QuantLib(XL) for Model Validation

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QuantLib User Meeting 2016 - IKB/Düsseldorf

Düsseldorf, 7th December 2016
Agenda

1. Introduction Model Validation
2. QuantLibXL for Model Validation
3. Typical Deliverables
4. Summary
Introduction Model Validation
Regulatory Requirements

**BCBS**
- BCBS 153, “Supervisory guidance for assessing banks’ financial instrument fair value practices”
  - Guidelines for fair value valuation (10 principles)
  - Valuation processing and valuation control by the bank
  - Risk management and disclosure of risk as a result of the model valuation
  - Monitoring of the valuation process by the supervision
  - Initial, periodic and event-based validation

**BaFin**
- Risk identification and risk measurement (§25a KWG, MaRisk)

**FED / OCC**
- Due to bank’s Comprehensive Capital Analysis and Review (CCAR) submissions, banks are required to submit documentation regarding their model risk management policy and practices.

Model validation should be in accordance with regulatory guidelines
A sound model validation and model certification is crucial for risk mitigation in an organisation.

### Operational Risk
Can systems process all products in current market environment and risk scenarios?

### Model Risk
Are models in line with peers and market standard given the current market environment (e.g. negative rates)?

### Market Risk
Can models calibrate to market environment and yield reasonable pricing and risk numbers?

#### What if the answer is ‘No’?

- **Operational Risk**
  - Interruption in EoD valuation runs
  - Limitations of new business

- **Model Risk**
  - Collateral disputes
  - Disadvantages when competing for deals

- **Market Risk**
  - Wrong prices/hedges/risks
  - Bleeding P&L due to potential arbitrage

Model validation is aimed at answering above questions, identifying potential gaps and proposing remediation actions.
Model validation is driven by the complexity of products/market data/models involved and the level of transparency desired.

<table>
<thead>
<tr>
<th>Complexity</th>
<th>Transparency</th>
<th>full</th>
</tr>
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<tbody>
<tr>
<td>low</td>
<td></td>
<td>» Can we independently reproduce all calibration pricing and risk results?</td>
</tr>
<tr>
<td>medium</td>
<td></td>
<td>» Does model replicate calibration inputs?</td>
</tr>
<tr>
<td>high</td>
<td></td>
<td>» Are model-independent properties preserved (e.g. put-call parity)?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>» Does model behave reasonable in stress (i.e. model limits)?</td>
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</table>

<table>
<thead>
<tr>
<th>Complexity</th>
<th>Transparency</th>
<th>basic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>» Are models and market data assigned and configured as specified?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>» Does the model capture all relevant risk factors?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>» Does the model produce all relevant prices and risk figures?</td>
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Model validation approaches to product scope and desired level of transparency taking into account timely and budgetary constraints.

PR ... Product, MD ... Market Data, MO ... Model

More effort, Longer time line, Quant skill sets
Less effort, Shorter time line, Analyst skill sets

low
PR: FRA
MD: IR Quotes
MO: Discounting

medium
PR: Caps/Floors
MO: Bachelier

high
PR: CMS-Spread
MD: Swaption Vol.
MO: 2F Hull-White
Validation processing is based on risk and product dependencies

Example: From 1CCY Vanilla IR products to callable swaps

Validation should start with risk factors and advance to (complex) products
Main criteria for reference pricer are product coverage, transparency and available analytical tools

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<th>Pricer</th>
<th>Pros</th>
<th>Cons</th>
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<tbody>
<tr>
<td>Commercial in-house library</td>
<td>‣ Very good product coverage of Vanilla and exotic products</td>
<td>‣ Model details not always transparent (proprietary software)</td>
</tr>
<tr>
<td></td>
<td>‣ Detailed documentation</td>
<td>‣ Extensions/Adjustments not possible (at most upgrade)</td>
</tr>
<tr>
<td></td>
<td>‣ In-house established</td>
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<tr>
<td><strong>Bloomberg Swap Manager</strong></td>
<td><strong>Pros</strong></td>
<td><strong>Cons</strong></td>
</tr>
<tr>
<td></td>
<td>‣ (Very) good product coverage of Vanilla and exotic products</td>
<td>‣ Model details not always transparent (proprietary software)</td>
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<tr>
<td></td>
<td>‣ Direct integration of market data</td>
<td>‣ Restricted analyse tools</td>
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<tr>
<td></td>
<td>‣ (In-house established)</td>
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<tr>
<td><strong>QuantLib</strong></td>
<td><strong>Pros</strong></td>
<td><strong>Cons</strong></td>
</tr>
<tr>
<td></td>
<td>‣ (Very) good product coverage of Vanilla and exotic products</td>
<td>‣ Expert tool with appropriate know-how requirements</td>
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<tr>
<td></td>
<td>‣ Full transparency since open source</td>
<td>‣ For the most part documentation in source code</td>
</tr>
<tr>
<td></td>
<td>‣ In principle flexibly extensible</td>
<td></td>
</tr>
<tr>
<td></td>
<td>‣ No licence fees</td>
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</table>
QuantLibXL for Model Validation
Using QuantLibXL for Model Validation

Why do we use QuantLibXL in validation projects instead of other QuantLib interfaces (e.g. Python)?

**Client’s IT infrastructure**
- Installation of special software usually not allowed due to security reasons
- Easy availability and integration via Excel addin
- Easy integration of additional required data (e.g. market data via Bloomberg Excel addin)
- Client and internal/external auditors should be able to reproduce the calculations

**Skill requirements and further use**
- Client and internal/external auditors are familiar with Excel/VBA applications
- To a certain extent only analyst skills are required
- Constructed QuantLib-Excel workbooks as repository for (re)validation or validation of new product features with (small) adjustments

» Remark: At the moment we use the “old” QuantLibAddin with gensrc Python script instead of the SWIG Reposit module

QuantLibXL is used due to infrastructure restrictions and skill requirements
We manage two repositories to maintain legacy QuantLibXL and updated QuantLib library

Prior Dec’15 setting
» Various projects in a single Git repository

Project split in Dec’15
» Keep legacy QuantLibXL and gensrc infrastructure
» Strip off QuantLib/ folder

Current setup
» include QuantLib library as independent submodule

We aim at migrating from gensrc/QuantLibXL to Reposit/QuantLibXL in 2017

QuantLib repository is forked from lballabio/QuantLib and set up as Git Submodule to keep up with recent developments
Using QuantLibXL for Model Validation

Product/Model Coverage

Available in QuantLibXL
- Direct use of QuantLib-Excel functions

Implemented in QuantLib, but not in QuantLibXL
- Transfer to Excel via “old” QuantLibAddin or SWIG Reposit required
- Test of successful transfer

Partially implemented in QuantLib
- Implementation
- Transfer to Excel via “old” QuantLibAddin or SWIG Reposit required
- Test of implementation and transfer

Vanilla linear products
- Vanilla Swaps
- Fix/Float Bonds
- Discounting CashFlow

Vanilla Options
- Caps/Floors
- Swaptions
- FX Options

Complex Products
- Callable Swaps
- CMS-Spread
- Asian Options

Less effort, Shorter time line, Analyst skill sets

More effort, Longer time line, Quant skill sets

Product/Model Complexity

Time effort for model validation depends also on product/model coverage in QuantLibXL

PR ... Product, MD ... Market Data, MO ... Model
Case: Required functionality available in QuantLibXL

» Test case: Validation of 1CCY swap curves and Vanilla swap

1CCY swap curves

» Construction
  › RateHelpers (qlOISRateHelper, qlDepositRateHelper, qlFraRateHelper, qlSwapRateHelper, …) are used for defining benchmark instruments of the curves
  › Yield curves are constructed with qlPiecewiseYieldCurve

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QuantLib(XL) for Model Validation | QuantLibXL for Model Validation (4/10)
Case: Required functionality available in QuantLibXL (cont.)

» Test case: Validation of 1CCY swap curves and Vanilla swap (cont.)

1CCY swap curves

» Validation
  » Compare bootstrapped QuantLib zero rates (qlYieldTSZeroRate) with zero rates of the respective system
  » Use QuantLibXL for further tests (e.g. impact on forward rates using different interpolation methods for zero rates)

<table>
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<th>Dates</th>
<th>Period</th>
<th>QuantLib zero rates</th>
<th>System zeros rates</th>
<th>Delta in BP</th>
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EUR-3M forward rates using different interpol. methods for zero rates
Case: Required functionality available in QuantLibXL (cont.)

» **Test case: Validation of 1CCY swap curves and Vanilla swap (cont.)**

Vanilla Fix-Float Swap

» **Construction and Validation**

› After successful validation of 1CCY swap curves use the zero rates of the system and `qlInterpolatedYieldCurve` for defining the respective discount and forward curves

› Construction and pricing of swap with `qlSchedule`, `qlFixedRateLeg`, `qlIborLeg`, `qlSwap` and `qlInstrument`

› In addition check schedule dates and cashflows with `qlLegFlowAnalysis`

› Use QuantLibXL for further tests (e.g. BPV sensitivity calculation)

Quick validation of products if all required functionality is available in QuantLibXL
Case: Partially implemented in QuantLib

« Test case: Implement “special cubic” local interpolation and convention “compounded”

Problem

» Some of client’s interest rate curves based on zero rates use
  » “special cubic” local interpolation method
  \[
  z(t_x) = z(t_a) + (z(t_b) - z(t_a)) \left( \frac{(t_x^3 - t_a^3)}{(t_b^3 - t_a^3)} \right)
  \]
  with
  \[t_a \leq t_x \leq t_b\]
  » and compounding convention “compounded”, i.e.
  \[
  D(t, T) = \frac{1}{(1 + z(t,T))^{T-t}}
  \]

» “Special cubic” interpolation is not implemented in QuantLib

» `qlInterpolatedYieldCurve(ObjectID, Dates, Data, Calendar, DayCounter, Jumps, JumpDates, TraitsID, InterpolatorID, Permanent, Trigger)` does not provide compounding argument and uses continuous compounding for zero rates (TraitsID = ZeroYield) by default

Tasks

» Implement “special cubic” interpolation in QuantLib

» Implement new class/ QuantLib-Excel function
  
  `(ql)InterpolatedYieldCurveFromInterpolatedZeroCurve` including compounding argument
Case B: Partially implemented in QuantLib (cont.)

» Test case: Implement “special cubic” local interpolation and convention “compounded”

- QuantLibAddin::InterpolatedYieldCurve based on YieldTermStructure is implemented using the factory pattern with TraitsID (Discount, ZeroYield, ForwardRate) and InterpolatorID
- Compounding argument with TraitsID “Discount” does not make sense
- Quick integration of “special cubic” interpolation due to the factory pattern after implementing it analogous to the linear Interpolation
Case B: Partially implemented in QuantLib (cont.)

Test case: Implement “special cubic” local interpolation and convention “compounded”

- InterpolatedYieldCurveFromInterpolatedZeroCurve is implemented analogous to InterpolatedYieldCurve using the factory pattern now with CompoundingID (Simple, Compounded, Continuous) and InterpolatorID.
- New classes ZeroYieldStructure2 and InterpolatedZeroCurve2 with appropriate adjustments incorporating compounding feature
- Quick integration of “special cubic” interpolation due to the factory pattern

Quick implementation and transfer to Excel of minor features
Some advanced extensions of QuantLib(XL) used in Model Validation

**1-Factor Hull-White**
- Current core implementation includes only 1-Factor Hull White process with scalar short rate volatility
- For validation of Callable swaps and bonds a generic 1-Factor Hull White model with time-dependent short rate volatility was implemented and transferred to Excel

**FX Barrier Options**
- For model validation purposes the valuation of FX Barrier options with analytic pricing formulas based on the Garman-Kohlhagen model was required
- Available in QuantLib, but had to be transferred to Excel

**(Capped/Floored) CMS**
- Implementation and transfer to Excel of an affine Terminal Swap Rate (TSR) model using normal swaption volatilities for analytic pricing of (Capped/Floored) CMS
Typical Deliverables
Typical Deliverables – QuantLib-Excel test workbooks

» Reproducibility of test processing and of test results are ensured by standardized QuantLib-Excel sheets
# Typical Deliverables – Validation Documents and Work Shops

## Standardized validation document

- Mathematical background and market standard valuation
- Portfolio analysis and reference trades
- Test processing and test results
- Criticality of findings and improvement proposals

## Work shops (~ 2 to 3 h)

- Work shops present the validation results with further information on mathematical background and market standard valuation
  - Advanced training on (new) models and valuation methods
  - Discussion on validation findings and improvement proposals
- Previous work shops
  - “Multi Curve Discounted Cashflow Method“
  - “Valuation of IR Options with Black76 Model and Bachelier Model“
  - “Valuation of (Capped/Floored) CMS“
  - “Hull White Model and Valuation of Callable Swaps“
Summary
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» Model Validation is important in view of regulatory requirements and risk organisation

» QuantLib(XL) is suitable for model validation in view of product coverage, transparency and available analytical tools

» In comparison to other interfaces QuantLibXL is used due to infrastructure restrictions and skill requirements

» Time effort for model validation depends also on product/model coverage in QuantLibXL

» Typical Deliverables in a validation project are QuantLib-Excel test sheets, validation documents and work shops
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