OpenGamma for NLX - Review

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1.1 Scenario Generation

Opengamma handles each risk factor independently during the scenario generation process.
Bank holidays (or incomplete scenario dates) are removed after the scenarios have been already calculated, this can cause the same scenario scenarios to be calculated with different start date across different risk factors with consequently loss off correlation and legitimate market moves.
Bank Holidays and incomplete scenario dates should be dealt with before the scenarios are calculated such that scenarios start date and end date are the same for all the risk factors.

Example below shows that because risk factor RF1 has additional market data for bank holidays 25th an 26th than the return provided RET1 for 27th and 28th are incorrectly based on start data from 25th an 26th and the upswing (+67) on 27th is completely missed whereas a down swing (-54) is captured on the 28th.

Current implementation

step 1 independently generate return for each RF

	RF1	RET1		RF2	RET2
21/12/2012 Fri	3		21/12/2012 Fri	3	
24/12/2012 Mon	11		24/12/2012 Mon	11	
25/12/2012 Tue	71	68	25/12/2012 Tue		
26/12/2012 Wed	70	59	26/12/2012 Wed		
27/12/2012 Thu	70	-1	27/12/2012 Thu	70	67
28/12/2012 Fri	16	-54	28/12/2012 Fri	16	5
31/12/2012 Mon	48	-22	31/12/2012 Mon	48	-22

step 2 remove scenario 25 and 26, left with 27,28,31

	RF1	RET1		RF2	RET2
27/12/2012 Thu		-1	27/12/2012 Thu		67
28/12/2012 Fri		-54	28/12/2012 Fri		5
31/12/2012 Mon		-22	31/12/2012 Mon		-22

Correct implementation

Removing the bank holiday data before

	RF1	RET1		RF2	RET2
21/12/2012 Fri	3		21/12/2012 Fri	3	
24/12/2012 Mon	11		24/12/2012 Mon	11	
25/12/2012 Tue	removed		25/12/2012 Tue		
26/12/2012 Wed	removed		26/12/2012 Wed		
27/12/2012 Thu	70	67	27/12/2012 Thu	70	67
28/12/2012 Fri	16	5	28/12/2012 Fri	16	5
31/12/2012 Mon	48	-22	31/12/2012 Mon	48	-22

Table below shows the current missing/additional risk factor data, last column (Swapclear va_zc) shows the dates used by Swapclear.

Row Labels	EUR BOND DE I016	EUR CASH	GBP BOND GB I022	GBP CASH	Swapclear va_zc
06/04/2015					1
03/04/2015					1
26/12/2014					1
17/07/2014	1	2(duplicated)	1	2(duplicated)	1
21/04/2014					1
26/12/2013					1
01/04/2013	1		1		1
29/03/2013	1		1		
01/01/2013	1		1		
26/12/2012	1		1		1
25/12/2012	1		1		
09/04/2012	1		1		
06/04/2012	1		1		
02/01/2012	1	1	1		1
27/12/2011	1	1	1		1
26/12/2011	1		1		
25/04/2011	1		1		
22/04/2011	1		1		
03/01/2011	1	1	1		1
28/12/2010	1	1	1		1
27/12/2010	1	1	1		1
05/04/2010	1		1		
02/04/2010	1		1		
01/01/2010	1		1		

Answer from OpenGamma:

The current set up of the system can still support user provided holiday calendars as part of its inputs to enforce venue holiday regimes and currency holidays.

The Linton tool has one holiday file for both, currencies and venue holidays. OG re-purposed the "ITL" column (as ITL currency does not exist) to contain venue holidays.

Since the last 2.0 release, a pre-processing step was added to auto-generate the simulation calendar and infer holidays from the risk factor population provided instead of using the "ITL" calendar (data provided by the user is ignored). This approach is a “non-standard” OG implementation and specific to Linton. It should be noted that this version hides potential issues with the inputs provided, as no valuation failure warning will be thrown anymore. Data gaps are removed.

The drawback is that margins can be wrong if the data is not consistent with what the model expects and it is not obvious to find out which gap is causing the issue.

OG can revert back to the original code by disabling the "auto-generation" and revert back to the standard behaviour where the user is in control and any gaps in data causes the valuation to fail safely and flag the error to the operator.

The general guiding principle with any risk system is to minimise "magic strings" and input data "massaging" that is not directly linked with the pricing methodology (i.e. interpolation). Holiday inference and logic to "fill data gaps" are not recommended.

By ensuring that the input datasets are clean and "well squared”, the code becomes more immutable. It means a clear separation of concerns between data management and valuation, thus reducing testing complexity.

When the valuation code is kept as immutable as possible (no execution path containing logic influenced by inferred data), risk numbers will be driven by the raw inputs provided. 99.9% of pricing failures will be down to data errors, making BAU support easier and possible without the need to change the code.

Status: OG changes – removal of pre processor step
Details: review and correct historical data, if possible aligning it to Swapclear calendar, remove pre-processing step such that the user is in control and any gaps in data causes the valuation to fail safely and flag the error to the operator.

1.2 OpenGamma Futures and Option prices differ from market price

The OpenGamma results file shows prices slightly off from the original input file prices:
This has several implications such as:
- If futures calculated prices are used instead of market prices for moneyness calculation, then an incorrect volatility is retrieved and consequently the calculated option price will be incorrect.
-for OTM options the prices usually represent the floor value of the Pnl, hence an incorrect option price will impact heavily the final IM. Example below shows the scenario pnl (varlosses) for an OTM option, market price is 1 tick, openGamma calculated price is 10 ticks, IM is overestimated by OpenGamma:

OpenGamma to propose a solution to these issues.

Answer from OpenGamma:
Currently, the price of bond futures in OpenGamma is computed from the curves in the following way:

- *The base price of the CTD bond is provided. A spread above the base government curves is calibrated in such a way that the price computed from the curves match the base bond price.*
- *Using that spread, the price of the bond future is computed as if the future was a forward and using a provided repo rate.*
- *The future price computed from the curves potentially does not match the market future price due to non-synchronisation of data, delivery option, futures convexity adjustment, ...*

The difference between computed base future price and market base price could be removed by one of the following adjustment:

- *Instead of calibrating the spread to match the price of the CTD bond, one could calibrate the spread to match the futures price.[]*
- *On top of the calibration of the government curve spread to match the bond price, one could calibrate the repo rate (and ignore the repo rate provided). The repo rate will then fluctuate and may not match the actual market repo rate but is used as an adjuster to match the more important future price.*

In both cases, it would require a code change to implement the computation of the adjustment at the beginning to the process, before the P/L series are computed.

A similar adjustment could be done for the STIR futures. We would have to discuss how this number would be computed and where the adjustment would be applied.

Status: OG Development
Details: It is requested that theoretical prices match market prices, reporate to be calibrated for bondfutures (rather than the bond spread), also STIRS are required to have an adjustment to match the market price.
We can provide further details explaining our PriceEngine implementation if requested.
Market Price matching to be added as a setting the settings will allow to revert to old behaviour if required.

1.3 Rounding to tick value

Listed contract are quoted to the tick value so it is expected that the historical simulation take in account such feature.
We do expect the internal calculations to be performed at full precision and rounding applied at the latest stages. We tried to reverse engineer the rounding or flooring applied by OpenGamma but haven't been able to match it.

Can OpenGamma please clarify where and how any rounding or intentional loss of precision occurs?
Please describe any rounding type (rounding, flooring, ceiling, truncation to the tick value etc..) and to which values (Simulated future price, Simulated option price, Base price, PnL, etc..) it is applied to?

Answer from OpenGamma:
Please also see Zero IM analysis 1.4
Your second point concern the removal of rounding for IM computation. Independently of the consideration about the skew introduced by the rounding, my opinion is that it would be a more natural methodology to avoid rounding in all the IM computations.

The reasoning that leads to that opinion is the following. Certainly there is a minimal price increment and one can not trade one contract with a price precision below that level. What we are assessing is to the price of one trade for one contract in a specific market situation. We are looking at the potential losses due to market movements. Each scenario is not representing an exact market movement, but is a representative of several market movement, for a probability of 1/1250. The scenario should not be viewed as one precise market but as the average of a family of potential markets. Also those different scenario values will be interpolated to find the VaR. Moreover the main risk that is encountered by LCH is not that a member with 1 outstanding contract will default. If the potential default that risk management is guarding against was only 1 contract, less effort could be invested. The risk is a large quantity of contracts, let say 1,000, will be involved in the default. In the subsequent liquidation of the contracts, like for a normal order, it is not certain that all of them will be liquidated at the same price. The scenarios computed for one contract are multiplied by the member number of contracts for the IM call. The value from the scenario should be viewed as the average of the prices on the member portfolio. To my opinion, if a rounding is taking place it should probably be only at the level of the full IM of one member. The values computed are not a specific value of an individual transaction, for which rounding would be natural, but the average of several transactions (the member position) on a set of several market movements represented by one scenario. What is your opinion about the rounding? Working without rounding would not change the overall margin computed for members by any significant amount, but may increase the transparency of the computation and smooth the outcome.
On the other question (1.3 - price of a future option), if I remember correctly, we are waiting for some contracts descriptions for which you want us to run the pricing and provide the details of the intermediary numbers (bond price, future price, interpolated vol, etc.). We have received the data set to use, but not the contract description.
Regards,
Marc Henrard
Advisory Partner

Simon,
I can confirm that for 1.3 the tick rounding can be adjusted for each contract type, i.e. NI, NB etc.
Regards,
Darren

Status: OG Development **Details:** Add a setting to use tick value as a rounding or not. The Description of the instrument is unchanged with the correct tick value but is used only in certain cases, according to the setting.

1.4 Zero IM

It has been identified that some calendar spread portfolios (bond futures) show a zero IM, the combined portfolio PnL from the varlosses file shows only positive PnL values, can Opengamma please clarify how this is possible? It might be linked with the rounding just discussed at point 0.
Example below, when contract PnL is positive first contract is always smaller than second contract, when contract PnL is negative first contract is always larger (in abs term) than second contract, this cause portfolio PnL to be always >=0 as depicted in plot below hence zero IM.

Answer from OpenGamma:

In a couple of words, the strange behaviour reported in the example is due to the rounding (and some bad luck). When computing the prices of the futures in the scenarios, the prices are rounded, according to the specification, using the exchange rules for minimum tick value. This means that there is a systematic bias in the scenario results. That bias is unpredictable and depend on the price rounding in the base scenario. In the case of the question, one price is rounded down from 128.41270148 to 128.41 and the other one is rounded up from 130.18682692 to 130.19. This create a bias of roughly 5 GBP on the long/short pair. The P/L is distributed around that number and with the rounding, the final numbers that are 0 or 9 GBP (and a couple of 18). The actual average is 5.07 GBP, which is very close to the rounding bias. If the same computation is done on the non-rounded prices, the average is 0.07 GBP and there are negative and positive P/L.
The details of the computations (with and without rounding) are provided in the attached spreadsheet. The first sheet as the full results without rounding and the second one with rounding. All the figures mentioned above are computed/reported in the sheet.
The same analysis done on a different date will in some cases report only negative numbers and in some case a split between positive and negative.
I hope this help to clarify the origin of the strange numbers.
Regards,
Marc Henrard

Status: No action required if: 1.2 market price match or 1.3 rounding removal are implemented **Details:** this is the effect of issue 1.2 or 1.3. By addressing the market price match and/or removing the rounding this issue should disappear.

1.5 Configurable parameters

It is expected that PAIRS methodology parameters to be configurable such as:

- EWMA parameters:
  - Lambda
  - Scaling type (no scaling, mid scaling, full scaling)
- Number of scenarios
- Expect shortfall or Var (quantlie)
  - number for observations (ie ES4 or var 13th)
- Holding period (2d or 5d)
- Multiplier (ie 25%)

CURRENT CONFIGURABLE PARAMETERS:

Name	Option	Default	Description
IR_FUTURE_POSITIONS_OPTION	ir	Off	Include STIRS in the calculations
BOND_FUTURE_POSITIONS_OPTION	b	Off	Include Bond Futures in the calculations
DELIVERABLE_SWAP_FUTURE_PRICE_TRADES_OPTION	dsf	Off	Include Price based DSFs in the calculations
DELIVERABLE_SWAP_FUTURE_YIELD_TRADES_OPTION	dsfy	Off	Include Yield based DSFs in the calculations
BOND_FUTURE_OPTION_TRADES_OPTION	bo	Off	Include Bond Future Options in the calculations
STIR_FUTURE_OPTIONS_TRADES_OPTION	iro	Off	Include STIRS Options in the calculations
SEED_VOL_SIZE_OPTION	seedVol	60	Seed vol size
NUMBER_OF_SCENARIOS	scenarios	1250	Number of scenarios
HOLDING_PERIOD_OPTION	hp	2	Length of holding period
CONFIDENCE_INTERVAL_OPTION	ci	0.997	Confidence level
IM_MULTIPLIER_OPTION	immulti	1.25	Multiplier
VOL_BOUNDARY_OPTION	vb	0.5	Cap/Floor value to be applied to the STIR/Future Option simulations
EWMA_DECAY_FACTOR_OPTION	lambda	0.97	Lambda in the EWMA calculation

Status: OG Development

Details: Please implement the following

Name	Option	Default	Description
SCENARIO_SCALING_TYPE		MID_SCALING	Scenario scaling type multiplier MID_SCALING = 0.5 *((sN/st)+1) =(sN+st)/(2 st) FULL_SCALING = (sN/st) NO_SCALING = 1 st and sN represent the dispersion of the corresponding time series for the scenario t with respect to the day N for which IM is calculated.
ROUND_TO_TICK_VALUE		Off	Round prices to tick value
MATCH_MARKET_PRICE	Futures or Options or both	On	Calibrate theoretical prices to match market prices
MINIMUM_OPTION_PRICE		ONE_TICK	Floor out of the money option prices to one tick

1.6 Calculation and use of PV01

[Extract from section 5.3 of NLXOptions_PricingAndRiskMethodology_v1]

Sensitivity Analysis

For risk management purposes, it is also a requirement for the NLX HVAR model to generate a range of sensitivity measures for each contract as follows:

- Zero-rate PV01 ladder for each STIR futures contract;
- Zero-rate PV01 ladder for each government bond futures contract;
- Repo rate PV01 for each government bond futures contract;
- Delta-weighted zero-rate PV01 ladder for each STIR future option contract;
- Expiry-bucketed gamma, vega and theta for each STIR future option contract;
- Delta-weighted zero-rate PV01 ladder for each government bond future option contract;
- Delta-weighted repo rate PV01 for each government bond future option contract; and
- Expiry-bucketed gamma, vega and theta for each government bond future option contract.

All these measures are calculated on a “per lot” basis without using the price rounding implied by each contract’s underlying tick denomination.

Unit of trading, tick size, and tick value should be correctly accounted for, such that the resulting analytical PV01 will be comparable to the impact of a simulated 1bp move on the underlying curve.

Nasdaq

FOR MORE INFORMATION, VISIT WWW.NLX.CO.UK.

ALL TIMES ARE LONDON TIMES

BOBL FUTURES

FUTURES PRODUCT SPECIFICATION

PRODUCT CODE	NB
UNIT OF TRADING	€100,000 nominal value notional Bobl with 6% coupon.
DELIVERY MONTHS	The Three closest quarterly delivery months.
PRICE QUOTATION	Per €100 nominal.
MINIMUM TICK SIZE AND VALUE	0.01 (€10)
LAST TRADING DAY	Two business days prior to the Delivery Day in the delivery month.
LAST TRADING TIME	On the Last Trading Day, trading in the front delivery month will stop at 11:30.
DELIVERY DAY	The tenth calendar day of the front delivery month, if this day is a business day; otherwise, the business day immediately following that day.
MATURITY RANGE OF DELIVERABLE BOBL	4.5 to 5.5 years.

OpenGamma_analyticalPV01_vs_scenarioPV01.xlsx - Microsoft Excel

MZ3 =(SUM(LB3:MV3)+SUM(JP3:KY3))/10

Data from Opengamma (resultsUnderlying.csv)

	Trade	Contract	Price	U/L Price	U/L Bond Spread	PV01 (Disc)	PV01 (Index)	PV01 (Repo)	total delta from PV01	total delta from PV10
3	176945888	F-NLX-FUT-NBNB-20150900	130.19	114.31	-0.00	-5.99		0.03	-60.00	-62.00
4	176945889	F-NLX-FUT-NBNB-20151200	128.41	114.31	-0.00	-5.95		0.35	-60.00	-58.00
5	176945890	F-NLX-FUT-NBNB-20160300	129.70	100.78	0.00	-6.61		0.68	-70.00	-65.00
6	176945894	F-NLX-FUT-NSNS-20150900	111.27	100.39	0.00	-1.99		0.02	-20.00	-20.00
7	176945895	F-NLX-FUT-NSNS-20151200	111.22	100.43	-0.00	-2.27		0.30	-20.00	-22.50
8	176945896	F-NLX-FUT-NSNS-20160300	111.36	109.84	-0.00	-2.60		0.60	-25.00	-26.00
9	176945897	F-NLX-FUT-NUNU-20150900	153.69	107.98	-0.00	-12.60		0.03	-130.00	-129.00
10	176945898	F-NLX-FUT-NUNU-20151200	153.98	103.40	0.00	-13.22		0.42	-120.00	-127.00
11	176945899	F-NLX-FUT-NUNU-20160300	155.79	98.26	0.00	-14.37		0.81	-130.00	-138.00
12	176945900	F-NLX-FUT-NINI-20150900	100.04				-24.66		-37.50	-25.00
13	176945901	F-NLX-FUT-NINI-20151000	100.04				-24.66		-25.00	-25.00
14	176945902	F-NLX-FUT-NINI-20151100	100.04				-24.66		-25.00	-23.75
15	176945903	F-NLX-FUT-NINI-20151200	100.04				-24.66		-12.50	-23.75
16	176945904	F-NLX-FUT-NINI-20160100	100.04				-24.66		-37.50	-25.00
17	176945905	F-NLX-FUT-NINI-20160200	100.03				-24.66		0.00	-22.50
18	176945906	F-NLX-FUT-NINI-20160300	100.03				-24.66		-25.00	-25.00
19	176945907	F-NLX-FUT-NINI-20160600	100.02				-24.66		-25.00	-25.00
20	176945908	F-NLX-FUT-NINI-20160900	100.00				-24.66		-37.50	-25.00
21	176945909	F-NLX-FUT-NINI-20161200	99.97				-24.65		-25.00	-25.00
22	176945910	F-NLX-FUT-NINI-20170300	99.93				-24.64		-12.50	-23.75
23	176945911	F-NLX-FUT-NINI-20170600	99.89				-24.64		-37.50	-25.00
24	176945912	F-NLX-FUT-NINI-20170900	99.84				-24.63		-25.00	-23.75
25	176945913	F-NLX-FUT-NINI-20171200	99.78				-24.62		-25.00	-22.50
26	176945914	F-NLX-FUT-NINI-20180300	99.72				-24.60		-50.00	-26.25
27	176945915	F-NLX-FUT-NINI-20180600	99.64				-24.59		-37.50	-26.25
28	176945916	F-NLX-FUT-NINI-20180900	99.56				-24.58		-12.50	-23.75
29	176945917	F-NLX-FUT-NINI-20181200	99.48				-24.56		-25.00	-25.00
30	176945918	F-NLX-FUT-NINI-20190300	99.39				-24.54		-50.00	-26.25

Simulated a 10 bp bump in order to have move the enough the price to overcome the min tick size (rounding)

bktdelta resultsUnderlying lintonShifts

Example of current issue: PV01 for bond futures (NB,NS,NU) is ~10 times smaller than the one calculated using curve bumps.

ScenarioIdentifier	RiskFactorName	ShiftType	ShiftValue
1001_PV01_EUR BOND DE I016 1D	EUR BOND DE I016 1D	ABSOLUTE	0.0001
1002_PV01_EUR BOND DE I016 1W	EUR BOND DE I016 1W	ABSOLUTE	0.0001
1003_PV01_EUR BOND DE I016 1M	EUR BOND DE I016 1M	ABSOLUTE	0.0001
1004_PV01_EUR BOND DE I016 3M	EUR BOND DE I016 3M	ABSOLUTE	0.0001
1005_PV01_EUR BOND DE I016 6M	EUR BOND DE I016 6M	ABSOLUTE	0.0001
1006_PV01_EUR BOND DE I016 1Y	EUR BOND DE I016 1Y	ABSOLUTE	0.0001
1007_PV01_EUR BOND DE I016 2Y	EUR BOND DE I016 2Y	ABSOLUTE	0.0001
1008_PV01_EUR BOND DE I016 3Y	EUR BOND DE I016 3Y	ABSOLUTE	0.0001
1009_PV01_EUR BOND DE I016 4Y	EUR BOND DE I016 4Y	ABSOLUTE	0.0001
1010_PV01_EUR BOND DE I016 5Y	EUR BOND DE I016 5Y	ABSOLUTE	0.0001

Example of curve bumps used in the stress test framework.

Status: Existing fix to be included in Option release.

Details: The latest release of OG in production (futures only) shows correct PV01 figure, it is required that no regressions are introduced for the Options release.

Fix included in v1.67 to be included in v2.0

1.7 Volatility Matching

The requirement is to match theoretical option prices with market prices. Although a granular grid should produce a close matches between theoretical and market prices, it is required to build an adjustment to match the option market price (in the similar way it is done for futures). This adjustment was originally not considered for the lack of option prices in current input dataset.
However to cover for the SVI (used for stress test) market prices/vols data is required, making this development feasible.
The matching (adjustment enabled/disabled) to be controlled by a setting.

Our preference is for OG to code up the volatility matching algo exactly in the same way as our backtesting engine:

- Find the target implied vol from the market's vol surface(interpolate if a particular strike needed is not quoted for that day) i.e `targetImpliedVol`
- Find the interpolated vol (for the contract) from fixedGrid, i.e `impVol`
- multiply `targetImpliedVol/impVol` to the 1250 scenarios' (interpolated) implied vol
- do the same for the baseline impVol so we calculate the (theorectical) baseline option price
- calculate option prices
- calculate VaR losses

Status: OG development request, volatility fitter development **Details:** Although a granular grid should produce close matches between theoretical and market prices, it is required to build an adjustment to match the option market price (in similar way as futures). Market prices/vols data will be the same input required for the SVI (see stress testing 1.9). The matching to be controlled by a setting (similar to 1.2) where price matching can be enabled/disabled for futures or options or both.

1.8 Minimum Option Price

Does OG floors the Option prices to 1 tick? Deep out of the money options should not price nil, but at least 1tick (no free lunch).

Status: OG Development **Details:** Add a setting to use the tick value as a minimum price.

1.9 Stress testing

1. We can use black volatilities as the base of the stress scenarios, therefore, it will need to take a whole surface of volatilities (by strike + tenor) of stresses into account when calculating the stressed losses per scenario.
2. Use parametric stresses (a variant of SVI), in which case the stress testing will use the same methodology as the skew add-on as I will adjust the calibration/model to match whatever is used for the Add-on so that it all fits in one framework.

I think going down route 2. is cleaner and if they are going to be required to implement something to process the Add-on then it would make sense we go down this path for the stress scenarios too.
Vinit

Status: **On-going**

Details: Preference is to support the parametric SVI stresses (point2), please see next point 1.10 for the SVI details, we can also circulate a specific document on SVI, OG to analyze and estimate effort.

1.10 Volatility Model

The natural SVI model has been assumed during this project an accurate model to described the options volatility smiles and surfaces, then the core IM is only accounting for relative changes in the ATM vol (or equivalently θ_t) while keeping ρ_t (skew) and φ_t (vol of vol) constant. As a result an add-on is required to account for these missing risk factors

$$w(k,t) = \frac{\theta_t}{2}\left\{1 + \rho_t\varphi_t k + \sqrt{1 + 2\rho_t\varphi_t k + (\varphi_t k)^2}\right\} \quad (1)$$

By definition the total variance $w(k,t)$ is defined as, where σ is the lognormal volatility and t is the option's time to expiry in annual basis.

$$w(k,t) = \sigma^2(k,t) \cdot t \quad (2)$$

Empirically it has been shown that φ_t is a function dependent on θ. For example the surface SVI (SSVI) parametric function below for φ_t seems to be consistent with the empirically observed term structure of the volatility.

$$\varphi_t(\theta_t) = \frac{\eta}{\theta^\gamma(1+\theta)^{1-\gamma}}$$

Following some observed results, γ has been assumed to be equal to 0.5 and since interest rate volatilities are normally low, the previous parameterisation can be simplified as follows.

$$\varphi_t(\theta_t) = \eta\theta^{-0.5} \quad (3)$$

1.10.1 Volatility Add-on

A simple approach to measure the potential impact of changes in skew and vol of vol in the IM model is by estimating the effect on the contract price by shifting those parameters to some calibrated extreme moves.

$$\rho_{Add\_on} =\cdot \frac{\partial P}{\partial \rho_t}\Delta\rho_t \quad \text{and} \quad \varphi_{Add\_on} =\cdot \frac{\partial P}{\partial \varphi_t}\Delta\varphi_t$$

Mathematically this can be achieved by directly multiplying the contract Vega (Black representation) by the relevant derivatives following the chain rule. The following two formulas present the definition of the two main components of the volatility add-on.

$$\rho_{Add\_on} = V_P \frac{\partial \sigma_t}{\partial w(\rho_t)} \frac{\partial w(\rho_t)}{\partial \rho_t}\Delta\rho_t \quad (4)$$

$$\varphi_{Add\_on} = V_P \frac{\partial \sigma_t}{\partial w(\varphi_t)} \frac{\partial w(\varphi_t)}{\partial \rho_t}\Delta\varphi_t \quad (5)$$

Where V_P and σ_t are the contract Vega and volatility respectively, while and $\Delta\rho_t$ and $\Delta\varphi_t$ are the 2-day extreme shifts in ρ_t and φ_t which are calibrated from historical data.

1.10.2 Linear effect of ρ_t

In order to solve equation (3), the following expressions are derived from equation (1) and (2).

$$\frac{\partial w}{\partial \rho_t} = \frac{\theta_t \varphi_t k}{2}\left\{1 + \frac{1}{\sqrt{1 + 2\rho_t \varphi_t k + (\varphi_t k)^2}}\right\}$$

$$\frac{\partial \sigma_t}{\partial w} = \frac{1}{\sqrt{w(k,t)\cdot t}}$$

Finally by combining all the relevant formulas, the ρ_t add-on is defined as.

$$\rho_{Add\_on} = \frac{V_P}{\sqrt{w(k,t)\cdot t}}\frac{\theta_t \varphi_t k}{2}\left\{1 + \frac{1}{\sqrt{1+2\rho_t\varphi_t k+(\varphi_t k)^2}}\right\}\Delta\rho_t \quad (6)$$

1.10.3 Linear effect of φ_t

Similarly, the effect on changes in φ_t is estimated from the following equations.

$$\frac{\partial w}{\partial \varphi_t} = \frac{\theta_t k}{2}\left\{\rho_t + \frac{\rho_t + \varphi_t k}{\sqrt{1 + 2\rho_t \varphi_t k + (\varphi_t k)^2}}\right\}$$

$$\varphi_{Add\_on} = \frac{V_P}{\sqrt{w(k,t)\cdot t}}\frac{\theta_t k}{2}\left\{\rho_t + \frac{\rho_t+\varphi_t k}{\sqrt{1+2\rho_t\varphi_t k+(\varphi_t k)^2}}\right\}\Delta\varphi_t \quad (7)$$

Equations (6) and (7) describe the potential p&l effect on a given contract due to changes in ρ and φ respectively. The last part is to provide a framework to estimate the extreme shifts in $\Delta\rho_t$ and $\Delta\varphi_t$.

1.10.4 $\Delta\rho_t$ and $\Delta\varphi_t$ extreme shifts

A well known and robust approach to estimate extreme but plausible parameter shifts is by directly multiplying a calibrated standard deviation of the parameter returns by a quantile for a given probability threshold, the benefit of this approach is that the business has the ability to increase, if needed, the size of the add-on by simply increasing the quantile level.

The formula below presents the proposed framework to estimate extreme shifts in $\Delta\rho_t$.

$$\Delta\rho_t = Q(p)\cdot sd_{\rho_t}$$

E.g. if a normal distribution is assumed with a probability of 99%, the quantile $Q(99\%) = 2.33$.

Similarly $\Delta\varphi_t$ uses the same approach, however as the total changes in φ can be attributed to changes in η and θ as defined in equation (3) and remembering that the core IM only considers changes in the vol in the first term on equation (1) the extreme shift is approximated as the linear contribution to extreme shifts in η and v .

$$\Delta\varphi_t = \frac{d\varphi_t}{dv_t}\Delta v_t + \frac{d\varphi_t}{d\eta_t}\Delta\eta_t$$

$$\Delta\varphi_t = -\eta v^{-2} t^{-0.5}\Delta v_t + \theta^{-0.5}\Delta\eta_t \quad (8)$$

$$\Delta\varphi_t = \left(-\eta v^{-2} t^{-0.5} sd_{v_t} + \theta^{-0.5} sd_{\eta_t}\right)Q(p) \quad (9)$$

1.10.5 Calibrations

Calibration of the Add-on parameters such as the SVI parameters and respective standard deviations, are directly obtained from the mean and the standard deviation of the 2-day returns of actual SVI calibrations from historical data. Below are the values obtained for each contract.

Contract	ρ_{Mean}	η_{Mean}
Schatz	-0.1536	0.5302433
Bobl	-0.2035	0.4445285
Bund	-0.119	0.4241529
EUR STIRS	-0.3818	0.8085619
GBP STIRS	-0.3774	0.768116
EUR 1Y Mid Curve	-0.45818	0.576123

GBP 1Y Mid Curve	-0.47272	0.564212

Contract	sd_ρ	sd_η	sd_ν
Schatz	0.1192077	0.1303496	
Bobl	0.08231465	0.08229	User defined (e.g sd, quantile, max, etc)
Bund	0.07421793	0.06851502	
EUR STIRS	0.1080094	0.1195193	
GBP STIRS	0.097057	0.089741	
EUR 1y Mid Curve	0.1174233	0.072223	
GBP 1y Mid Curve	0.1126546	0.067541	

1.10.6 **Volatility add-on scenarios**

As previous framework splits the contributions from skew and vol of vol to core IM, 4 individual scenarios are generated as a result: $\Delta\boldsymbol{\rho_t}$ up, $\Delta\boldsymbol{\rho_t}$ down, $\Delta\boldsymbol{\varphi_t}$ up and $\Delta\boldsymbol{\varphi_t}$ down which can be combined to produce 4 more scenarios.

In order to avoid creating an overly conservative combined scenario, if changes in $\Delta\boldsymbol{\rho_t}$ and $\Delta\boldsymbol{\varphi_t}$ are assumed to be independent, these scenarios can be implied from the intermediate points in the isoquantile ellipse using the following formulas.

Core Scenarios		Combined Scenarios	
Scenario 1	$\boldsymbol{\rho_{Add\_on}}(+\Delta\boldsymbol{\rho_t})$	Scenario 5	$(\mathrm{Scen}_1 + \mathrm{Scen}_3)\frac{\sqrt{2}}{2}$
Scenario 2	$\boldsymbol{\rho_{Add\_on}}(-\Delta\boldsymbol{\rho_t})$	Scenario 6	$(\mathrm{Scen}_1 + \mathrm{Scen}_4)\frac{\sqrt{2}}{2}$
Scenario 3	$\boldsymbol{\varphi_{Add\_on}}(+\Delta\boldsymbol{\varphi_t})$	Scenario 7	$(\mathrm{Scen}_2 + \mathrm{Scen}_3)\frac{\sqrt{2}}{2}$
Scenario 4	$\boldsymbol{\varphi_{Add\_on}}(-\Delta\boldsymbol{\varphi_t})$	Scenario 8	$(\mathrm{Scen}_2 + \mathrm{Scen}_4)\frac{\sqrt{2}}{2}$

For each contract in the portfolio, all 8 scenarios are calculated and aggregated at a scenario level. The total add-on will be the scenario that produces the worst p&l for the portfolio.

Status: On-going
Details: OG to analyze and estimate effort.

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