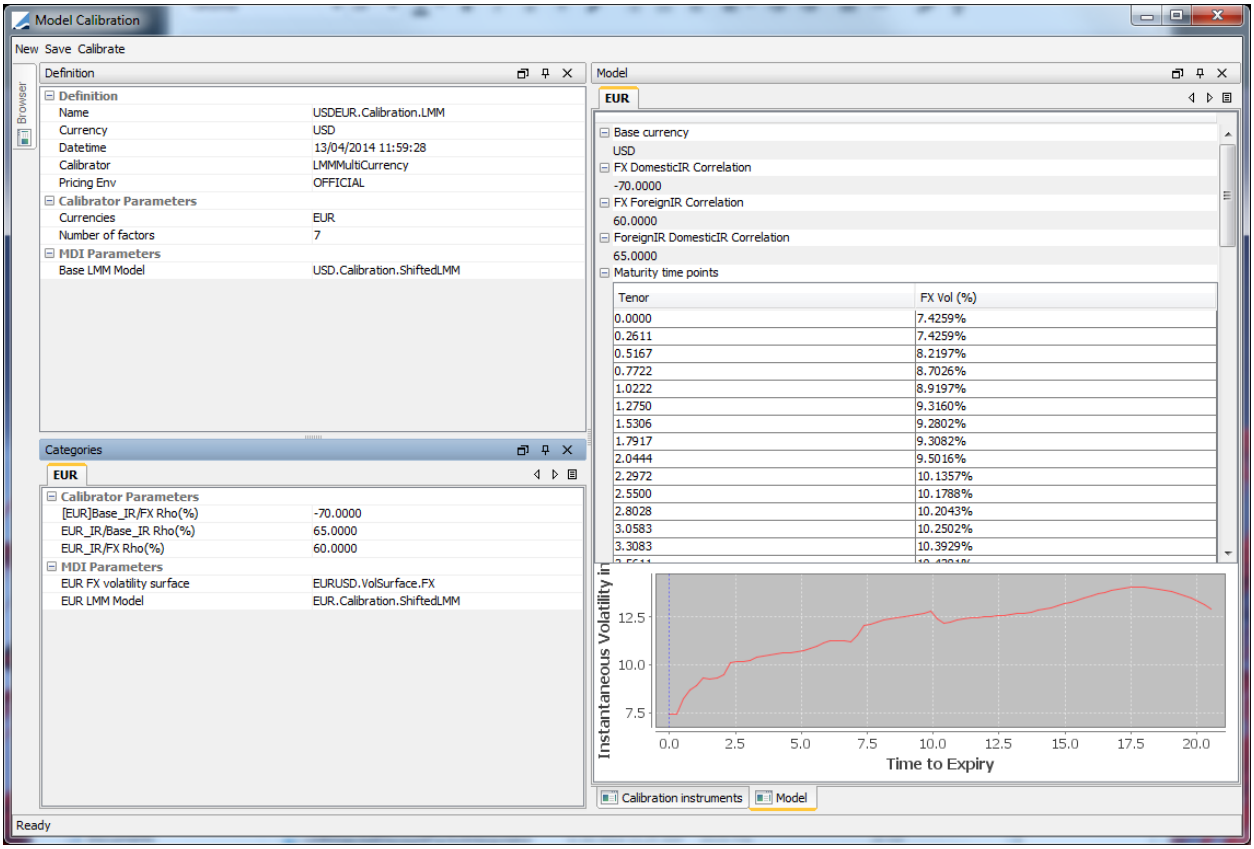
- The name of the calibration
- The base currency
- The calibration date/time
- The calibrator - **LMMMultiCurrency** in this case
- The pricing environment to be used
- The additional currencies (*excluding the base currency*)
- The number of factors of the Cross-Currency model
- The LMM (single currency) calibration for the base currency

For each additional currency AC there is a tab that is used for specifying

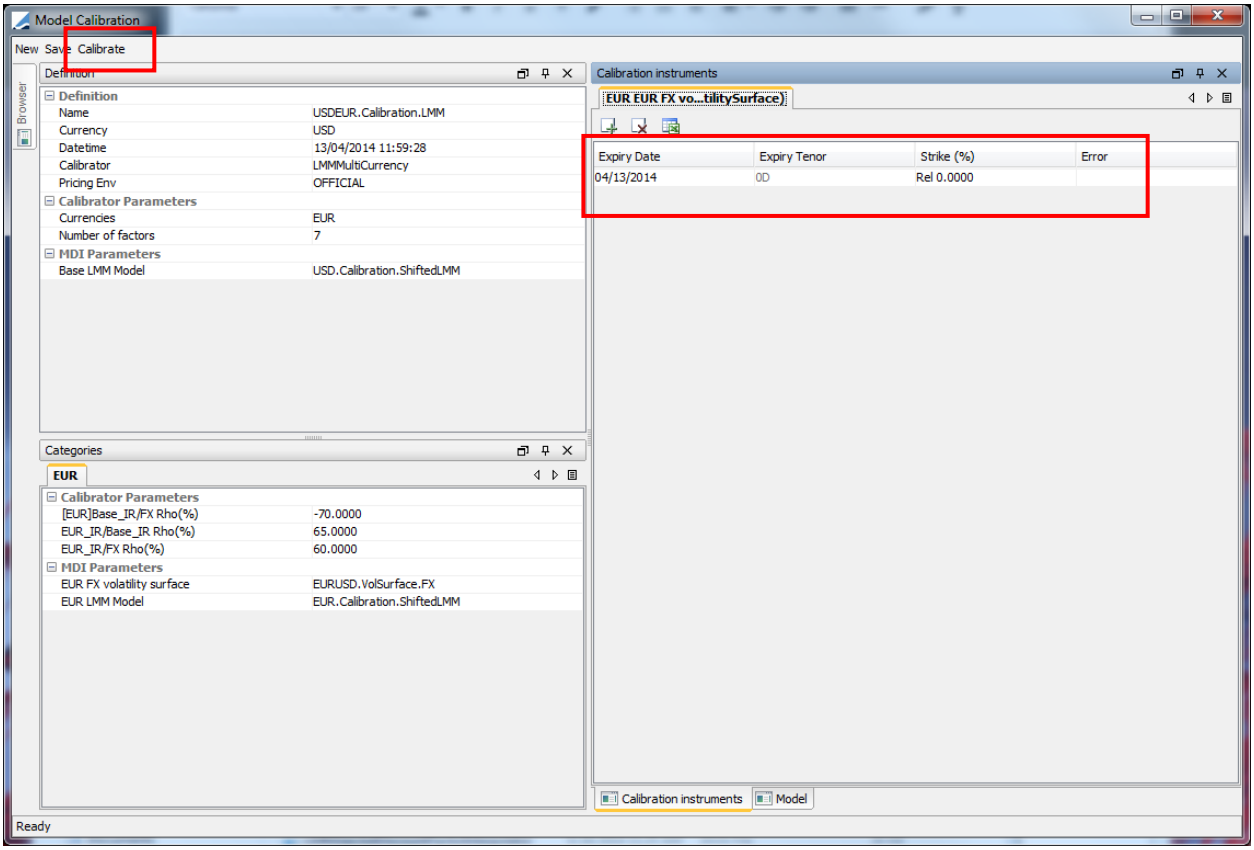
- **[AC]Base_IR/FX Rho:** the correlation of the base IR market with the Base_IR/AC_IR FX rate
- **[AC]_IR/Base_IR Rho:** the correlation of the base IR market with the AC_IR market
- **[AC]_IR/FX rho:** the correlation of the AC_IR market with the Base_IR/AC_IR FX rate
- The volatility surface of the FX rate of the currency against the specified base currency
- The single currency LMM calibration of the currency

Using the screenshot below as an example with USD being the base currency and EUR being an additional currency those 3 correlations would be

- USD_IR / FX Rho, the correlation of USD interest rates with the USDEUR FX rate
- EUR_IR/USD_IR Rho, the correlation of USD interest rates with EUR interest rates
- EUR_IR/FX Rho, the correlation of EUR interest rates with the USDEUR FX rate



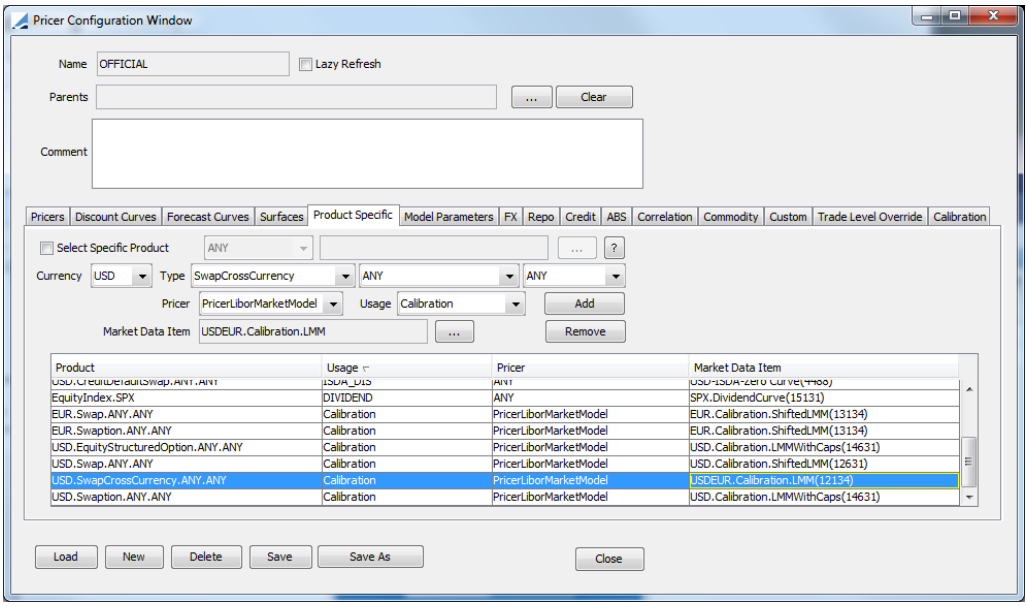
Finally, for each additional currency, a single (template) underlying needs to be specified whose tenor is 0D and its strike is a relative strike to ATF



At that point, the model can be calibrated by hitting 'Calibrate'. For each currency, the calibrated FX volatility curve appears on the Model tab.

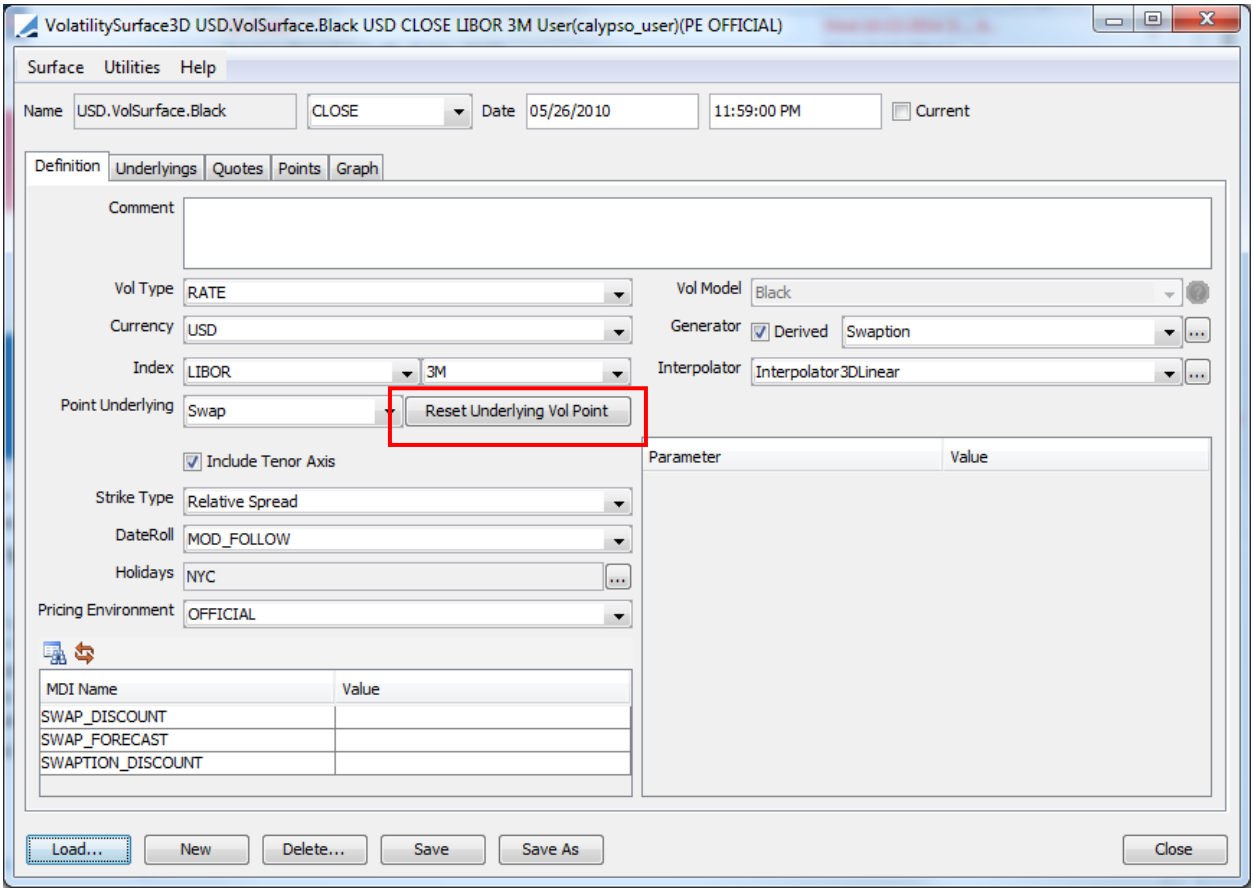
Pricer Config

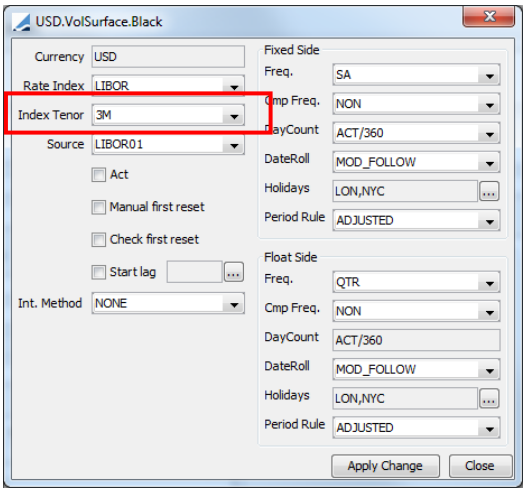
Similarly to the single currency model, the MDI gets assigned according to the base currency



Additional requirements and FAQ

- As the simulation is based on the time grid of the base currency model, all the additional models that are used in the cross-currency calibration need to have the same model tenor. You set that when specifying the volatility surface swap underlying. Note that the model tenor is independent of the LIBOR tenor of the market that is calibrated; it only specifies the tenor of the forward rates that are used as the building blocks of the LMM model. In the USD/EUR cross-currency model example, the natural model tenor for USD might be 3M wherein the EUR model tenor would have to also be specified as 3M.





- When valuing a cross currency trade there is a base currency allocated to the trade according to some standard Calypso logic – e.g. for a cross-currency Swap this may be the currency of the Pay leg. This is the currency that will then be used to retrieve the calibration through the Pricer Config and express the trade valuation in. If this is not the natural currency for a particular trade you can use the parameter LMM_MEASURE_CURRENCY for that purpose. For instance, for valuing a cancelable Pay AUD / Rec EUR swap you may want to have EUR as the base currency and use a EUR/AUD (base currency/additional currency) LMM calibration, in that case you can specify EUR as the LMM_MEASURE_CURRENCY.

References

[1] Engineering BGM, A. Brace

http://www.amazon.co.uk/Engineering-Chapman-Hall-Financial Mathematics/dp/1584889683/ref=sr_1_1?ie=UTF8&s=books&qid=1292504752&sr=8-1

[2] Extended Libor Market Models with Stochastic Volatility L. Andersen & R. Brotherton-Ratcliffe

http://www.globalriskguard.com/resources/fideriv/andersen.pdf

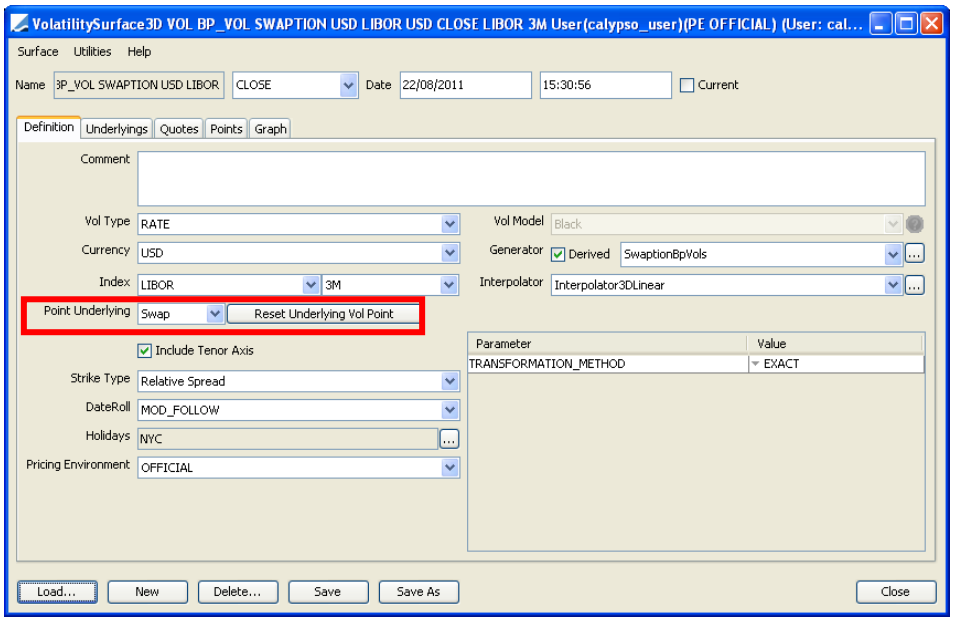
[3] Efficient Pricing and Greeks in the Cross-Currency LIBOR Market Model, C. Beveridge, M.S. Joshi & W.M. Wright http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1662229

3.3 Pricers for Callable Notes - PricerLGMM1FSaliTree

Overview

Calypso Analytics currently supports pricing of notes with PricerLGMM1FSaliTree: callable notes, cancellable notes, Bermudan "Notes" with step up/down coupons, American notes and Cancellable Flippers with optionalities. The model used for the valuation of each of these variations of products is the LGM model discussed in detail within this document.

Calibration is performed to standard European swaption with characteristics specified in the surface Point Underlying

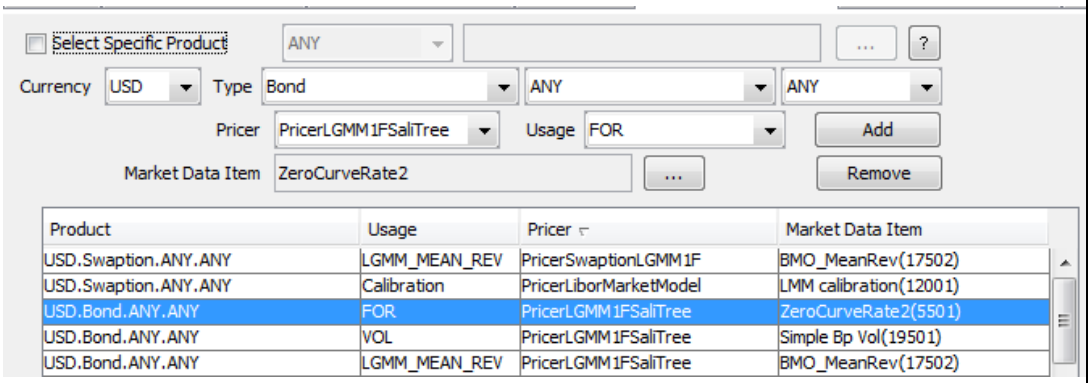


Option notional and exercise fees

The option notional is the Bond trade nominal – which is split between the bond Face Value (specified in the Bond product) and the (implied) trade quantity. The Issue Price and Redemption Price are assumed to be 100% and not used by the option pricer. The exercise fee is a percentage of the *initial* nominal.

Market Data Configuration

Market Data	Description
Discount Curve	Same as PricerSwaption - Standard Configuration if not set up in the Volatility surface Alternatively a funding curve can be defined as a MDI parameter in volatility surface under SWAPTION_DISCOUNT. MDI Name / Value SWAP_DISCOUNT SWAP_FORECAST SWAPTION_DISCOUNT: BMO_FUNDING 26/02/13 09:04:48...
Forecast Curve	Defined on the Product Specific tab in the Pricer Configuration shown as below if the coupon is floating.

Market Data	Description
	Ignore this step if the bond has fixed rates only. In this case the discount curve will be used for forecasting as well during calibration. 
Additional Zero Curves	Using the same generator and surface underlyings as before. In the MDI parameter area, you will see the below three new items, all of kind CurveZero. SWAP_DISCOUNT – this MDI will be used as the vanilla discount curve. SWAP_FORECAST – this MDI will be used as the vanilla forecast curve. MDI Name / Value SWAP_DISCOUNT / USD.3M.LIBOR.FLAT/2.5% 6/26/18 7:... SWAP_FORECAST / USD.3M.LIBOR.FLAT/2.5% 6/26/18 7:... SWAPTION_DISCOUNT /
Swaption Volatility	Same as PricerSwaption - Standard Configuration
LGMM Mean Reversion Matrix	Same as PricerSwaptionLGMM1F

Pricing Parameters

Pricing Parameter	Type	Description	Typical Value
LGMM_MEAN_REV	Rate	Same as PricerLGMM1Fbackward	
LGMM_MODEL_VOL	Rate	Same as PricerLGMM1Fbackward	
LGMM_IR_RATE	Rate	Same as PricerLGMM1Fbackward	
LGMM_CALIBRATION_INSTRUMENTS	Choice	Same as PricerLGMM1Fbackward – Calibration for PricerSwaptionLGMM1F is controlled via pricing parameters only, it does not use the calibration framework	

Pricing Parameter	Type	Description	Typical Value
LGMM_CALIBRATION_SCHEME	Choice	Same as PricerLGMM1Fbackward - Calibration for PricerSwaptionLGMM1F is controlled via pricing parameters only, it does not use the calibration framework	
LGMM_CONTROL_VARIATE	Boolean	When pricing the Bermudan, also price the first European numerically and use it as a control variate.	FALSE
LGMM_LATTICE_NODES	Integer	The number of nodes in the discretisation of the state space of the Markov process.	35
LGMM_QUAD_ORDER	Integer	The number of point in the local quadrature rule used in the roll-back routine.	20
LGMM_LATTICE_CUTOFF	Double	The number of deviations to the outer model node in the state space discretisation.	6
LGMM_RISK_OPTIMISE	Boolean	Controls whether or not optimization techniques are used within scenario analysis, in particular for shift and re-values of the volatility surface.	TRUE
LGMM_MIN_MEAN_REVERSION	Rate	When using CALIBRATION_SCHEME=BEST_FIT_LM the user can control the minimum level of mean reversion permitted within the calibration.	-1%
LGMM_MAX_MEAN_REVERSION	Rate	When using CALIBRATION_SCHEME=BEST_FIT_LM the user can control the maximum level of mean reversion permitted within the calibration.	5%
LGMM_MIN_SIGMA	Rate	When using CALIBRATION_SCHEME=BEST_FIT_LM the user can control the minimum level of model volatility permitted within the calibration.	0.01%
LGMM_MAX_SIGMA	Rate	When using CALIBRATION_SCHEME=BEST_FIT_LM the user can control the maximum level of model volatility permitted within the calibration.	2%
LGMM_BEST_FIT_GRAPH_MESH_SIZE	Integer	When the Pricer Measure LGMM_BEST_FIT_ERR is used, this parameter controls how fine	30

Pricing Parameter	Type	Description	Typical Value
		the mesh used in the brute force search is.	
***MAX_DAYS_SPACING** (*Implemented and applicable for American fixed tenor swaptions only)	Integer	Maximum number of days between time splices in the lattice to be used when pricing American Fixed tenor swaptions. User enters an integer related to the number of days to approximate exercise schedule used in pricing e.g. 30 days	30
LGMM_CALIB_SPACING	Integer	For American swaptions a flag pertaining to the minimum number of days between successive exercise dates becomes visible. Ensure that this spacing is less than or equal to the frequency of the exercise schedule	7
LGMM_CALIB_SPACING_SWITCH	Integer	For American Swaptions a flag decides the option could be exercised daily up until X days after val Date.	0
LGMM_LAST_EXERCISE_DATE	String	Option to set last exercise date for long-term American options. Could be of format '10y', '5m', '3d' or 'dd=10/mm=03/yy=2010'	Null
LGMM_CALIB_MIN_CALENDAR_DAYS	Integer	Parameter to control the construction of the calibration instruments, the aim is to remove instruments with short dated expiries from the calibration process. If >0, the lag between the value date and the next exercise date will be at least the number of days assigned to the parameter.	7
LGMM_CALIBRATE_TO_OTM_OPTIONS	Boolean	If set to true it will calibrate to OTM options when valuing regular (with no variation in the notional or coupon) Bermudan options.	False
LGMM_ADJUST_FOR_MIDFLOW_EXERCISE	Boolean	If set to true, a flat forward approximation is used in γ(Tex, Te) * (F(Tex, Tex, Te) + [F(t, Ts, Te) - F(t, Tex, Te)])	True
LGMM_CALIBRATE_TO_STD_OPTIONS	Boolean	if set to true, it calibrates to vanilla swaptions as specified by the point underlying swap on the volatility surface used.	True

Pricing Parameter	Type	Description	Typical Value
		Note that Bermudan options on irregular swaps (i.e. with amortising notional, fixed coupon schedule, zero coupon payment) use standard swaption calibration always.	
CALIBRATION_VOL_TYPE	Choice	BLACK_VOL, BP_VOL The volatility model used when calibrating the model.	BLACK_VOL
SWAP_REPLICATION_METHOD	Choice	swap_rate_offset, overlap_negative_weights Defines swap replication method – methodology described below.	swap_rate_offset
DATES_TO_TENOR_THRESHOLD	Integer	The number of days within which a whole year is preserved	7
NPV_INCLUDE_COST	Boolean	If set to True for Bond pricing, settlement amount is included in the bond NPV pricer measure.	True
NPV_INCLUDE_COST_AFTER_SETTLE_DATE	Boolean	Should be set to False for Bond pricing. It means that once the bond trade is settled, the settlement amount is no longer included in the NPV.	False
ZD_PRICING	Boolean	If True for Bond, the price is discounted until today instead of settlement date.	True
LGMM_CALC_FUNDING_SPREAD	Boolean	If true we calculate the OAS described below and apply the same to the funding curve before pricing.	false

Type 1: Callable Bermudan "Notes"

In this variant the bond is callable.

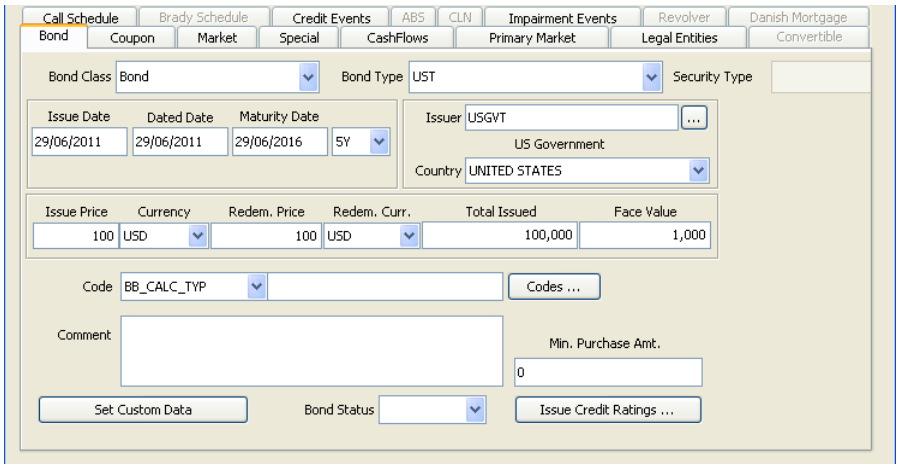
An example trade would be

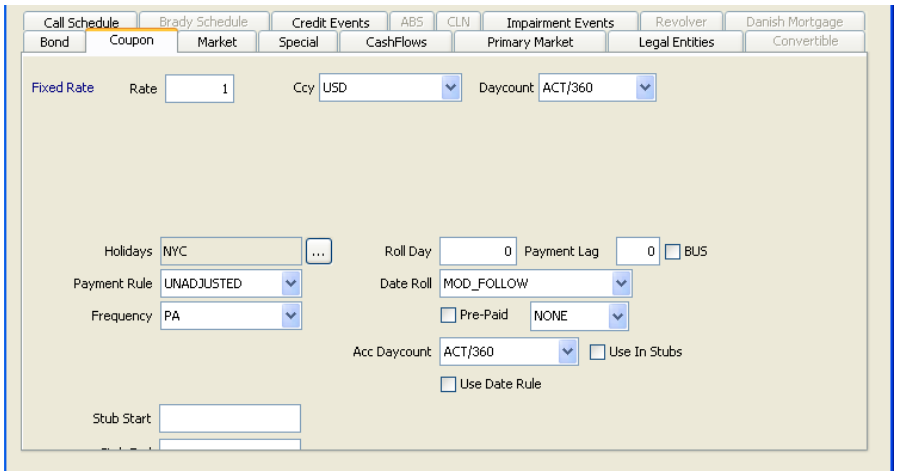
Calypso Product: Bond

Maturity 5y

Notional USD 1000

Coupon: 1%

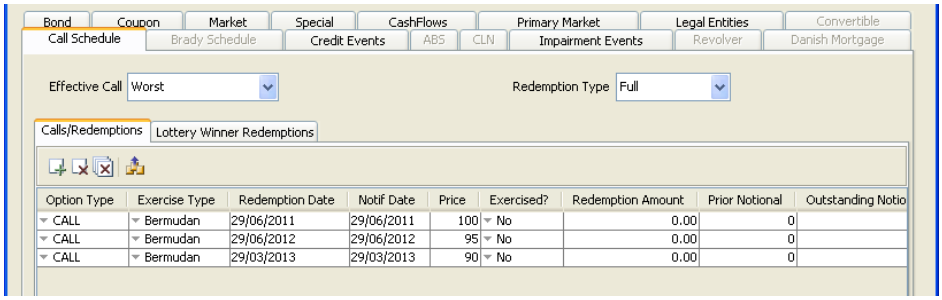




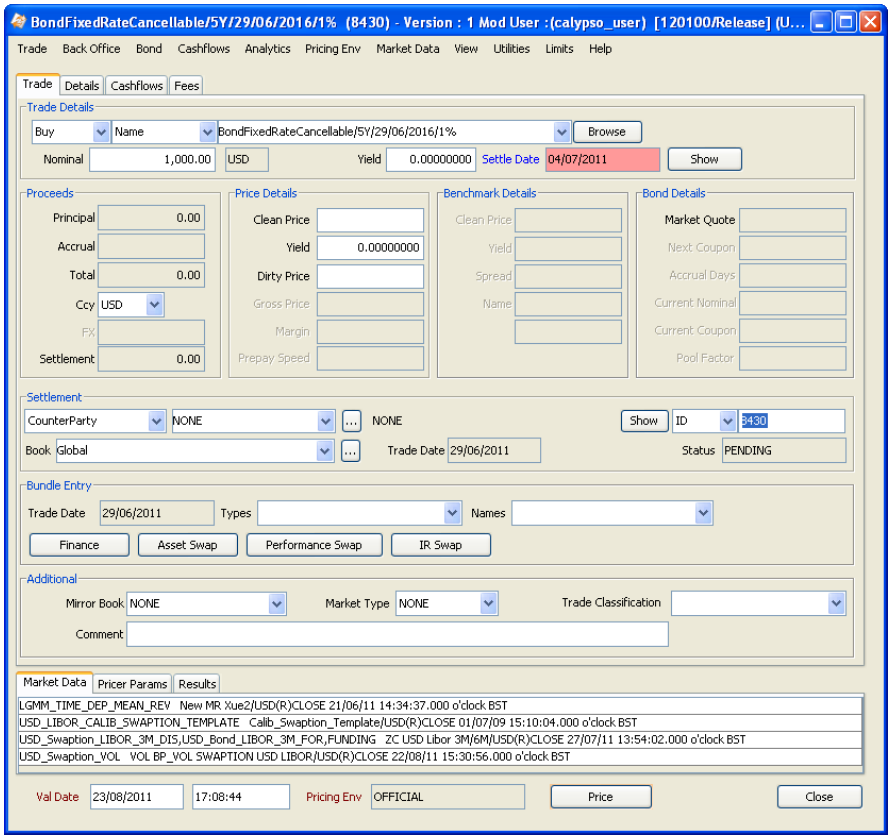
The trade is booked as a callable bond with exercise dates, see example below. The fee at each exercise date is the percentage of the bond face value paid/received if the option holder exercises into the bond.

The Option Type of all exercise dates is set to CALL.

The price of 100 indicates callable price is 100% of original notional.

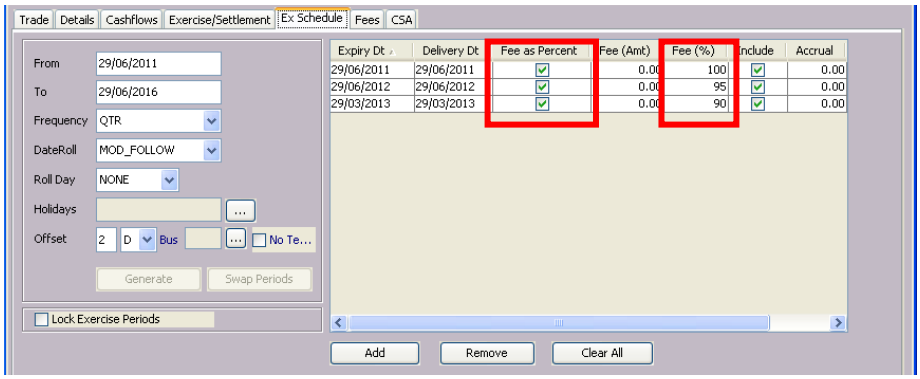


The bond is booked as usual with the callable bond being populated with the callable details. Nominal in the trade shows the notional used in the trade, which can be different from notional (Total Issued) set in the product window.



The pricer to use is PricerLGMM1FSaliTree and the usual LGM parameters need to be setup.

The callable bond in this case is similar to a Bermudan swaption that receives a fixed leg with same fixed rate and exercise schedules:



Type 2: Cancellable Bermudan "Notes"

In this variant the bond is cancellable.

An example trade would be similar as a callable bond only the call schedules should have option types PUT.

Bond

Maturity 5y

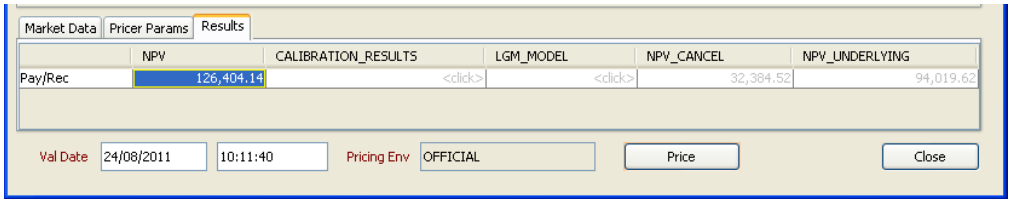
Notional USD 100,000

Coupon: 1%

Option Schedule: All exercise dates have option type set to PUT.

This trade is booked as a cancellable bond as before. In this case, the price of a bond is the sum of an option and the value of the bond (calculated from bond itself).

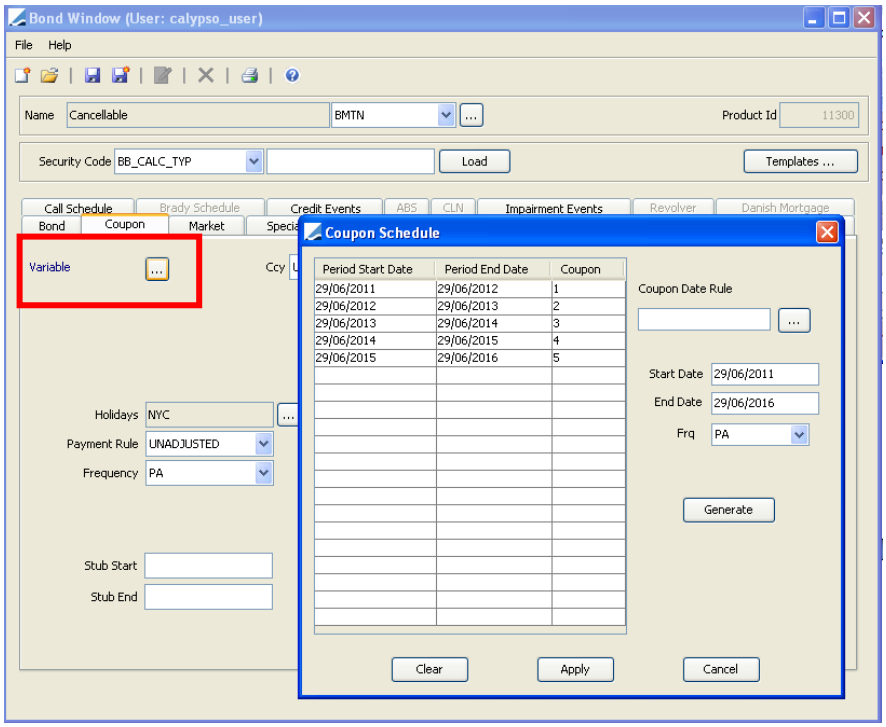
Below is an example of a cancellable bond pricing results. NPV_CANCEL indicates the value of the cancellable bond and NPV_UNDERLYING indicates the value of the bond.



NPV_CANCEL should be close to the value of a similar payers Bermudan Swaption.

Type 3: Bermudan "Notes" with step up/down coupons

This is essentially an accreting bond and can be booked as such using the bond definition window.



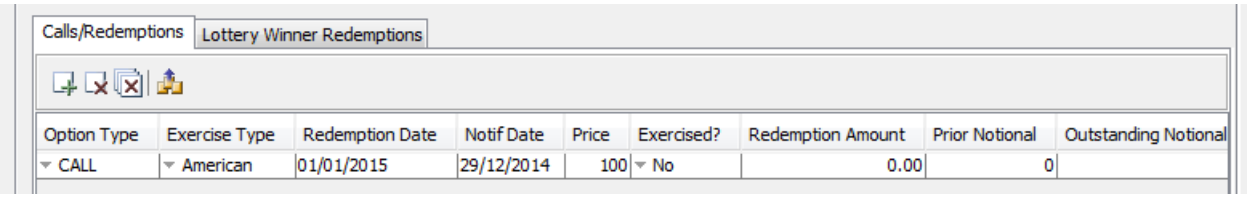
Note that this note is an 'irregular' option type and, therefore, the SWAP_REPLICATION_METHOD parameter needs to be defined. **Currently the only supported method is swap_rate_offset.**

Type 4: Cancellable American "Notes"

Similar as cancellable Bermudan notes, a cancellable American note has one and only one cancellable schedule exercise type American.

Redemption date indicates the first call date with the minimum of X business days notice. This X is defined by (Redemption date - notification date). The bond can be cancelled daily until the bond maturity date.

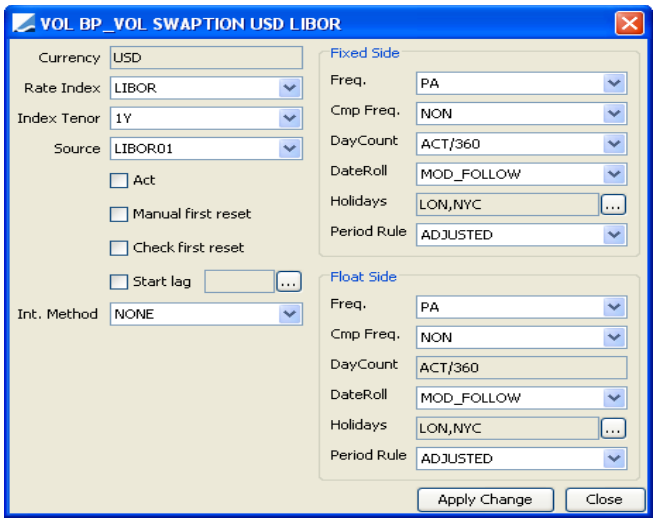
The parameter STUB_TOLERANCE is hard coded to 0 when creating standard calibration swaptions, so that the first short period of cashflow will always be taken into account.



Two transient/global parameters are supported for American cancellable bonds:
CALIB_SPACING_SWITCH - initial number of days for which the valuation model assumes daily exercise
CALIB_SPACING - call frequency after the initial daily exercise period at the front end of the trade

Calibration to Standard Swaptions

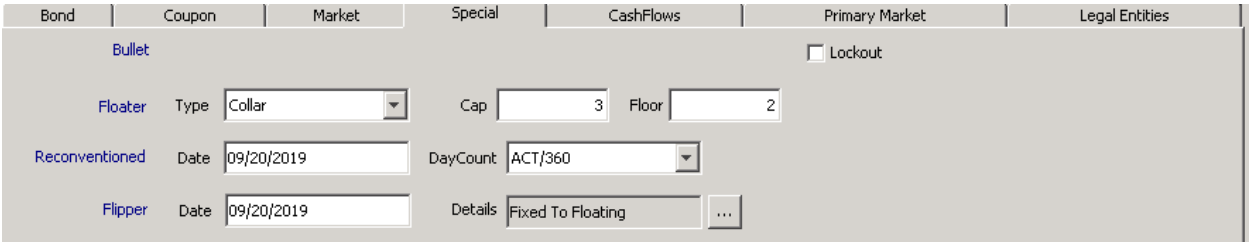
When using PricerLGMM1FSaliTree any callable trade can be valued by calibrating to the *standard swaptions* of the reference swaption market. The conventions used to define the standard swaptions are set on the Point Underlying of the volatility surface. **This feature is only available on volatility surface in Calypso v12.0 onwards.**



Type 5: Cancellable Flipper "Notes" with optionality's.

Similar as cancellable Bermudan notes, a cancellable flipper is a fixed couple cancellable note that "flips" at a couple date and turns into a cancellable FRN.

Optionality type Collar, Cap and Floor are also supported.



Pricer Measures

EFFECTIVE_DURATION and EFFECTIVE_CONVEXITY

The measures EFFECTIVE_DURATION and EFFECTIVE_CONVEXITY are computed by shifting the Trade Funding Curve by a fixed amount (1bp) up as well as down and computing the derivatives numerically.

$$\text{EFFECTIVE DURATION} = \frac{\text{PvDown} - \text{PvUp}}{2 * \text{shift} * \text{PvBase}}$$

The EFFECTIVE_CONVEXITY is computed as the second derivative, using the same values:

$$\text{EFFECTIVE CONVEXITY} = \frac{\text{PvDown} - 2 * \text{PvBase} + \text{PvUp}}{\text{shift}^2 * \text{PvBase}}$$

This method requires a change when the BOND_FROM_QUOTE parameter is set to true. In such a case the naïve calculation will return a value of zero for both parameters. Therefore, in this case we compute the Option Adjusted Spread at the same time as the PvBase, and we store this parameter as the INSTRUMENT_SPREAD quote. After that, the calculation proceeds as in the previous case.

OPTION_ADJUSTED_SPREAD (OAS)

This is a new pricer measure that's introduced to calculate the funding spread. When one shifts the funding curve by this spread, the NPV(price) of the bond should match that from the market quote.

We can also replicate the result by using a new funding curve built from the original funding curve and this spread. NPV should be the same.

There are two ways to calculate OAS –

- By putting the OAS pricer measure in the pricing results. In this case we calculate the OAS only and display it in the pricing results.
- By setting LGMM_CALC_FUNDING_SPREAD to true. In this case we not only calculate the OAS but apply the same to the funding curve before pricing.

3.4 Pricers for IDI derivatives

3.4.1 PricerIDIAnalytic

Overview

PricerIDIAnalytic supports the valuation of vanilla options, where the underlying is the IDI index. (IDI options)

Definition of the IDI (as per BM&F):

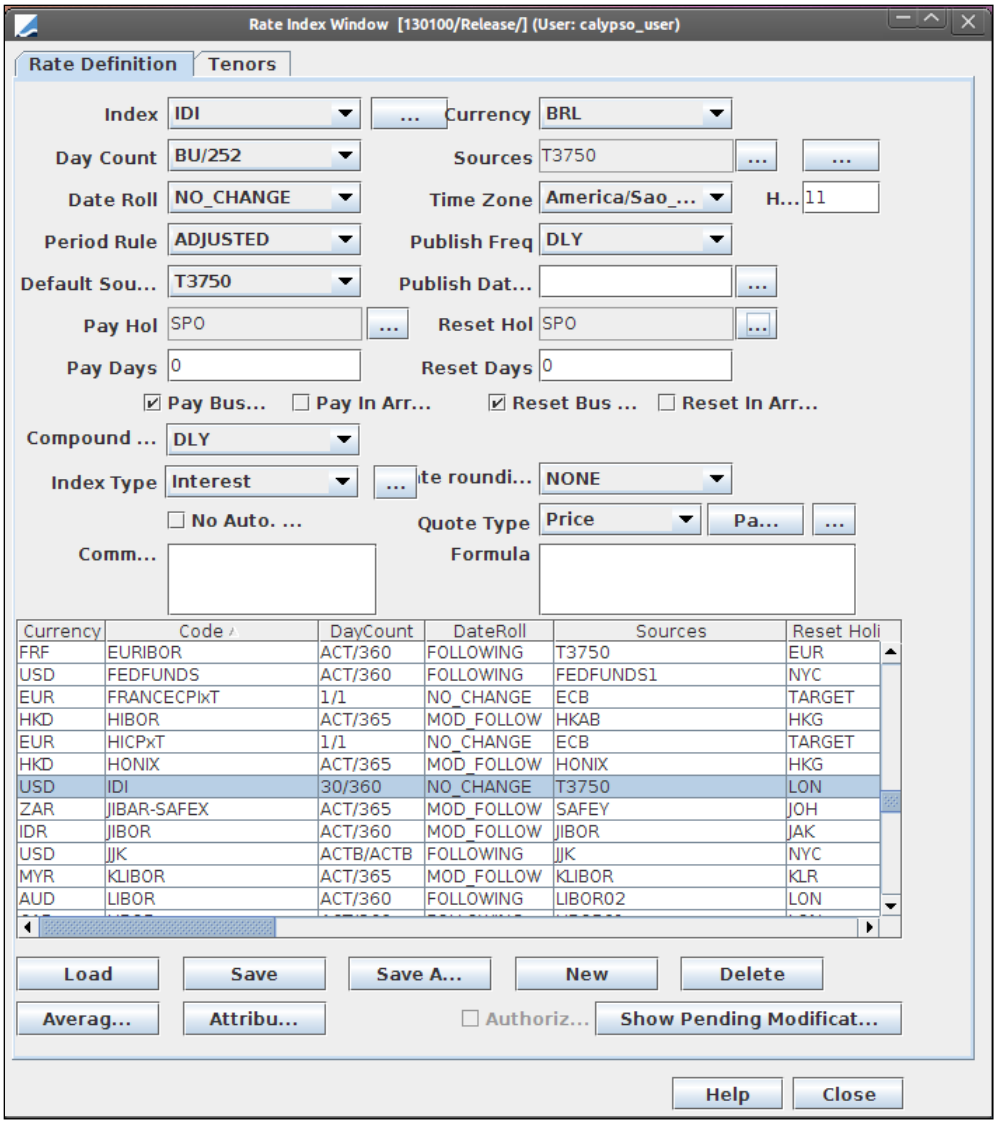
The Average One-Day Interbank Deposit Rate Index (IDI) shall be defined as the theoretical value of 100,000.00 points on the date, established by BM&F, when its indexation by the Average One-Day Interbank Deposit Rate (ID) calculated by the CETIP – Custody and Settlement initiates, in accordance with the following formula:

$$IDI_t = IDI_{t-1} \times \left(\frac{i_{t-1}}{100} + 1 \right)$$

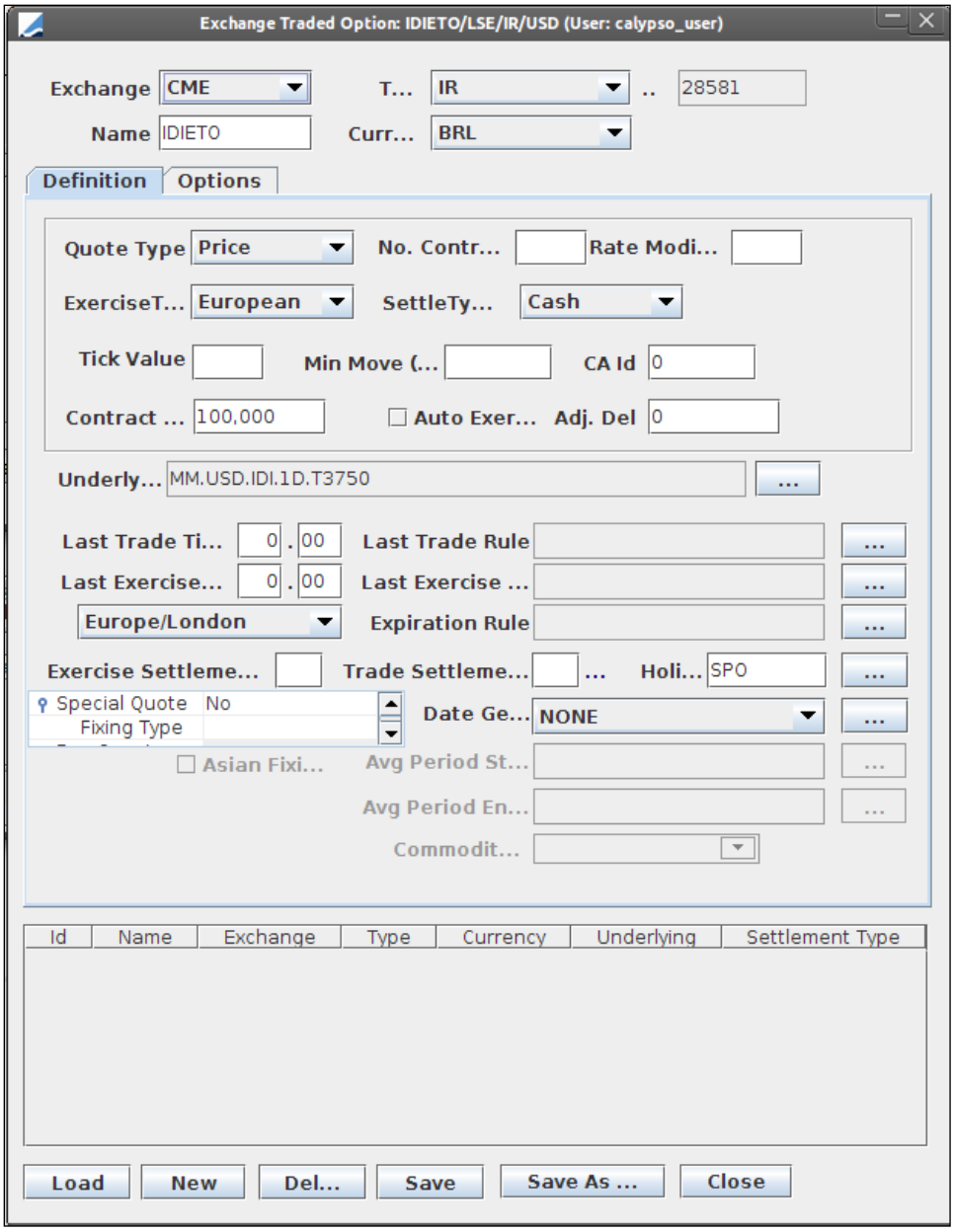
Where:
IDI_t = the Average One-Day Interbank Deposit Rate Index (IDI) on day "t," to two decimal places;
IDI_{t-1} = the Average One-Day Interbank Deposit Rate Index (IDI) on day "t–1," to two decimal places;
i_{t-1} = the Average One-Day Interbank Deposit Rate (ID) calculated by CETIP, corresponding to the previous day and expressed as a percentage rate per day (the daily compound rate) to seven decimal places.

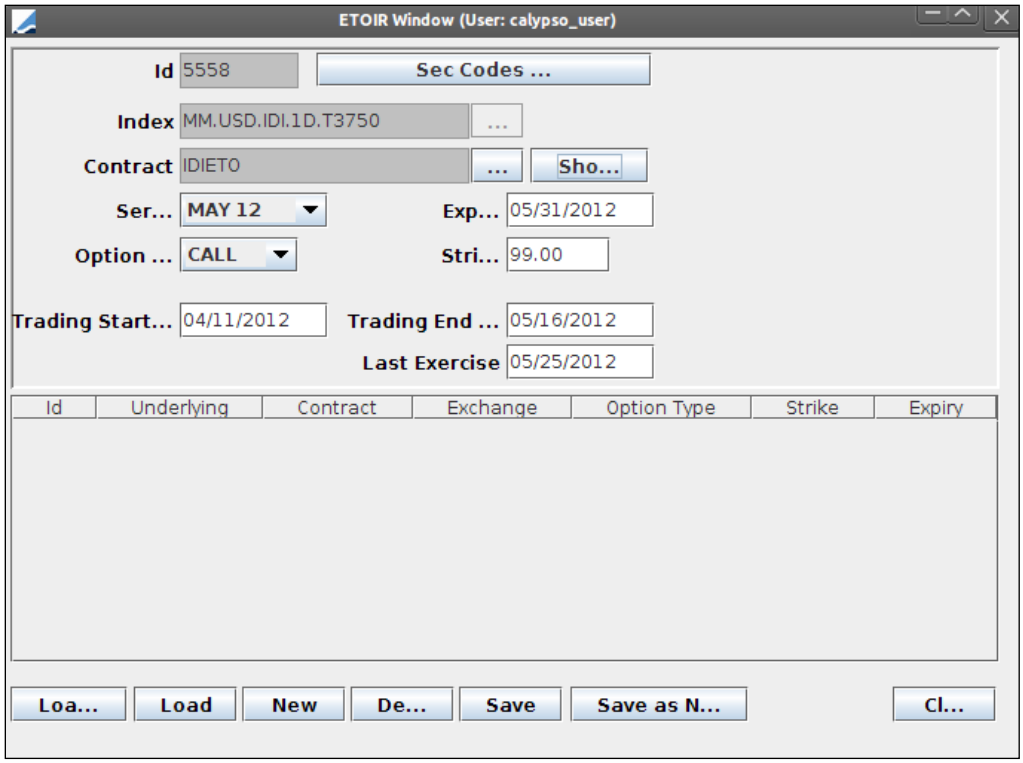
Setup of index and option contract

Rate index definition:

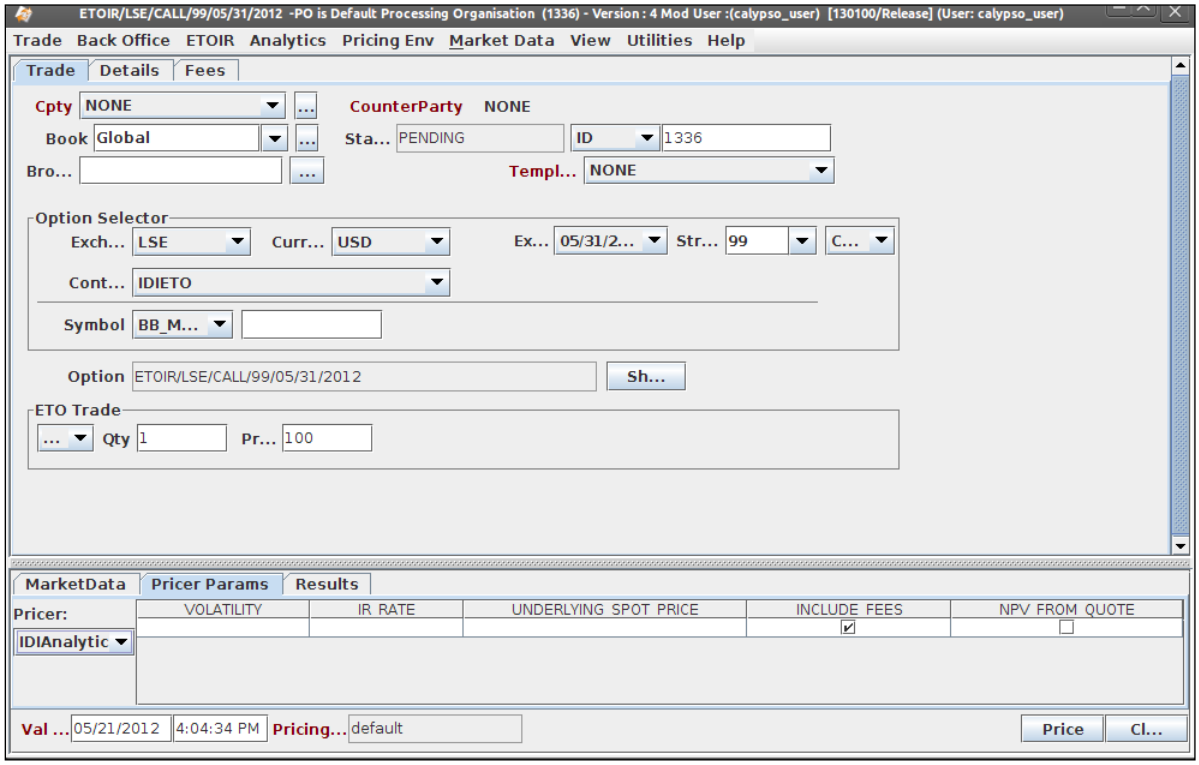


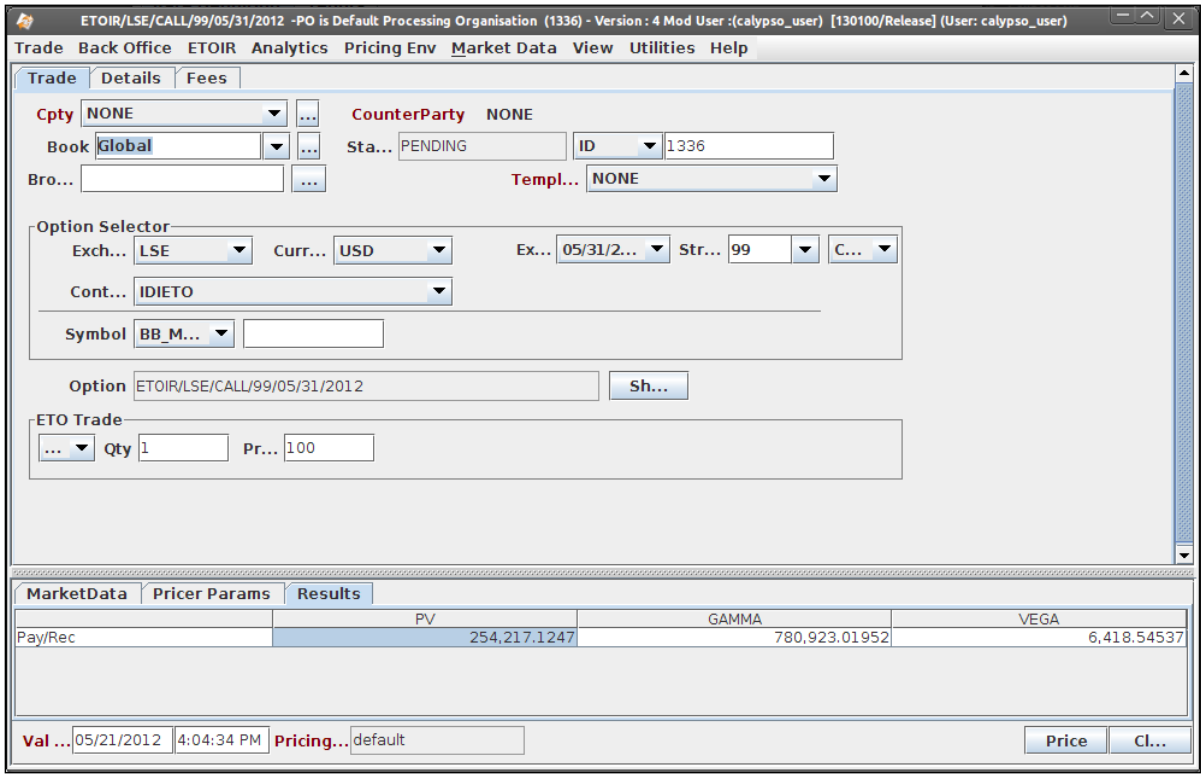
Option contract definition:


Exchange Traded Option: IDIETO/LSE/IR/USD (User: calypso_user)
Exchange
CME
T...
IR
..
28581
Name
IDIETO
Curr...
BRL
Definition
Options
Quote Type
Price
No. Contr...
Rate Modi...
ExerciseT...
European
SettleTy...
Cash
Tick Value
Min Move (...
CA Id
0
Contract ...
100,000
Auto Exer...
Adj. Del
0
Underly...
MM.USD.IDI.1D.T3750
Last Trade Ti...
0
00
Last Trade Rule
Last Exercise...
0
00
Last Exercise ...
Europe/London
Expiration Rule
Exercise Settleme...
Trade Settleme...
Holi...
SPO
Special Quote
No
Fixing Type
Date Ge...
NONE
Asian Fixi...
Avg Period St...
Avg Period En...
Commodit...
Id
Name
Exchange
Type
Currency
Underlying
Settlement Type
Load
New
Del...
Save
Save As ...
Close



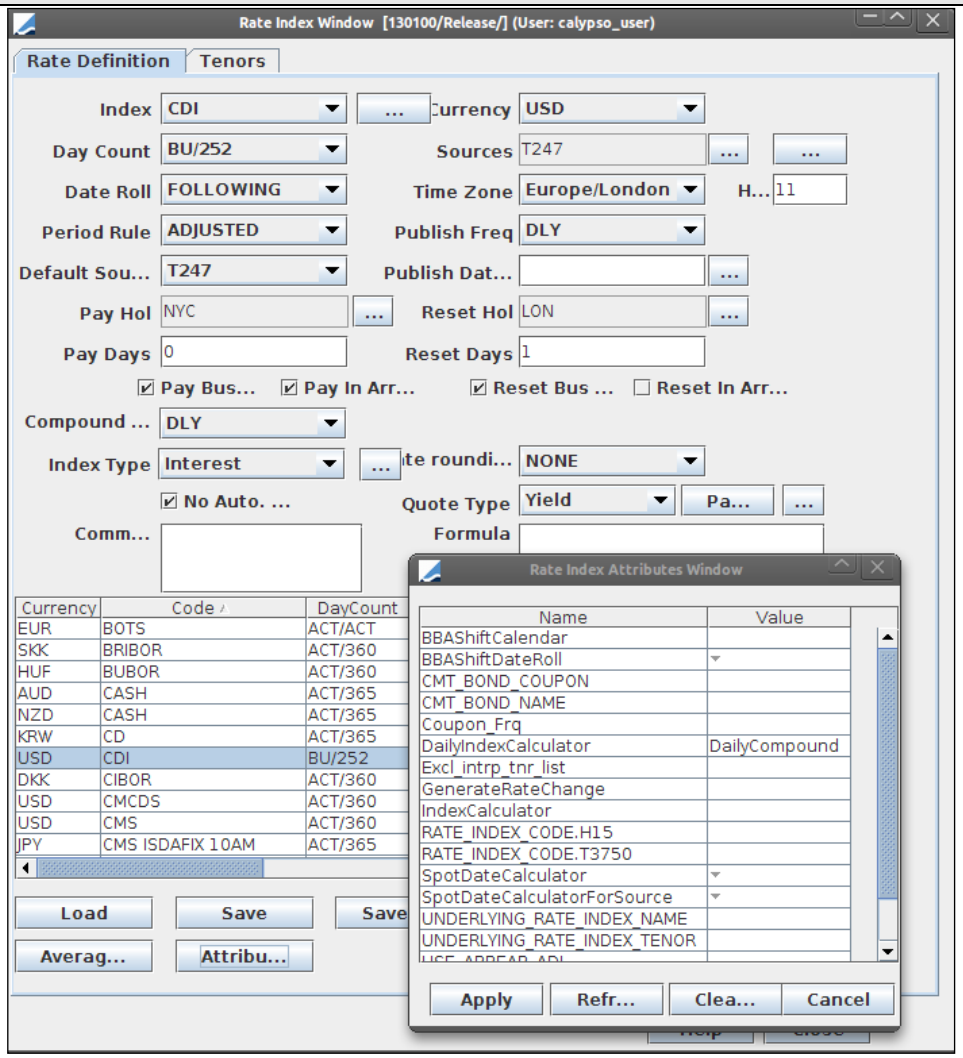
Example of a call IDI option:

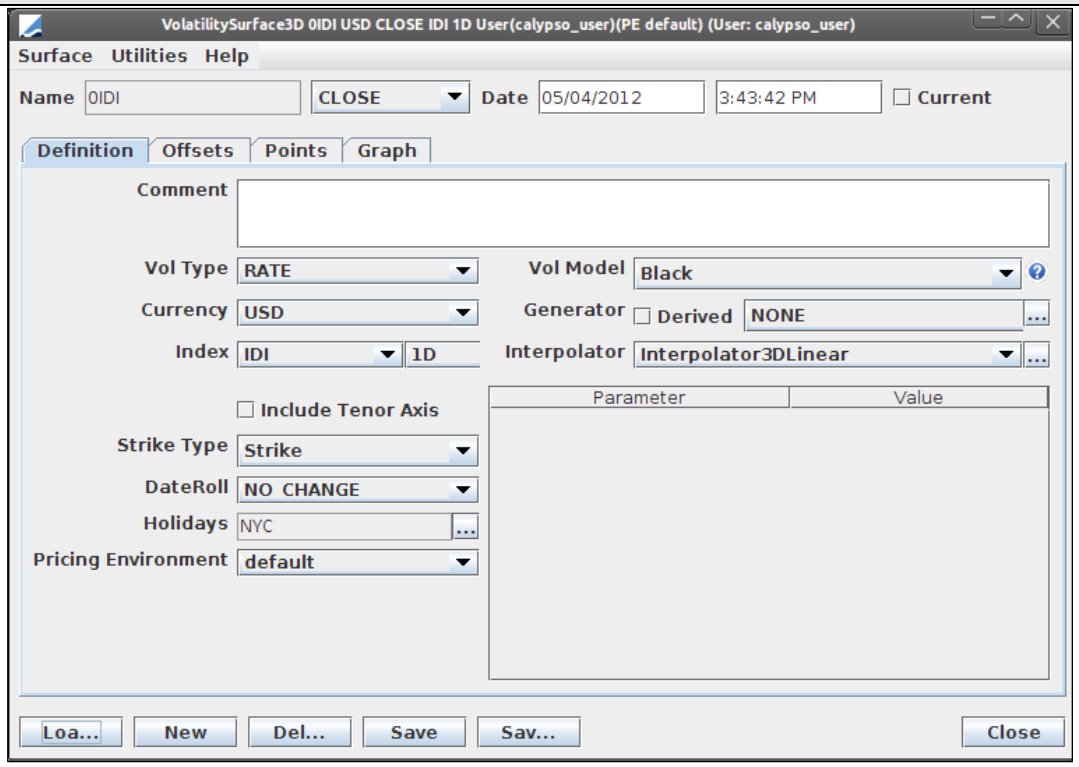




Market Data Configuration

Market Data	Description
Discount Curve	Overall Standard Configuration. Remark: The Attribute DailyIndexCalculator of the rate index should have the value "DailyCompound" as shown in the screeshot below.

Market Data	Description
	
Volatility Surface	Simple vol surface (i.e. not derived by instruments) containing the volatilities per strike and maturity of the Guassian process.

Market Data	Description
	 The details of the volatility used for pricing are in the paper [1] below.

Pricing Parameters

Pricing Parameter	Type	Description	Typical Value
VOLATILITY	Rate	Transient volatility that overrides the volatility of the market data.	-
IR_RATE	Rate	Transient rate that overrides the rate of the market data.	-
UNDERLYING_SPOT	Anount	Transient spot that overrides the spot IDI quote value.	-

Pricer Measures

Pricer Measures	Description
PV	Analytic scaled premium of the option. Scaling: premium * contract size * trade quantity
PRICE	Analytic premium of the option.
DELTA	Analytic scaled Delta. Scaling: Delta * contract size * trade quantity * spot
GAMMA	Analytic scaled Gamma. Scaling: Gamma * contract size * trade quantity * spot * spot * 0.01
VEGA	Analytic scaled Vega. Scaling: Vega * contract size * trade quantity * 0.01
VANNA	Analytic scaled Vanna. Scaling: Vanna * contract size * trade quantity * spot * 0.01
VOLGA	Analytic scaled Volga. Scaling: Volga * contract size * trade quantity * 0.0001
NTHETA	Numerical theta with one day shift.

References

[1] Calypso Technology (2012). Pricing of BOVESPA products.

[2] Almeida, C. and Vicente, J. (2006). Pricing and hedging Brazilian fixed income options. Working Paper, (July.)

[3] Almeida, C. and Vicente, J. (2010). Term structure movements implicit in Asian options prices. Working Paper, (Feb.).

[4] Brace, A. (2007). Engineering BGM, volume 10. Chapman & Hall.

3.4.2 PricerIDIAnalyticBarrier

Overview

PricerIDIAnalyticBarrier supports the valuation of barrier options, where the underlying is the IDI index.

The type of barrier options supported by PricerIDIAnalyticBarrier are as follows:

- Excercise Type: European.
- Barrier Window Type: Full.
- Barrier Type: Double, IN/OUT - UP/DOWN.
- Monitoring: Discrete.
- Rebates: No Rebates.

Pricing of double barriers can be done using the methodology in described Ikeda and Kuintomo (1992).

The Dicrete monitoring case will be reflected by the adjustement of Broadie et al. (1997).

Definition of the IDI (as per BM&F):

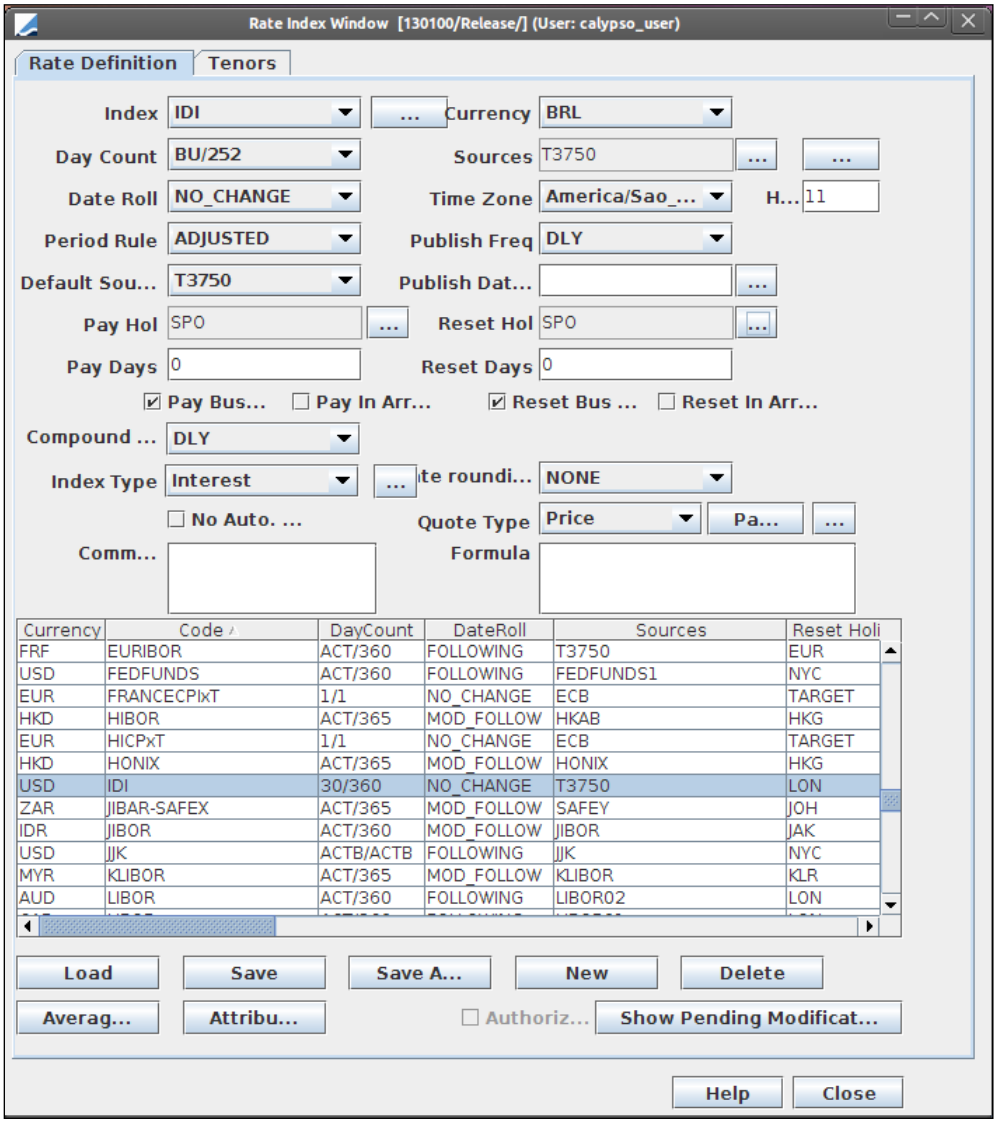
The Average One-Day Interbank Deposit Rate Index (IDI) shall be defined as the theoretical value of 100,000.00 points on the date, established by BM&F, when its indexation by the Average One-Day Interbank Deposit Rate (ID) calculated by the CETIP – Custody and Settlement initiates, in accordance with the following formula:

$$IDI_t = IDI_{t-1} \times \left(\frac{i_{t-1}}{100} + 1 \right)$$

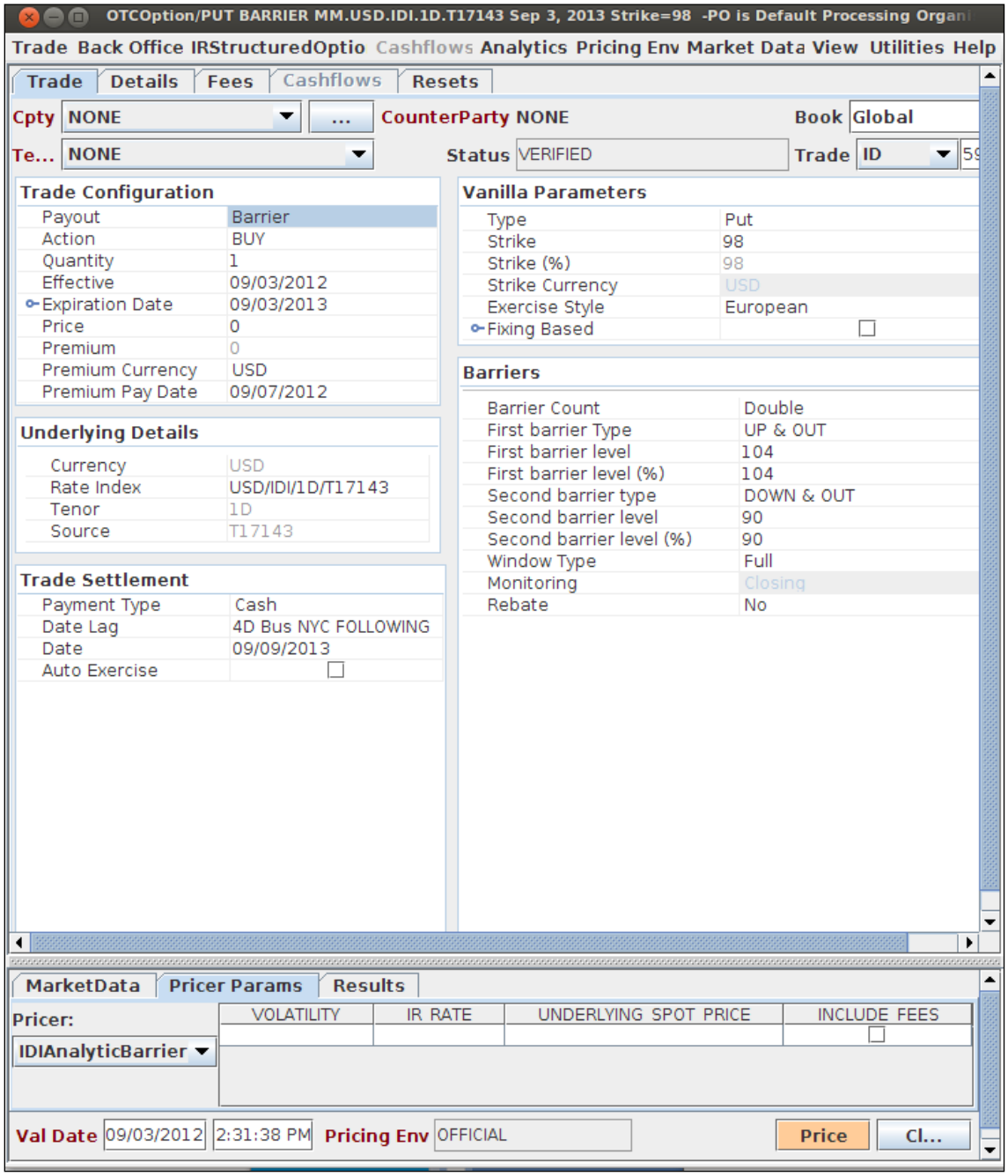
Where:
IDI_t = the Average One-Day Interbank Deposit Rate Index (IDI) on day "t," to two decimal places;
IDI_{t-1} = the Average One-Day Interbank Deposit Rate Index (IDI) on day "t–1," to two decimal places;
i_{t-1} = the Average One-Day Interbank Deposit Rate (ID) calculated by CETIP, corresponding to the previous day and expressed as a percentage rate per day (the daily compound rate) to seven decimal places.

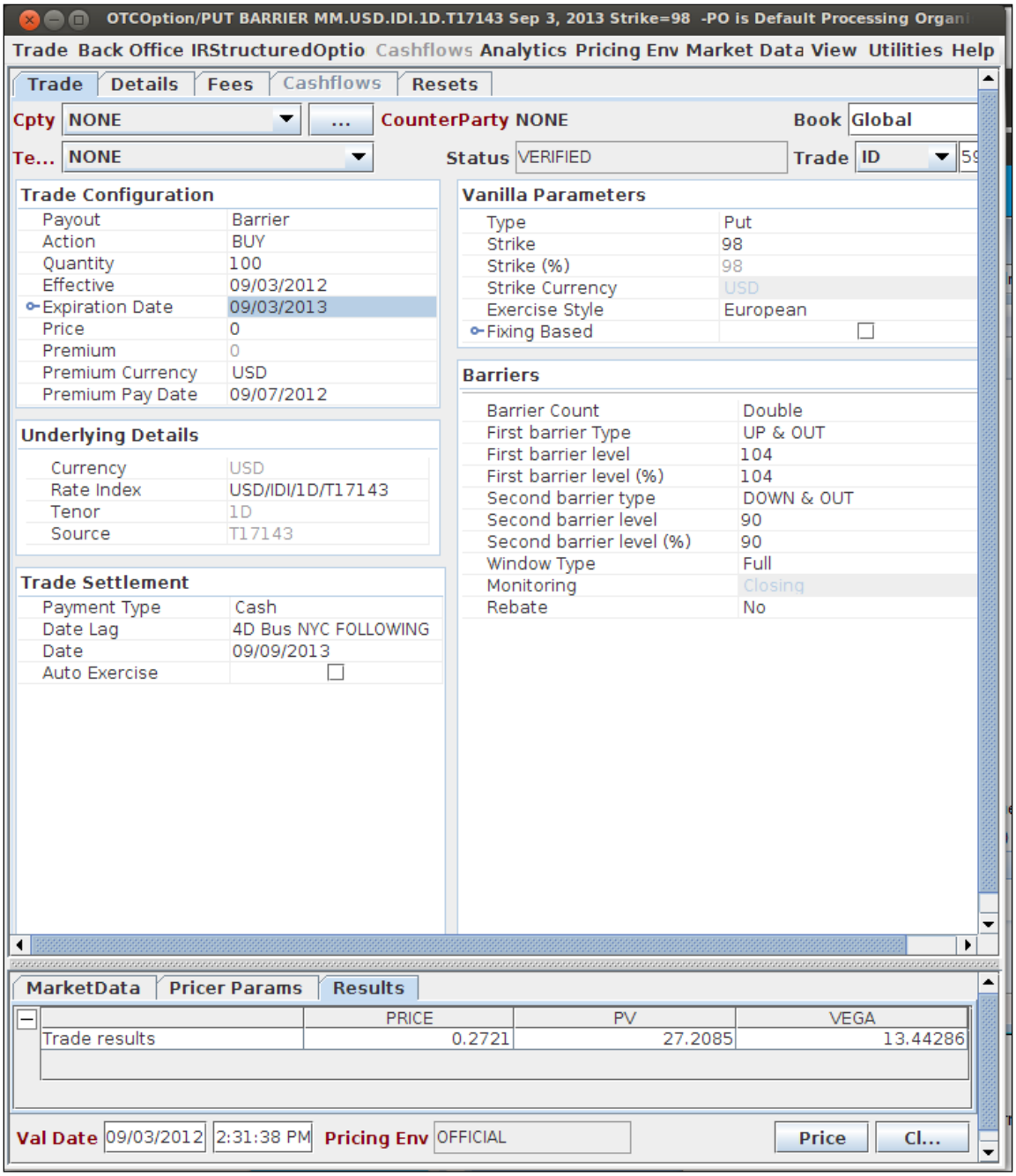
Setup of an IDI barrier option trade

Rate index definition:

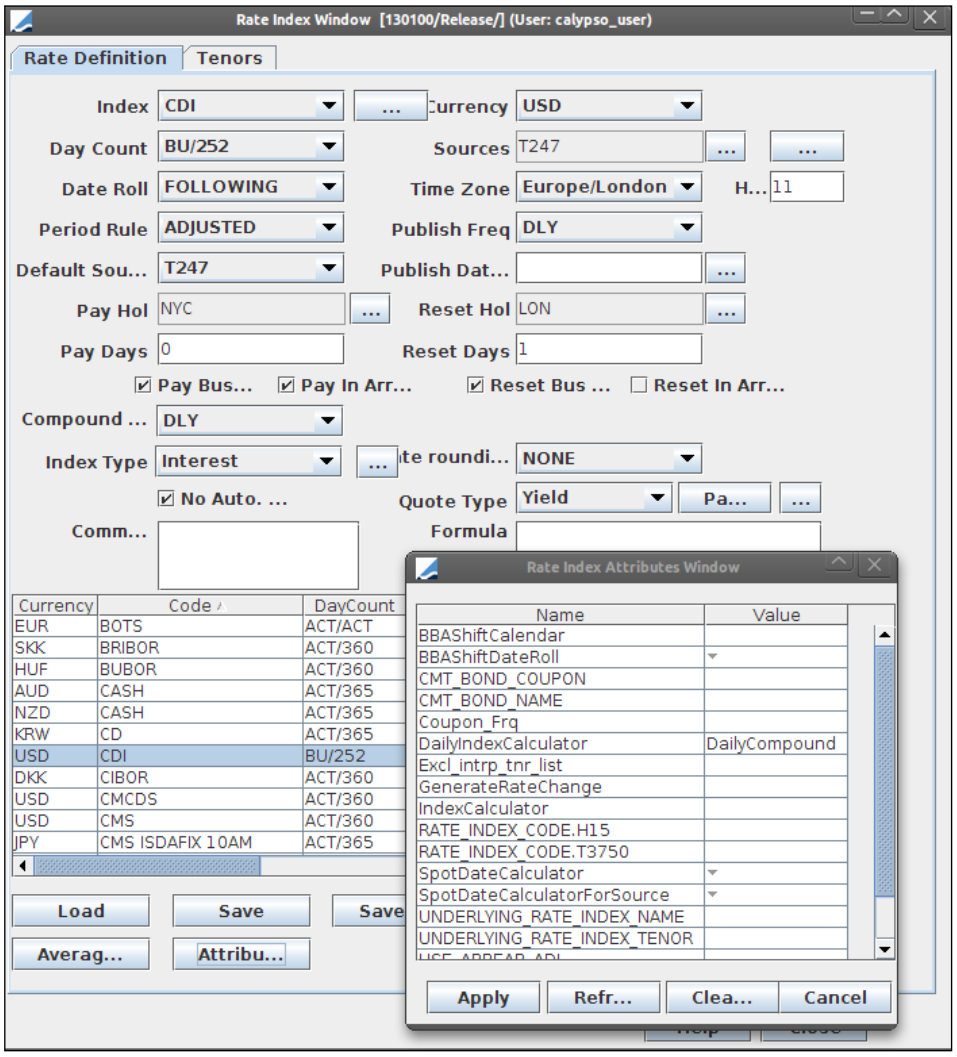


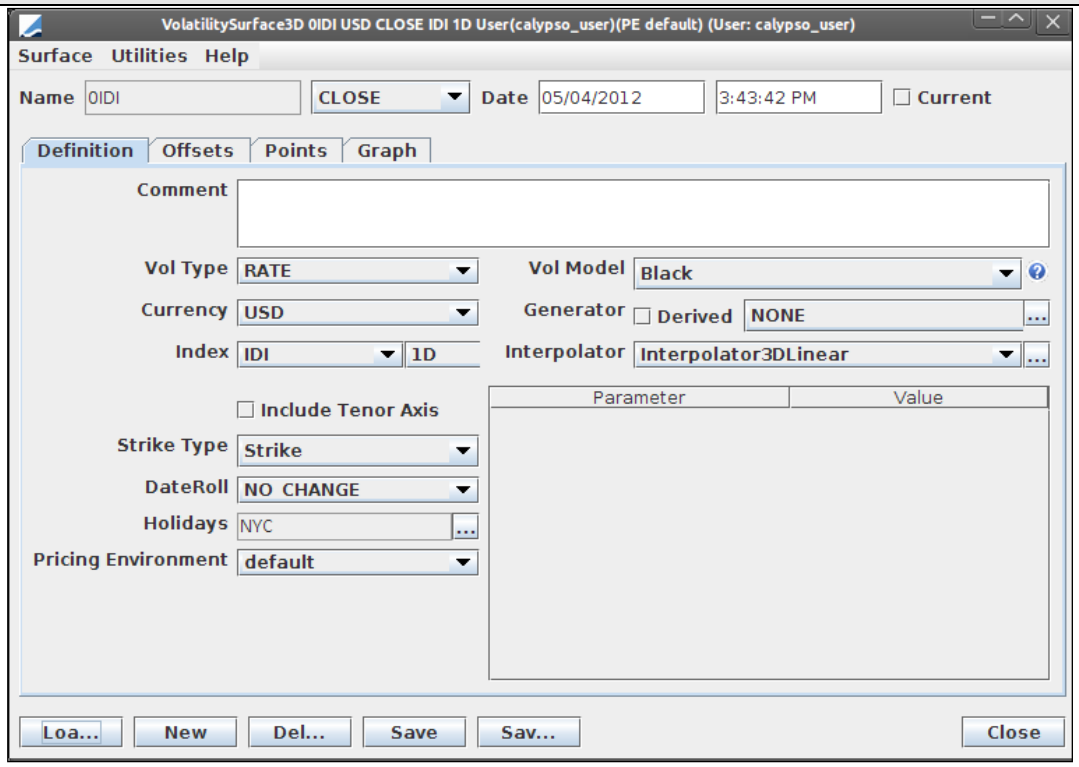
Example of an IDI barrier option:





Market Data Configuration

Market Data	Description
Discount Curve	Overall Standard Configuration. Remark: The Attribute DailyIndexCalculator of the rate index should have the value "DailyCompound" as shown in the screeshot below. 
Volatility Surface	Simple vol surface (i.e. not derived by instruments) containing the volatilities per strike and maturity of the Guassian process.

Market Data	Description
	 The details of the volatility used for pricing are in the paper [1] below.

Pricing Parameters

Pricing Parameter	Type	Description	Typical Value
VOLATILITY	Rate	Transient volatility that overrides the volatility of the market data.	-
IR_RATE	Rate	Transient rate that overrides the rate of the market data.	-
UNDERLYING_SPOT	Anount	Transient spot that overrides the spot IDI quote value.	-

Pricer Measures

Pricer Measures	Description
PV	Analytic scaled premium of the option. Scaling: premium * trade quantity
PRICE	Analytic premium of the option.
DELTA	Analytic scaled Delta. Scaling: Delta * trade quantity * spot
GAMMA	Analytic scaled Gamma. Scaling: Gamma * trade quantity * spot * spot * 0.01
VEGA	Analytic scaled Vega. Scaling: Vega * trade quantity * 0.01
VANNA	Analytic scaled Vanna. Scaling: Vanna * trade quantity * spot * 0.01
VOLGA	Analytic scaled Volga. Scaling: Volga * trade quantity * 0.0001
NTHETA	Numerical theta with one day shift.

References

[1] Calypso Technology (2012). Pricing of BOVESPA products.

[2] Almeida, C. and Vicente, J. (2006). Pricing and hedging Brazilian fixed income options. Working Paper, (July.)

[3] Almeida, C. and Vicente, J. (2010). Term structure movements implicit in Asian options prices. Working Paper, (Feb.).

[4] Brace, A. (2007). Engineering BGM, volume 10. Chapman & Hall.

[5] Broadie, M., Glasserman, P., and Kou, S. (1997). A continuity correction for the discrete barrier options. Mathematical Finance, 7(8):325–348.

[6] Haug, E. G. (2006). The complete guide to option pricing formulas. McGraw-

Hill, New York, 2nd. edition.

[7] Ikeda, M. and Kuintomo, N. (1992). Pricing options with curved boundaries.

Mathematical Finance, 2:275–298.

Section 4. Equity Pricing

4.1 Pricers for realized variance and volatility derivatives - PricerCarrLeeVolatilityDerivative

The most common variance derivative is the variance swap: a forward contract in which one counterparty agrees to pay the other a notional amount, N, multiplied by the difference between a fixed level and a realized level of variance. The fixed level is called the variance strike and the realized variance is determined by the variance of the asset's return over the life of the swap.

Similarly there are volatility swaps: forward contracts on the square root of variance.

Eventually those can be capped or floored. Finally options on realized variance or volatility can also be defined.

Overview

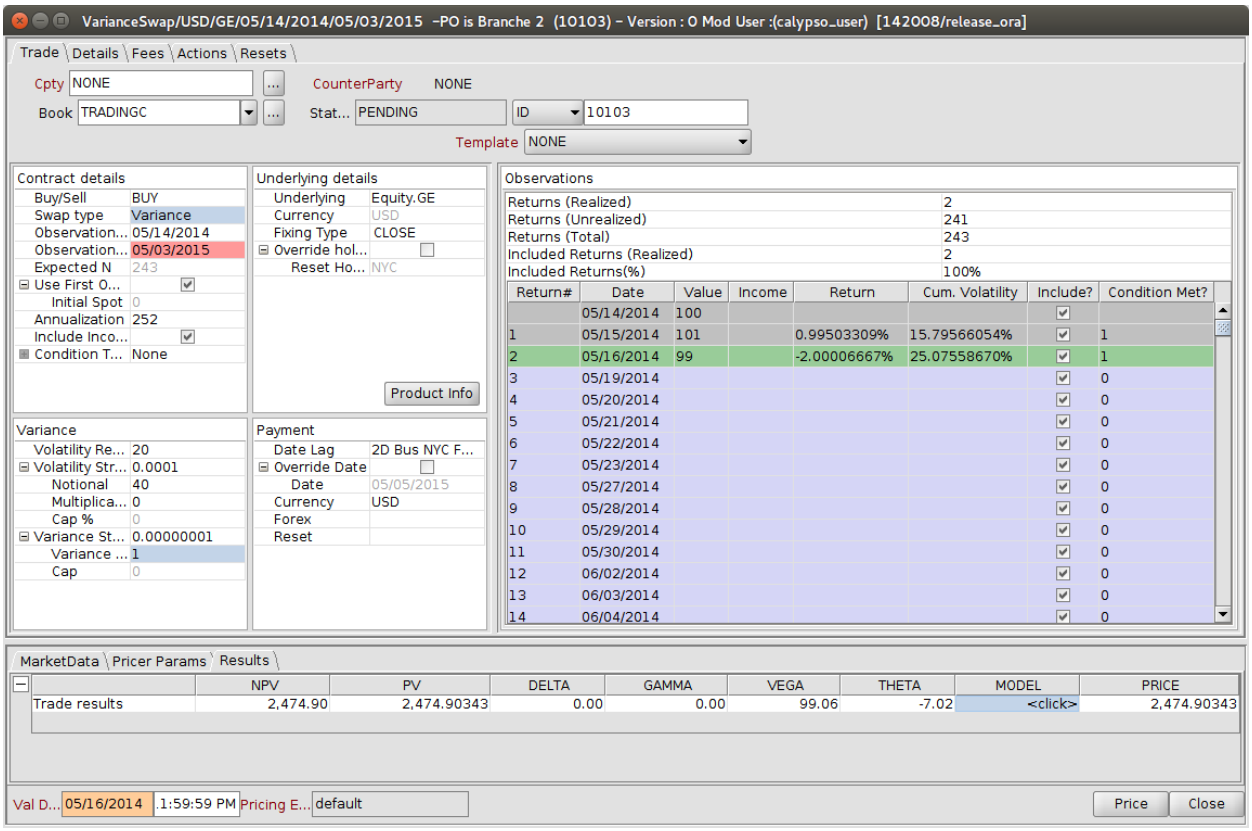
PricerCarrLeeVolatilityDerivative prices Variance Swaps (eventually forward starting, capped or floored), volatility swaps, variance options and volatility options using the method of Carr, Lee "Robust replication of volatility derivatives" (2008) and Carr, Lee "Realized volatility and variance: Options via swaps" (Risk, 2007).

The variance swap is priced by static replication using a portfolio of vanilla options, where modeling assumptions are continuous trading and continuum of strikes: jumps and transaction costs are excluded.

The volatility swap is priced using the correlation immune methodology from Carr, Lee.

Variance and volatility options are priced assuming a lognormal remaining volatility, indirectly using synthetic variance and volatility swaps prices.

More details can be found in the associated whitepaper.



Market Data Configuration

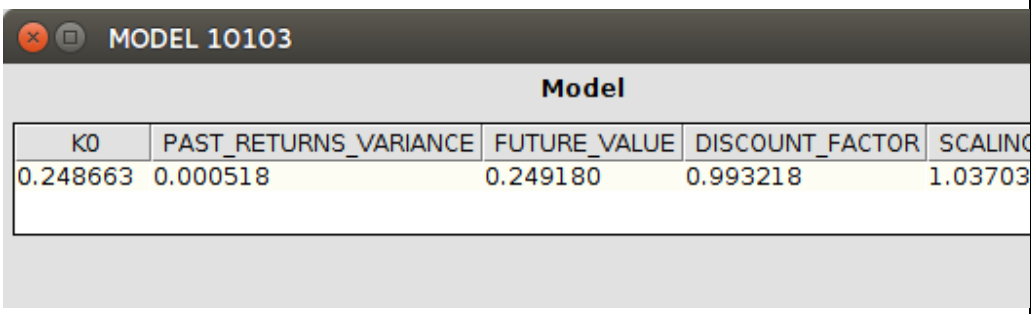
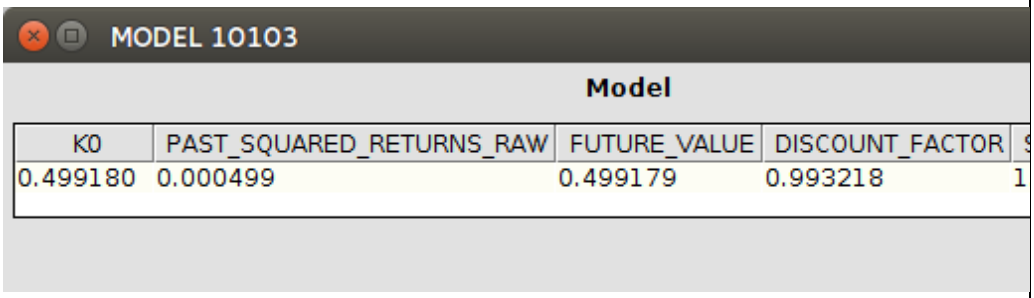
Market Data	Description
Discount Curve	Standard configuration (used for forecasting & discounting – optional additional CSA discount curve for discounting)
Dividend Curve	Standard configuration
Borrow Curve	Optional
Volatility Surface	Standard configuration

Pricing Parameters

Pricing Parameter	Type	Description
BORROW_SPREAD	Rate	Overrides borrow curve rate
DISCOUNT_RATE	Rate	Overrides discount curve rate
DIVIDEND_RATE	Rate	Overrides dividend curve rate
IR_RATE	Rate	Overrides forecast curve rate
UNDERLYING_SPOT_PRICE	Double	Overrides underlying spot quote
VOLATILITY	Percent	Overrides volatility surface and define a constant volatility surface.

Pricer Measures

Pricer Measures	Description
NPV	Net Present Value
PV	Present Value
PRICE	unit present value
DELTA, DELTA_PCT	PV (absolute, relative) difference calculated numerically
GAMMA, GAMMA_PCT	Calculated numerically
VEGA, VEGA_PCT	Calculated numerically
THETA	Calculated numerically
VANNA	Calculated numerically
VOLGA	Calculated numerically
RHO	Calculated numerically

Pricer Measures	Description
RHO3	Calculated numerically
EXPECTED_VARIANCE	The strike that would make a newly issued variance swap price of zero.
MODEL	Model input details. For a variance/volatility swap, it displays: K0 – *variance swap*: the strike that makes its value zero in the absence of past variance. *Volatility swap*: strike that would make volatility swap value zero (includes past returns implicitly). UNSCALED_K0: for variance swaps only, K0 divided by the scaling factor. It corresponds to the pure expected returns part (it won't vary for various variance swaps starting a different dates and with the same maturity). PAST_SQUARED_RETURNS_RAW – sum of past squared log returns. PAST_RETURN_VARIANCE – scaled sum of past squared log returns (by the scaling factor for a variance swap) FUTURE_VALUE – undiscounted PV for a notional of 1/(100*100) DISCOUNT_FACTOR – discount factor to payment date SCALING_FACTOR – u^2 for a variance swap u for a volatility swap where u is defined in the whitepaper, typically u=SQRT(252/N). Model measure example for a variance swap:  MODEL 10103 Model K0 | PAST_RETURNS_VARIANCE | FUTURE_VALUE | DISCOUNT_FACTOR | SCALINC 0.248663 | 0.000518 | 0.249180 | 0.993218 | 1.03703 For a variance swap, we have PV = NOTIONAL*100*100*DISCOUNT_FACTOR*(K0+PAST_RETURN_VARIANCE-STRIKE) where NOTIONAL is the variance notional. The sum of the past squared log returns is PAST_RETURN_VARIANCE/SCALING_FACTOR Model measure example for a volatility swap:  MODEL 10103 Model K0 | PAST_SQUARED_RETURNS_RAW | FUTURE_VALUE | DISCOUNT_FACTOR 0.499180 | 0.000499 | 0.499179 | 0.993218 | 1 For a volatility swap, we have PV = NOTIONAL*100*DISCOUNT_FACTOR*(K0-K) where NOTIONAL is the volatility notional as K0 includes past returns here (there is no way of splitting the value between known and future due to the non-linearity of the square root function). The PAST_SQUARED_RETURN_RAW is directly used in Carr-Lee pricing formula, which is why we expose it instead of the PAST_RETURN_VARIANCE. On this example we can see the

Pricer Measures	Description
	PAST_RETURN_VARIANCE(variance swap) = PAST_SQUARED_RETURNS_RAW(volatility swap) * SCALING_FACTOR(variance swap)

References

- Carr, Lee "Robust replication of volatility derivatives" (2008).
- Carr, Lee "Realized volatility and variance: Options via swaps" (Risk, 2007).
- Calypso Technology, "Volatility Derivatives Practical Notes".

4.2 Pricers for Exotic Equities and Hybrids (eXSP/PricingScript)

4.2.1 PricerBlackNFMonteCarloExotic

Overview

PricerBlackNFMonteCarloExotic supports the valuation of exotic derivatives defined with the PricingScript on one or mutlple assets. The pricer supports eXSP/PricingScript products defined within BondExoticNote and ScriptableOTCProduct (through the pricing sheet) for respectively exotic IRD/FX/EQD/CMD notes and options or swaps. Backward compatibility support for eXSP is available in EquityStructuredOption and Swap products. A basket can be defined with eXSP on other products, e.g. bonds; these other products are not supported by PricerBlackNFMonteCarloExotic. The model used is an n-factor Black-Scholes model, where each component of the basket is model is modelled using a lognormal diffusion, and each diffusion is correlated. Rates are assumed deterministic, CSA discounting is supported. Foreign assets are automatically quantoed to the pricing measure. The valuation direction is forward and is made using a Monte Carlo valuation routine.

eXSP Grammar Support

The table below describes the eXSP grammar supported in the pricer.

Operator	Purpose		Operator	Purpose
+	addition of numbers		&&	Boolean AND
-	Subtraction		||	Boolean OR
*	Multiplication		()?():()	Conditional, if-then-else
/	Division		Max	maximum of two values
>	greater than		Min	minimum of two values
>=	greater than or equal to		<=	less than or equal to
<	less than			

XFunction	Parameter supported

Xperf	(<BasketVariable>,'Initial') (<BasketVariable>,'Initial', <param3>), where param3 is a choice from 'min','max','avg','xmin','xmax','xavg'. The Basket Variable's initial schedule is required to be customised with only one period to define the initial level. The final schedule must not be customised, but should be generated. More than period is supported, that is interim level within a period.
Xbreaks	(<BasketVariable>,<barrier1>,<onBarrier1Type>,'NONE', <barrierAggregationStyle>). The barrier aggregation style can be either 'All','Group','Members'. A second barrier is not supported. The BasketVariable's initial schedule is required to be customised with only one period to define the initial level. The final schedule must not be customised, but should be generated. More than period is supported, that is interim level within a period.

QuoteVariables supported are equity and equityindex quotables only. They may be used directly in formulae as well as within basket variables.

Beyond the backward compatible eXSP, the pricer supports the full grammar of the PricingScript, which is the recommended way to model exotic derivatives.

4.2.2 PricerLocalVolatilityNFMonteCarloExotic

Overview

PricerLocalVolatilityNFMonteCarloExotic supports the valuation of exotic payoffs defined with PricingScript on one or multiple equities, FX rates, interest rates. The pricer supports eXSP/PricingScript products defined within BondExoticNote and ScriptableOTCProduct (through the pricing sheet) for respectively exotic IRD/FX/EQD notes and options or swaps. Backward compatibility support for eXSP is available in EquityStructuredOption and Swap products. The model used is an n-factor local volatility model, where each component is a diffusion, and each diffusion is correlated. Equity underlyings follow a local volatility diffusion, typically stemming from the application of Dupire on SVI parameterization (through SVI or SVISimple generators) but SABR parameterization and plain splines implied volatility surfaces are also supported (through Spline or SplineSimple generator). FX rates are represented as a lognormal diffusion. Rates are assumed deterministic, CSA discounting is supported. Foreign assets are automatically quantoed to the pricing measure. The valuation direction is forward and is made using a Monte Carlo valuation routine.

4.2.3 PricerSVJMonteCarloExotic

Overview

PricerSVJMonteCarloExotic supports the valuation of exotic payoffs defined with PricingScript on a single equity. The pricer supports eXSP/PricingScript products defined within BondExoticNote and ScriptableOTCProduct (through the pricing sheet) for respectively exotic EQD notes and options or swaps.

Various stochastic volatility models are supported: Heston, Schobel-Zhu, Bates (Heston with stochastic jumps), Double-Heston (two CIR stochastic volatility processes). The relevant model is automatically selected from the volatility surface generator (SVJ).

Rates are assumed deterministic, CSA discounting is supported. The valuation direction is forward and is made using a Monte Carlo valuation routine.

Pricing Parameters

Pricing Parameter	Type	Description	Typical Value
ACCURACY_LEVEL	Integer	Accuracy level with the forward numerical scheme, any value between 0 and 11.	5

Pricing Parameter	Type	Description	Typical Value
		0-lowest accuracy but highest speed 11-highest accuracy but slowest speed	

Pricer Measures

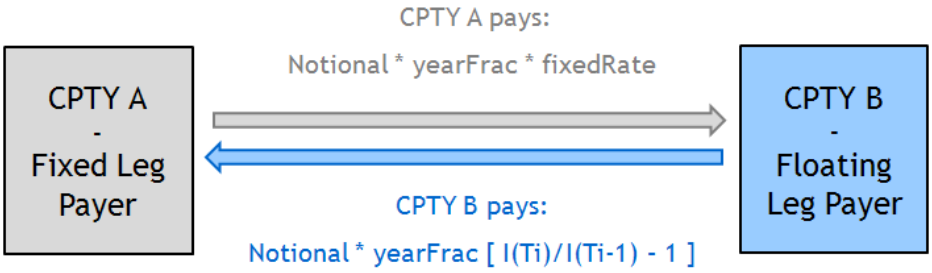
Pricer Measures	Description
NPV	Calculated from numerical valuation scheme
GRID_EVENTFLOWS	Shows the event grid. Provides detailed diagnostics of how the Monte Carlo engine has interpreted the eXSP payoff. Typically used to check how the eXSP formulae have been interpreted.
MC_GRAPH	Convergence graph from valuation routine.
PRICE	NPV/Notional
DELTA	Sum of component delta. Double click on the result value to pop-up the component values.
GAMMA	Sum of component cross gamma. Double click on the result value to pop-up the cross-gamma
VEGA **NVEGA**	Change in value of NPV for a 1% additive parallel shift in all volatility surfaces. The total cannot be broken out by component.

Section 5. Inflation Pricing

5.1 Pricers for Year on Year Inflation Swaps

Overview

A year on year (or period on period) swap is a contract whereby a counterparty agrees to receive an annual coupon determined by the inflation rate at the end of each year in return for paying a fixed rate. For more information about year-on-year and other inflation products see: Kerkhof, J. (2005). "Infation Derivatives Explained". *Lehman Brothers Fixed Income Quantitative Research.*

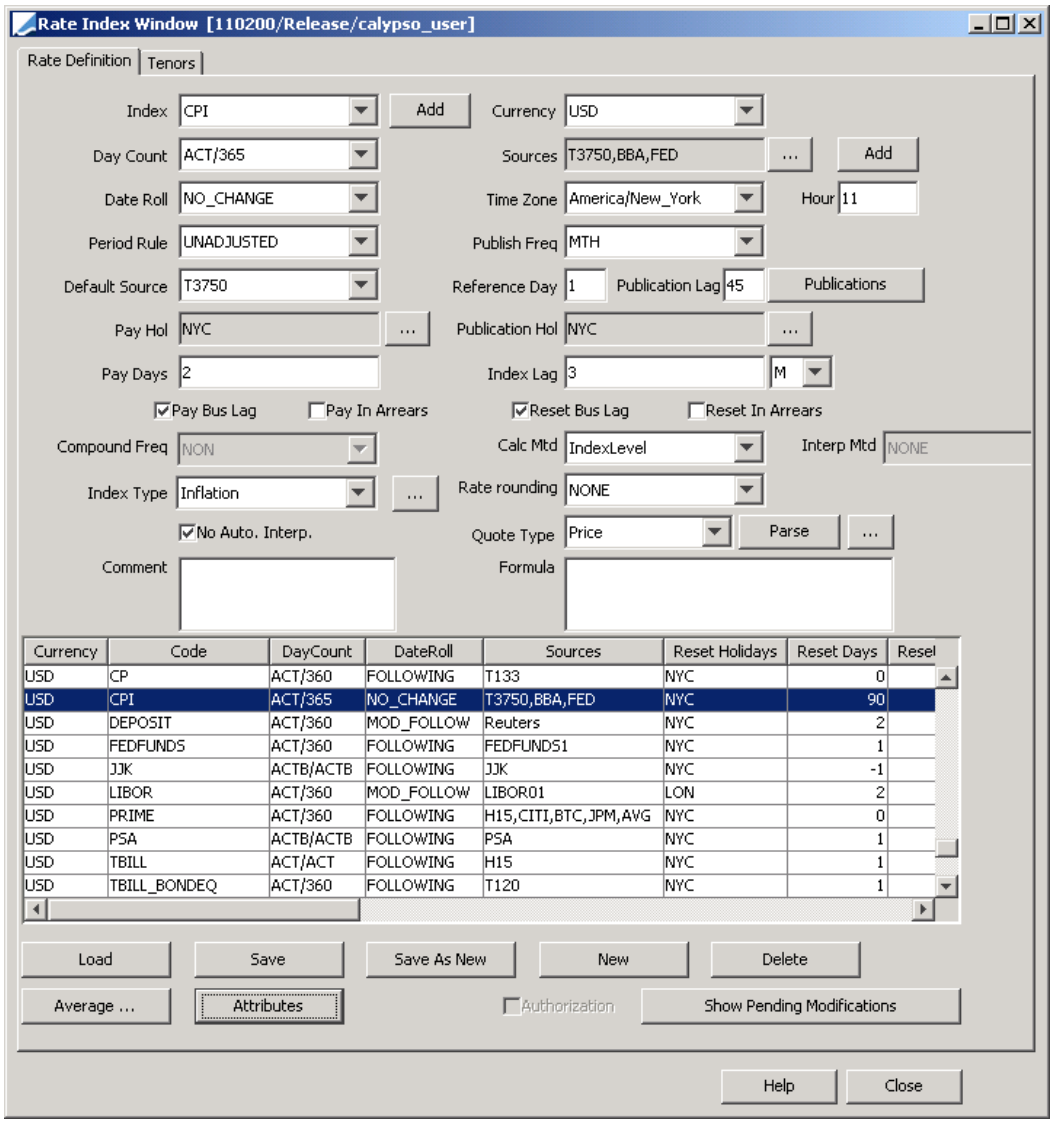


Market Data Configuration

Year-on-year inflation swaps require the following market data configuration to enable successful trade capture and pricing.

Rate index definition

An inflation index must be defined in the system. The settings for a rate index are defined in the following location: Main Entry > Configuration > Interest Rates > Rate Index Definitions.



Configuration of typical CPI inflation index used in year-on-year

Please reference Calypso Help – 'Inflation Curve', for further information on the settings shown in the above window.

Important settings for rate index definition:

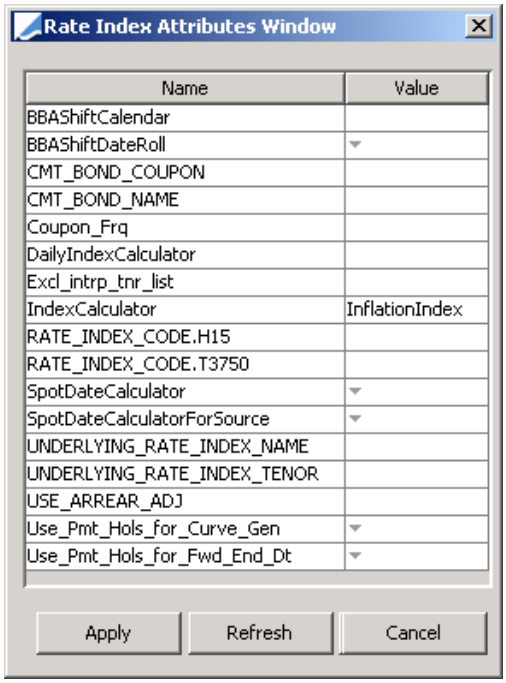
- Index type: Inflation
- Publish Frequency e.g. Monthly
- Reference day e.g. 1 (1st day of the month)
- Publication lag e.g. 45 days
- Index lag e.g. 3 months
- Calc Method – IndexLevel or Interpolated

In the 'Attributes' section at the bottom of the Rate Index definitions pane further configuration of the index is required. The index calculator (IndexCalculator) used in the curve generation process should be defined as per below:

Inflation Index

IndexCalculator: InflationKerkhof.

See documentation on the Kerkhof market data generator for more information.



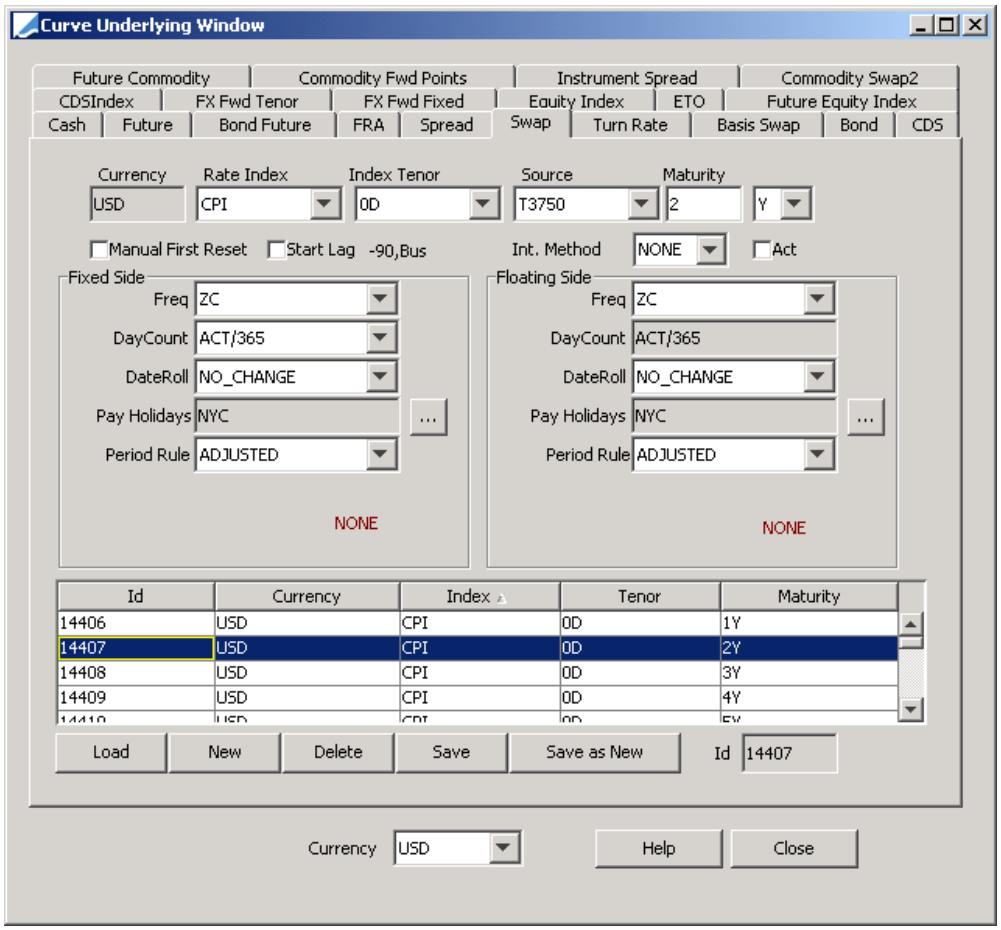
Attributes of Rate index definition

Once a rate index is defined, a 1Y (or specific period) tenor should be defined for the index on the tenor tab of the rate index definition window.

Curve underlying's

To construct the inflation curve required for pricing year on year swaps, the underlying instruments for the curve generation process must first be defined. The settings for each curve underlying are defined in the following location: Main Entry > Configuration > Market Data > Curve Underlying's.

- Select required currency
- Select 'Swap' tab
- Click 'Load' – to open instruments currently saved in the database
- Configure the zero coupon swap underlying's for an inflation rate index with the required maturities (0D index should be used for the tenor)
- Click 'Save as New'
- Repeat process for each of the maturities by selecting the previously configured inflation swap.



Configuration of typical inflation curve underlying's

Market Data Quotes

Past fixings of the inflation index should be entered into Calypso (Main Entry > Market Data > Market Quotes > Quotes). If the required inflation index quotes are not saved into the Calypso environment the user will be alerted when attempting to price the trade.

PricerSwap (Inflation swaps)

Overview

The pricing of the following inflation trade types are supported in Calypso.

Types of Trades	Calypso Product	Pricer
Inflation Swap (vanilla)	Swap	PricerSwap PricerSwapHagan (Pricing model is identical to PricerSwap)

A standard inflation swap could be one of the following types:

- Fixed-Floating
- Floating-Fixed
- Floating-Floating

The supported characteristics are the following: no amortization structure, the floating leg tenor matches the index payment frequency I.e. zero coupon (0D tenor) or period on period (e.g. year on year YoY).

We will focus on the fixed-floating type of standard swap, since we have both types of swap legs to valuate.

Let's introduce the notations first:

All dates are calculated using the appropriate day count usage (the corresponding curve's day count).

Each cash-flow i starts at date T_i , ends at date T_{i+1} , has a reset date $\tilde{T}_i$ and a payment date $\overline{T_i}$

- N_i is the notional
- yf_i is the year fraction between T_i and T_{i+1}
- df_t is the discount factor between valuation date and t .
- $I(x)$ inflation value at time x.
- K is the fixed rate.

For the fixed leg, the NPV is the following $NPV_{fix} = \sum_{i=0}^{i=N-1} N_i \cdot yf_i \cdot df_{\overline{T_i}} \cdot K$

For the floating leg, the NPV is the following $NPV_{flt} = \sum_{i=0}^{i=N-1} N_i \cdot \frac{I(T_{i+1})}{I(T_i)} \cdot df_{\overline{T_i}}$

Convexity Adjustment

Currently for inflation swaps priced with PricerSwap there is no convexity adjustment.

5.2 Pricers for Inflation Cap/Floors - PricerCapFloorInflationBlack

An inflation cap/floor is a derivative, similar to an interest rate cap/floor swap, in which the buyer/seller receives/pays payments at the end of each period in which the inflation rate exceeds the agreed strike price.

The option itself can be one of the following types:

- Cap — the option to buy the underlying at a specific value at maturity or exercise date.
- Floor — the option to sell the underlying at a specific value at maturity or exercise date.

Once exercised, the user enters into the corresponding underlying swap, which is in general an inflation swap.

Overview

In order to price an Inflation CapFloor, PricerCapFloorInflationBlack, uses a modified version of the Black-Scholes model which will be discussed in detail below.

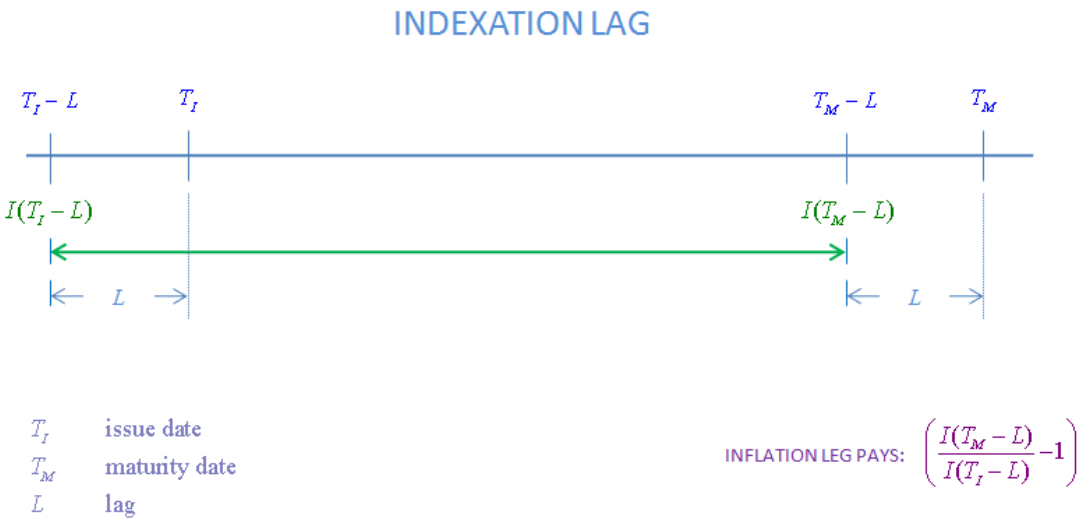
It is important to note that PricerCapFloorInflationBlack supports zero coupon and Year on Year (Period on Period) options.

Let's introduce the notation:

- K is the strike of the option
- S is the spot.
- T_S is the start date of the option.
- T_e is the expiration time of the option.
- L is the indexation lag.
- $I(T_S)$ is the inflation value at the start of the option
- $I(T_e)$ is the inflation value at the maturity of the option
- $I(t)$ is the inflation value at the valuation date
- $D(x)$ represents the cumulative normal distribution function at *x*.
- σ is the volatility of the forward swap rate.
- df is the discount factor at T_e.
- N is the notional
- r is the risk free interest rate (for inflation derivatives, it is always zero)

According to when the valuation date is, before or after the start date, different analytic solutions are used.

An example of the indexation lag effect with respect to the product life cycle is given as follows:



Due to the indexation lag there are therefore two different analytic approaches: first one, when valuation date occurs before start date, second one, when valuation date occurs after start date.

Scenario 1: Valuation Date before Start Date

For the case when Valuation Date is before start date, the NPV is computed as follows:

Effective Strike (K_e):

$$K_e = (1+k)^{(Ts-Te)}$$

Spot (S):

$$S = \frac{I(T_s)}{I(T_e)}$$

Black-Scholes Method (for call):

$$d_1 = \frac{\ln\left(\frac{S}{K_e}\right) + \left(r + \frac{\sigma^2}{2}\right)(\Delta T)}{\sigma\sqrt{\Delta T}}$$

$$d_2 = \frac{\ln\left(\frac{S}{K_e}\right) + \left(r - \frac{\sigma^2}{2}\right)(\Delta T)}{\sigma\sqrt{\Delta T}}$$

$$B = D(d_1)S - D(d_2)K$$

Then finally scale and discount the value obtained from the Black-Scholes model:

$$NPV = df * B * N$$

For the put option, the same approach is used, with the Black-Scholes formula changed for the put option case.

Please refer to section 3 of this guide for more details regarding Black Scholes model.

Scenario 2: Valuation Date after Start Date

For the case when Valuation Date is after Lag, the NPV is computed as follows:

Effective Strike (K_e):

$$K_e = \left[\frac{I(T_S)}{I(t)}\right](1+k)^{(Ts-Te)}$$

Spot (S):

$$S = \frac{I(T_e)}{I(t)}$$

Black-Scholes Method (for call):

$$d_1 = \frac{\ln\left(\frac{S}{K_e}\right) + \left(r + \frac{\sigma^2}{2}\right)(\Delta T)}{\sigma\sqrt{\Delta T}}$$

$$d_2 = \frac{\ln\left(\frac{S}{K_e}\right) + \left(r - \frac{\sigma^2}{2}\right)(\Delta T)}{\sigma\sqrt{\Delta T}}$$

$$B = D(d_1)S - D(d_2)K$$

Then finally scale and discount the value obtained:

$$NPV = \left[\frac{I(T_e)}{I(T_S)}\right] df * B * N$$

For the put option, the same approach is used, with the Black-Scholes formula changed for the put option case.

Configuration

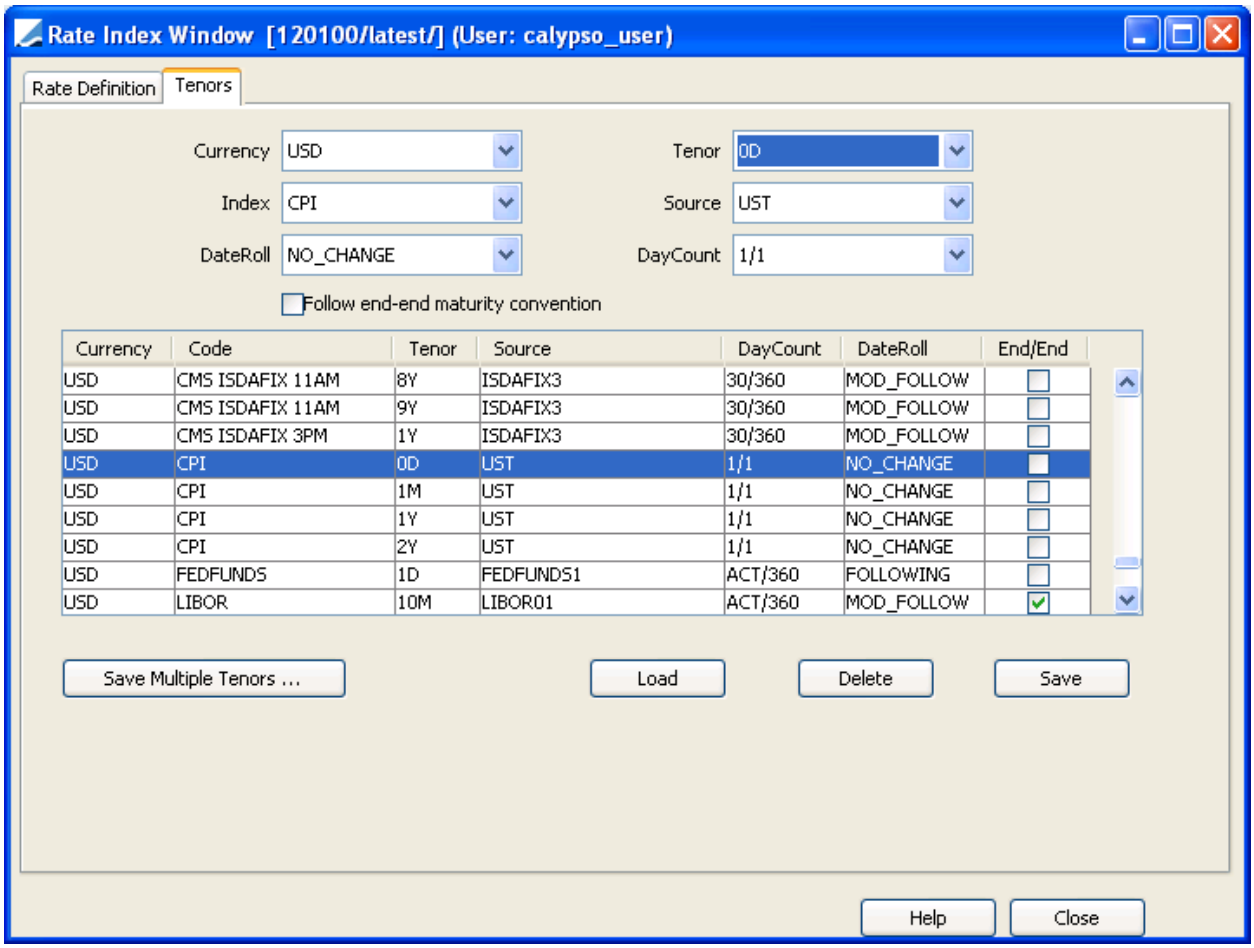
In order to use PricerCapFloorInflationBlack it is necessary to ensure that the following configurations has been setup correctly.

Inflation index tenor (rate index definition)

Window Location: Main Entry → Configuration → Interest Rates → Rate Index Definitions

The desired inflation tenor in the rate index definition must be configured. To add a specific tenor to an inflation index, it is necessary to select the inflation index, the required tenor from the tenor box and save.

Please see below as example:



If the trade window was open, before or during this rate index definition process, it is necessary to close and reopen the screen to see the new tenors on the trade window.

Trade Panel Configuration

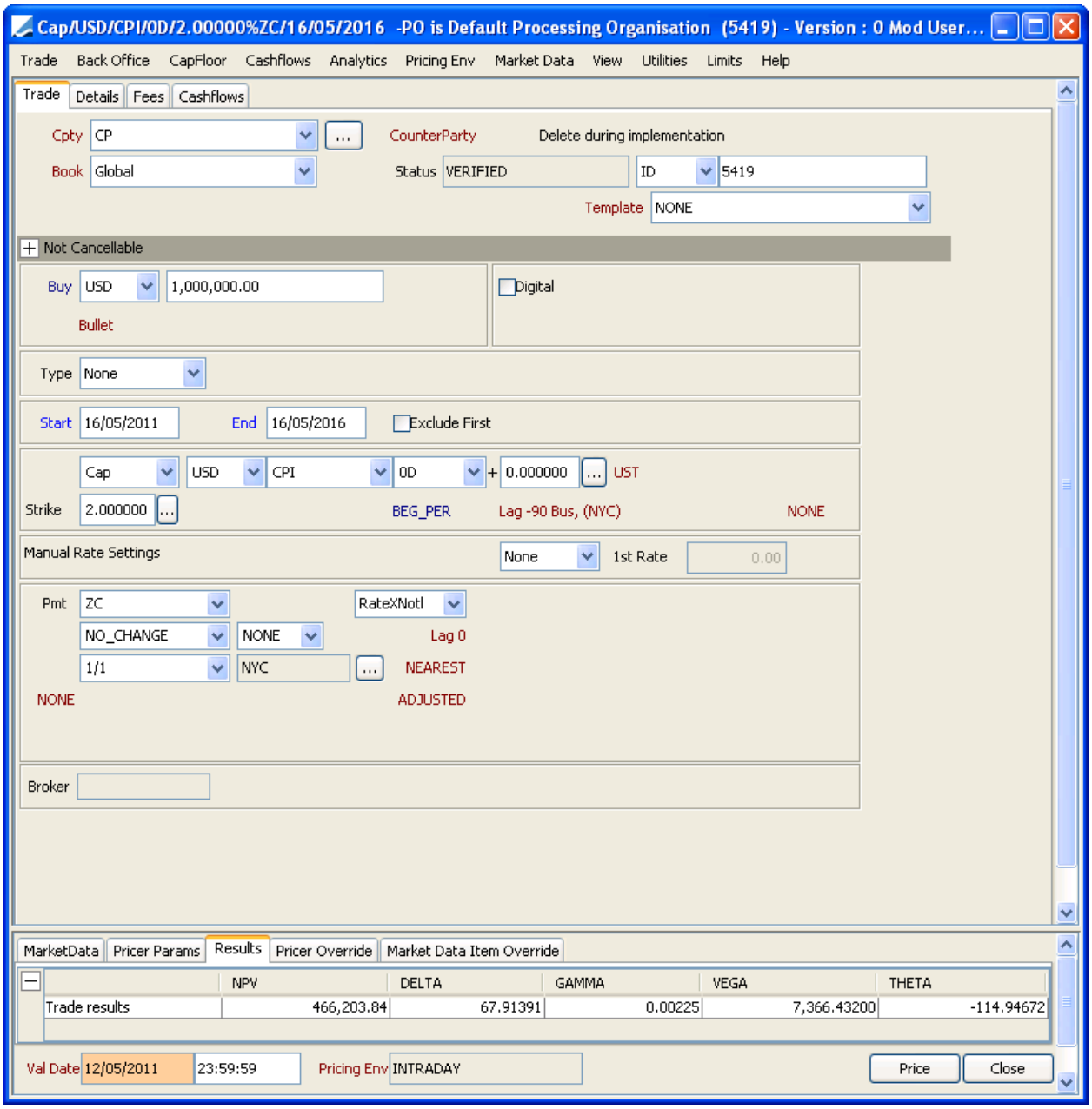
As mentioned previously the PricerCapFloorInflationBlack both supports zero coupon and Year on Year trades, therefore it is necessary to ensure that the configuration in the trade panel is correctly specified.

Zero coupon:

The key elements that should be configured correctly are:

- Pmt = ZC (Zero Coupon)
- RateXNotl (selected on the box on the right to Pmt)
- Inflation Index
- Tenor

Please see below trade screen as example of such configuration:



Results

Cashflow analysis

Main results are displayed in the trade screen results tab, however more details regarding the cashflows results can be observed in the cashflows tab.

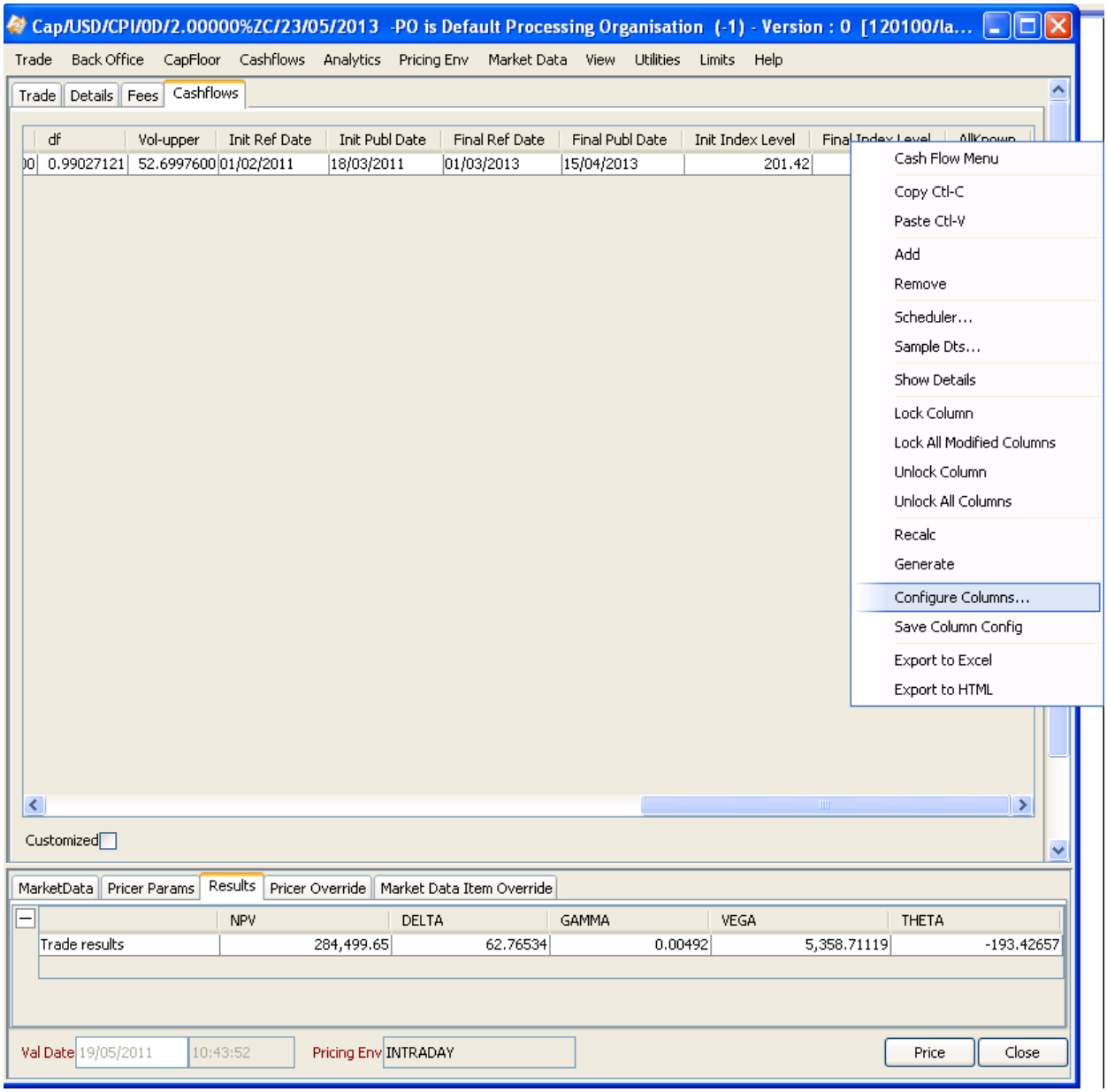
Important Outputs that could be observed in this type of trade are:

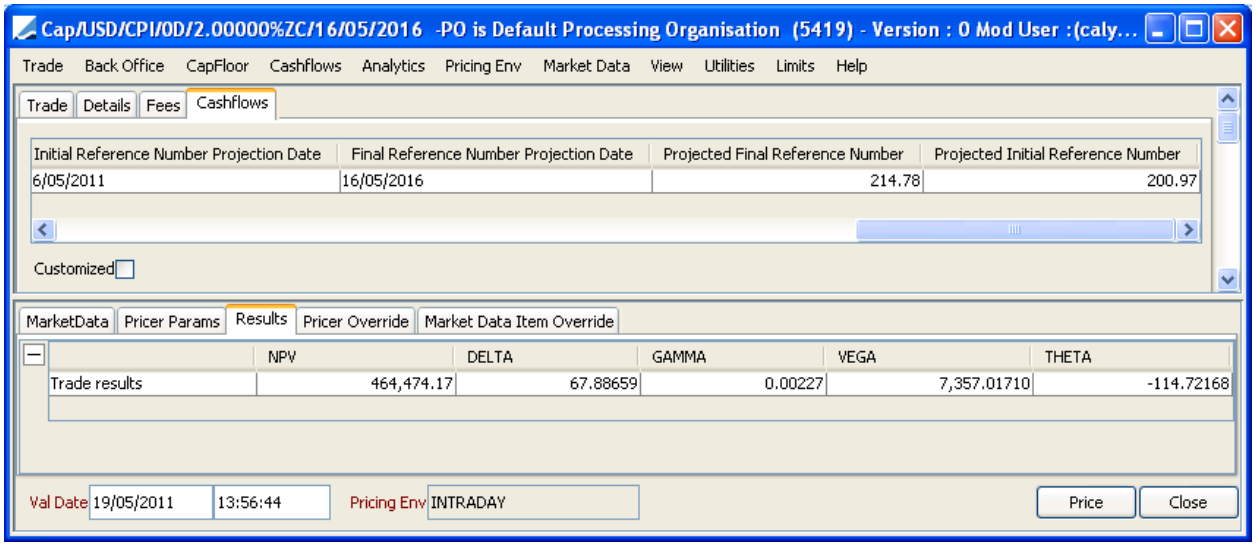
- Projected Initial Reference Number
- Projected Final Reference Number
- Initial Reference Number Projection Date

- Final Reference Number Projection Date

The above columns do not appear automatically in the cashflow tab, in order to obtain such value it is necessary

1. Select Cashflows Tab
2. Right-click on the cashflow
3. Select "Configure Columns"
4. Insert to the right Columns the variables required





Note: The above columns show information on the reference numbers and dates are actually used in pricing. The lagged inflation index levels (initial and final) are also available to the user.

Section 6. FX Pricing

6.1 Pricers for FX Variance Swaps - PricerVarianceSwapReplicationFX

Overview

The FX variance swap pricer PricerVarianceSwapReplicationFX is based on the replication method of E. Derman from Goldman. The setup and configuration is almost identical to the equity variance swap pricer, PricerVarianceSwapReplication documented in section **Error! Reference source not found.**. Only the differences a re highlighted in this section;

Market Data Configuration

Market Data	Description
Foreign Curve	Standard configuration
Domestic Curve	Standard configuration
Volatility Surface	Standard configuration. The pricing will support volatility surface with delta as strike axis

The use of fwd points based curve is not supported; only domestic and foreign discount curves are used.

Pricing Parameters

Pricing Parameter	Type	Description	Typical Value
REPLICATION_STRIKES	Choice	VOL_SURFACE – This method is not supported in the of an FX volatility surface with a delta strike axis.	CONTINUOUS

Section 7. Commodity Pricing

7.1 PricerCommodityOTCOptionAnalytic

Overview

This pricer supports pricing of Asian, Compo, Forward Start, Digital and Expiry Barrier options. Strategies (combinations of Call and Puts) are also supported: Call Spread, Put Spread, Straddle, Strangle and Risk Reversal.

This is the recommended pricer for CommodityOTCOption2.

The following combinations are possible:

- Vanilla options with and without barriers
- Digital options with and without barriers
- Asian vanilla options with and without barriers
- Forward start options

- Vanilla compo options with and without barrier
- Digital compo options with and without barriers
- Asian vanilla compo options with and without barriers.
- Asian digital compo option with and without barriers

To price commodity options using this pricer, we recommend using the Commodity Option trade window.

Main Entry>Trade> Commodities > OTCOption

Key inputs in the Commodity OTCOption window

Market Data	Description
Pmt Ccy	Main currency for the trade. It Pmt Ccy is different from the underlying commodity currency a Compo option is assumed.
Option Type	Allows to define the main pay-off: Vanilla, Forward Start, Digital and some strategies (combinations of Calls and Puts, e.g.: Straddle, Strangle)
Option Style	**Not used**
Avg Method	Different averaging method supported for Asian options.
Barriers	Barrier descriptor are added to the pay-off. A non-empty barrier descriptor defines a barrier option.

7.1.1 Pricing Asian Options

Asian options are valued using the Levy Turnbull approximation. Different types of averaging methods are possible. Check Calypso reference manual for "Commodity Averaging Methods" for a full list of averaging types and description.

Price and Greeks are computed analytically.

See next section for more details on the averaging methods.

7.1.2 Pricing Compo and Compo Asian Options

Compo options are assumed whenever the currency of the underlying is different from the currency of the option. The currency of the option is given by the Pmt Ccy. It is assumed the currency of the Strike is equal to the currency of the option.

It is also possible to deal with Asian Compo options. In this case, there are different types of averaging methods that can be applied. For example, it is possible to average the commodity prices and multiply for the average fx rate (ATC or Average Then Convert method) or it is possible to convert each of the prices with the corresponding daily fx rate and average afterwards (CTA or Convert Then Average method). Check Calypso reference manual for "Commodity Averaging Methods" for a full list and description.

The more general formula for the Asian Compo average is:

$$\mathrm{Av} = \sum_{\mathrm{i}=1}^{\mathrm{N}} \sum_{\mathrm{j}=1}^{\mathrm{N}} \mathrm{C_i}\, \mathrm{X_j}\ \mathrm{w_{i,j}}$$

Where C represents the price of the underlying commodity, X the corresponding exchange rate and w are the weights. The summation is done over the averaging days. The weights depend on the type of average method. Examples of the different average types are:

$$\mathrm{CTA} = \frac{1}{\mathrm{N}} \sum_{\mathrm{i}=1}^{\mathrm{N}} \mathrm{C_i}\, \mathrm{X_i} \qquad \mathrm{ATC} = \left(\frac{1}{\mathrm{N}} \sum_{\mathrm{i}=1}^{\mathrm{N}} \mathrm{C_i}\right)\left(\frac{1}{\mathrm{N}} \sum_{\mathrm{i}=1}^{\mathrm{N}} \mathrm{X_i}\right) \qquad Compo = X_T C_T$$

The Pay-off for the Asian option will be given by:

$$Pay\_off = Max(\phi(Av - K), 0)$$

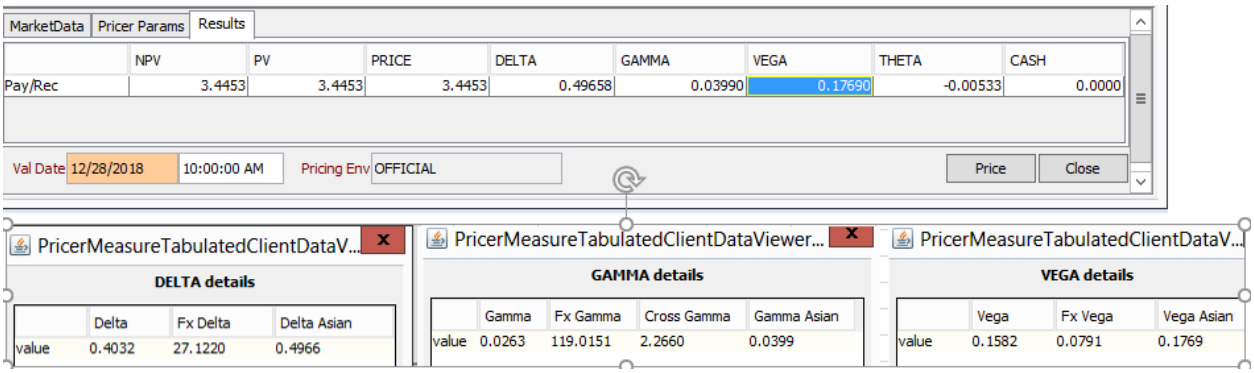
Where $\phi = +1, -1$ for call and puts respectively.

Extended set of Greeks for Asian Compo

Delta Greeks	Vega Greeks	Gamma Greek
Delta (delta with respect to the underlying commodity) Fx Delta Delta Asian	Vega (underlying vega) Fx Vega Vega Asian	Gamma Fx Gamma Cross Gamma (i.e. sensitivity of delta to the changes in Fx rate) Asian Gamma

The Asian Greeks (Delta Asian. Vega Asian and Gamma Asian) are the sensitivity with respect to F_A and σ_A . These that are the expected value and volatility of Average Av defined above.

The full list of Greeks can be seen by right-clicking on the corresponding price measure output box.



Market Data Configuration

Compo options require

Market Data	Description
Foreign Curve	Standard configuration
Domestic Curve	Standard configuration
Fx-Commodity	Standard configuration
Volatility Surface	Standard configuration. The pricing will support volatility surface with delta as strike axis
Fx Volatility Surface	Standard configuration. The pricing will support volatility surface with delta as strike axis. Only ATM vols are used in the analytical approximation
correlation	Correlation standard input.

Transient values for the Fx volatility, commodity volatility and correlation between Fx and commodity can be defined through the Pricing Parameters.

Pricing Parameters

Pricing Parameter	Type	Description
VOLATILITY	Value	Volatility of the underlying commodity
FX_VOLATILITY	Value	Volatility of the fx rate.
CORRELATION	Value	Correlation between the underlying commodity and the relevant Fx rate.

References

- Calypso Technology, “CMD Asian option using Levy approximation”.

7.1.3 Pricing Forward Start Options

Two different types of forward start options are supported: Quantity and Notionally quoted. The respective pay-of are as follow:

Pay-off of a quantity quoted forward Start Option

$$\text{Pay\_off} = \text{Q}\,\text{Max}(\phi(\text{F}_\text{T} - \text{K}_{\%}\text{F}_\text{t}), 0)$$

Where $\text{K}_{\%}$ represent the strike as a percent of the fixing price F_t, where t is the fixing time and T is the maturity time.

Pay-off of a nominal quoted forward Start Option

$$\text{Pay\_off} = \frac{\text{N}}{\text{F}_\text{t}}\text{Max}(\phi(\text{F}_\text{T} - \text{K}_{\%}\text{F}_\text{t}), 0)$$

Where N represent the notional of the options, $\text{K}_{\%}$ represent the strike as a percent of the fixing price F_t, where t is the fixing time and T is the maturity time.

Forward start options don't support Asian averages, barriers or compo options.

Additional inputs

Trade window inputs	Type	Description
Put Strike%/Call Strike%	Value	Strike is fixed as a percentage of the underlying price at the fixing date
Fixing Date	Date	Date at which the forward start option fixes its strike
Quantity	Value	If Quantity is non-zero, Notional is set to zero and the option is understood to be Quantity quoted.
Notional	Value	If Notional is non-zero, Quantity is set to zero and the option is understood to be Notional quoted.

7.1.4 Pricing Digital Options

Digital Call and Digital Put options are priced by replication: they are price as a call or put spread respectively. Replication allows to value the options in terms of traded products. This approach captures the dependency of the volatility on the strike. The value using replication is given by:

$$\text{DC}_\text{r}(\text{F}, \text{X}, \alpha) = \frac{\alpha}{|\text{DX}_1 - \text{DX}_2|}\left(\text{C}(\text{F}, \text{X} + DX_1) - \text{C}(\text{F}, \text{X} + \text{DX}_2)\right)$$

$$\text{DP}_\text{r}(\text{F}, \text{X}, \alpha) = \frac{\alpha}{|\text{DX}_1 - \text{DX}_2|}\left(\text{P}(\text{F}, \text{X} + \text{DX}_1) - \text{P}(\text{F}, \text{X} + \text{DX}_2)\right)$$

Where α represents the digital payment, DX_1 and DX_2 represent the shift in the strikes. For Asian digital F is replaced by the average Av defined above.

Three different replication methods are used: Super, Sub and Mid. Each of them each characterize for a different set of DX_1 and DX_2.

	Digital Call		Digital Put	
	DX_1	DX_2	DX_1	DX_2
Super	-DX	0	DX	0
Sub	0	DX	0	-DX
Mid	-DX/2	DX/2	DX/2	-DX/2

For flat volatilities and in the limit of very small values of DX, the value of this approach is equivalent to the value of the textbook formula for Digital options.

Pricing Parameters

Pricing Parameter	Type	Description
STRIKE_SPREAD_EPSILON	Value	This is the DX that controls the value of the strike shift (see table above)
DIGITAL_VALUATION_METHOD	Choice	SUPER_REPLICATE (Super) SUB_REPLICATE (Sub) CENTRAL_REPLICATE (Mid) THEORETICAL -**Not supported**.

References

- Calypso Technology, "Expiry Barriers and Digital options: Definition and Valuation".

7.1.5 Pricing Barrier Options

Only single expiry barriers are supported. Expiry barriers are those in which the barrier is consider only at the expiry date.

Four different types of barriers are supported: UP&IN, UP&OUT, DOWN&IN and DOWN&OUT. However UP&IN and DOWN&OUT are identical, and UP&OUT and DOWN&IN are also identical.

The price of the barriers can be replicated using a combination of Call, Put and Digital options.

The digital options are valued using replication (see previous section) and it used the Pricing parameters corresponding to Digital options.

Pay-off for the single expiry barriers

	Call	Put
UP&IN or DOWN&OUT with $H \geq X$	$Max(F-H,0)+(H-X)\theta(F-H)+r\,\theta(H-F)$	$r\,\theta(H-F)$

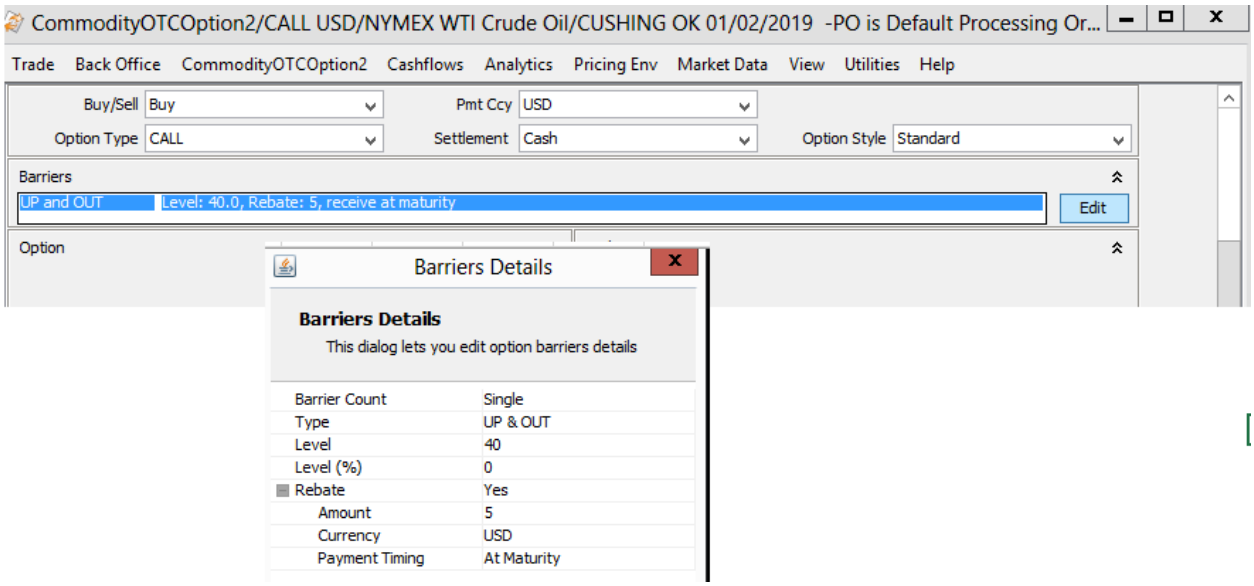
	Call	Put
UP&IN or DOWN&OUT $H < X$	$Max(F - X, 0) + r\,\theta(H - F)$	$Max(X - F, 0) - \big(Max(H - F, 0) + (X - H)\theta(H - F)\big) + r\,\theta(H - F)$
UP&OUT or DOW&IN with $H \geq X$	$\mathrm{Max}(\mathrm{F} - \mathrm{X}, 0) - \big(Max(F - H, 0) + (H - X)\theta(F - H)\big) + r\,\theta(F - H)$	$Max(X - F, 0) + r\,\theta(F - H)$
UP&OUT or DOW&IN $H < X$	$r\,\theta(F - H)$	$Max(H - F, 0) + (X - H)\theta(H - F) + r\,\theta(F - H)$

Where r is the rebate; $\theta(x)$ is 1 for x>0, zero otherwise. For Asian Barriers F is replaced by the average Av defined above. The expiry barrier options and rebate pay-off involves the computation of digital options. These digital options are calculated by replication. (See previous section)

Barrier Parameters

Pricing Parameter	Type	Description
Barrier Count	Choice	None or Single
Type	Choice	UP&IN, UP&OUT, DOWN&IN and DOWN&OUT
Level	Value	Barrier level
Amount	Value	Value of the rebate to be paid if the barrier is hit. See pay-off table for clarification.

Input window for the barrier descriptors appears by clicking on the edit button in the barrier summary.



References

- Calypso Technology, "Expiry Barriers and Digital options: Definition and Valuation".

Section 8. IRD Market Data Generation

8.1 IRD Cap Stripping

8.1.1 Generator CapATM

Overview

This is a generator for stripping ATM caplet volatilities. Given flat volatilities from the market this bootstrapping algorithm will generate forward volatilities under the Black Scholes model.

An at-the-money cap is a cap whose strike price is corresponding forward swap rate. All caplets within a cap share the same agreed strike price.

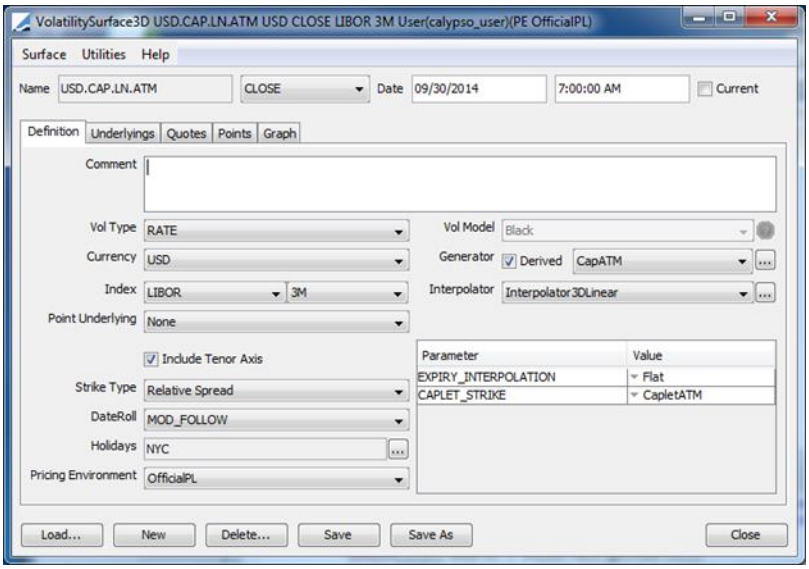
As of Aug 2015 new functionality has been added, where each caplet can have its own at-the-money rate. This simply corresponds to the LIBOR rate determined at the start date of the caplet with a tenor equal to the caplet tenor.

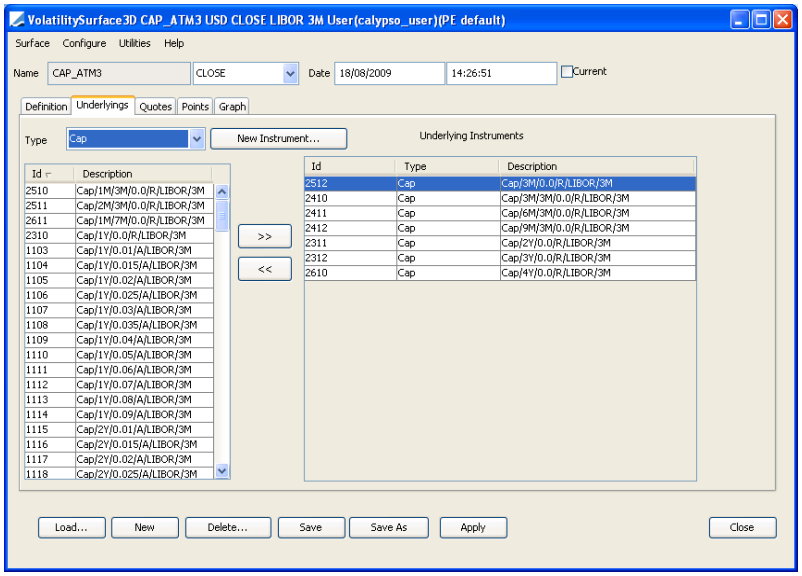
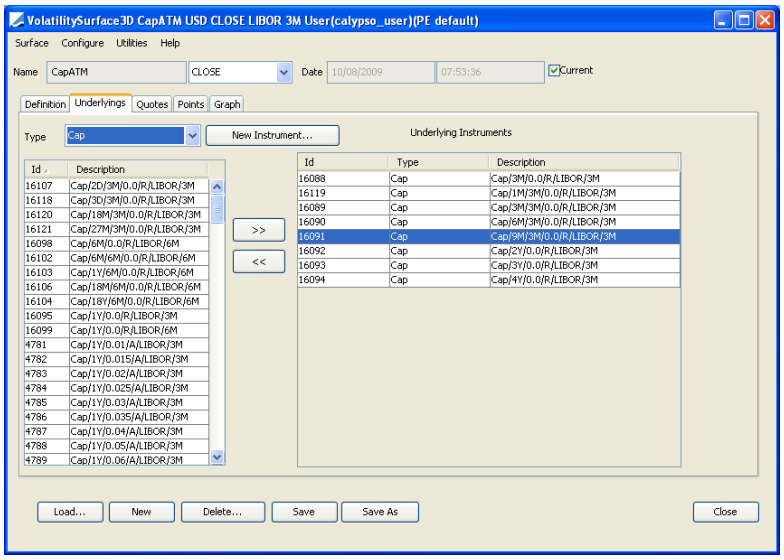
If caplets/floorlets are used as the volatility surface underlying instruments, then generation simply places the input volatilities on the respective vertex point (expiry/tenor/strike) of the volatility surface.

The market quotes are for the expiry date of each cap. When bootstrapping the caplet vols, the user can choose whether the caplet vol will be kept flat or interpolated linearly between cap expiries.

Configuration of Generator CapATM

Description of the required configuration of the CapATM generator in the volatility surface window

Definition tab	Description
	Select the generator to be CapATM, the vol type to be RATE and use a Derived surface. Set the EXPIRY_INTERPOLATION parameter to “Flat” to keep the caplet vol constant between cap expiries, or to “Linear” to interpolate the caplet vols between cap expiries. Set the CAPLET_STRIKE parameter to “SwapATM” to use the swap rate as the strike for all caplet, or “CapletATM” to select the LIBOR rate as the strike for each individual caplet. Default values are “Flat” and “SwapATM”.

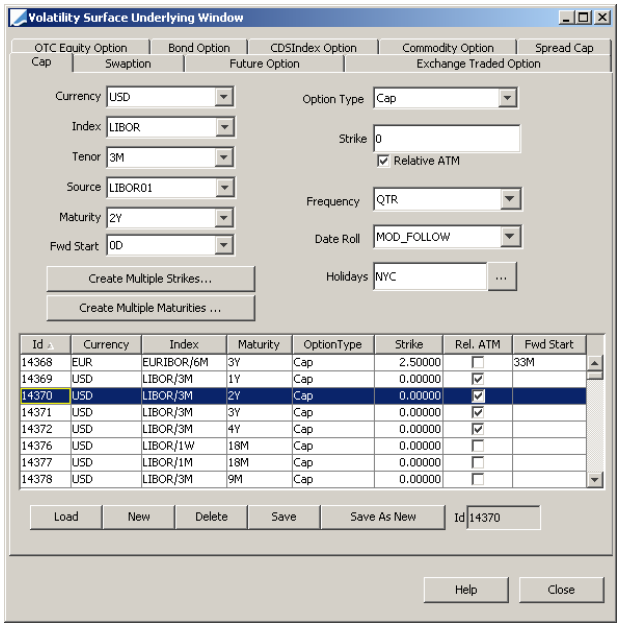
Underlying tab - Define caplets/caps	Description
	Enter the required underlyings for generation. This is a sample set of caps and caplets that will be used for the stripping algorithm. Example configuration: 0x3 Caplet (optional) 3x6 Caplet 6x9 Caplet 2Y Cap 3Y Cap 4Y Cap The last caplet has a start date in 9M and an end date in 12M. In that case there is no need to add a one year cap since all the caplets of this cap would be already known.
	If caplets are added in the underlying set, one should be careful to add a continuous set of caplets (i.e. without gaps), and only with maturities smaller than the first cap. Overlapping caplets can be entered if required. See example, the vol for the 1x4 caplet will be recovered correctly.

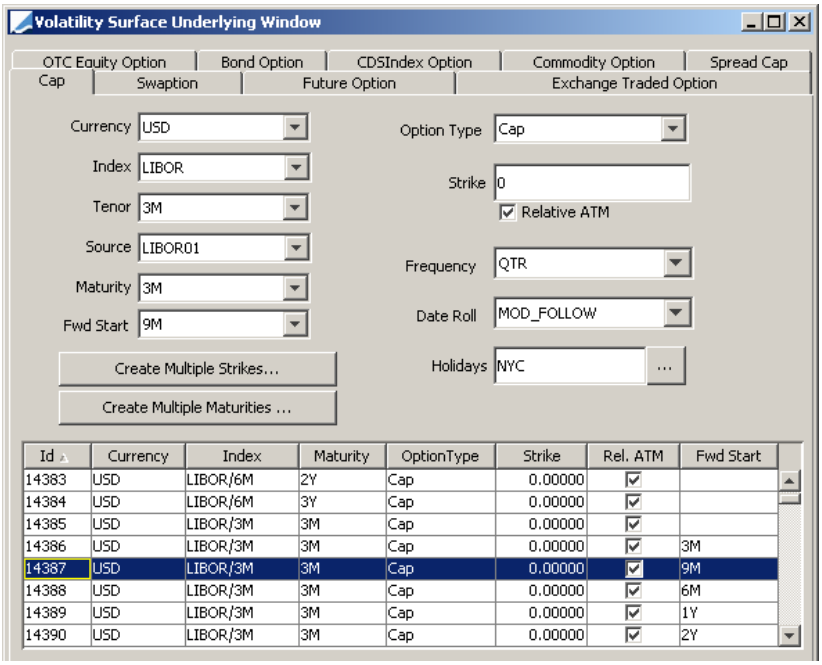
After the above configuration is complete the volatilities for the cap and caplets should be added to the quotes tab then one should click 'Generate'. The generated surface will be displayed on the points tab.

Configuration of the Cap / Caplet underlying's

Description of the required configuration of the cap underlying's from Main Entry> Configuration> Market Data> Volatility Surface Underlying's

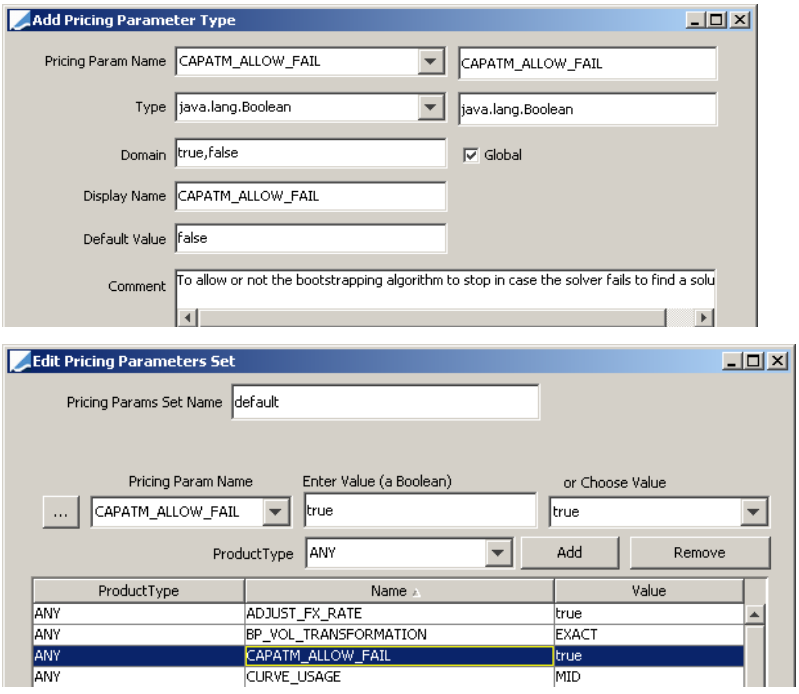
Cap Underlying Fields	Description
Currency	Should be common to all caps and caplets used for the stripping algorithm.
Index	Should be common to all caps and caplets used for the stripping algorithm.
Tenor	Should be common to all caps and caplets used for the stripping algorithm.
Source	Should be common to all caps and caplets used for the stripping algorithm.
Maturity	For Caplets it is the amount of time added to the "Fwd Start" field.
Fwd Start	For Caps choose "0D". For Caplets it is the start date and can be higher or equal to "0D".
Option Type	Should be common to all caps and caplets used for the stripping algorithm.
Strike	This field should contain "0".
Relative ATM	Should be common to all caps and caplets used for the stripping algorithm and checked.
Frequency	Should be common to all caps and caplets used for the stripping algorithm.
Date Roll	Should be common to all caps and caplets used for the stripping algorithm.
Holidays	Should be common to all caps and caplets used for the stripping algorithm.

Caplet Underlying Fields Example	Description
	This is an example of how to setup a cap with maturity 2 years.

Caplet Underlying Fields Example	Description
	This is an example of how to setup a caplet underlying with start date in 9 months and end date 12 months.

Configuration of Pricing Parameters

Main Entry> configuration > Market Data> Pricing Parameter set.

Pricing Parameters	Description
	CAPATM_ALLOW_FAIL This is a global switch for the ATM Cap Generator, it allows the stripping algorithm to fail while solving for forward volatilities. Typically the market data can cause the algorithm to fail should the set of quotes include big jumps between one maturity and another. Failing algorithm means that the stripping couldn't find any solution while solving for forward volatilities given the set of flat volatilities that seem to be inconsistent. If the global Pricing Parameter "CAPATM_ALLOW_FAIL" is set to true, the algorithm will stop and the stripping will not be completed. For the global Pricing Parameter "CAPATM_ALLOW_FAIL" set to false, if the stripping algorithm fails to find a solution, the stripping algorithm will continue and use the previous forward volatility as a solution.

8.1.1 Generator CapBlack

Overview

This is a generator for stripping fixed strike cap volatilities. Given flat volatilities from the market this bootstrapping algorithm will generate forward volatilities under the Black Scholes model.

If caplets/floorlets are used as the volatility surface underlying instruments, then generation simply places the input volatilities on the respective vertex point (expiry/tenor/strike) of the volatility surface.

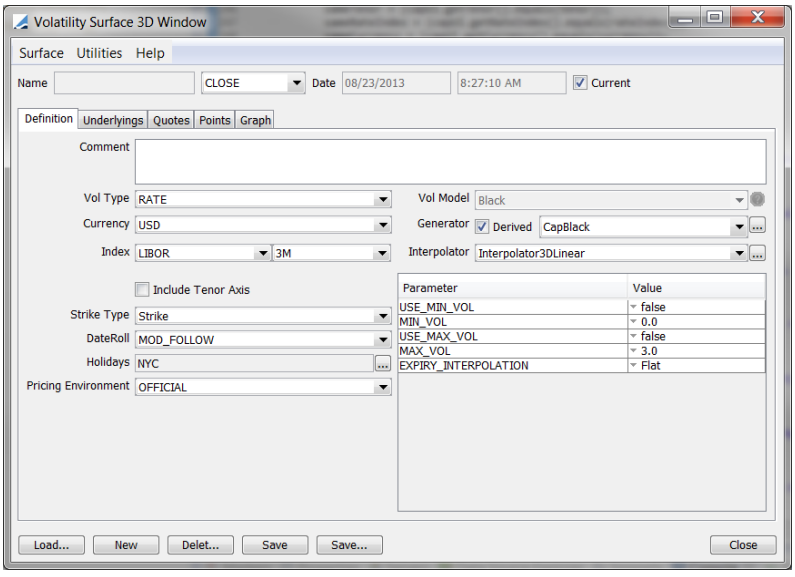
If caps/floors are volatility surface underlying instruments, then the following steps are followed to bootstrap volatilities given term volatilities:

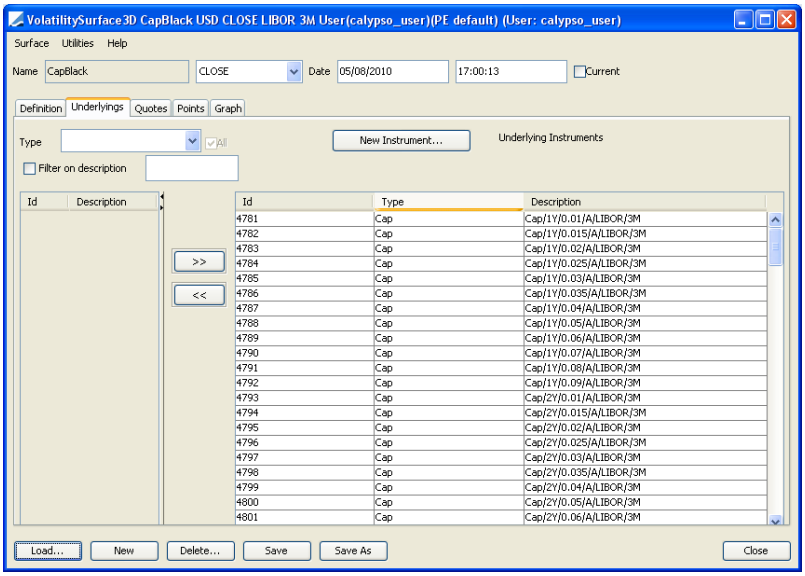
1. A preliminary volatility surface is built for the expiry/tenor/strike points using the surface underlying instruments and their term quotes.
2. Each cap/floor is decomposed into its equivalent caplets/floorlets. Synthetic caps/floors matching the end date of each caplet/floorlet are created and priced using interpolated term volatilities (i.e. same volatility is used for all caplets/floorlets of the given synthetic cap/floor). This produces a set of target present values for a series of caps/floors.
3. Solve for the volatility of the last caplet of each synthetic cap such that it re-prices exactly.
4. It should be noted that cap/floor maturity dates are transformed on the expiry axis to true expiry dates by taking the expiry dates of the generated caplets/floorlets.

The solver used in the CapBlack generator is the Brent solver routine.

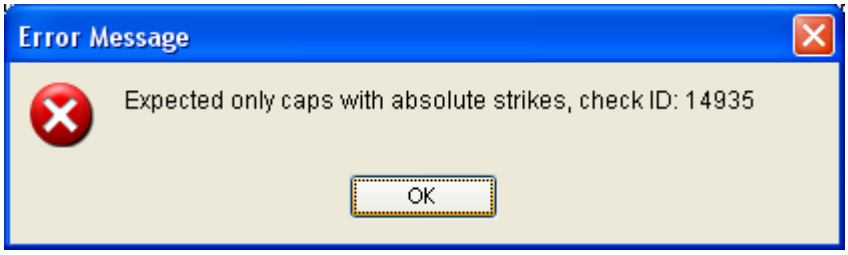
Configuration of Generator CapBlack

Description of the required configuration of the CapBlack generator in the volatility surface window

Definition tab	Description
	Select the generator to be CapBlack, the vol type to be RATE and use a Derived surface.

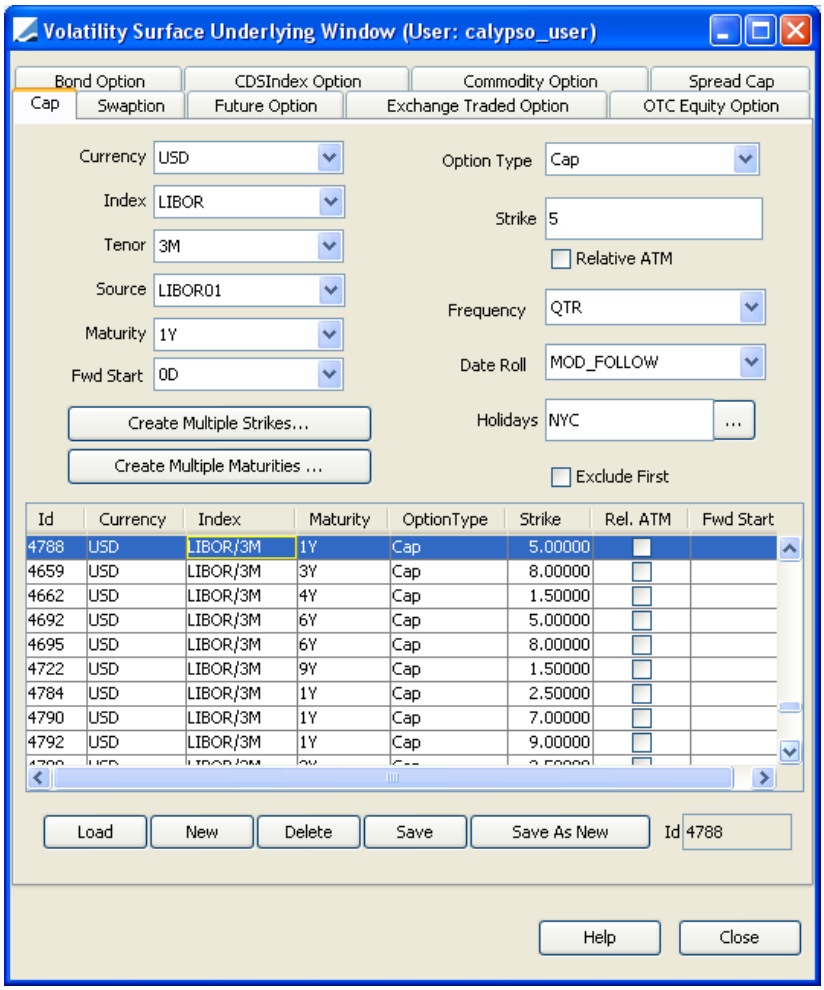
Underlying tab - Define caplets/caps	Description
	Select Fixed strike Caps or Caplets

If caps with relative strikes are selected for use with the CapBlack generator an error message is shown.



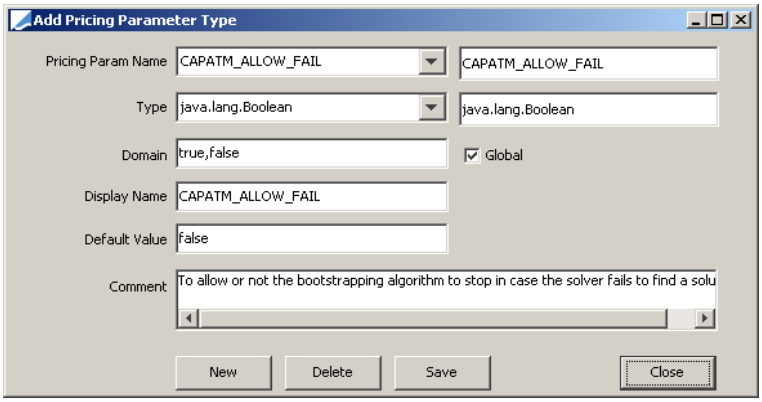
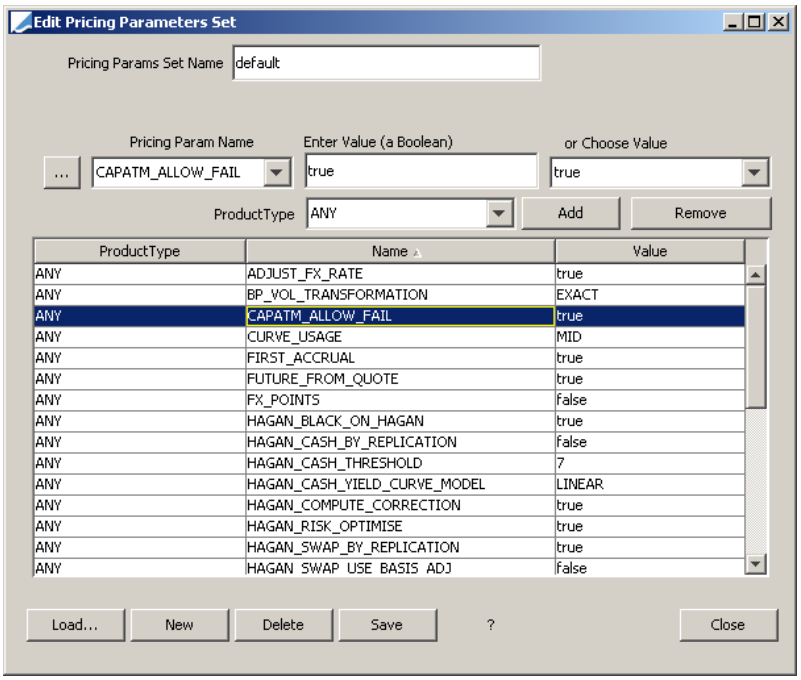
Configuration of the Cap / Caplet underlying's

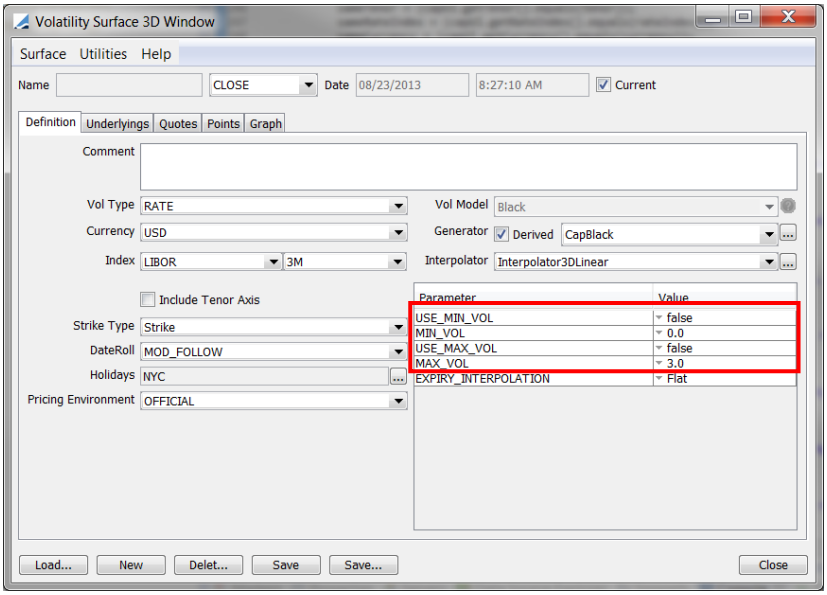
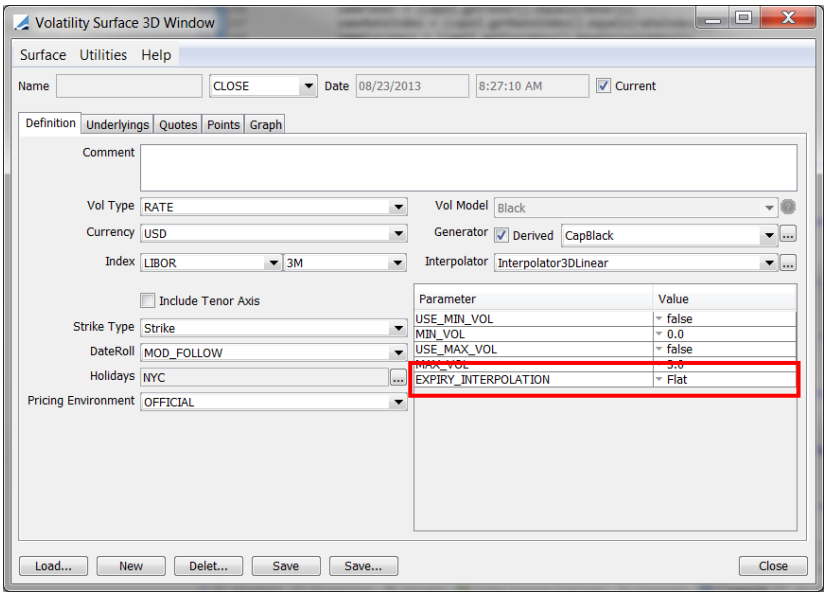
Description of the required configuration of the cap underlying's from Main Entry> Configuration> Market Data> Volatility Surface Underlying's

Cap – Volatility surface underlying's	Description
	This is an example of how to setup a cap with maturity 1 years and fixed strike at 5%.

Configuration of Pricing Parameters

Main Entry> configuration > Market Data> Pricing Parameter set.

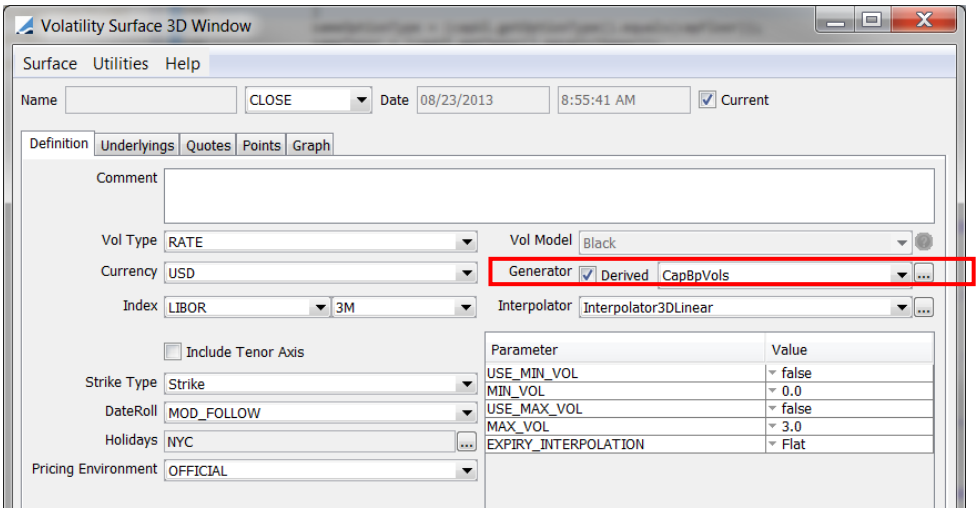
Pricing Parameters	Description
 	CAPATM_ALLOW_FAIL This is a global switch for the ATM Cap Generator, it allows the stripping algorithm to fail while solving for forward volatilities. Typically the market data can cause the algorithm to fail should the set of quotes include big jumps between one maturity and another. Failing algorithm means that the stripping couldn't find any solution while solving for forward volatilities given the set of flat volatilities that seem to be inconsistent. If the global Pricing Parameter "CAPATM_ALLOW_FAIL" is set to true, the algorithm will stop and the stripping will not be completed. For the global Pricing Parameter "CAPATM_ALLOW_FAIL" set to false, if the stripping algorithm fails to find a solution, the stripping algorithm will continue and use the previous forward volatility as a solution. Note this Parameter Controls the behaviour of both the CapATM and CapBlack generator.

Pricing Parameters	Description
	USE_MIN_VOL / MIN_VOL If "USE_MIN_VOL" = "true" then the calibration algorithm will floor all forward caplet volatilities to "MIN_VOL". USE_MAX_VOL / MAX_VOL If "USE_MAX_VOL" = "true" then the calibration algorithm will cap all forward caplet volatilities to "MAX_VOL".
	EXPIRY_INTERPOLATION If "EXPIRY_INTERPOLATION" = "Flat", the forward caplet volatilities will be flat-interpolated along the expiry axis. If "EXPIRY_INTERPOLATION" = "Linear", the forward caplet volatilities will be linearly-interpolated along the expiry axis.

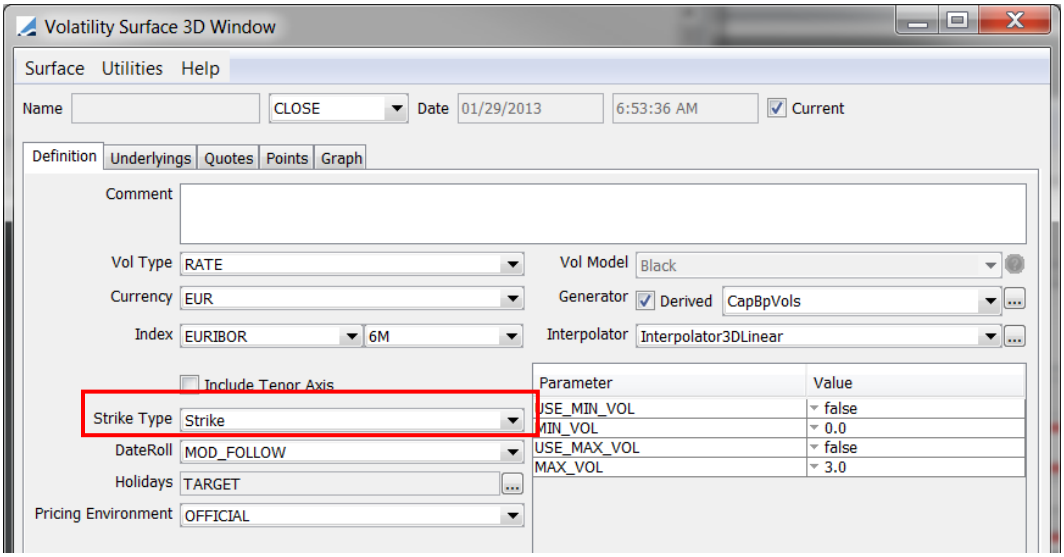
8.1.2 Generator CapBpVols

Generator CapBpVols, in this case the bootstrapping algorithm is using the BpVol (a.k.a. Normal) model to generate forward volatilities. Volatility surfaces built using this generator can then expose Black or BpVol volatilities to pricers.

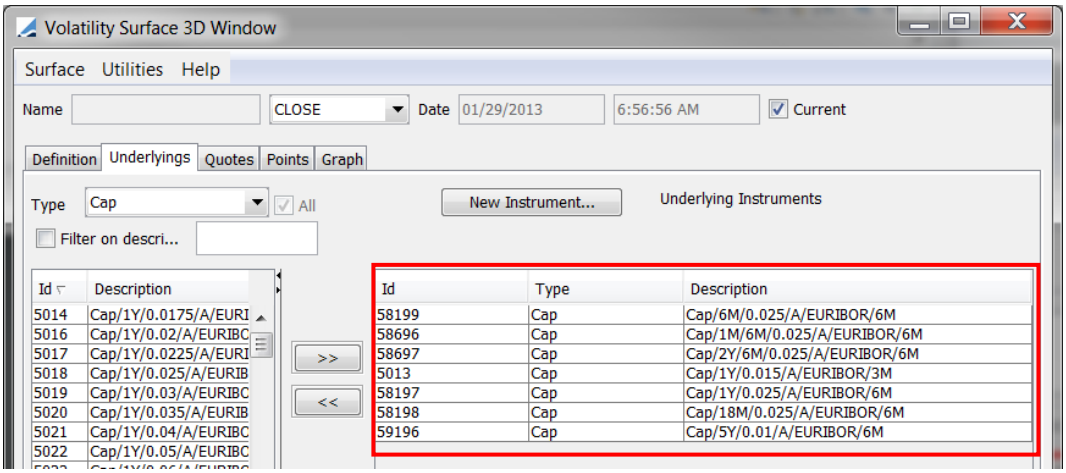
The settings are similar to the configuration of the CapBlack generator, in particular the Pricing Parameters are the same.



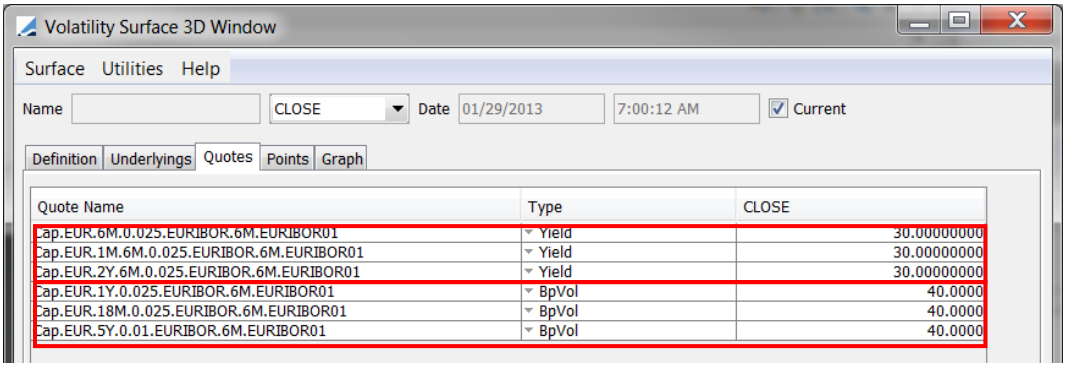
As with the CapBlack generator, only absolute strikes can be defined for the underlying instruments:



Underlying instruments can then be selected in the Underlyings tab as with the CapBlack generator :



They can then given either Black or BpVol quotes. Please notice that the Black quotes (Yield) are specified as percentages, while the BpVol quotes are given in "bips" :



Cap Generator References

- Hagan, P. and Konikov, M. (2004). "Interest rate volatility cube: Construction and use".

8.1.3 Generator CapShiftedLognormal

Overview

This generator computes the forward caplet volatilities from the market quoted Cap volatilities.

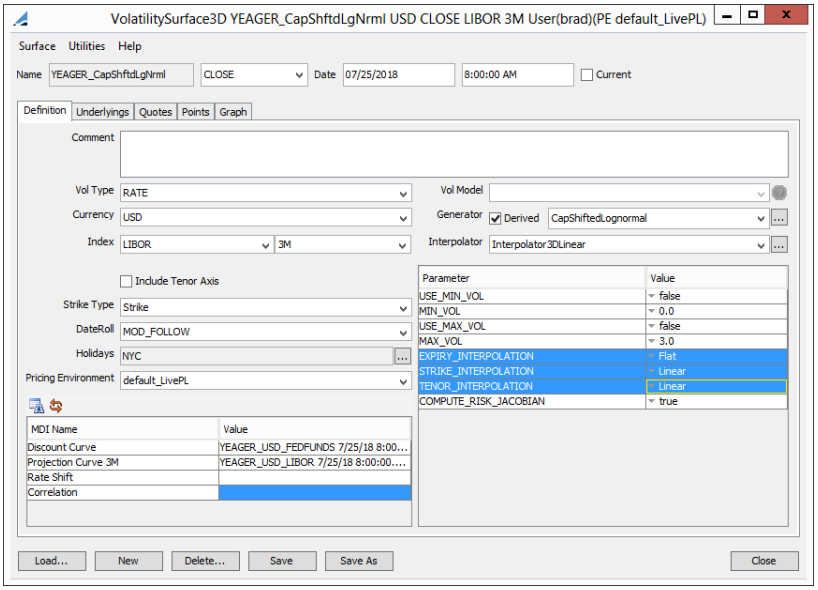
It supports rate shifts (at the moment, a uniform shift specified by a single value) in order to bootstrap volatilities even if the interest rates are negative.

It also supports caps with different tenors for the underlying caplets. The current implementation is limited to two such different tenors, (for example, 3M and 6M LIBORs) and the short tenor caps must have expiry dates coming before those of the long tenor caps. The generator does not support mixing the caps of different tenors in arbitrary order.

The caplet volatilities are computed by first calculating the prices of the forward caps; that is the difference in price between a cap of a certain expiry date and the cap with immediately shorter expiry date. Each cap is priced with the quoted market volatility and shift. After that, the volatilities of the caplets of the forward cap are determined numerically (respecting the interpolation method specified by the user) in order to match the price of the forward cap.

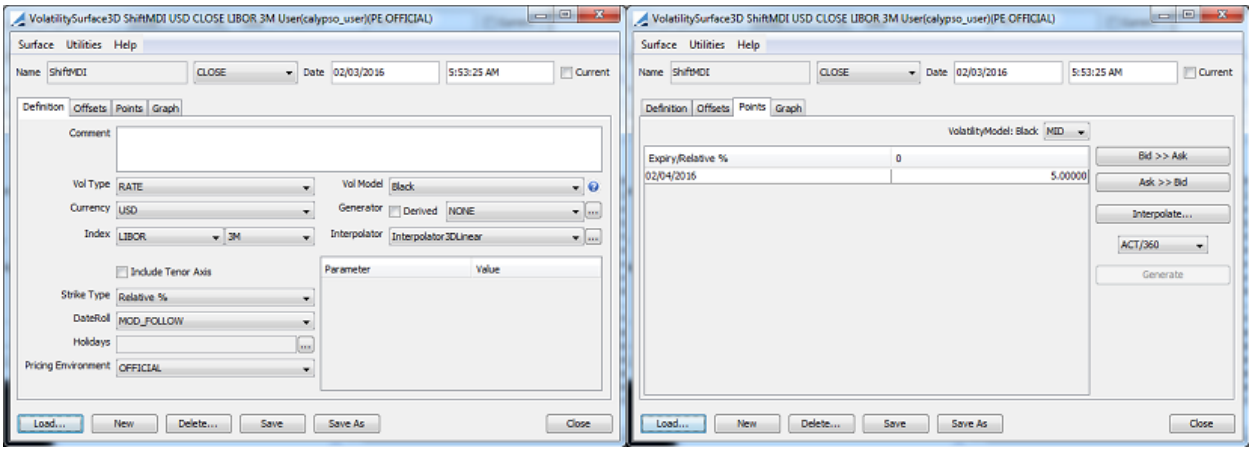
One thing to keep in mind is that in the case where the cap volatilities decrease steeply with increasing expiries it is possible that the price of the forward cap becomes negative. In this case the bootstrapping will fail, and the last

successful value of the caplet volatility will be repeated for later expiries until the forward cap price becomes positive again, or the last expiry date of the caps is reached.

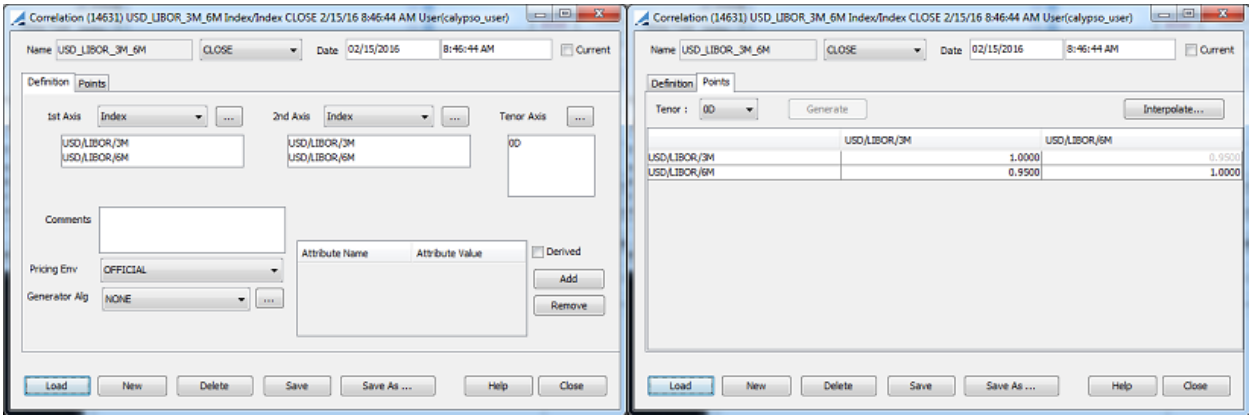
Definition Tab	Description
	MDI PARAMETERS Discount Curve : User-specified, will supersede the one in the Pricing Environment Projection Curve 3M : User-specified forecasting curves for the short-tenor caps. The tenor in the label is extracted from the actual cap underlyings. Projection Curve 6M : Same, but for the long-tenor caps. Rate Shift : The lognormal shift for the quoted market vols. The object holding it is a VolatilitySurface with only one point set to the value of the rate shift. Correlation : The correlation between the Brownian motions driving the dynamics of the 3M and the 6M LIBORs. Specified as an Index-Index correlation matrix object. **PARAMETERS** • USE_MIN_VOL • MIN_VOL • USE_MAX_VOL • MAX_VOL • EXPIRY_INTERPOLATION • STRIKE_INTERPOLATION • TENOR_INTERPOLATION These parameters specify the way the volatility is bootstrapped for individual caplets. One can set different interpolation methods (Flat or Linear) to Expiry/Strike/Tenor and the interpolator set in the surface is ignored.

The remaining MID Parameters:

The "Rate Shift" parameter can be left blank, in this case the shift will be set to zero.



The "Correlation" parameter is needed only if the surface is a multi-tenor one. It can be left blank for a single-tenor surface, as a correlation value is not needed. The important value here is the off-diagonal value, which is the one used in the conversion of the caplet volatilities between tenors.

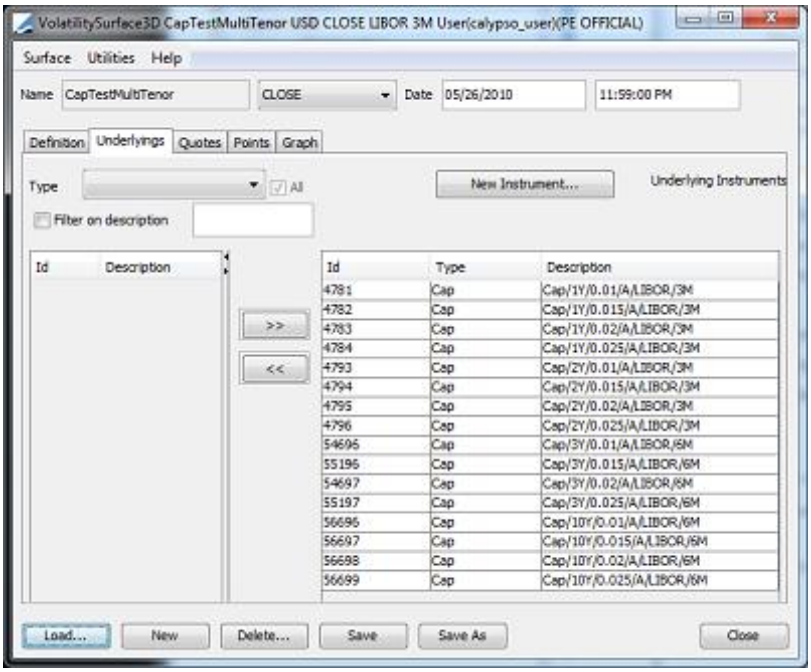


The "Underlyings" tab:

In this tab we specify the underlying caps that will be used for bootstrapping the caplet volatilities. Here we can select the caps for the short tenor and the ones for the long tenor for each strike. The caps for the short tenor must all have shorter expiries than the ones for the long tenors. In the current implementation we cannot have short tenor caps with expiries longer than those of the long tenor caps for the same strike.

Please notice that the Projection Curves labels in the MDI parameters list are updated based on the underlyings.

However, as mentioned earlier, the list of labels will not be automatically refreshed if the underlyings are changed. To obtain the refreshed list the generator has to be re-selected in the Definition tab.



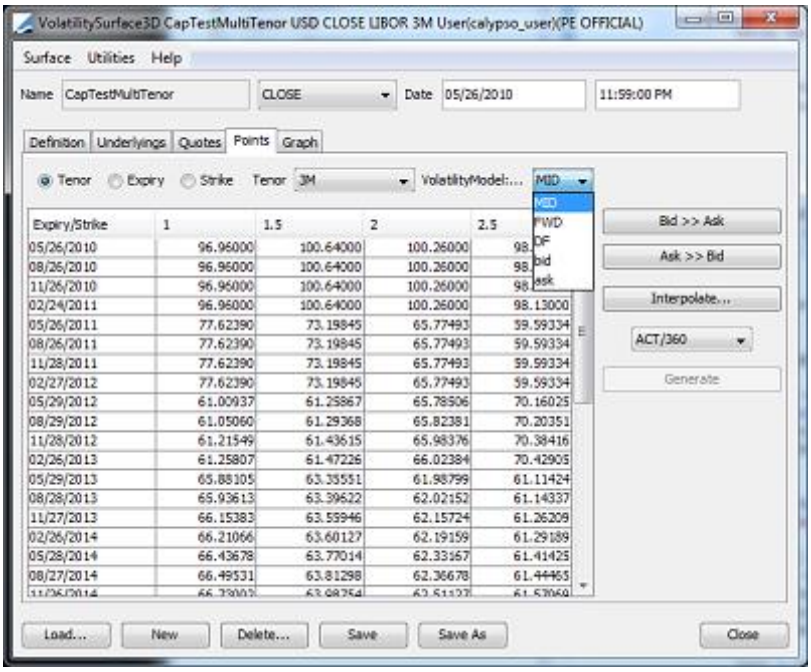
In this example, the underlyings are caps on 3M LIBOR up to the 2Y expiry date and caps on 6M LIBOR for expiries longer than 2Y.

Please notice that simply using the >> and << buttons to update the underlyings will NOT update the forecasting curves labels on the "Definition" tab. For example, if the underlying contain only caps on 3M LIBOR, adding caps on 6M LIBOR with the >> button will not result in the additional label "Projection Curve 6M" being added.

The user will have to go back to the "Definition" tab and select the generator again, in order to refresh the MDI parameters list.

The "Points" tab and adjustment layers:

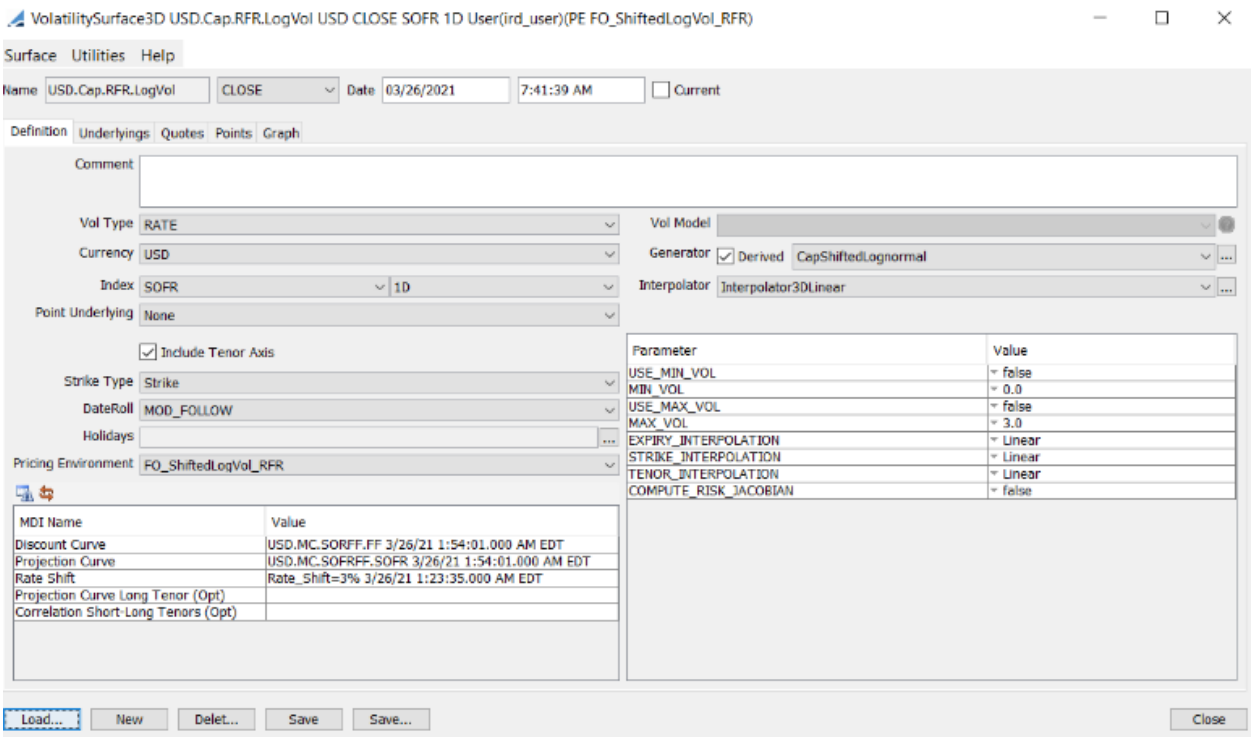
The vol is stored in the "bid" and "ask" layers. Also, the "Tenor" drop-down menu will contain both tenors and the corresponding volatility. Please notice that in the case of a 3M plus 6M volatility surface, the 6M tenor volatility will be super-sampled and shown in the Points tab every 3 months. That is because the volatility will be shown at the highest caplet expiry frequency.



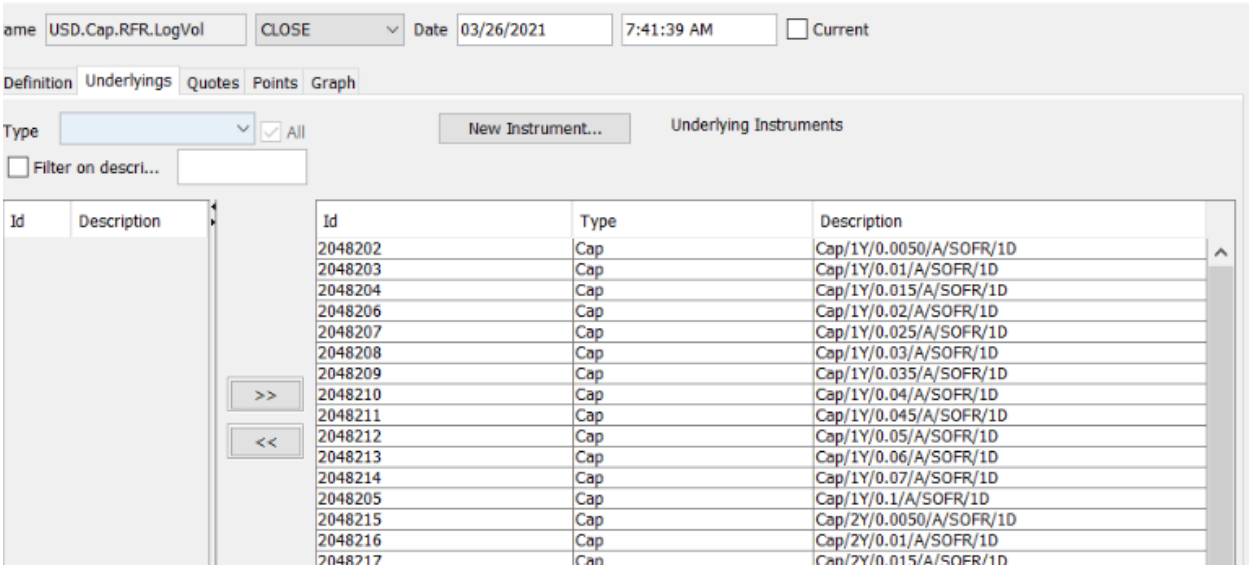
Support for RFR

Generator CapShiftedLognormal supports generation on RFR Cap underlyings.

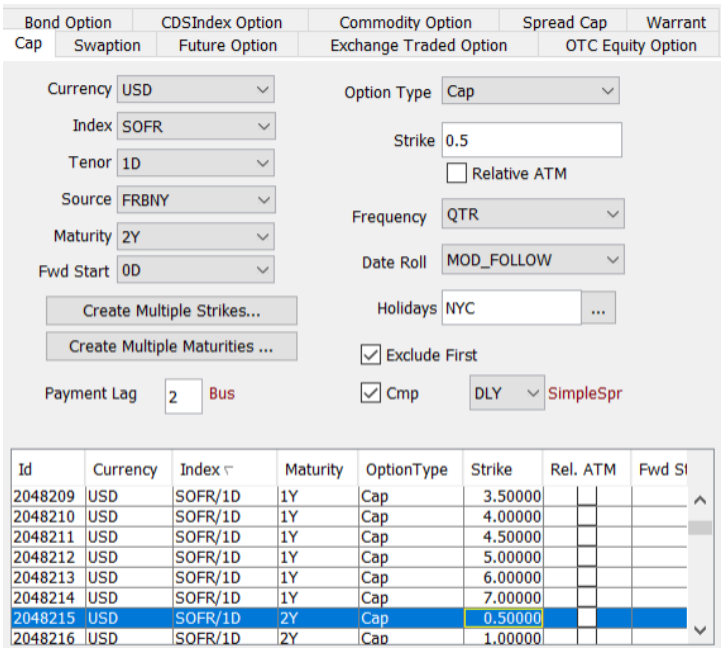
Definition should have the correct RFR index as surface index.



Underlyings:



A typical RFR Cap underlying needs to be set as below:

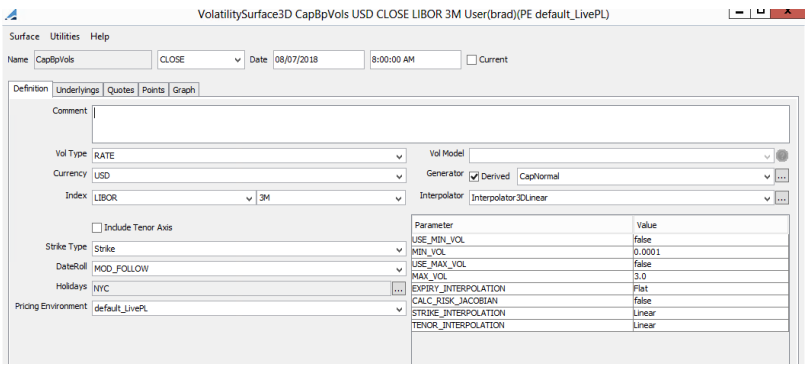


8.1.4 Generator CapNormal

This generator computes the forward caplet Normal (Gaussian) volatilities from the market quoted Cap volatilities. The generator works in tandem with the CapFloorNormal pricer and supersedes the CapBpVols generator. Similar to its shifted lognormal counterpart (CapShiftedLognormal) it also provides risk optimizations using Jacobian calculations (cf. the discussion below in 'Computation of the Risk Jacobian (V15.1)').

See also the general discussion about the underlyings and the adjustment layers in the CapShiftedLognormal and CapBpVols generator sections.

Also note that, at this time, the projection and discount curves are picked up through the Pricing Environment using the settings for the Cap pricer.

Definition Tab	Description
	**PARAMETERS** • USE_MIN_VOL • MIN_VOL • USE_MAX_VOL • MAX_VOL • EXPIRY_INTERPOLATION • STRIKE_INTERPOLATION • TENOR_INTERPOLATION These parameters specify the way the volatility is bootstrapped for individual caplets. One can set different interpolation methods (Flat or Linear) to Expiry/Strike/Tenor and the interpolator set in the surface is ignored.

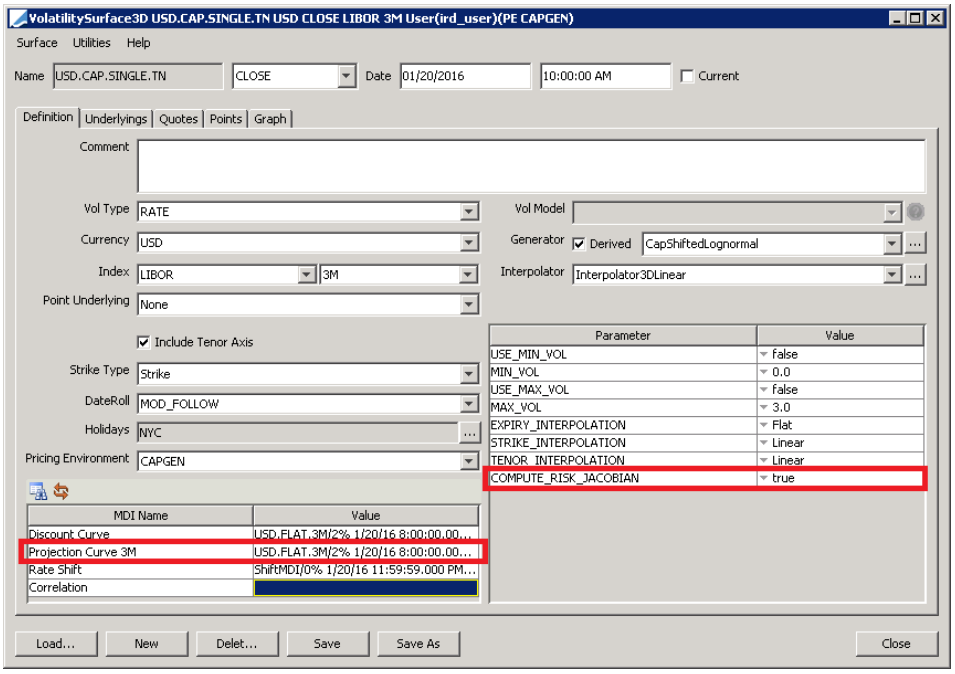
CapNormal generator also supports generation on RFR cap underlyings. Similar as in CapShiftedLognormal generator.

8.1.5 Computation of the Risk Jacobian (V15.1)

As of V15.1 it is now possible to compute the sensitivities matrix of the bootstrapped caplet vols with respect to the market quotes of the surface underlyings. We call this matrix the Risk Jacobian. When a user wants to compute the change in price of a Cap/Floor/Collar trade when an underlying quote is bumped, there is no need to re-generate the surface. All that is required are the vegas of the individual caplets that make up the trade product and the Risk Jacobian, and the change in price can be computed much faster, as the re-generation of the volatility surface is no longer necessary.

In order to compute the Risk Jacobian the Generator Parameter COMPUTE_RISK_JACOBIAN must be set to true. Please note that, for the moment, the computation is supported only for surfaces containing underlyings of a single tenor (e.g. 3M). For multi-tenor surfaces we will have to revert to the bump-and-reprice method.

The values of the Risk Jacobian can be serialized and saved to the Database, but, as of now, there is no functionality to display these values in the GUI.



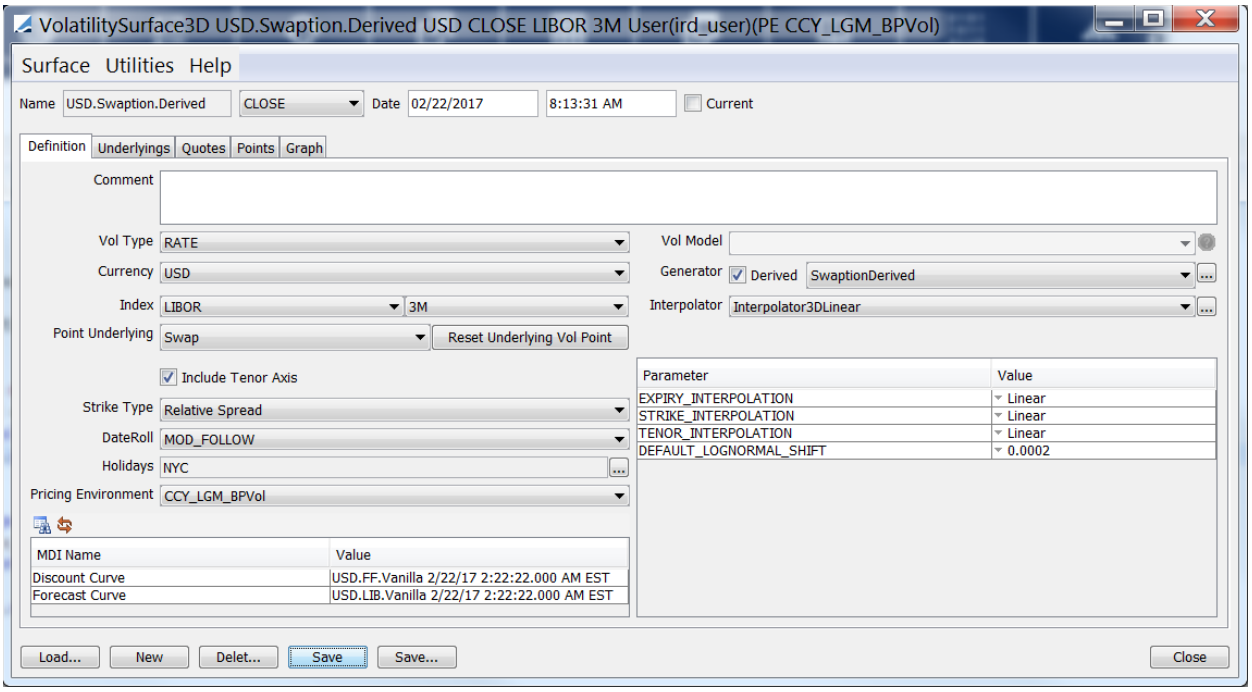
The value of COMPUTE_RISK_JACOBIAN

is set to "true" when all the underlyings have the same tenor. Please note that there is only one projection curve specified, for the 3M tenor.

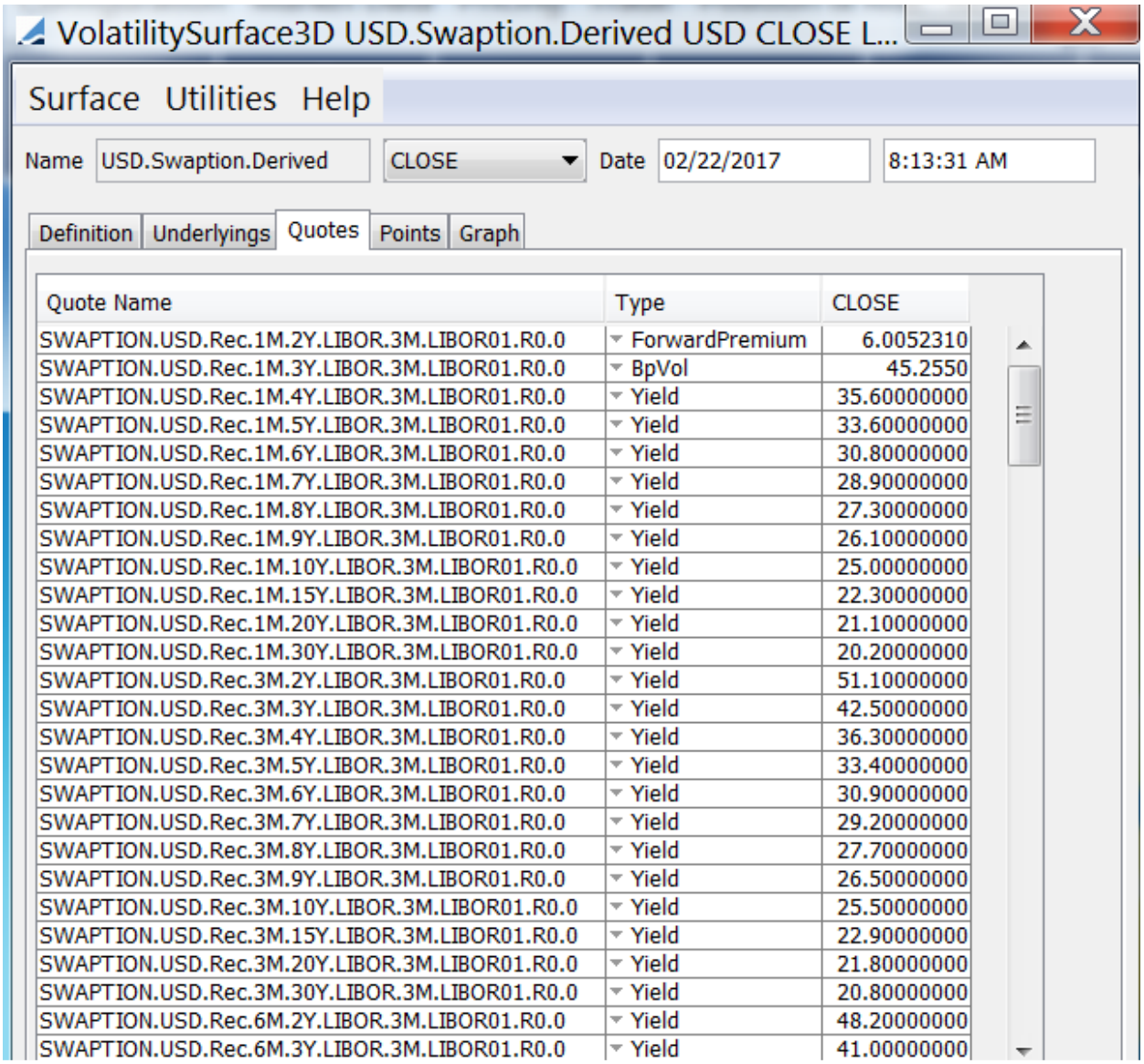
8.2 IRD Swaption Volatility Stripping

8.2.1 Generator SwaptionDerived

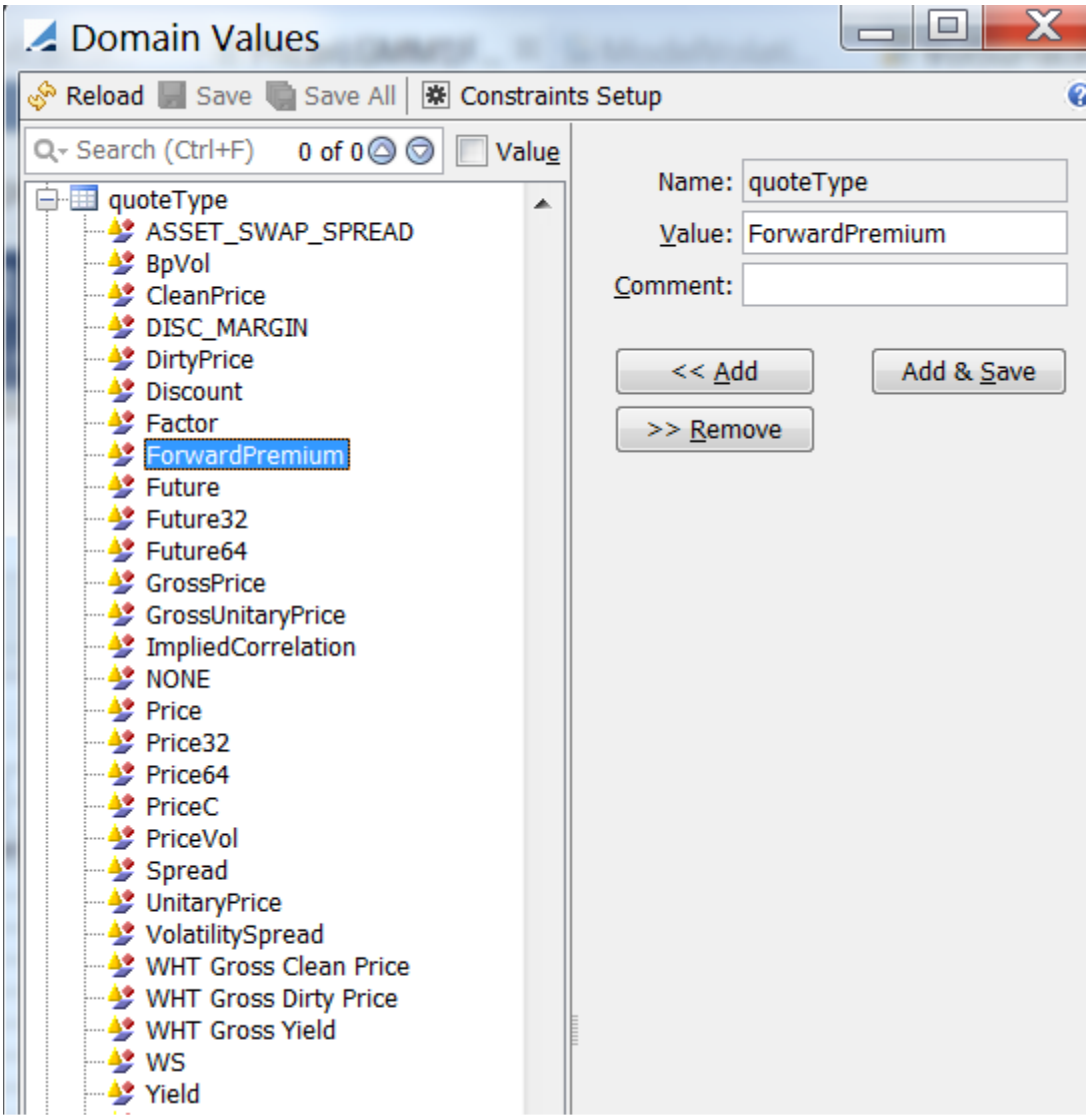
The SwaptionDerived is a Derived vanilla swaption generator that can handle mixed swaption inputs and provide vols to both the shifted lognormal and normal swaption pricers.



The user can provide a blend of inputs – {Black, BpVol, ForwardPremium}, with the types added as necessary in Configuration -> System -> Domain Values -> QuoteType:

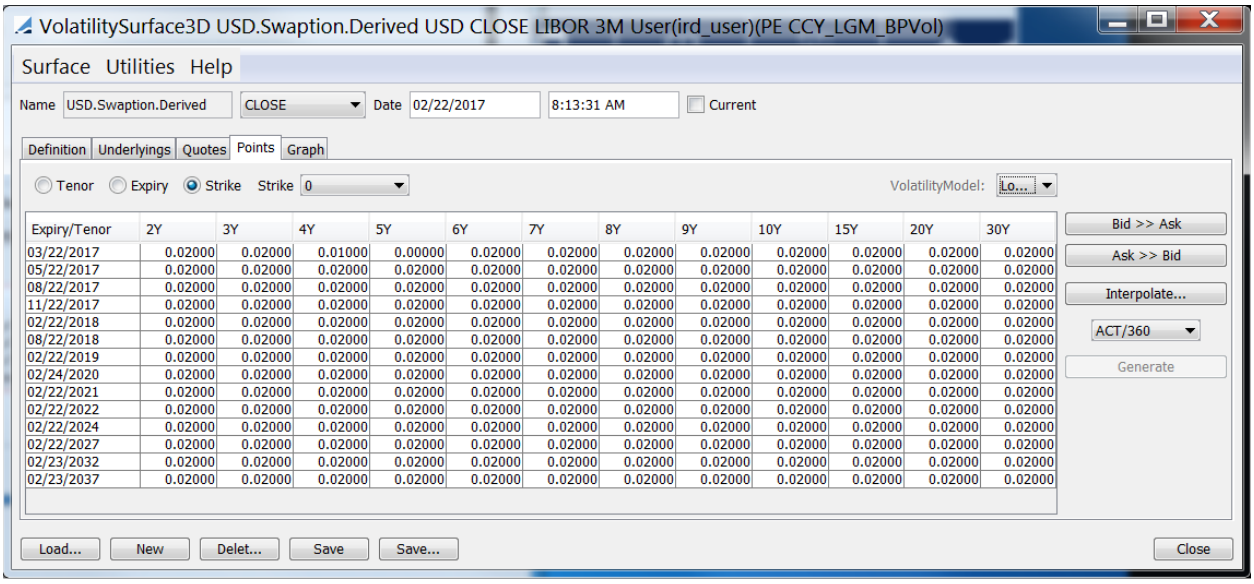


Quote Name	Type	CLOSE
SWAPTION.USD.Rec.1M.2Y.LIBOR.3M.LIBOR01.R0.0	ForwardPremium	6.0052310
SWAPTION.USD.Rec.1M.3Y.LIBOR.3M.LIBOR01.R0.0	BpVol	45.2550
SWAPTION.USD.Rec.1M.4Y.LIBOR.3M.LIBOR01.R0.0	Yield	35.60000000
SWAPTION.USD.Rec.1M.5Y.LIBOR.3M.LIBOR01.R0.0	Yield	33.60000000
SWAPTION.USD.Rec.1M.6Y.LIBOR.3M.LIBOR01.R0.0	Yield	30.80000000
SWAPTION.USD.Rec.1M.7Y.LIBOR.3M.LIBOR01.R0.0	Yield	28.90000000
SWAPTION.USD.Rec.1M.8Y.LIBOR.3M.LIBOR01.R0.0	Yield	27.30000000
SWAPTION.USD.Rec.1M.9Y.LIBOR.3M.LIBOR01.R0.0	Yield	26.10000000
SWAPTION.USD.Rec.1M.10Y.LIBOR.3M.LIBOR01.R0.0	Yield	25.00000000
SWAPTION.USD.Rec.1M.15Y.LIBOR.3M.LIBOR01.R0.0	Yield	22.30000000
SWAPTION.USD.Rec.1M.20Y.LIBOR.3M.LIBOR01.R0.0	Yield	21.10000000
SWAPTION.USD.Rec.1M.30Y.LIBOR.3M.LIBOR01.R0.0	Yield	20.20000000
SWAPTION.USD.Rec.3M.2Y.LIBOR.3M.LIBOR01.R0.0	Yield	51.10000000
SWAPTION.USD.Rec.3M.3Y.LIBOR.3M.LIBOR01.R0.0	Yield	42.50000000
SWAPTION.USD.Rec.3M.4Y.LIBOR.3M.LIBOR01.R0.0	Yield	36.30000000
SWAPTION.USD.Rec.3M.5Y.LIBOR.3M.LIBOR01.R0.0	Yield	33.40000000
SWAPTION.USD.Rec.3M.6Y.LIBOR.3M.LIBOR01.R0.0	Yield	30.90000000
SWAPTION.USD.Rec.3M.7Y.LIBOR.3M.LIBOR01.R0.0	Yield	29.20000000
SWAPTION.USD.Rec.3M.8Y.LIBOR.3M.LIBOR01.R0.0	Yield	27.70000000
SWAPTION.USD.Rec.3M.9Y.LIBOR.3M.LIBOR01.R0.0	Yield	26.50000000
SWAPTION.USD.Rec.3M.10Y.LIBOR.3M.LIBOR01.R0.0	Yield	25.50000000
SWAPTION.USD.Rec.3M.15Y.LIBOR.3M.LIBOR01.R0.0	Yield	22.90000000
SWAPTION.USD.Rec.3M.20Y.LIBOR.3M.LIBOR01.R0.0	Yield	21.80000000
SWAPTION.USD.Rec.3M.30Y.LIBOR.3M.LIBOR01.R0.0	Yield	20.80000000
SWAPTION.USD.Rec.6M.2Y.LIBOR.3M.LIBOR01.R0.0	Yield	48.20000000
SWAPTION.USD.Rec.6M.3Y.LIBOR.3M.LIBOR01.R0.0	Yield	41.00000000



The lognormal shift can be provided in two ways

- The default shift, specified as the "DEFAULT_LOGNORMAL_SHIFT" generator parameter
- On the lognormal shift tab in Points



Different interpolation methods are also supported for the 3 available axes (expiry, strike, tenor).

8.2.2 Generator SwaptionSABRDerived (*)

(* : requires Calypso version 12 or higher)

Overview

The SwaptionSABRDerived generator builds SABR volatility interpolators along strikes, on a user-specified grid of swaption expiries and swap tenors. It allows for

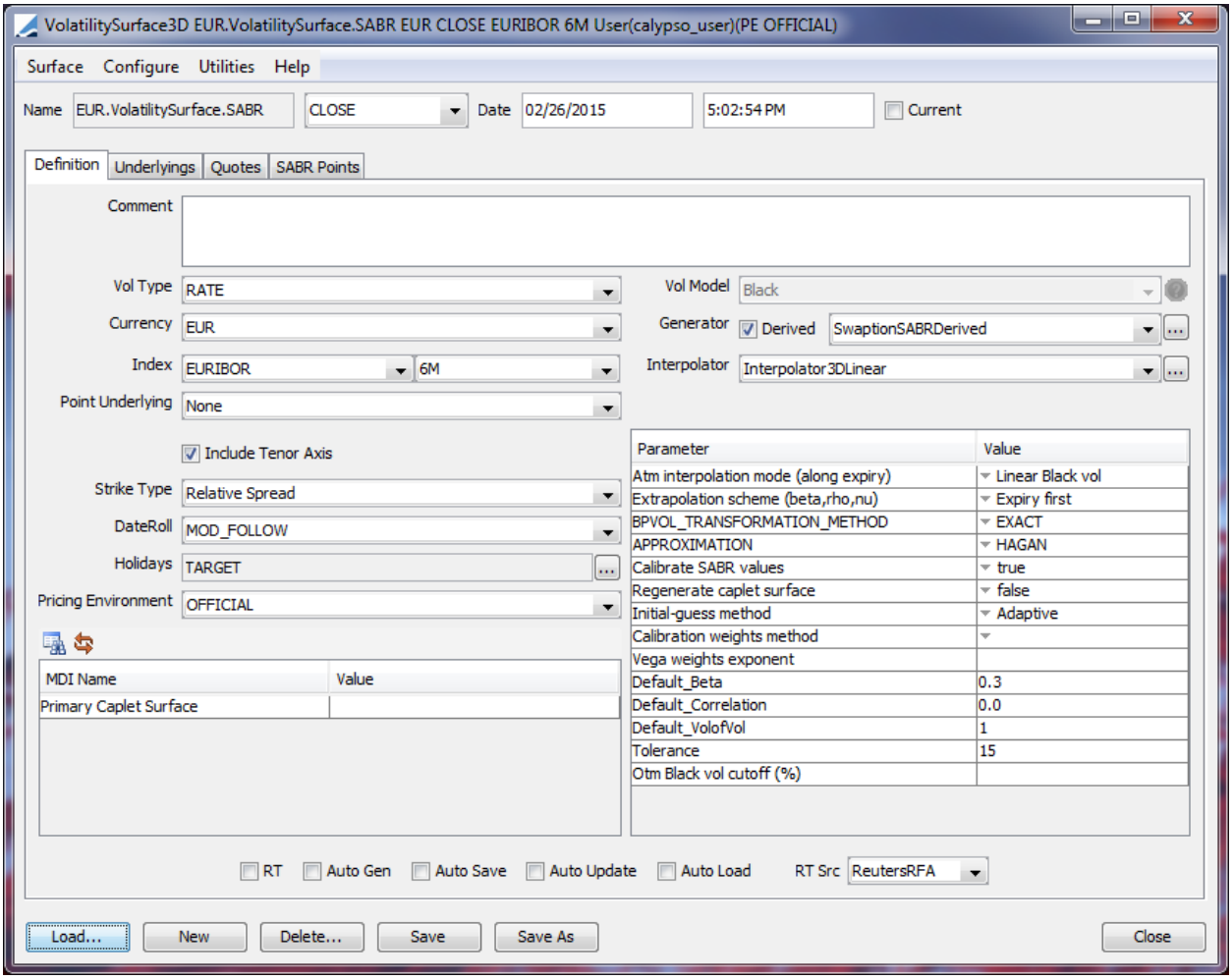
- explicit calibration to away-from-the-money and at-the-money swaption data
- calibration to caplet skews and at-the-money swaptions
- manual SABR parameter inputs

or a combination thereof. When skew data is sparse, the SABR parameters (β,ρ,ν) that control the volatility smile are interpolated bilinearly in expiry and tenor space, with flat extrapolation where necessary.

Definition

Generator

Tick the Derived tick-box and select SwaptionSABRDerived generator; this will bring up the Definition panel:

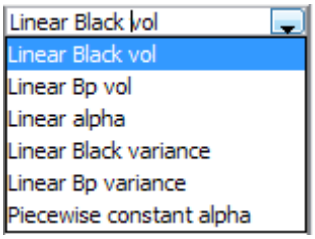
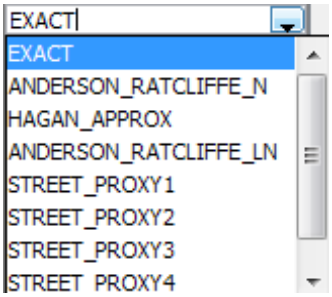


As for the remaining inputs:

- Vol Type : choose RATE.
- Currency : select the swap currency, e.g., USD.
- Index : select the appropriate swap underlying index, e.g., LIBOR-3M.
- Include Tenor Axis : not used
- Strike Type : not used. (See however the section on SABR Points below).
- DateRoll : select as appropriate.
- Holidays : select as appropriate.
- Pricing Environment : select as appropriate.
- MDI Name Primary Caplet Surface: optional.

  Lets the user select a caplet volatility surface to infer swaption SABR parameters for the corresponding single-period swaptions; see Section Example: swaption skew from caplets, for further details.
- Vol Model : not used;
- Interpolator : not used;

Configuration parameters

Configuration Parameters	Description
Atm interpolation mode (along expiry) 	Determines how at-the-money data is interpolated along expiries, i.e., for a fixed tenor: Linear Black vol : Black vols are linearly interpolated; Linear Bp vol : normal vols are linearly interpolated; Linear alpha : the SABR alpha parameter is linearly interpolated; Linear Black variance : Black variances are linearly interpolated; Linear Bp variance : basis-point variances are linearly interpolated; Piecewise constant alpha : alpha is kept constant (left-continuous) between successive expiries.
Extrapolation scheme (beta,rho,nu)	Selects a bilinear extrapolation scheme for the SABR parameters that control the skew/smile (β,ρ,v) when away-from-the-money vol quotes are not available. Default value is 'Expiry first'. Expiry first: extrapolate (or interpolate) along columns first; then interpolate along rows; Tenor first: extrapolate (or interpolate) along rows first; then interpolate along columns; *See also Section 'On interpolation/extrapolation' below;*
BPVOL_TRANSFORMATION_METHOD 	Controls how normal vol is converted into lognormal (Black vol) or vice-versa during vol surface generation and volatility retrieval; For an explanation of the algorithms, see Ref. [CAL2009]
APPROXIMATION	Selects a specific asymptotic SABR formula that yields implied volatility in terms of SABR parameters; HAGAN : use the Obloj correction to the Hagan et al. formula (see Ref. [HAGAN2002])
Calibrate SABR values	**True** : generate will trigger full recalibration on each grid point where skew data is available; **False** : generate will re-fit the backbone only (alpha, ATM vol, spot);
Regenerate caplet surface	**True** : if present, a local copy of the MDI caplet surface is regenerated before any data is accessed. **False** : the caplet surface is not regenerated. When out-of-date, a local copy is rolled instead.

Note: while the SABR β (CEV parameter) is kept fixed and would be specified exogenously, a calibration seeks optimal values for the smile parameters (ρ,v). For given (β,ρ,v), the backbone parameter alpha is adjusted to match the at-the-money volatility level. The final RMS error is calculated using thus found alpha and (β,ρ,v).

The remaining parameters let the user fine-tune the behaviour when ‘Calibrate SABR values’ =true. They are not referenced otherwise.

Configuration Parameters	Description
Initial-guess method	Controls how an initial point is found to initiate each calibration: **Use defaults** : use the values provided as configuration parameters Default_Beta, Default_Correlation, Default_VolofVol. **Use previous calibration** : for each slice, retrieve the values that were stored after a previous calibration run to be used as initial guess. **Adaptive** : use a guess algorithm to find an initial point near the optimal value. If no such point can be calculated, fall back into Use defaults mode. **Global**: use a global optimisation to find an initial point near the optimal value. *See also Section ‘On (re)calibration with manual overrides’ below.*
Calibration weights method	Controls what weight is assigned to each caplet or swaption when a slice is calibrated. **Use equal calibration weights**: all the caplets/swaptions have the same weight. **Use vega-based calibration weights**: the weight of each caplet/swaption is determined according to its vega and the *Vega Weights Exponent* below
Vega weights exponent	The exponent used to determine the vega-based calibration weight.
Default_Beta	A CEV exponent between 0.0 and 1.0 to be used in conjunction with ‘Initial-guess method = Use defaults’. Note: when ‘Calibrate SABR values’ = ‘true’, this value must not exceed 0.99999 or else the calibration will fail.
Default_Correlation	An initial spot-vol correlation level to be used with ‘Initial-guess method = Use defaults’.
Default_VolofVol	An initial value for the SABR nu parameter for use with ‘Initial-guess method = Use defaults’.
Tolerance	An integer (1:low-15:high) that heuristically indicates a tolerance at which to stop the optimization search. A value of 8 yields acceptable calibrations, in general.
Otm Black vol cutoff (%)	Volatility level. Away-from-the-money input volatilities will be ignored if they exceed this value. ‘98.0’ means: 98%, i.e., 0.98 as a fraction.

Configuration Parameters	Description
	When blank, no filter is applied and all numerical volatilities available will be included. This cutoff does not apply to ATM vol levels.

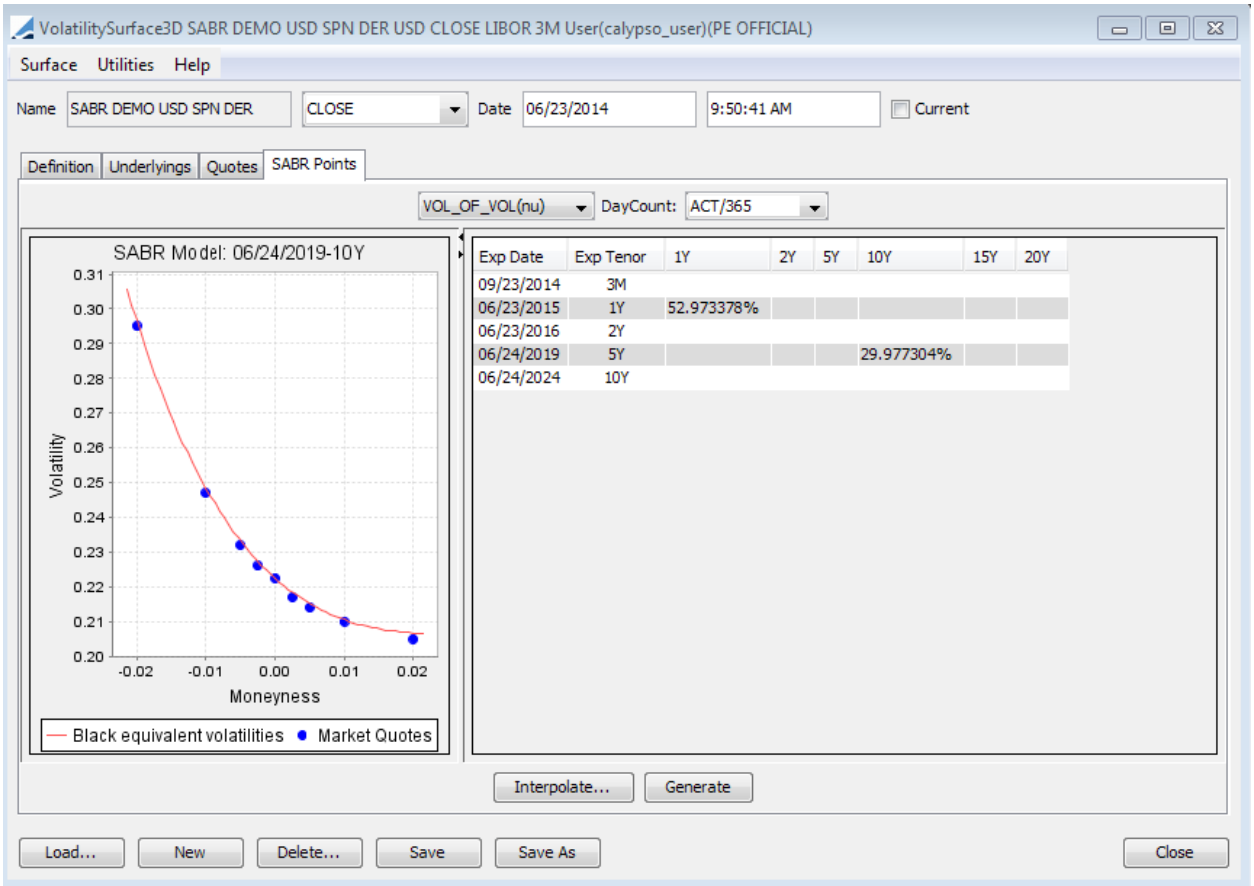
Underlyings

Underlyings are either ATM swaptions (struck at relative strike 0.0) or away-from-the-money swaptions (at relative strikes different from 0.0). The swaption grid is defined as the Cartesian product of the span of all ATM expiries and tenors, and it is assumed that all at-the-money volatilities are available as quotes.

Either a caplet surface must be set (see Section Definition above), or alternatively, at least one slice of skew data points must be provided. A minimal slice of skew data consists of two or more away-from-the-money swaptions with same expiry and tenor. Each of the away-from-the-money swaption (expiry,tenor) pairs is assumed to lie on the ATM swaption grid.

SABR Points

The SABR Points panel allows the user to kick off a manual surface (re-)generation and to inspect the results. The generation is controlled by the Configuration Parameters in the Definition panel.



The shown data sets are:

- CORRELATION(rho) : calibrated values for rho, supplemented with saved manual entries from previous calibrations; blank otherwise;

- VOL_OF_VOL(nu) : calibrated values for nu, and/or saved manual entries from previous calibrations; blank otherwise;
- ALPHA : generated values for alpha; blank when backbone interpolation happens in a space other than 'alpha' space (i.c., Black/Bp vol/variance);
- BETA : generated values for beta at calibration points, supplemented with saved manual entries from previous runs;
- SPOT : break-even forward-swap rates;
- Shift : exogenously-specified spot shift per (expiry/tenor); the shift defaults to 0 if left blank; if non-zero, all Hagan/Obloj formulas are understood to apply in a shifted context (a.k.a. Displaced-Diffusion), i.e., instead of f(SPOT, k), the formulas are modified to f(SPOT+shift, k+shift);
- ERR : total root-mean-square error at calibration points; blank otherwise;
- Convergence : number of iterations at calibration points, blank otherwise; a value of 0 indicates calibration failure (e.g., when initial β exceeds 0.99999);
- ATMVOL : at-the-money volatility, when interpolation mode is Black vol or Black variance;

On selecting any of the grid points on the right, the corresponding volatility profile will be displayed on the left. For display purposes, it is recommended to select Strike Type = 'Relative Strike' in the Definition panel.

NOTE: when setting up a new surface, the 'Shift' tab will not be visible; to make it visible: provide an atm grid of underlyings + quotes, then generate a dummy surface; the shifts in 'Shift' tab can then be manually provided as required.

Where desirable, each grid point in BETA, CORRELATION(rho) and VOL_OF_VOL(nu) grids can be manually overridden and then saved down. When skew data is very sparse, this allows the user to express a view in a parsimonious way; it will be propagated down the grid according to the interpolation scheme (see below).

The ERR and Convergence grids hold the values of the last generation run with 'Calibrate SABR values=true'.

Note: while the number of iterations shown in Convergence tab may exceed the value of the maxIterations parameter, this does not necessarily imply that the corresponding calibration failed. Occasionally, the search heuristic winds up in a cycle, and while the calibration error is typically small, no further reduction of the calibration error is possible, unless one restarts from a different initial guess. Inspection of the corresponding skew curve and of the value in the ERR grid let the user assess whether the found 'optimal point' is acceptable.

On interpolation/extrapolation

As the interpolation – and likewise, extrapolation - is anisotropic in expiries, tenors and strikes, the order of operations influences the final interpolated value.

- All extrapolations in Expiry or Tenor are flat
- Any interpolations along Tenor are linear, while those along Strike are governed by the SABR parameters.
- Expiry-interpolations in SABR skew parameters beta, rho and nu are linear.

The backbone interpolation method along the Expiry direction takes place in one of alpha, Black vol, Bp vol, Black variance or Bp variance spaces, as set by the Configuration Parameter 'Atm interpolation mode (along expiry)'. Time-to-expiry is measured using the chosen day-count (SABR Points panel).

When skew data (β,ρ,ν) is sparse, the user is offered a choice between (Expiry first, then Tenor, then Strike) and (Tenor first, then Expiry, then Strike). This scheme is applied to each parameter grid individually. The choice becomes relevant only in the presence of lacunarities in the respective grids.

Example 1: given 3 grid points (expiry,tenor,value) = { (1Y,2Y,0.20), (2Y,1Y,0.97), (3Y,2Y,1.2) }. What is the value at (2Y,2Y, ??) ?

Expiry-first will interpolate between 0.20 and 1.2, yielding 0.7.

Tenor-first, however, extrapolates from 0.97, which results in 0.97.

Example 2: on the same data as Example 1, the value at (2Y, 18M, ??) is found similarly:

Expiry-first interpolates along the tenor=2Y column, yielding 0.7; subsequently, the scheme interpolates along the expiry=2Y row between 0.97 and 0.7; thus, a value of 0.835 is obtained.

Tenor-first extrapolates flat along the row and 0.97 is found.

In the special case where skew data comes entirely from caps only, the expiry-first extrapolation scheme reduces to that of Hagan-Konikov [HAGAN2004].

On (re)calibration with manual overrides (*)

(*) This Section is only applicable when the configuration parameter 'Calibrate SABR values' = 'true'. A few typical use cases are provided, to illustrate the interplay of calibration configuration parametres.

Case 1: manually-set betas

To use exogenously-specified betas, instead of 'Default_Beta', it suffices to populate the BETA grid in the SABR Points panel. Note that values must not exceed 0.99999 for the calibration to succeed.

The value of the 'Initial-guess method' parameter has no impact on betas.

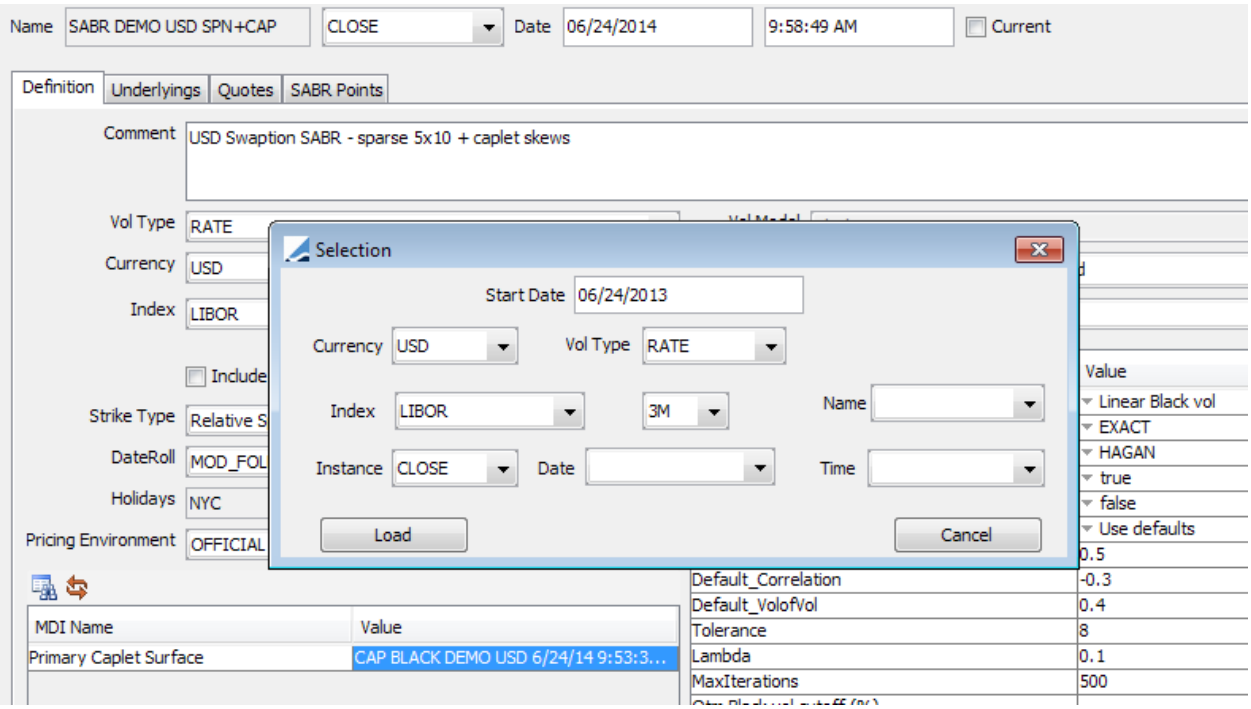
Case 2: rho/nu overrides

When the user wants to supply explicit (non-calibrated) values for ρ or v, she can do so by providing the desired values in the CORRELATION(rho) resp. VOL_OF_VOL(nu). This may be desirable to express a view on the smile shape; also, in rare cases of failing slice calibration, say only the 1Y x 1Y slice fails, to manually override (ρ,v) may provide relief.

To avoid that subsequent recalibrations erase these explicit values, one must set 'Initial-guess method' = 'Use previous calibration'.

Example: swaption skew from caplets

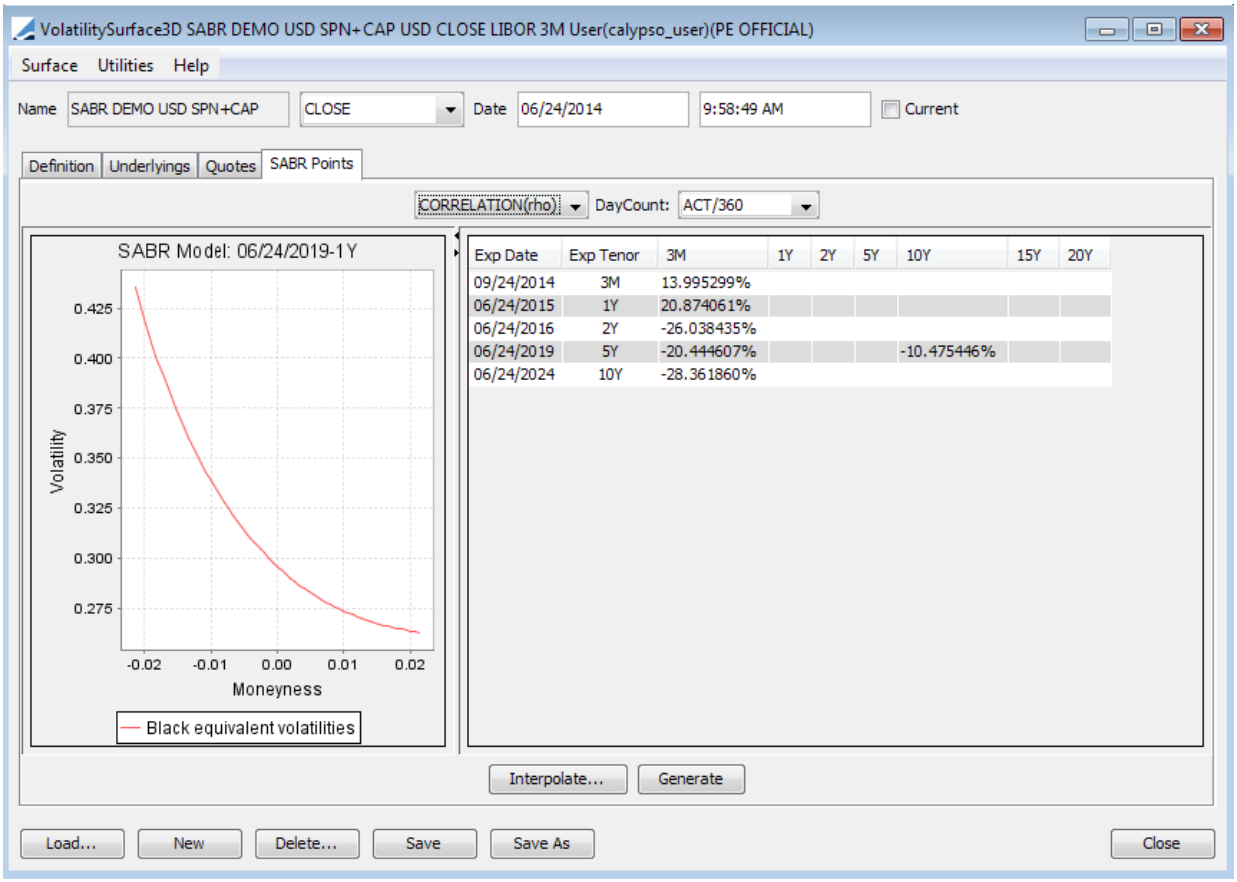
To use an existing caplet volatility surface, click in the Value column in the MDI area, and select a surface from the Name dropdown list in the pop-up window:



The referenced surface id will be displayed in the Value box.

Then, proceed as before, and generate a calibration grid as shown in the next Figure.

In this example, a surface with a CapBlack generator was used.



The caplet data causes insertion of an extra caplet-tenor column (3M, in this example), with expiries following the ATM swaption expiries. Where necessary, e.g., when caplet and swaption expiries do not perfectly align, SABR skew parameters (β,ρ,v) are interpolated linearly along expiries from individual caplet slice calibrations.

Backward compatibility mode

This generator is compatible with the SwaptionSABRDirect generator with Definition->Interpolator = LinearInterpolator3D, and further:

- No caplet surface is referenced;
- SABR parameter grids (β,ρ,v) are complete; either by providing swaption skew quotes at each grid point, or by manual insertions.
- The ATM interpolation modes Linear alpha, Linear Black vol, Linear Bp vol translate to the respective USE_VOL_TYPE settings: USE_ALPHA_VOL_SPACE, USE_BLACK_VOL_SPACE, USE_BP_VOL_SPACE;

See Ref. [CAL-IRD] for details on SwaptionSABRDirect.

Logging

When logging is turned on and using the name of the generator as the log category, the strike, Black vol and calibration weight is logged for every caplet/swaption and every slice calibration.

Additional Notes

- For caplets
    - A non-zero shift is only supported for Black/Bp vol backbone/ATM interpolation
    - the shift for all expiries must be the same.
- In general, we would strongly recommend the use of the same shift for caplets and swaptions as interpolation between shifted Black vols would be non-sensical for different shifts
- The grid of expiry dates that the generator calibrates to, and stores down in the vol surface, is driven off the swaption expiry dates. If a fit to caplets is the primary purpose then this can be achieved by
    - Specifying the base caplet surface as an MDI for this generator
    - Defining a vector of ATM Swaptions with expiry dates matching the caplet expiry date (e.g. every 3M) and a single underlying swap. As an example, if a SABR fit to the caplets with expiry tenors {6M, 12M, 18M, 24M} is desired, the user can select a swap tenor – e.g. 1Y, it's not really important - and specify the {6M x 1Y, 12M x 1Y, 18M x 1Y, 24M x 1Y} ATM swaptions as the swaption calibration set.

References

- [HAGAN2004] Hagan, P. and Konikov, M. (2004). "Interest rate volatility cube: Construction and use".
- [HAGAN2002] Hagan, P., Kumar, D., Lesniewski, A. and Woodward D. (2002). "Managing Smile Risk".
- [CAL2009] Calypso white paper (2009). "Basis point volatility".
- [CAL-IRD] Calypso Documentation – Interest Rate Derivative Analytics

Section 9. Inflation Market Data Generation

9.1 Inflation Curve Generator

Inflation curves are a required input for pricing inflation swaps and inflation caps/floors, this section provides an overview of the construction techniques that are implemented in Calypso.

9.1.1 InflationKerkhof Generator

Overview

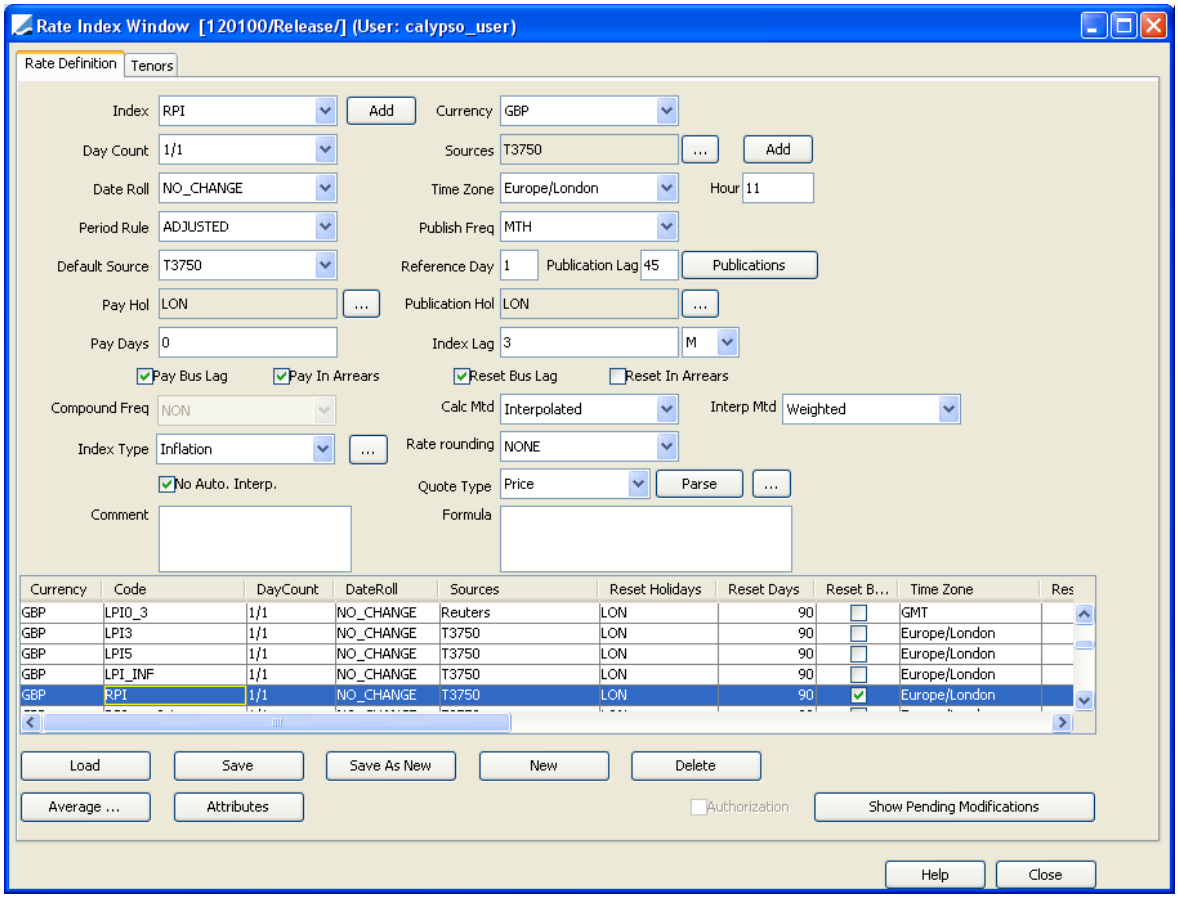
The InflationKerkhof generator should be regarded as the default generator for inflation indices and is used to generate an inflation curve from underlying instruments using Kerkhof's approach[3]. See the Calypso white paper: 'Implementation of Kerkhof inflation curve construction' for further information on the model description.

This documentation shows the configuration required for the InflationKerkhof generator.

Configuration

Rate index definition:

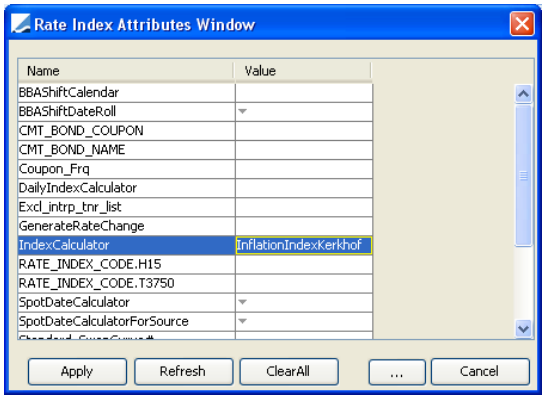
Define the inflation index: Main Entry > Configuration > Interest Rates > Rate index Definitions. See Calypso documentation for further information on the various configuration details of the inflation rate index.



[3] Inflation Derivatives Explained, *J. Kerkhof*, Lehman Brothers, July 2005

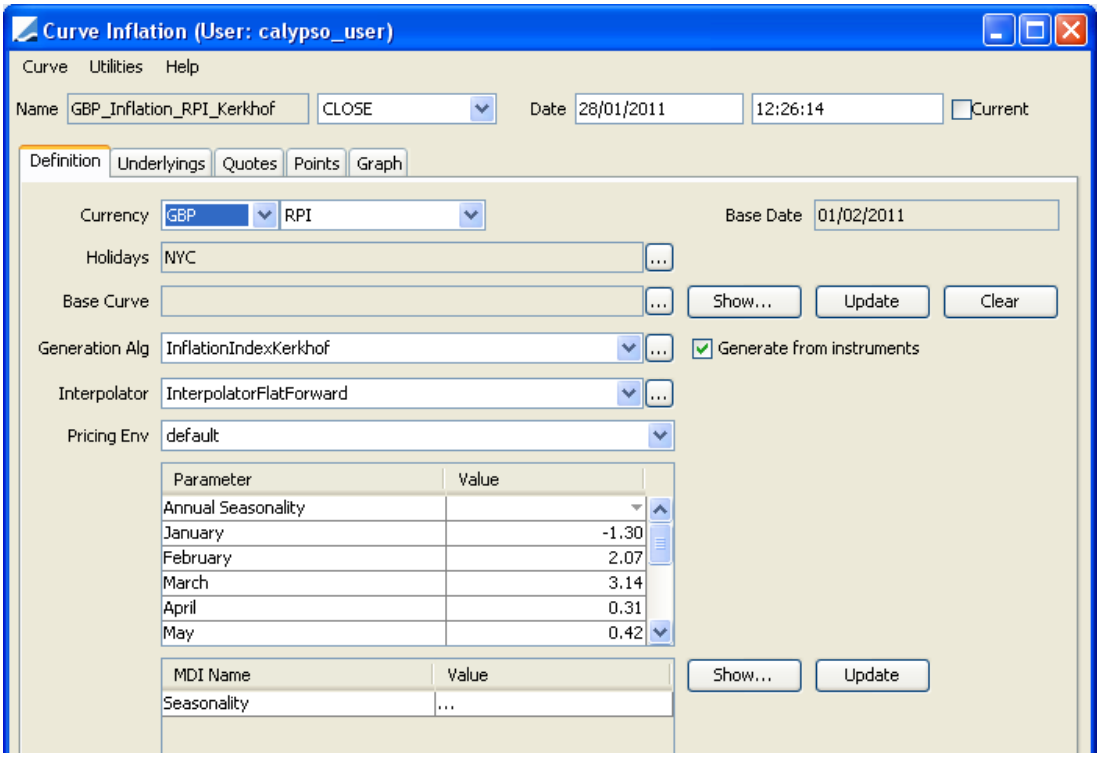
-Note the InflationKerkhof generator supports both interpolated (weighted) and non interpolated (Index Level) inflation indicies.

In the attributes section of the rate index definition, for each inflation index to be constructed via the InflationKerkhof generator, it is important the index calculator is set to InflationKerkhof



Inflation Curve definition:

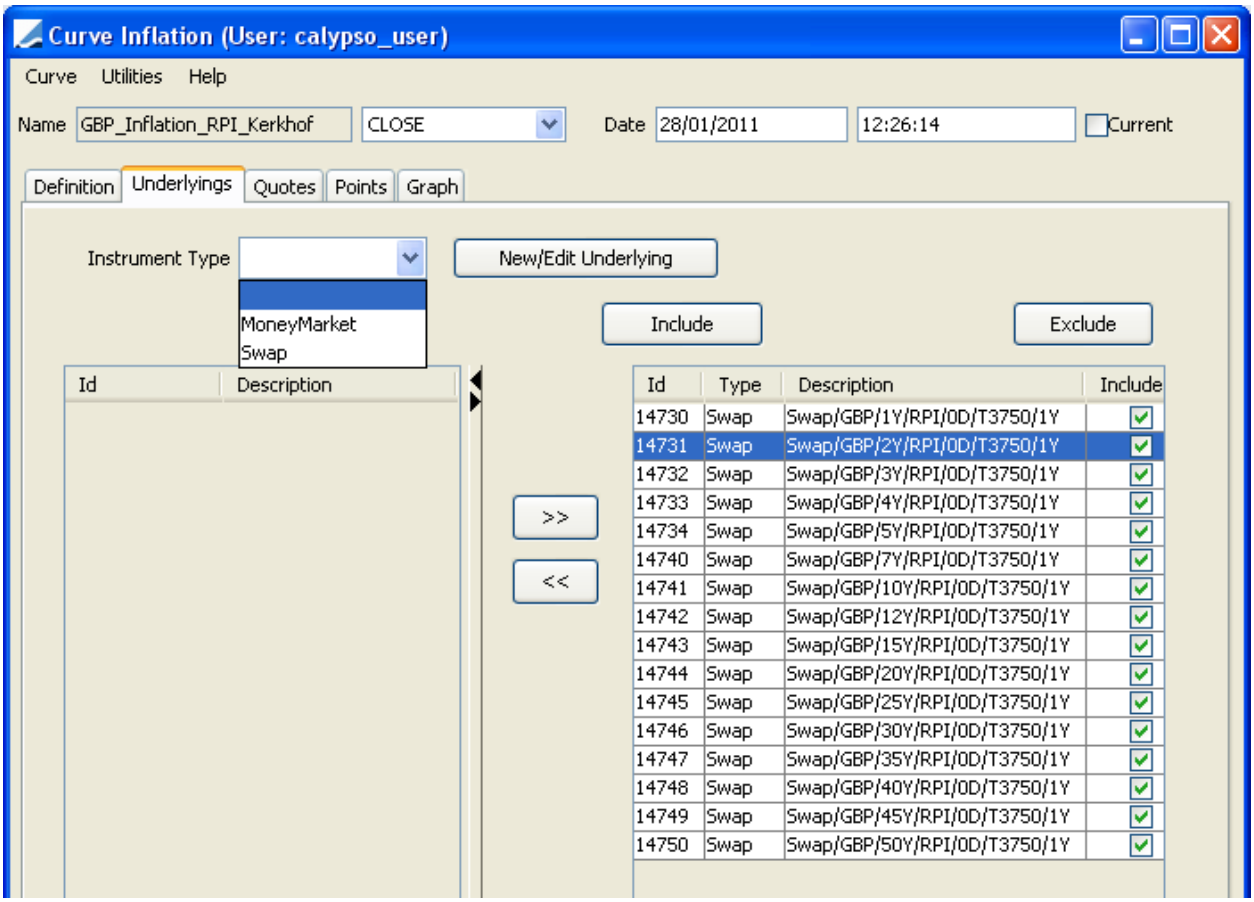
On the inflation curve (Main Entry > Market data > Interest Rate Curves > Inflation Curve) select the generator InflationKerhof. This is a derived generator, i.e. generate from instruments should be set to true:



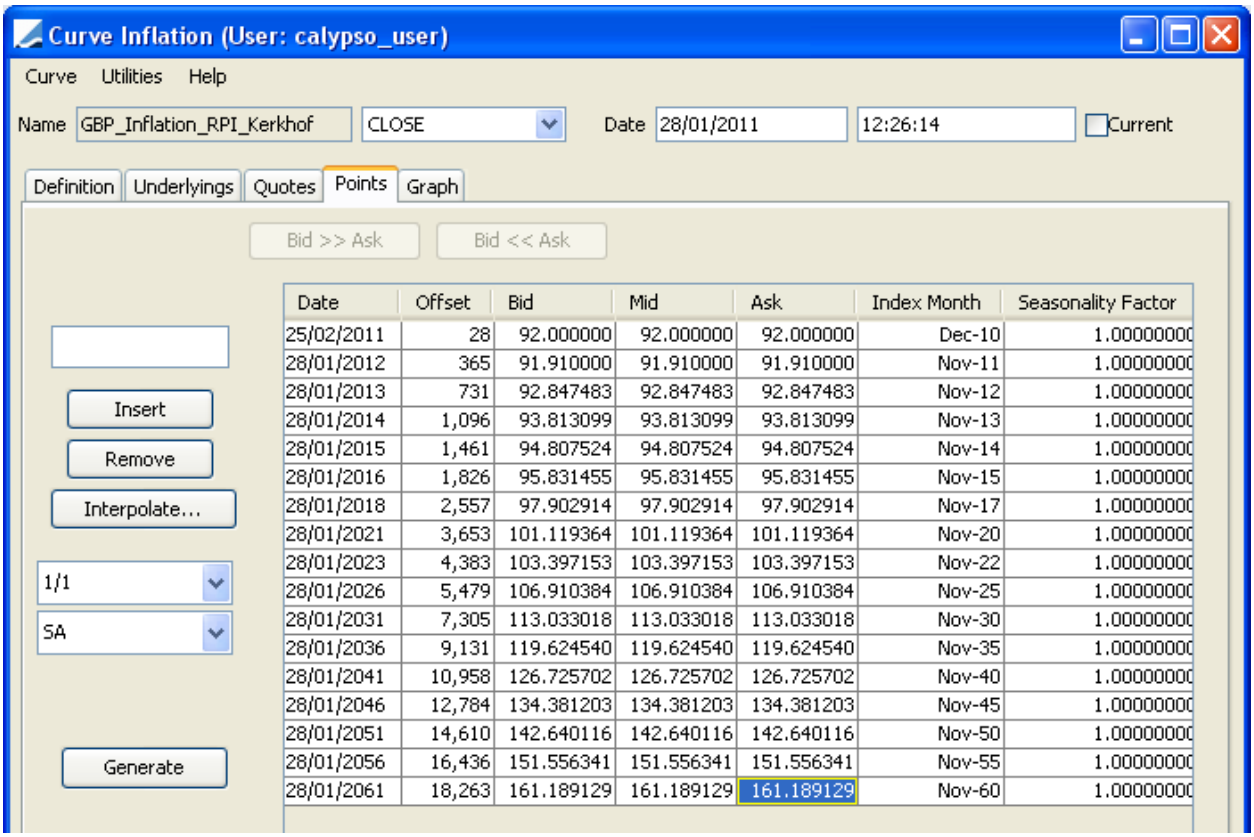
The underlying instruments that are available to construct the curve are zero coupon inflation swaps and MM (levels) for the selected inflation index. The user has the ability to select MM instruments up to the tenor of the first ZC inflation swap selected. This allows the user to control the specific level of the inflation curve at the front end of the curve by entering assumed inflation levels at defined tenors. (The typical use would be to use ZC inflation swaps only).

The user can select the instrument type from the drop down menu, a list of instruments available from the curve underlying's definition will be shown on the left hand panel. The curve underlying's used to construct the curve can then be selected by moving the instrument to the right hand panel using the arrows buttons available.

Note the precise details of the curve underlying's can be modified via 'New/Edit underlying'. Ensure the correct definition of curve underlying's before constructing the inflation curve.



After the required curve underlying's are selected and quotes entered, click generate on the point tab. The generated curve points are displayed and shown as reference levels and dates. Note the published inflation levels for the index should also be added to the quote set. If the required inflation levels are not saved to the database a warning message will be displayed.



Date	Offset	Bid	Mid	Ask	Index Month	Seasonality Factor
25/02/2011	28	92.000000	92.000000	92.000000	Dec-10	1.00000000
28/01/2012	365	91.910000	91.910000	91.910000	Nov-11	1.00000000
28/01/2013	731	92.847483	92.847483	92.847483	Nov-12	1.00000000
28/01/2014	1,096	93.813099	93.813099	93.813099	Nov-13	1.00000000
28/01/2015	1,461	94.807524	94.807524	94.807524	Nov-14	1.00000000
28/01/2016	1,826	95.831455	95.831455	95.831455	Nov-15	1.00000000
28/01/2018	2,557	97.902914	97.902914	97.902914	Nov-17	1.00000000
28/01/2021	3,653	101.119364	101.119364	101.119364	Nov-20	1.00000000
28/01/2023	4,383	103.397153	103.397153	103.397153	Nov-22	1.00000000
28/01/2026	5,479	106.910384	106.910384	106.910384	Nov-25	1.00000000
28/01/2031	7,305	113.033018	113.033018	113.033018	Nov-30	1.00000000
28/01/2036	9,131	119.624540	119.624540	119.624540	Nov-35	1.00000000
28/01/2041	10,958	126.725702	126.725702	126.725702	Nov-40	1.00000000
28/01/2046	12,784	134.381203	134.381203	134.381203	Nov-45	1.00000000
28/01/2051	14,610	142.640116	142.640116	142.640116	Nov-50	1.00000000
28/01/2056	16,436	151.556341	151.556341	151.556341	Nov-55	1.00000000
28/01/2061	18,263	161.189129	161.189129	161.189129	Nov-60	1.00000000

Seasonality adjustments to the inflation curve can be handled by two methods; both are selected on the definitions tab on inflation curve

1. Monthly adjustment (Enter annualized adjustments)
2. Seasonality curve market data item (MDI)

The seasonality curve defined via in the separate MDI takes precedence.

For method 1, monthly adjustments, set the 'Annual Seasonality' Boolean flag to true and define adjustment on the curve window. Adjustment will be applied by month for every year that is constructed.

For method 2, Seasonality curve market data item, select the seasonality curve on the UI then generate the inflation curve as required.

The seasonality adjustments required for the Kerkhof methodology implemented in Calypso are an additive adjustments i.e. the monthly annualized adjustments for a 1 year period add up to 0. See the Calypso user documentation on how to define a seasonality curve.

References

Inflation Derivatives Explained, J. Kerkhof, Lehman Brothers, July 2005

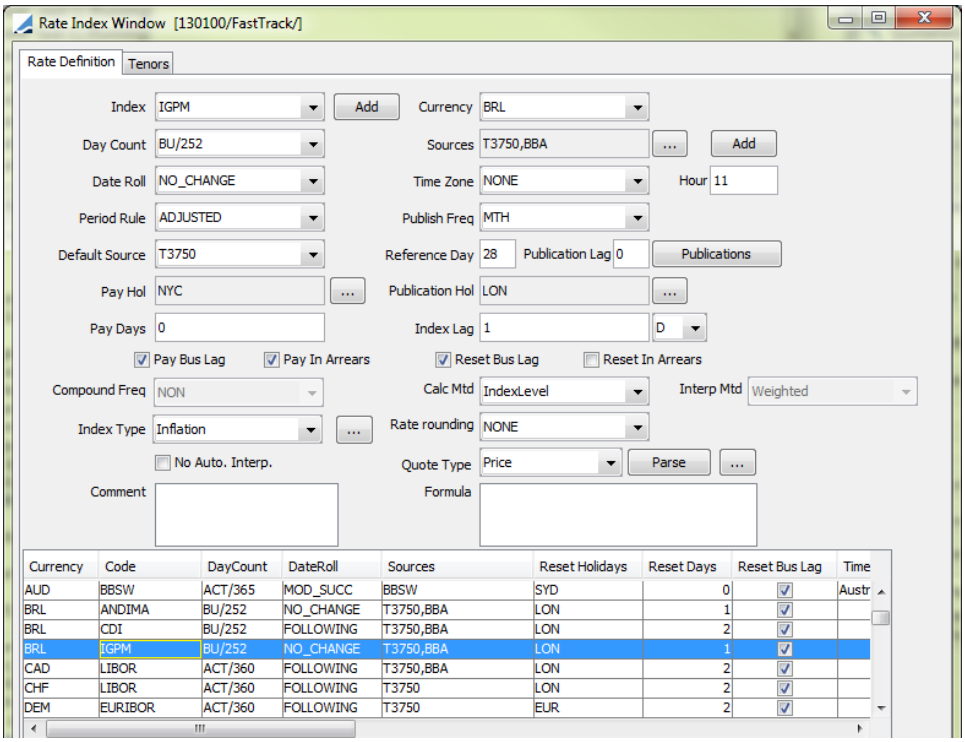
9.1.2 InflationBRL Generator

Overview

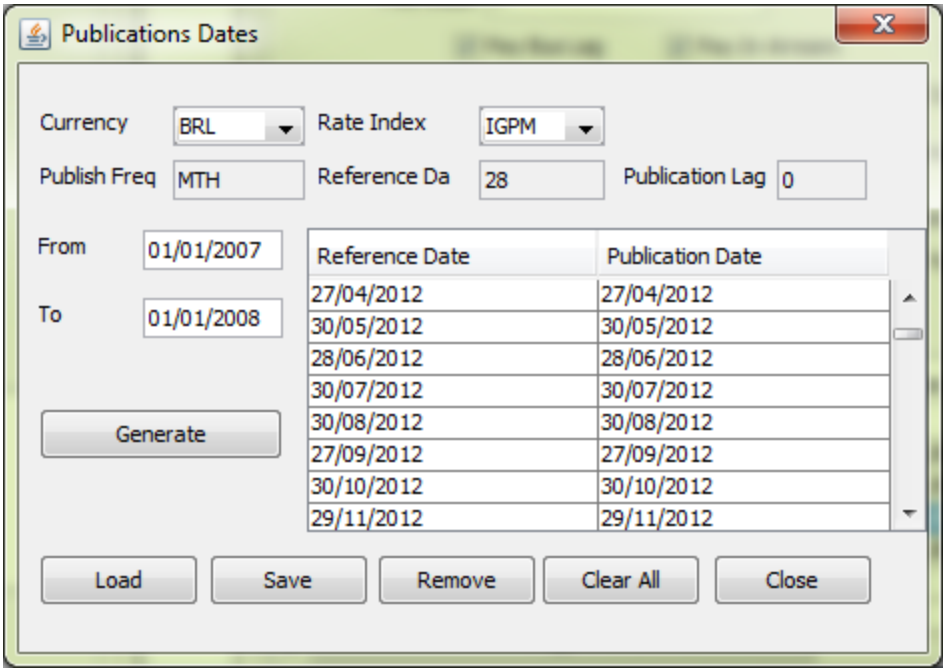
This documentation shows the configuration required for the InflationBRL generator.

Configuration

Rate index definition:Define the inflation index: Main Entry > Configuration > Interest Rates > Rate index Definitions. See Calypso documentation for further information on the various configuration details of the inflation rate index.

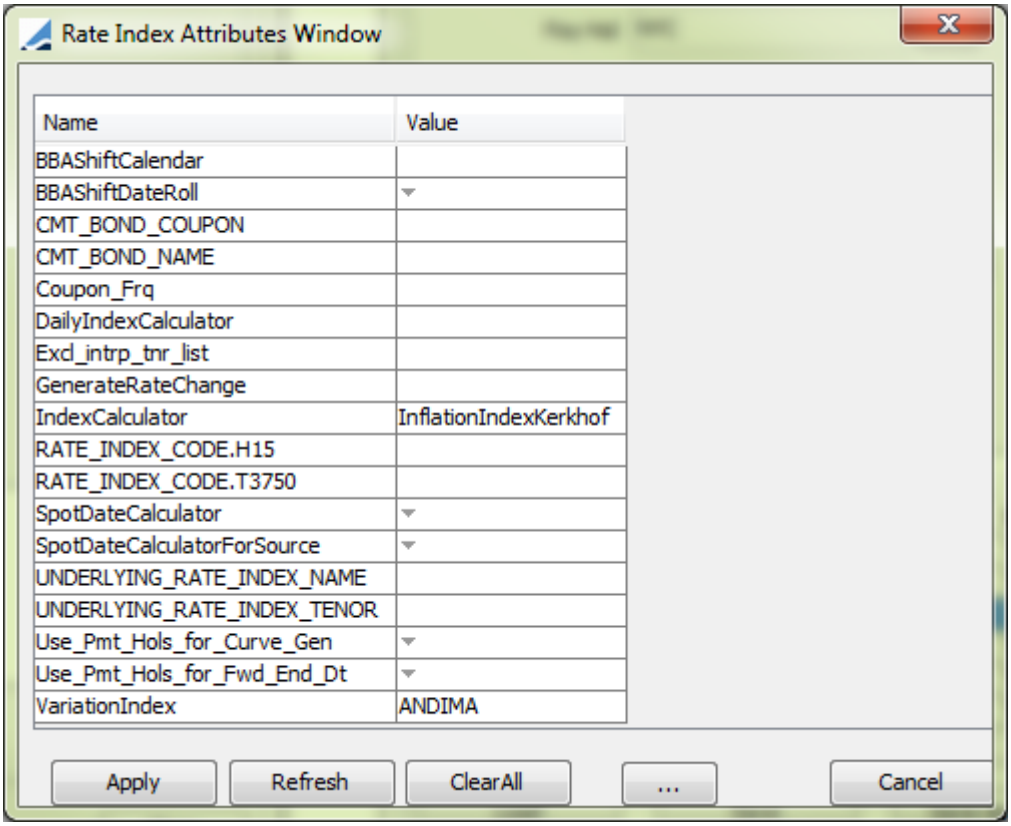


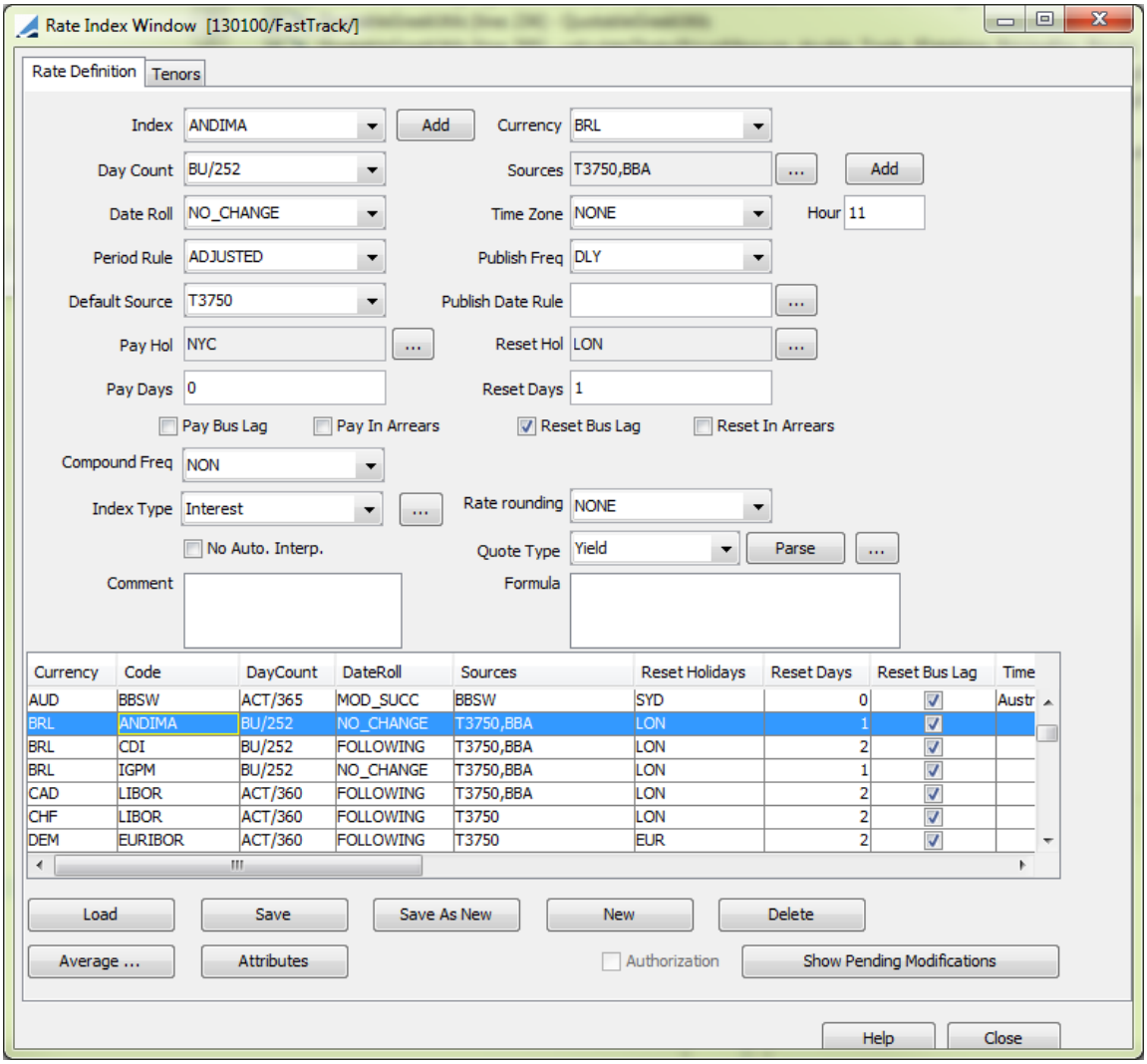
Reference Dates and Publication Dates can be manually put in. They should be the same because the publication lag is 0.



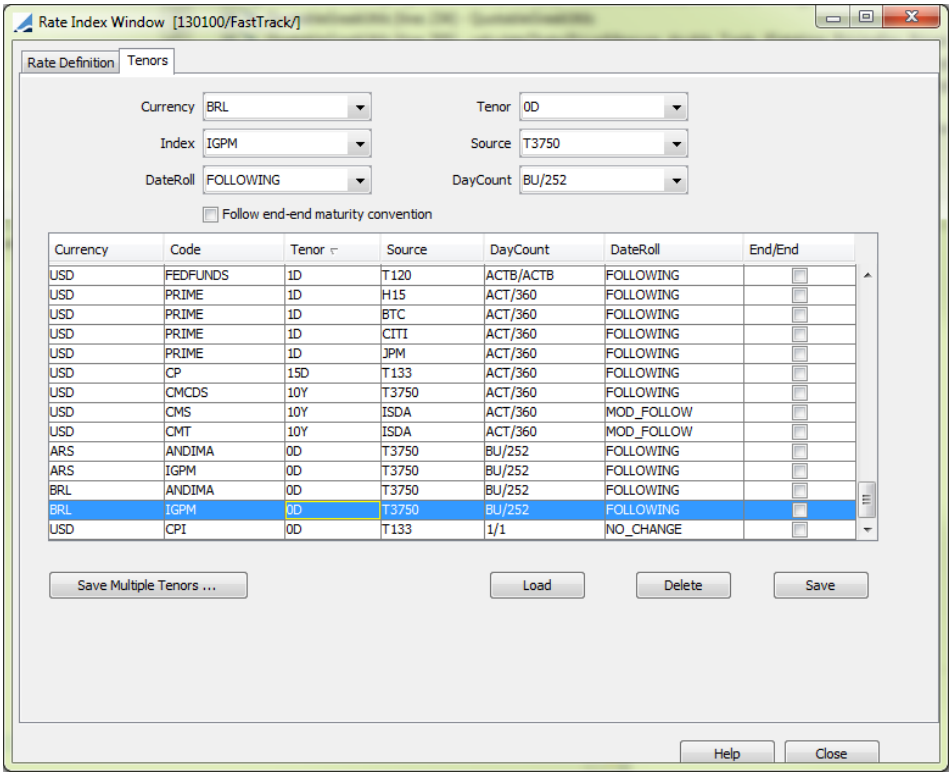
-IGPM Index could support Pro-Rata and non Pro-Rata. In the Pro-rata case, IGPM index will also be linked to another dummy index which is used to save andima rates in the quotes.

In the attributes section of the rate index definition, for each inflation index to be constructed via the InflationKerkhof generator, it is important the index calculator is set to InflationKerkhof





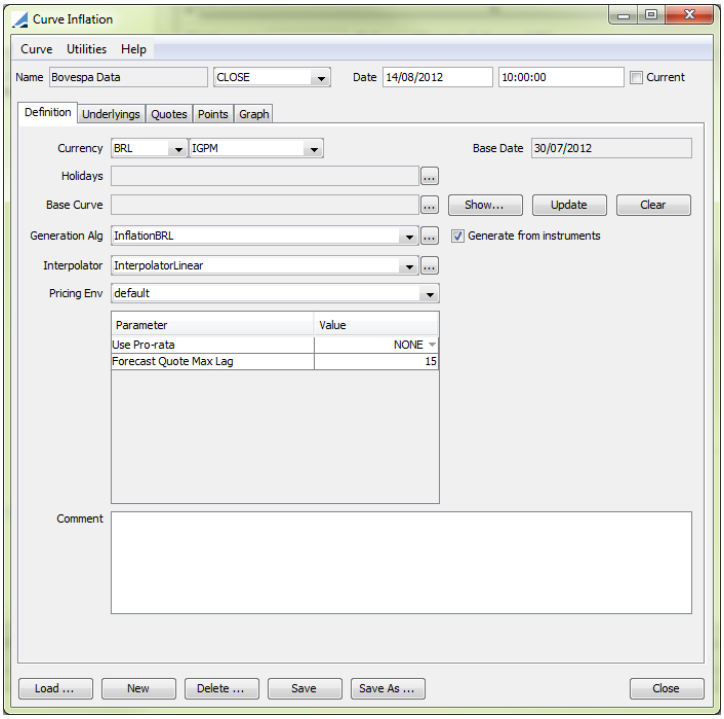
IGPM index and ANDIMA index should have the same tenors 0D so they will be linked.



-Note the InflationBRL generator supports both interpolated (weighted) and non interpolated (Index Level) inflation indicies.

Inflation Curve definition:

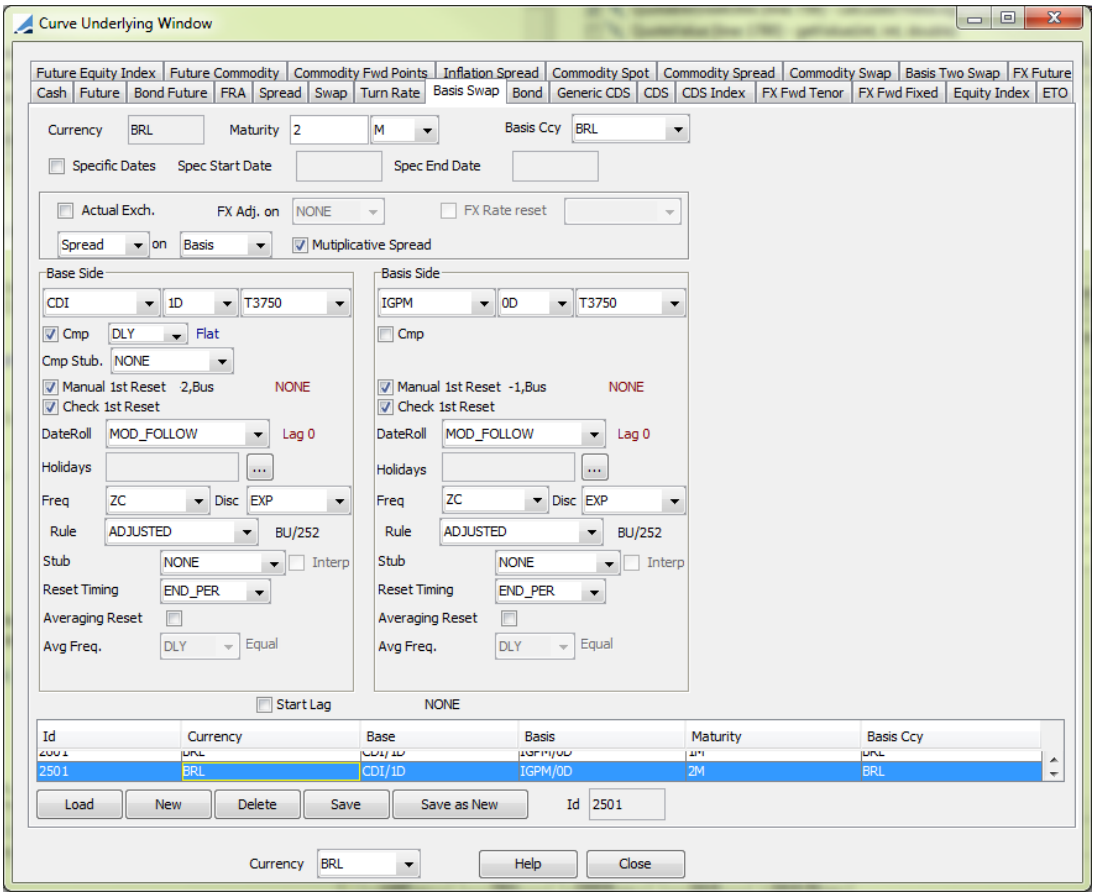
On the inflation curve (Main Entry > Market data > Interest Rate Curves > Inflation Curve) select the generator InflationBRL. This is a derived generator, i.e. generate from instruments should be set to true:



The underlying instruments that are available to construct the curve are basis swaps for the selected inflation index.

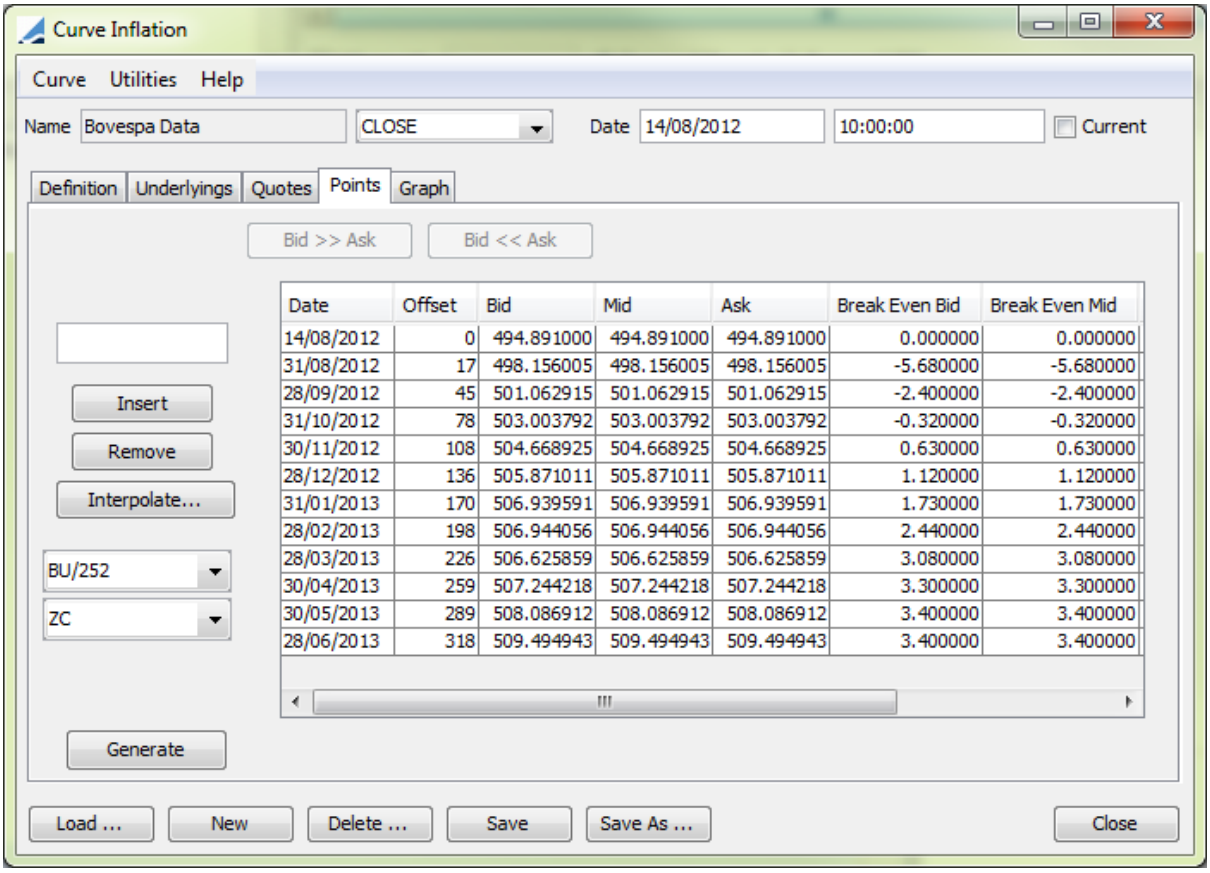
The user can select the instrument type from the drop down menu, a list of instruments available from the curve underlying's definition will be shown on the left hand panel. The curve underlying's used to construct the curve can then be selected by moving the instrument to the right hand panel using the arrows buttons available.

Note the precise details of the curve underlying's can be modified via 'New/Edit underlying'. Ensure the correct definition of curve underlying's before constructing the inflation curve.



Before generating, a zero curve should be assigned to the index on the base side of the underlyings for discounting. In the example above a discount curve should be assigned to index BRL/CDI/1D/T3750.

After the required curve underlying's are selected and quotes entered, click generate on the point tab. The generated curve points are displayed and shown as reference levels and dates. Note the published inflation levels for the index should also be added to the quote set. If the required inflation levels are not saved to the database a warning message will be displayed.



Date	Offset	Bid	Mid	Ask	Break Even Bid	Break Even Mid
14/08/2012	0	494.891000	494.891000	494.891000	0.000000	0.000000
31/08/2012	17	498.156005	498.156005	498.156005	-5.680000	-5.680000
28/09/2012	45	501.062915	501.062915	501.062915	-2.400000	-2.400000
31/10/2012	78	503.003792	503.003792	503.003792	-0.320000	-0.320000
30/11/2012	108	504.668925	504.668925	504.668925	0.630000	0.630000
28/12/2012	136	505.871011	505.871011	505.871011	1.120000	1.120000
31/01/2013	170	506.939591	506.939591	506.939591	1.730000	1.730000
28/02/2013	198	506.944056	506.944056	506.944056	2.440000	2.440000
28/03/2013	226	506.625859	506.625859	506.625859	3.080000	3.080000
30/04/2013	259	507.244218	507.244218	507.244218	3.300000	3.300000
30/05/2013	289	508.086912	508.086912	508.086912	3.400000	3.400000
28/06/2013	318	509.494943	509.494943	509.494943	3.400000	3.400000

Section 10. Equity Market Data Generation

10.1 Dupire Local Volatility

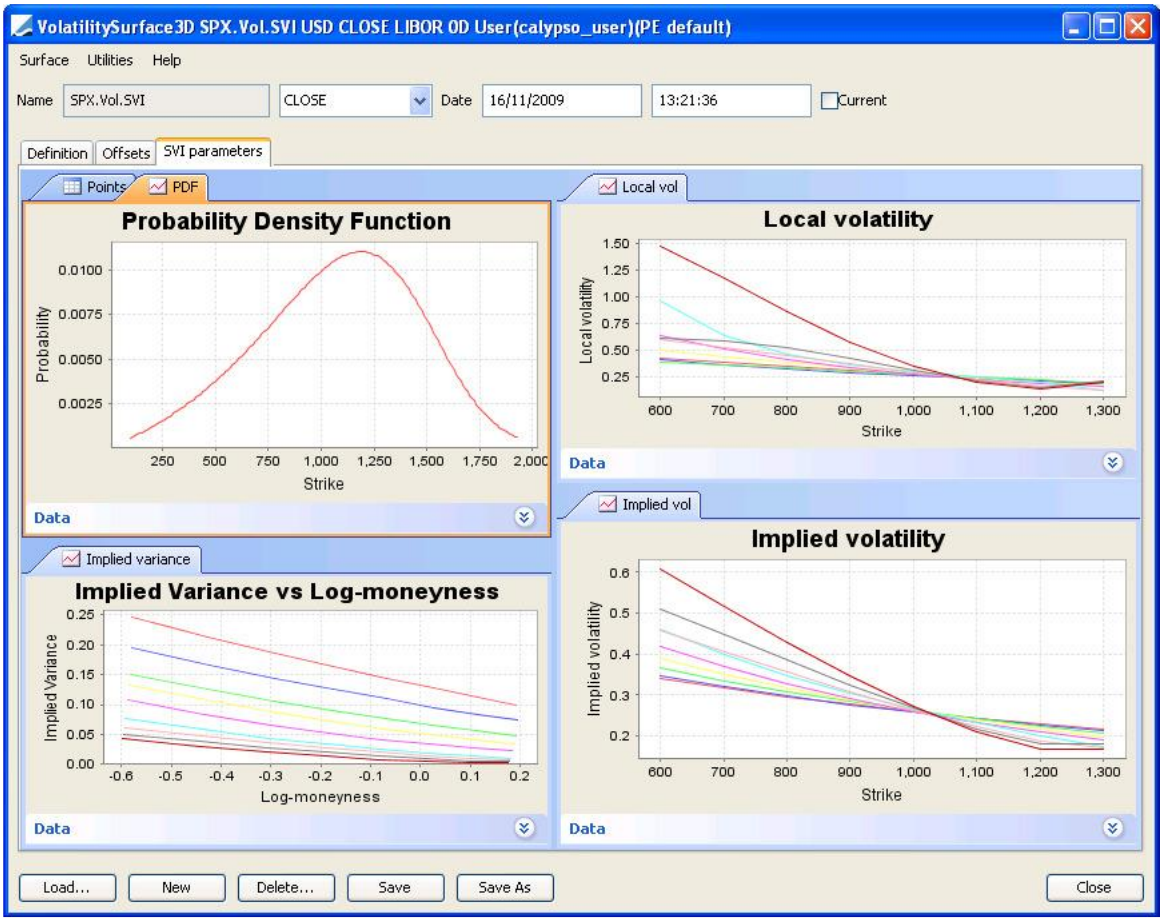
Overview

A Dupire Local Volatility model extends the Black model assumption of a constant volatility by making the volatility of the underlying dependent on both time and the level of the underlying and in a way that, by construction, reproduces the input vanilla option prices:

$$\frac{dS_t}{S_t} = \mu_t dt + \sigma(S_t, t) dW_t$$

This allows the valuation of simple equity derivative exotics without any built-in discrepancy to the liquid vanilla derivatives that are normally used as hedges. Such a model is particularly applicable to single- and multi-name derivatives whose primary dependence is on the (joint) distribution of the reference underlying assets such as Barriers, Asians and Best-Of.

The implied volatility surface for each underlying asset is fitted using a smooth parameterization that has sufficient versatility to fit the market whilst avoiding arbitrage in the wings.



The local volatility surface is then computed from the implied volatility surface and the prevailing interest rate and dividend curves such that all the vanilla option prices are reconstructed.

As an example, the value of a short-dated, ATM Put Option on the S&P with an Up-And-Out Barrier under Black (using the ATM volatility) and Local Volatility can be rather different between the two models:

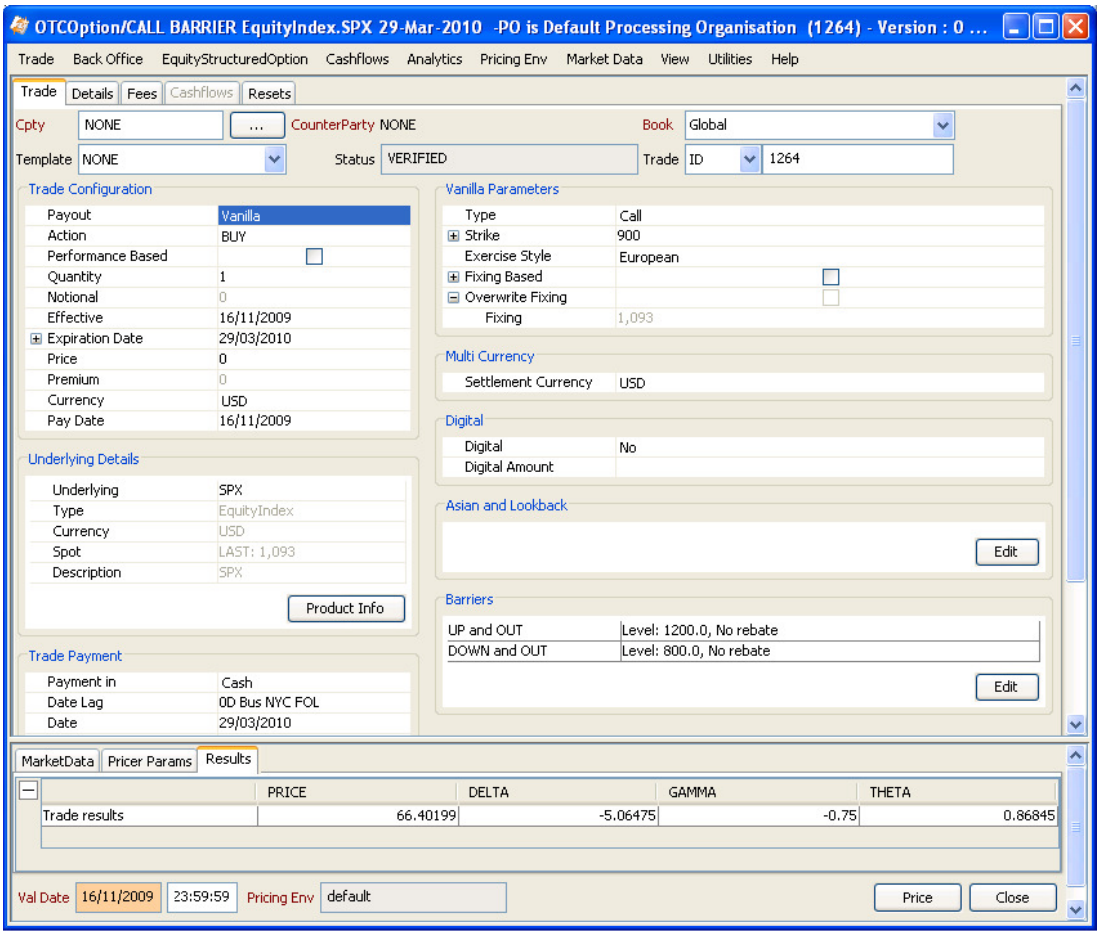
Barrier Level (Spot=1093)	Black Price	Local Vol Price	Relative Error
5000	57.24	57.43	0.3%
1500	50.56	57.12	11.5%
1350	31.54	50.80	37.9%
1200	3.99	6.30	36.7%

Valuation in a single framework

Unlike valuing exotics in a Black model where each instrument requires its own, sometimes manufactured, Black volatility, the Local Volatility model allows the valuation of all simple exotics in a single, easy-to-understand, model framework.

The valuation is performed in the Calypso® Equity Structured Option window where the user can use a saved implied volatility surface to value a Vanilla, Barrier or Asian option.

A number of transient parameters allow the override of various valuation inputs such as the spot level of the underlying, the borrowing spread, the dividend yield and the discount rate as well as the accuracy level required.


OTCOption/CALL BARRIER EquityIndex.SPX 29-Mar-2010 -PO is Default Processing Organisation (1264) - Version : 0 ...
Trade
Back Office
EquityStructuredOption
Cashflows
Analytics
Pricing Env
Market Data
View
Utilities
Help
Trade
Details
Fees
Cashflows
Resets
Cpty
NONE
CounterParty NONE
Book
Global
Template
NONE
Status
VERIFIED
Trade
ID
1264
Trade Configuration
Payout
Vanilla
Action
BUY
Performance Based
Quantity
1
Notional
0
Effective
16/11/2009
Expiration Date
29/03/2010
Price
0
Premium
0
Currency
USD
Pay Date
16/11/2009
Underlying Details
Underlying
SPX
Type
EquityIndex
Currency
USD
Spot
LAST: 1,093
Description
SPX
Product Info
Trade Payment
Payment in
Cash
Date Lag
0D Bus NYC FOL
Date
29/03/2010
Vanilla Parameters
Type
Call
Strike
900
Exercise Style
European
Fixing Based
Overwrite Fixing
Fixing
1,093
Multi Currency
Settlement Currency
USD
Digital
Digital
No
Digital Amount
Asian and Lookback
Edit
Barriers
UP and OUT
Level: 1200.0, No rebate
DOWN and OUT
Level: 800.0, No rebate
Edit
MarketData
Pricer Params
Results
PRICE
DELTA
GAMMA
THETA
Trade results
66.40199
-5.06475
-0.75
0.86845
Val Date
16/11/2009
23:59:59
Pricing Env
default
Price
Close

10.1.1 SVISimple generator

Configuration of Generator SVISimple

Description of the required configuration of the SVISimple generator in the volatility surface window

Definition tab	Description
Currency	The currency of the underlying
Vol Type	The type of the underlying asset (e.g. EQUITY for SPX)
Product	The underlying product
DateRoll, Holidays	The volatility surface conventions used
Pricing Env	The pricing environment used to save the surface
Interpolator	Generally, the surface interpolation method. Not used here.
Generator	The name of the underlying generator. For SVI use SVISimple

The relevant option expiry dates are specified in the **Offsets** tab. One or more strikes should be specified for graphing purposes at the next tab, **SVI Parameters**, where the SVI parameters can be set up. For more information about the SVI parameterization and the effect the various parameters have on the volatility smile please refer to the book *"The Volatility Surface: A Practitioner's Guide" by Jim Gatheral.*

10.1.2 SVI generator

The SVI generator is a derived generator, calibrating the SVI parameters against options (OTC, ETO, Warrants) quotes in terms of volatilities or prices using either a quasi-explicit method or a good initial guess combined with a Levenberg-Marquardt local minimizer.

It also supports all the various scenarios shifts, with the ability to eventually recalibrate after shift or not.

It can be used with the standard Calypso Black-Scholes pricers as well as the Local volatility pricers PricerLocalVolatility1FFiniteDifference and PricerLocalVolatilityNFMonteCarloExotic.

Much more details can be found in the corresponding whitepaper.

Generator parameters:

Name	Default	Description
Solver	QuasiExplicit	Solver used to find the best fit, alternatives are "LM" and "LM2" corresponding to Levenberg-Marquardt with numeric or analytic jacobian. "QuasiExplicit" reduces the problem to a 2 variables optimization, and is seen as more robust.
InitialGuessType	A_POSITIVE	Initial guess for the local LM and LM2 solvers or constraint for QuasiExplicit.
ArbitragePreCheck	FALSE	Convexity check of the implied volatility input quotes.
ArbitragePostCheck	FALSE	Numerical search for calendar spread and butterfly spread arbitrage in the output surface.
MonotonicFilter	NONE	SIMPLE will keep the total variance increasing on the current maturity input quotes compared to the previous maturity SVI fit, reducing the risk of calendar-spread arbitrages in practice. SIGMA_INCREASING will keep the sigma increasing with the time to maturity: the volatility surface will flatten with the

Name	Default	Description
		time to maturity. This works only with the QuasiExplicit solver.
RecalibrateOnShift	FALSE	Recalibrate the surface after a shift of the (fitted) volatility surface through the scenario.
Repair	SEARCH	Repair a broken local volatility surface. SEARCH will search for a defined local volatility towards the moneyness and stop at the moneyness, it will then revert to CAP_FLOOR. CAP_FLOOR will use the Cap value if there is a butterfly spread arbitrage, it will use the Floor value if there is a calendar spread arbitrage. If Cap and Floor are blank, nothing is done.
Cap	10.0	Cap for the local volatility. If blank, no cap is applied.
Floor	1E-6	Floor for the local volatility. If blank, no floor is applied.
CorrelationSwing	1.0	Floating point number describing the stickiness dynamic for the volatility surface: 1.0 corresponds to sticky forward moneyness, 0.0 to sticky strike, -1.0 is usually close to local volatility stickiness

10.1.3 Spline generator

The Spline generator is a derived generator, interpolating options (OTC, ETO, Warrants) quotes defined in terms of volatilities or prices. It supports a strike axis in terms of absolute strike, relative strike (moneyness), as well as delta.

Each volatility slice is interpolated with a natural cubic spline, with flat extrapolation. In between slices, volatility is interpolated linearly in total variance.

It can be used with the standard Calypso Black-Scholes pricers as well as the local volatility pricers PricerLocalVolatility1FFiniteDifference and PricerLocalVolatilityNFMonteCarloExotic.

10.1.4 SABRSimple generator

The SABRSimple generator allows the user to define SABR parameters per given option expiries.

It can be used with the Calypso local volatility pricers PricerLocalVolatility1FFiniteDifference and PricerLocalVolatilityNFMonteCarloExotic as well as with the equity Black1F/BlackNF pricers.

10.2 Heston

The Heston stochastic volatility model extends the original Black & Scholes model by making the variance of the underlying asset stochastic, thereby the differential equation for the evolution of the underlying

$$\frac{dS_t}{S_t} = \mu_t dt + \sqrt{\eta_t} dW_t^1$$

is complemented by another differential equation that describes the evolution of its *instantaneous variance*

$$d\eta_t = \kappa(\theta - \eta_t)dt + \sigma\sqrt{\eta_t} dW_t^2$$

with the correlation between the underlying asset and its variance specified as

$$d\left\langle W_t^1, W_t^2 \right\rangle = \rho\, dt$$

10.2.1 HestonSimple generator

The setup of the Heston generator is very similar to the SVISimple one. The model parameters are specified for each option expiry date and are used by the Monte Carlo simulation in a piecewise-constant fashion.

10.2.2 SVJ generator

The SVJ generator is a derived generator, calibrating the stochastic volatility parameters against options (OTC, ETO, Warrants) quotes in terms of volatilities or prices for Heston, Schobel-Zhu, Bates (Heston with jumps), and Double-Heston. The model parameters define the full surface as per the standard definition, in particular, they are not piecewise constant per expiry.

It can be used in "Black-Scholes" mode with the existing Black-Scholes Calypso equity pricers, or with the exotic Monte-Carlo pricer PricerSVJMonteCarloExotic.

More details can be found in the corresponding whitepaper.

Section 11. Appendix

11.1 Registering Functionality - CALIB

The following tables describe the content from SchemaDataLGMM.xml file, therefore manual configuration of the analytics can be performed if required.

11.1.1 Add LGM Pricers to Product Types

Product	Pricer Name	Description
Bond.Pricer	PricerLGMM1FBackward	LGMM1F pricer for backward pricing deals
Bond.Pricer	PricerLGMM1FForward	LGMM1F pricer for forward pricing deals
Bond.Pricer	PricerLGMM1FSaliTree	LGMM1F pricer for bonds
CapFloor.Pricer	PricerLGMM1FBackward	LGMM1F pricer for backward pricing deals
CapFloor.Pricer	PricerLGMM1FForward	LGMM1F pricer for forward pricing deals
SingleSwapLeg.Pricer	PricerLGMM1FBackward	LGMM1F pricer for backward pricing deals
SingleSwapLeg.Pricer	PricerLGMM1FForward	LGMM1F pricer for forward pricing deals
Swap.Pricer	PricerLGMM1FBackward	LGMM1F pricer for backward pricing deals
Swap.Pricer	PricerLGMM1FForward	LGMM1F pricer for forward pricing deals
Swap.Pricer	PricerSwapLGMM1F	LGMM1F pricer for swaps
Swaption.Pricer	PricerLGMM1FBackward	LGMM1F pricer for backward pricing deals
Swaption.Pricer	PricerSwaptionLGMM1F	LGMM1F pricer for swaptions

11.1.2 LGM Pricer Domain Values

Domain name	Domain value	Description
VolSurface.gensimple	LGMMMeanRev	Generator adds an additional point adjustment surface to store a matrix of mean reversion values for the LGMM model
volUsages	CALIB_SWAPTION_TEMPLATE	Defines the volatility surface containing the swaption template used to generate calibration swaptions.
volUsages	CALIB_SWAPTION_VOL	
CustomCalibrationFrameConfig	AnalyticsFrameConfig	
CustomCalibrationMeasureConfig	AnalyticsCalibrationMeasureConfig	
calibratibleModels	AnalyticsCalibratibleLGMModel	
calibrators	LGMCalibratorFromTemplate	

11.1.3 LGM Pricer Measures

Measure Name	Measure Class Name	Measure ID	Measure Comment
DETAILED_DATA	tk.pricer.measure.CalypsoMappedPricerMeasure	250	
DISCOUNT_FACTOR	tk.pricer.measure.CalypsoMappedPricerMeasure	287	
MC_GRAPH	tk.pricer.measure.CalypsoMappedPricerMeasure	279	
NET_VOLATILITY	tk.pricer.measure.CalypsoMappedPricerMeasure	259	
NPV_CANCEL	tk.pricer.measure.CalypsoMappedPricerMeasure	321	
NPV_UNDERLYING	tk.pricer.measure.CalypsoMappedPricerMeasure	253	
REALIZED_VOLATILITY	tk.pricer.measure.CalypsoMappedPricerMeasure	260	
LGMM_MEANREV_SCEN	tk.pricer.measure.LGMMPricerMeasure	275	
LGMM_BESTFIT_ERROR	tk.pricer.measure.LGMMPricerMeasure	270	Graphs the best-fit error function
VALUATION_TIME_MS	tk.pricer.measure.AnalyticsPricerMeasure	294	

CALIBRATION_TIME_MS	tk.pricer.measure.AnalyticsPricerMeasure	295	
NPV_CANCEL	tk.pricer.measure.CalypsoMappedPricerMeasure	321	
PAY_PROJECTED_FLOWS	tk.pricer.measure.LGMMPricerMeasure	28000	Computes model based estimates of future cashflows on the pay leg
REC_PROJECTED_FLOWS	tk.pricer.measure.LGMMPricerMeasure	28001	Computes model based estimates of future cashflows on the receive leg
GRID_EVENTFLOWS	tk.pricer.measure.LGMMPricerMeasure	28002	Shows a detailed low-level description of the events on the evaluation grid of the valuation scheme

11.1.4 LGM Pricer Parameters

Pricing Parameter Name	Parameter Type	Parameter Domain	Parameter Comment	Global variable	Display Name	Default Value
MAX_DAY_SPACING	java.lang.Integer		Maximum number of days between time splices in the lattice	No	MAX_DAY_SPACING	30
LGMM_CALIB_MIN_CALENDAR_DAYS	java.lang.Integer			No	LGMM_CALIB_MIN_CALENDAR_DAYS	7
LGMM_CALIBRATE_TO_OTM_OPTIONS	java.lang.Boolean	true,false	If set to true it will calibrate to OTM options when valuing regular (with no variation in the notional or coupon) Bermudan options.	No	LGMM_CALIBRATE_TO_OTM_OPTIONS	False
LGMM_ADJUST_FOR_MIDFLOW_EXERCISE	java.lang.Boolean	true,false	If set to true, a flat forward approximation is used	No	LGMM_ADJUST_FOR_MIDFLOW_EXERCISE	False
LGMM_CALIBRATE_TO_STD_OPTIONS	java.lang.Boolean	true,false	if set to true, it calibrates to vanilla swaptions as specified by the point underlying swap on the volatility surface used.	No	LGMM_CALIBRATE_TO_STD_OPTIONS	False
CALIBRATION_VOL_TYPE	java.lang.String	BLACK_VOL, BP_VOL	The volatility model used when calibrating the model.	No	CALIBRATION_VOL_TYPE	BLACK_VOL
SWAP_REPLICATION_METHOD	java.lang.String	swap_rate_offset, overlap_negative_weights	Defines swap replication method – methodology described below.	No	SWAP_REPLICATION_METHOD	swap_rate_offset
LGMM_CALIB_SWAPTION	java.lang.String		Swaption template used to define calibration instruments	No	CALIB_SWAPTION	
LGMM_CALIB_SPACING	java.lang.Integer		Minimum spacing between calibration instruments	No	CALIB_SPACING	30

LGMM_CALIBRATION_INSTRUMENTS	java.lang.String	CORE_SWAPTION,CORE_AND_SHORT_SWAPTION,CORE_SWAPTION_ATM,CORE_AND_SHORT_SWAPTION_ATM	Controls which instruments are used in auto-calibration	No	CALIBRATION_INSTRUMENTS	CORE_SWAPTION
LGMM_CALIBRATION_SCHEME	java.lang.String	EXACT_STEP_SIGMA,BEST_FIT_LM,APPROX_STEP_SIGMA	Controls how the model is parameterised and the scheme for calibration	No	CALIBRATION_SCHEME	EXACT_STEP_SIGMA
LGMM_CONTROL_VARIATE	java.lang.Boolean	true, false	Use a European option as a control variate	No	CONTROL_VARIATE	True
LGMM_LATTICE_NODES	java.lang.Integer		Number of vertical nodes use in the discretisation is 2N+1, where N is number of lattice nodes	No	LATTICE_NODES	35
LGMM_QUAD_ORDER	java.lang.Integer		Number of points used in the quadrature rule in rollback algorithm	No	QUAD_ORDER	20
LGMM_LATTICE_CUTOFF	java.lang.Double		Number of standard deviations to cut-off the discretisation	No	LATTICE_CUTOFF	6.0
LGMM_BEST_FIT_GRAPH_MESH_SIZE	java.lang.Integer		Number of discrete points used in the best-fit error graph	No	BEST_FIT_GRAPH_MESH_SIZE	30
LGMM_MEAN_REV	com.calypso.tk.core.Rate		Sets the mean reversion parameter of the LGM model to a constant value	No	MEAN_REV	
LGMM_MAX_SIGMA	com.calypso.tk.core.Rate		The maximum value of the mode volatility to use in certain calibration methods	YES	MAX_SIGMA	
LGMM_MIN_SIGMA	com.calypso.tk.core.Rate		The minimum value of the model volatility to use in certain calibration methods	YES	MIN_SIGMA	
LGMM_MAX_MEAN_REVERSION	com.calypso.tk.core.Rate		The maximum value of the model mean reversion to use in certain calibration methods	YES	MAX_MEAN_REVERSION	
LGMM_MIN_MEAN_REVERSION	com.calypso.tk.core.Rate		The minimum value of the mode mean reversion to use in certain calibration methods	YES	MIN_MEAN_REVERSION	

LGMM_MODEL_VOL	com.calypso.tk.core.Rate		Sets the volatility parameter of the LGM model to a constant value	NO	MODEL_VOL	
LGMM_IR_RATE	com.calypso.tk.core.Rate		Sets the yield curve to a constant interest rate on a continuously compounded, ACT/365F basis	NO	IR_RATE	
RISK_OPTIMISE	java.lang.Boolean	true,false	Flag controls whether or not the pricer makes any attempt to optimise in the getRiskExposure method	NO	RISK_OPTIMISE	true
ACCURACY_LEVEL	java.lang.Integer		Controls the level of accuracy in pricing, 0-lowest accuracy, 11-highest accuracy	NO	ACCURACY_LEVEL	5