ORE Applied:
Dynamic Initial Margin and MVA

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QuantLib User Meeting at IKB, Düsseldorf

8 December 2016

Agenda

Open Source Risk Engine

Dynamic Initial Margin and Margin Value Adjustment

Conclusion and Next Steps

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Open Source Risk Engine

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Conclusion and Next Steps

Released 7 October 2016

Web site, FAQ, Forum:

`http://www.opensourcerisk.org`

Code base:

```
https://github.com/OpenSourceRisk/Engine
https://github.com/OpenSourceRisk/Dashboard
```

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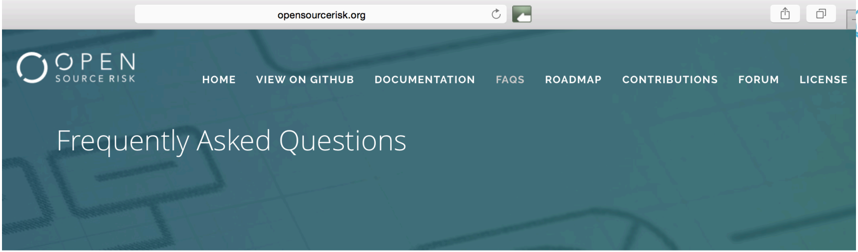
opensourcerisk.org



General

+ What is Open Source Risk Engine?
+ What is QuantLib?
+ Is there a user guide for ORE?
+ Are there any tutorials for ORE?
+ Is there a technical document describing ORE?
+ What is it written in?

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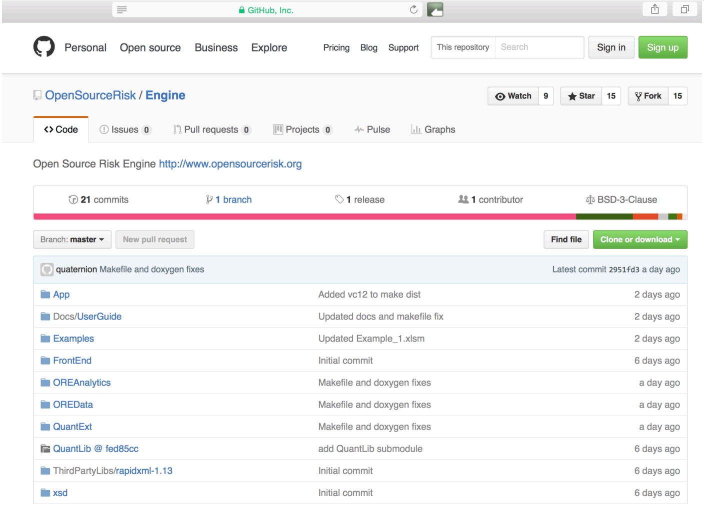
github.com/OpenSourceRisk/Engine



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Risk Management

Analytics Scope

Portfolio pricing and cash flow projection

Derivative portfolio analytics based on a Monte Carlo simulation framework

- Credit exposure evolution with netting and collateral (EE, EPE, EEPE, PFE) supporting regulatory capital charge calculation under internal model methods
- Collateral modeling with Dynamic Initial Margin (DIM)
- Derivative value adjustments (CVA, DVA, FVA, COLVA, **MVA**)
- Market risk measures

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Roadmap

Analytics:

- SA-CCR, the new standard for derivatives capital
- Sensitivity analysis and stress testing
- Parametric VaR and initial margin methods

Asset classes and simulation models:

- Credit simulation, credit derivatives and loan products
- Default risk modeling and credit portfolio analysis
- Inflation simulation and inflation derivatives
- Equity simulation, equity derivatives
- Commodity simulation, commodity derivatives

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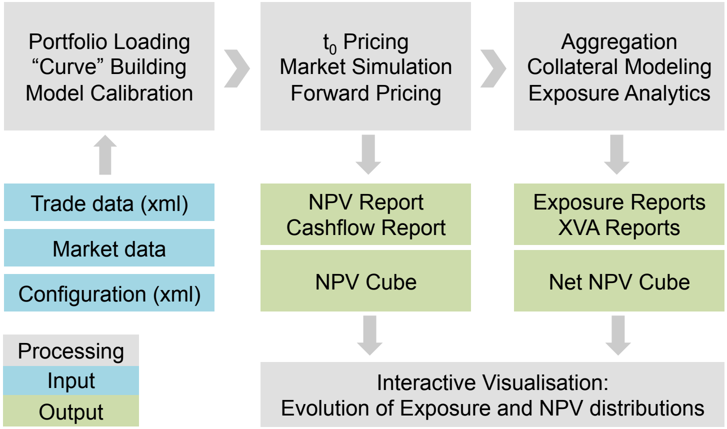
Data Flow



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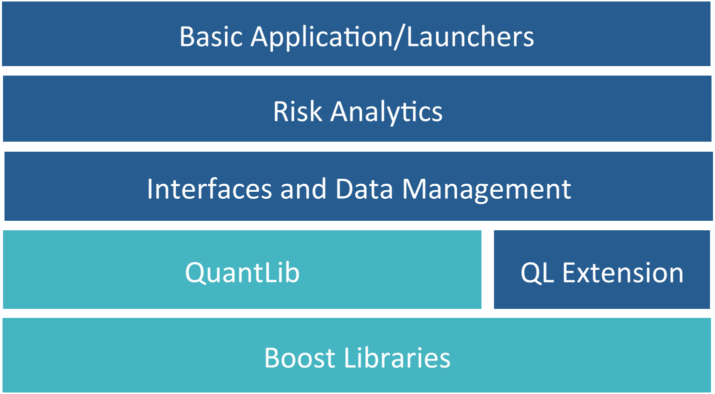
Components



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Open Source Risk Engine

Dynamic Initial Margin and Margin Value Adjustment

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Initial Margin

The introduction of Initial Margin (**IM**) posting in non-cleared OTC derivatives business reduces residual credit exposures and associated value adjustments, **CVA**/**DVA**.

On the other hand, it introduces additional funding cost. The value of the latter is referred to as **MVA** (Margin Value Adjustment).

To quantify these two effects one needs to model IM under future market scenarios, *Dynamic Initial Margin* (**DIM**).

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Margin Value Adjustment

Given the state-dependent dynamic initial margin $DIM(t)$, we can compute the associated MVA in analogy to CVA/DVA:

$$MVA = \sum_{i=1}^{n} (f_b - s_I)\, \delta_i\, S_C(t_i)\, S_B(t_i) \times \mathbb{E}^N \left[DIM(t_i)\, D(t_i) \right]$$

with

- borrowing spread f_b as in FVA calculation
- spread s_I received on initial margin
- $S_{B,C}(t)$ cumulative survival probability of the two parties
- $D(t)$ stochastic discount factor

and both spreads relative to the cash collateral rate.

DIM via Regression

Consider the netting set values $NPV(t)$ and $NPV(t+\Delta)$ one margin period of risk Δ apart.

Let $F(t,t+\Delta)$ denote cumulative netting set cash flows between time t and $t+\Delta$, converted into the NPV currency.

Let $X(t)$ then denote the *clean* netting set value change during the margin period of risk, i.e. excluding cash flows, in that period:

$$X(t) = NPV(t+\Delta) + F(t,t+\Delta) - NPV(t)$$

ignoring discounting/compounding over the margin period of risk.

DIM via Regression

Task: Find the distribution of $X(t)$ and pick a high (99%) quantile to determine the Initial Margin amount for each time t and conditional on the 'state of the world' at time t.

Simplify:

- Estimate the conditional variance of $X(t)$, $\mathbb{V}(t) = \mathbb{E}_t[X^2] - \mathbb{E}_t^2[X]$, by regression
- Assume a normal distribution of $X(t)$
- Scale the standard deviation of $X(t)$ to the desired quantile

Which regressors? Which basis functions?

DIM via Regression: Simple Swap

Simple swap pricing, notional 1:

$$NPV = \sum_{i=1}^{n} c\, e^{-z\, t_i} + e^{-z\, t_n} - 1$$

$$\Delta NPV \approx \frac{\partial NPV}{\partial z}\, \Delta z$$

$$\frac{\partial NPV}{\partial z} = -\sum_{i=1}^{n} c\, t_i\, e^{-z\, t_i} - t_n\, e^{-z\, t_n}$$

$$\frac{\partial NPV}{\partial z} = -D(z) \times (NPV + 1)$$

with ‘Duration’

$$D(z) = \frac{\sum_{i=1}^{n} c\, t_i\, e^{-z\, t_i} + t_n\, e^{-z\, t_n}}{\sum_{i=1}^{n} c\, e^{-z\, t_i} + e^{-z\, t_n}}$$

weakly depending on z (if $n > 1$) and when z is in a realistic range

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DIM via Regression: Simple Swap

Variance and Standard Deviation of NPV moves:

$$\mathbb{V}[\Delta NPV] \approx \left(\frac{\partial NPV}{\partial z}\right)^2 \underbrace{\mathbb{V}[\Delta z]}_{=\sigma^2 \Delta t}$$

$$\approx D^2 \times (1 + NPV)^2 \times \sigma^2 \Delta t$$

$$= D^2 \times (1 + 2NPV + NPV^2) \times \sigma^2 \Delta t$$

The main z-dependence is in $NPV(z)$

DIM via Regression: Recipe

The Swap example suggests first or second order polynomials as basis functions.

For a single currency Swap, NPV may work as regressor, but we rather use a rate instead, for the following reason:

Extension to multi-currency portfolios (of Swaps) then by

- multi-dimensional regression
- extending the list of regressors to several rates (one for each economy) and relevant FX spot rates

Demo

Run Swap DIM/MVA example (Example_13)

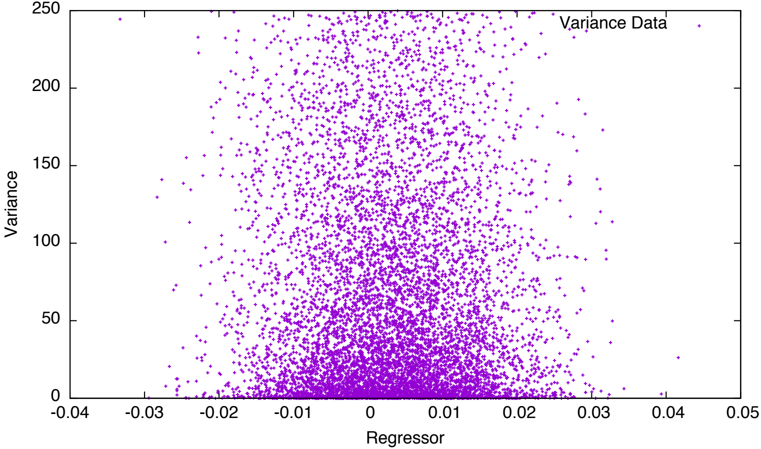
Validation: Dynamic Delta-Gamma VaR (ORE+)

Methodology:

- Compute sensitivities (deltas and gammas) under scenarios, analytically during instrument pricing
- Compute model-consistent covariance matrix (in ORE's evolution model just time-dependent, not scenario-dependent)
- Delta-Normal VaR under scenarios, quantile estimate via simple scaling
- Delta-Gamma VaR under scenarios, quantile estimate using Cornish-Fisher expansion using first four moments

DIM via Regression: EUR Swap

ATM Vanilla Swap in EUR, 10Y maturity, flat market, regression in 4Y



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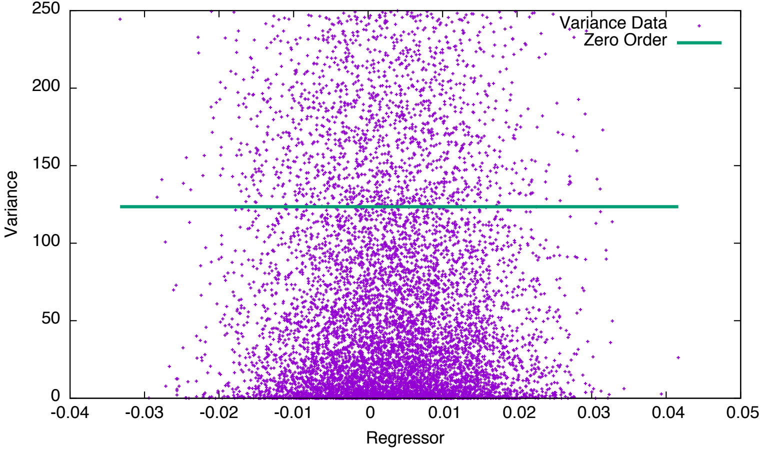

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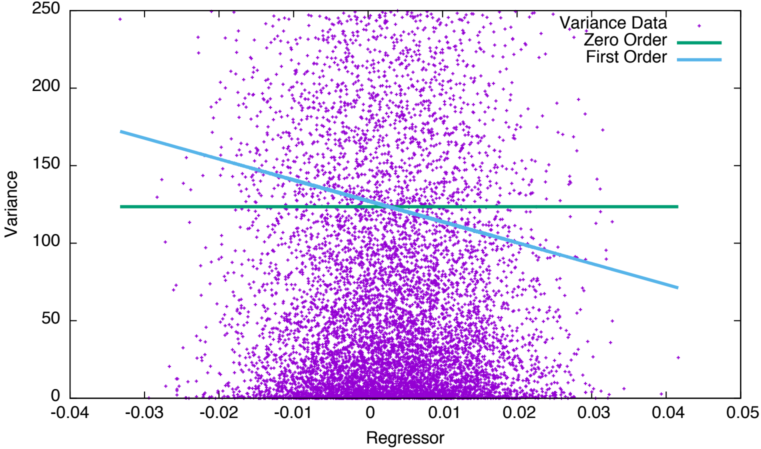

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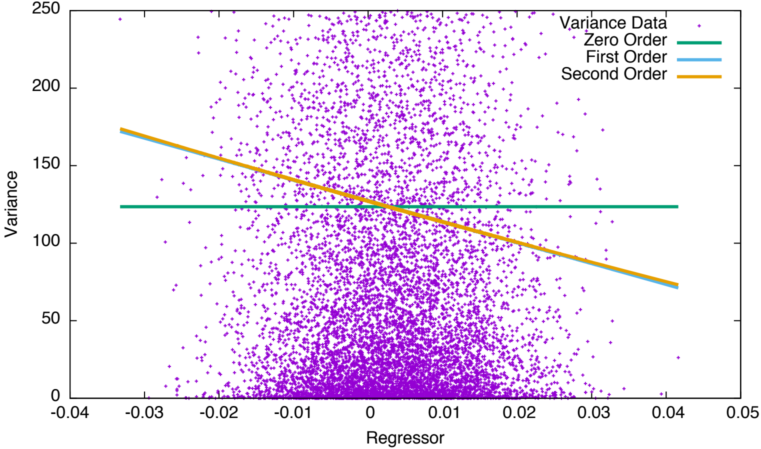
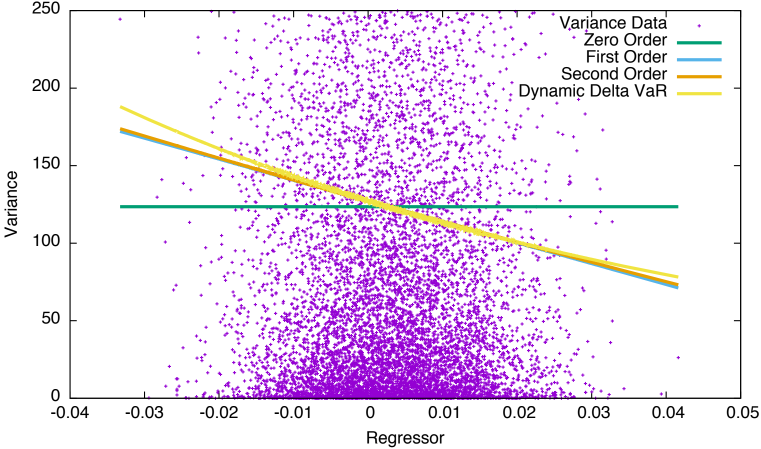


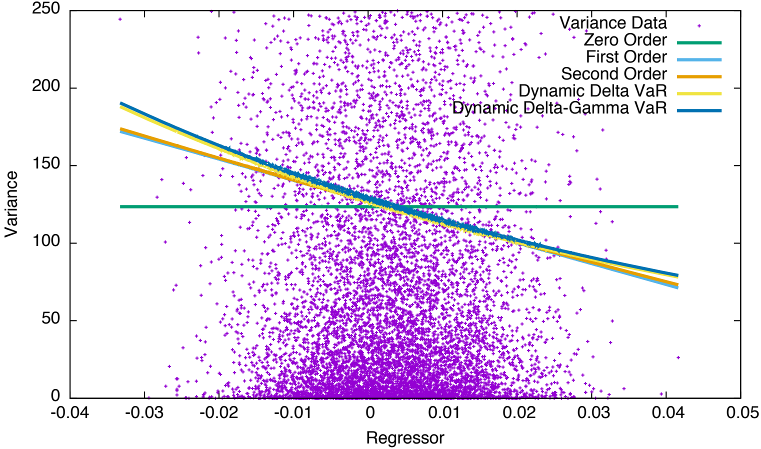
Dynamic Delta VaR

ATM Vanilla Swap in EUR, 10Y maturity, flat market, regression in 4Y



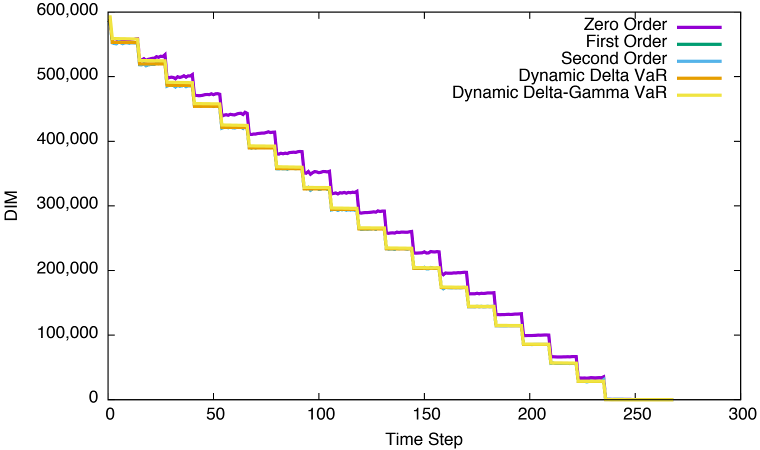
Dynamic Delta Gamma VaR

ATM Vanilla Swap in EUR, 10Y maturity, flat market, regression in 4Y



Evolution of Expected DIM

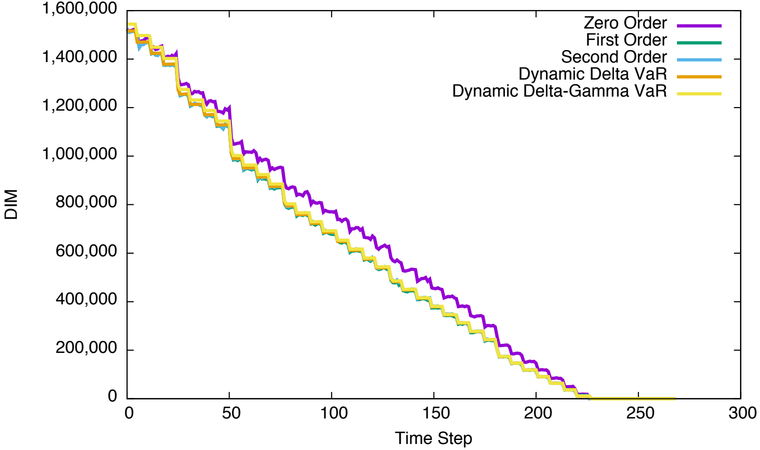
ATM Vanilla Swap in EUR, 10Y maturity, flat market, regression in 4Y



Evolution of Expected DIM: USD Swap

Vanilla Swap in USD, 10Y maturity

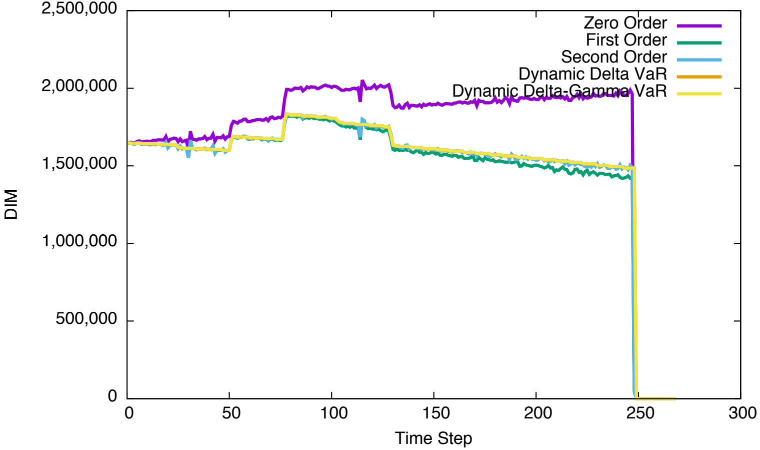
Two Regressors: USD/EUR FX, USD-LIBOR-3M (since NPV in EUR)



Evolution of Expected DIM: USD/EUR CC Swap

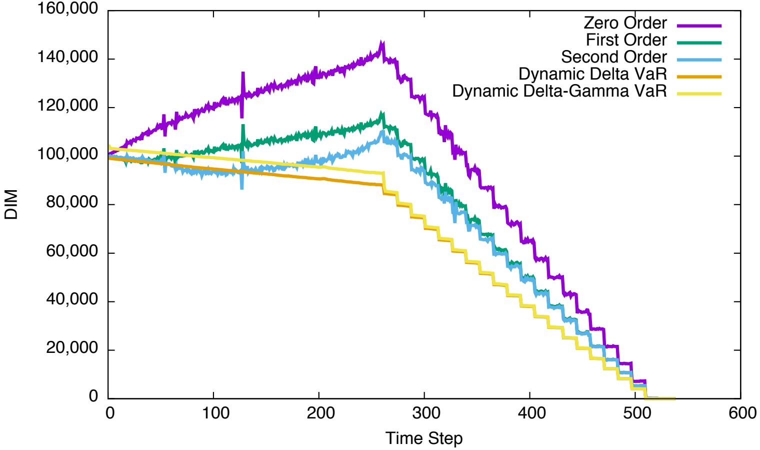
Cross Currency EUR/USD Swap, 10Y maturity

3 Regressors: USD/EUR FX, USD-LIBOR-3M, EUR-EURIBOR-3M



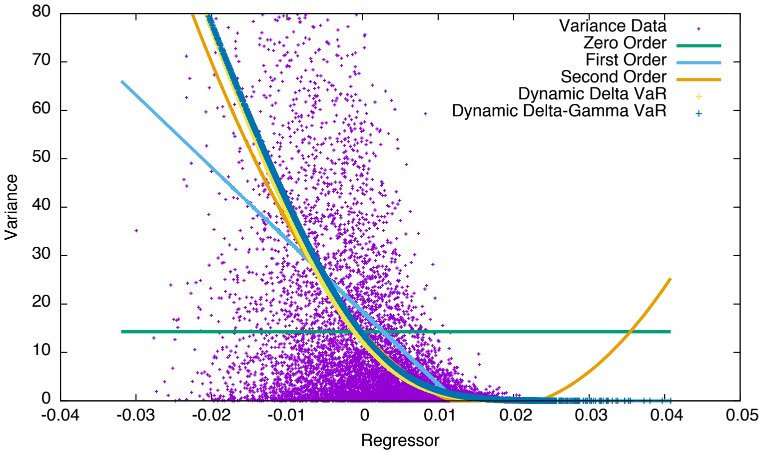
Evolution of Expected DIM: European Swaption

European Swaption in EUR, 10Y expiry, physical, 10 year swap
One Regressor: EUR-EURIBOR-3M



DIM Regression: European Swaption

European Swaption in EUR, regression in 4Y (**before expiry**)
One Regressor: EUR-EURIBOR-3M



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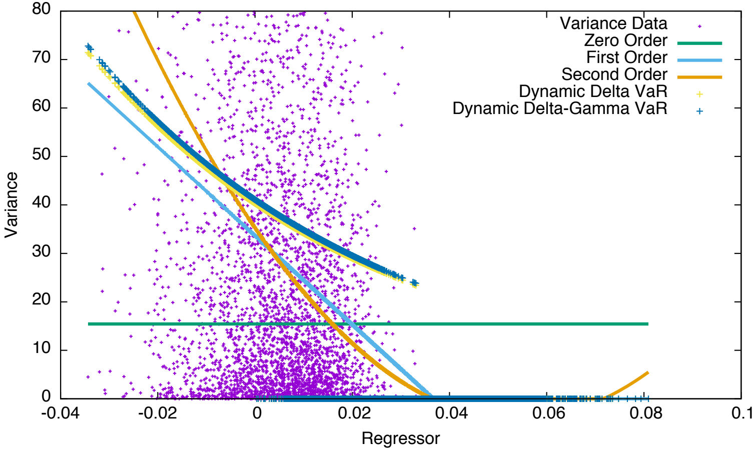
DIM Regression: European Swaption

European Swaption in EUR, regression in 12Y (**beyond expiry**)
One Regressor: EUR-EURIBOR-3M



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DIM Regression

Preliminary summary (work in progress):

- ORE supports DIM/MVA via single- and multi-dimensional regression
- Regression DIM validated with Dynamic Delta(-Gamma) VaR in ORE+
- Excellent agreement for single currency and cross currency Swaps with first and second order polynomials as basis functions
- Reasonable agreement for European Swaptions before expiry, second order polynomials better than first order
- Discrepancy from Dynamic Delta VaR increases beyond expiry in case of physical settlement, similar ’performance’ of first and second order polynomials

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DIM Regression

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SSRN paper to appear shortly with further benchmarking results.

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Conclusion

ORE is available now, free, open source

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ORE provides exposure simulation and almost all XVAs

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Next: complete asset class coverage, extend the analytics scope

Conclusion

ORE is available now, free, open source

ORE provides exposure simulation and almost all XVAs

Next: complete asset class coverage, extend the analytics scope

Get it, use it, comment on it, add to it

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Next Step: Q1 Release

1. Equity products
2. Inflation products
3. Market Risk
   - Sensitivity analysis
   - Stress testing
   - Parametric and Historical Simulation VaR/Expected Shortfall

Thank you

Quaternion
Risk Management

Firm locations and details

Quaternion™ Risk Management is based in four locations:

Ireland
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Ireland,

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London
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London E14 5DY.
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24th floor
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