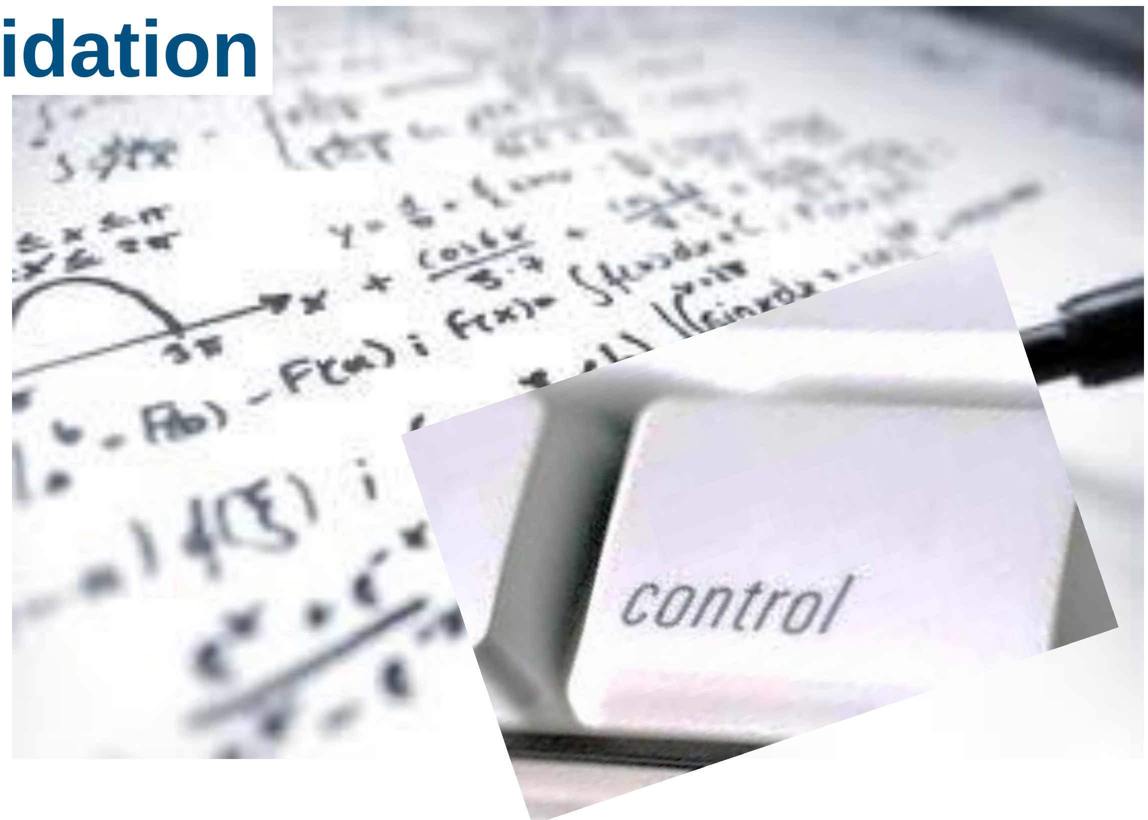
Nordea

Marcus Evans

Pricing Model Validation



Jens Jakob Baltzer Rasmussen,
Head of Model Validation

London, September 9th, 2013

Agenda

- The scope of (pricing) model validation
- Post-implementation monitoring
- Model risk governance and model reviews

The scope of (pricing) model validation

Any “model” that could - directly or indirectly - result in a loss for the institution or errors in reporting of should in principle be validated and controlled. This (may) include:

- Models (and systems) used for official PL, risk (desk level) and reporting
- Local spread sheets used by traders to calibrate certain model input
- Decision supporting tools (e.g. pricing tools not used in official reporting)

For resource reasons we usually focus only on those models hitting our “official” valuation and risk.

Other types of model risks (e.g. calibration spread sheets) may be mitigated through the design and implementation of effective controls (input/model/output).

Expectations in OCC guideline on both model *development*, *validation* and on-going *monitoring*.

The scope of (pricing) model validation

Validation and control efforts and rigor should be commensurate with the level of model risk posed by the a model when applied to a particular product or task.

Level of model risk:

Complexity

- Complexity of dynamics
- Use of elaborate numerical schemes
- Reliance on model assumptions
- Use of unobservable input
- Non-standard approximations

✖

Exposure

Economic materiality of the models uncertainty

- Size of the business
- Portfolio sensitivity to market input

✖

Reliance

The extend to which the model's outcome influence the institutions financials or decision processes

- Direct feed to PL and risk?
- Decision support (along with several other models?)

The scope of (pricing) model validation

The model triplet:

1. Underlying dynamics: X
2. Contractual payoff: $f(X)$
3. Expectations: $E[f(X)]$

Model risk relates to the combinations of 1, 2 and 3.

These components are subject to different types of risks and require different methods for testing

The *value approach* (Derman) relates primarily to (1) wile the *price approach* (Rebonato) relates primarily to (3). Model risk is minimized when the two approaches meet, i.e. when you are able to explain *observable* prices using *realistic* dynamics!

Focus validation and control efforts on model *use* rather than the model itself!

From Validation to Model Risk Control

We distinguish between two different categories of model risk:

Model *choice* risks

Risks related to the choice of model for a particular product

- Model application
- Market standard
- Model observability
- Parameter specification

Model *consistency* risks

Risks related to the internal consistency of a particular model choice

- Mathematical derivation
- Implementation
- Payoff representation
- Numerical approximations

Nordea

Model Risk Control

A lot of different tests are in our tool box:

- ✓ Math review
- ✓ Code review
- ✓ Payoff review
- ✓ Arbitrage tests
- ✓ Convergence analysis
- ✓ “Bump-and-run”
- ✓ PL vs. Risk reconciliation
- ✓ Calibration: Fit and smoothness
- ✓ Distribution of underlying
- ✓ Sensitivity analysis
- ✓ Benchmark against other models
- ✓ Benchmark against external price/value
- ✓ Test validity of assumptions
- ✓ “Market intelligence”

The tests differ wit respect to complexity and generality (e.g. trade, product or model level)

Also they differ with respect test outcomes to being predominantly qualitative or quantitative

Model Risk Control

Properties of model tests

Test	Generalization	Complexity	Quantitative	Object
Math review	medium	high	no	model
Code review	low	medium	no	model
Script review	low	medium	no	trade
Arbitrage test	low	low	yes[a]	[?]
Convergence	high	low	yes	trade
Bump-and-run	high	low	yes	trade
PL reconciliation	high	medium	yes	trade
Calibration fit	medium	medium	yes	trade/model
Calibration stability	medium	medium	yes	trade/model
Distr. of underlying	medium	high	yes[b]	model
Sensitivity analysis	high	low	yes	trade
Benchmark internal	medium	low	yes	trade
Benchmark external	medium	low	yes	trade/prod.
Assumption test	low	high	yes[c]	model
Market intelligence	low	high	no	model

[a] Even if the outcome of an arbitrage test is either fail or pass, in practise it is often reasonable to accept arbitrage opportunities that are small, e.g. compared to bid/offer spread. Hence the test can be seen as semi-quantitative.

[b] Various quantitative measures can be used to represent the distribution or compare distributions to each other.

[c] As with arbitrage tests, small violations of assumptions may sometimes be acceptable in practise, why this is often a semi-quantitative test.

Model Risk Control

Potential causes to fail model *choice* tests

	Choice				External	Secondary
	Choice			Specification		
	non-consensus	too simple	unobservable	specification	test errors	Calibration fit
Math review					x	
Code review					x	
Script review					x	
Arbitrage test					x	
Convergence					x	
Bump-and-run					x	
PL reconciliation					x	
Calibration fit	x	x			x	
Calibration stability	x	x			x	
Distr. of underlying		x			x	
Sensitivity analysis			x		x	
Benchmark internal					x	x
Benchmark external	x			x	x	
Assumption test					x	
Market intelligence	x				x	

Model Risk Control

Potential causes to fail model *consistency* tests

	Consistency						
	Derivation	Implementation	Payoff	Arbitrage	Numerical approx.		
	math error	code error	script errors	arbitrage	convergence	calibration tech	risk calculation[a]
Math review	x						
Code review		x					
Script review			x				
Arbitrage test	x	x	x	x	x		
Convergence	x	x	x		x		
Bump-and-run	x	x	x		x		x
PL reconciliation	x	x	x		x		x
Calibration fit	x	x	x			x	
Calibration stability	x	x	x			x	
Distr. of underlying	x	x			x		
Sensitivity analysis	x	x	x				
Benchmark internal	x	x	x		x		
Benchmark external	x	x	x		x		
Assumption test	x	x	x				
Market intelligence							

Model Risk Control

Using the properties of the different tests and the potential failure causes, one can *in principle* choose the optimal test strategy in the model validation processes when operating under constraints on e.g. time, human resources, data availability, model availability etc.

In practice we distinguish between ***approval*** (initial validation) and ***control*** (ongoing validation)

Model *approval*

- Examine variety of scenarios (including stressed scenarios)
- Not essential to automate
- Include verification of math, code/implementation, assumptions and examination of alternatives
- Identify model weaknesses

Model *control*

- Focus on actual (market) scenarios
- Need to automate
- Focus on “performance” of chosen model
- Design particular controls targeting identified model weaknesses

Model Risk Control: Some examples

- Convergence analysis
  - ✓ Examination of the monte carlo properties of a particular risk figure
- “Bump & run” analysis
  - ✓ Examination of the implementation and accuracy of a particular risk figure
- PL vs. risk reconciliation analysis
  - ✓ Examination of the ability to “predict” PL from risk (Taylor expansion)
  - ✓ Examination of drivers for PL recon errors
- Calibration analysis
  - ✓ Fit to market
  - ✓ Parameter smoothness

Common for these tests are that they are of medium/low complexity and medium/high generality → A high “payoff” on test efforts!

Model Risk Control: Convergence analysis

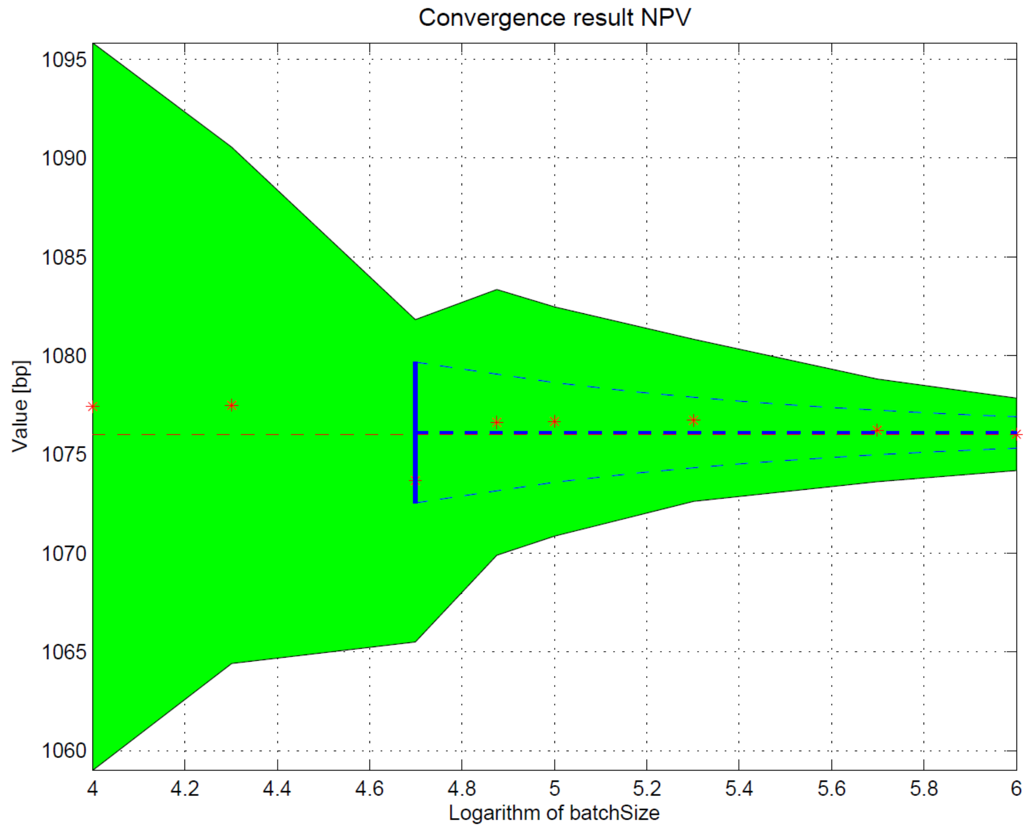
Examine the distribution of MC estimator:

Increasing number of simulations

Running simulation many times (changing seeds)

Notice the effect of an imposed variance reduction – this is not seen from model output MC error.

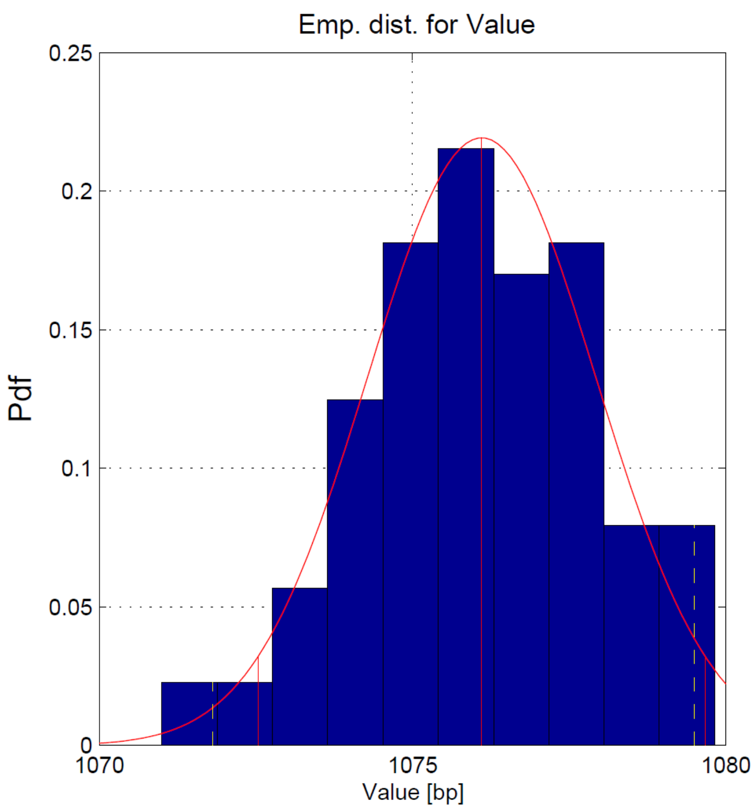
Note that the "seeds analysis" can run on either trade, portfolio or model level.

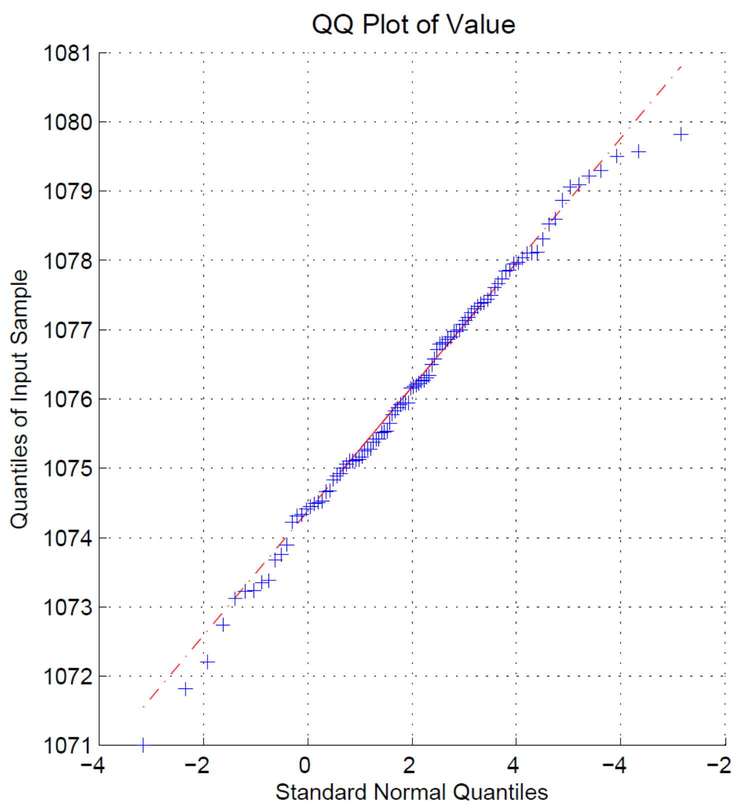


Nordea

Model Risk Control: Convergence analysis

Distributional properties of MC estimator

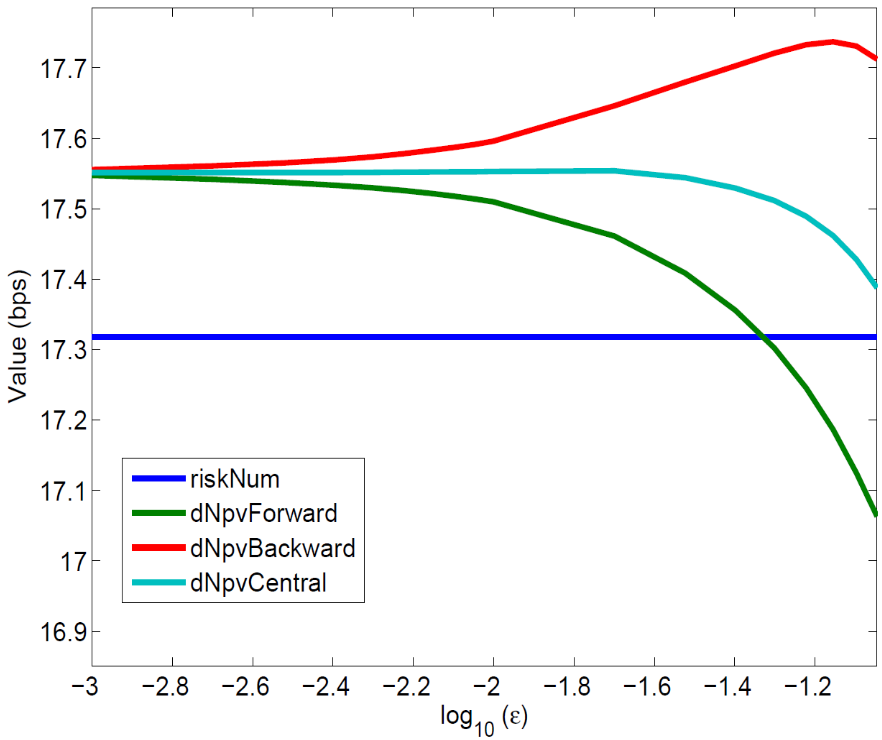


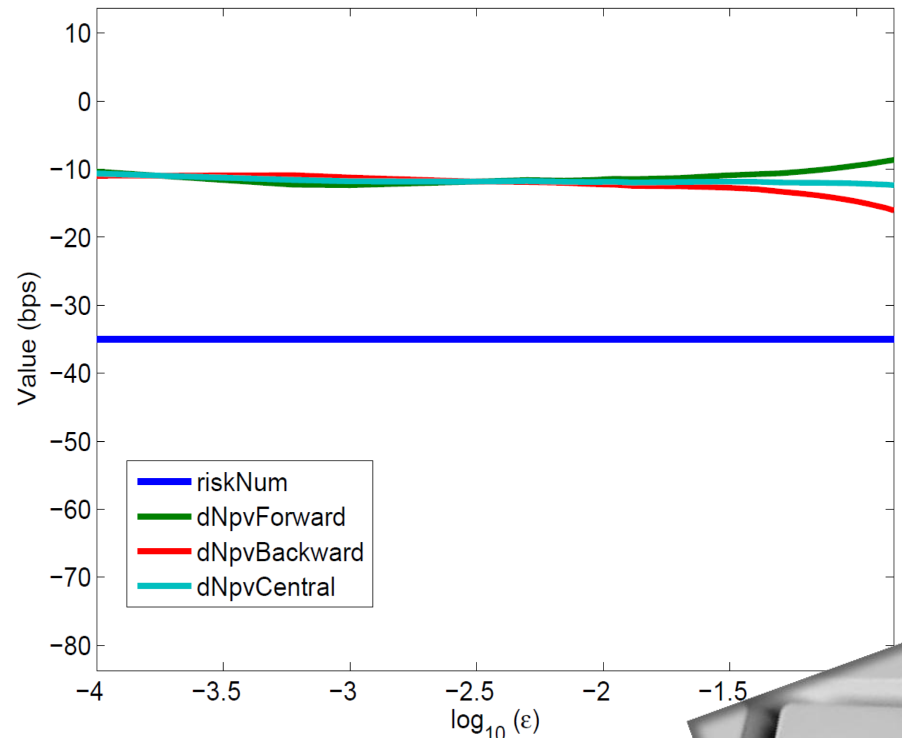


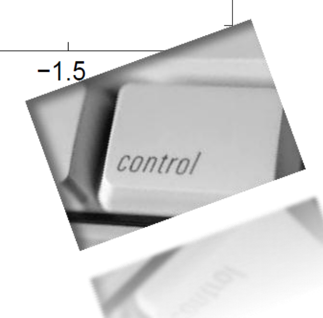
Model Risk Control: Bump & run

Reconciling greeks against simple bump of input and recalculation of NPV. A simple method to simultaneously examine:

- Implementation of risk figure (left figure indicates correct implementation of “forward delta” – left indicates error)
- Choice of numerical shift size
- Convexity in payout





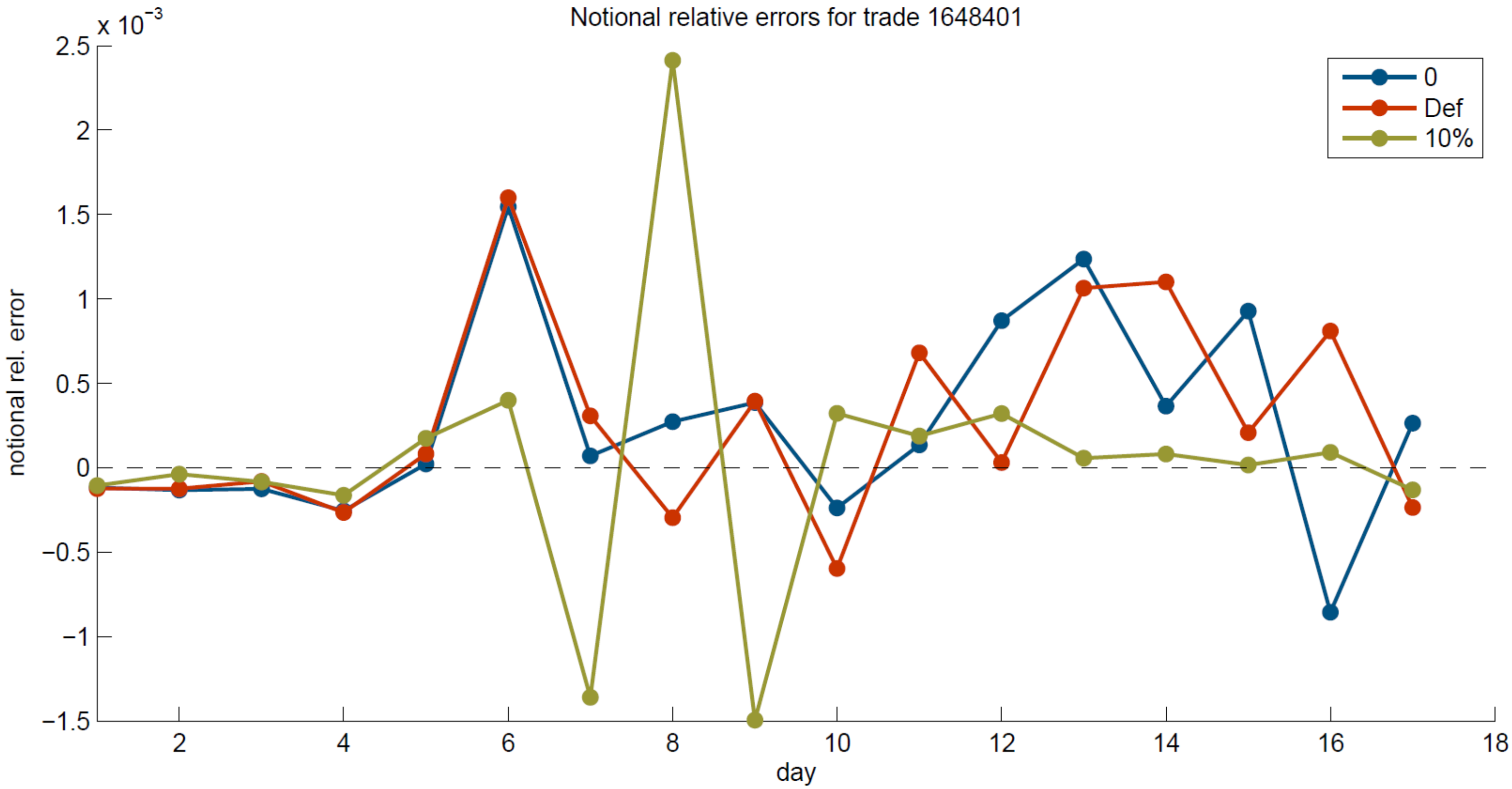


Nordea

Model Risk Control: PL vs. risk reconciliation

Errors from PL recon for different levels of internal parameter regularization

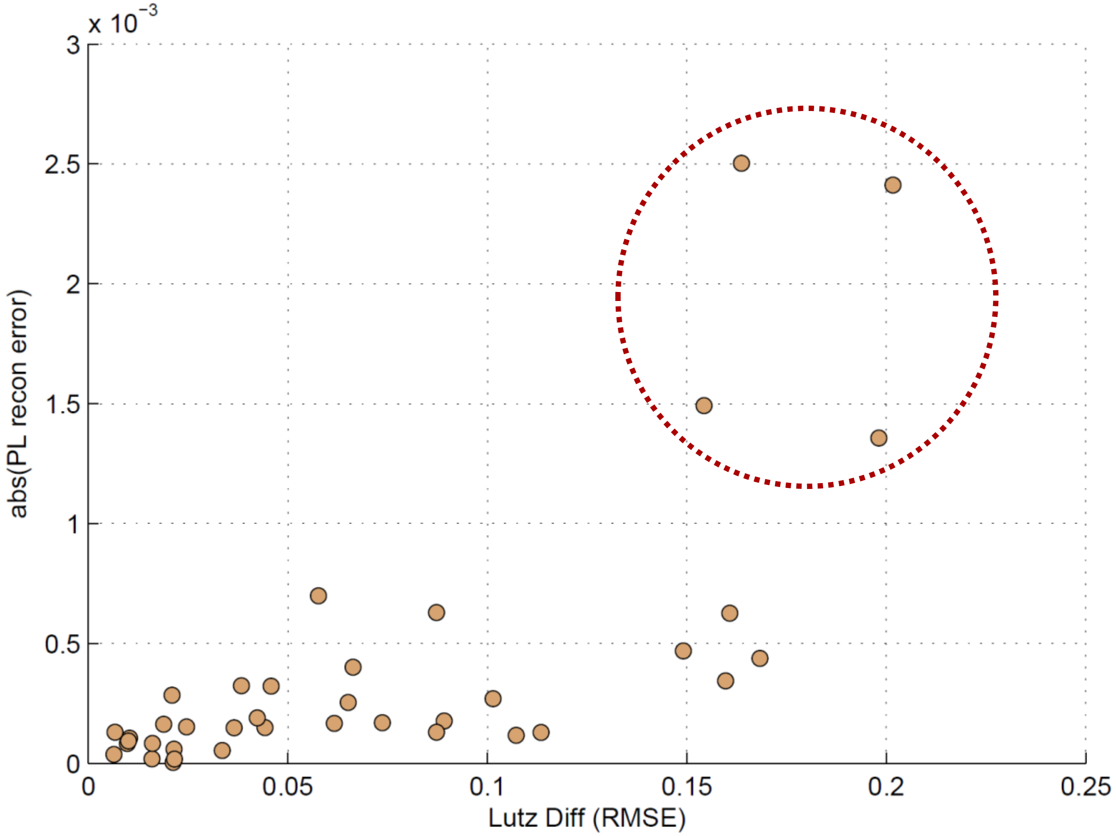
- Measured in relation to notional (i.e. prediction error in bp price terms)
- On most days higher degree of regularization gives smoother PL reconciliation…
- …although some distinct jumps are seen on a few dates. What is causing this?



Model Risk Control: PL vs. risk reconciliation

An attempt to explain noise in PL reconciliation:

- Plotting absolute PL recon error against a measure of internal model parameter (in)stability
- Internal parameter stability: Day-to-day changes of parameter levels in a parameterized correlation matrix
- Apparently largest PL recon errors coincide with parameter instability



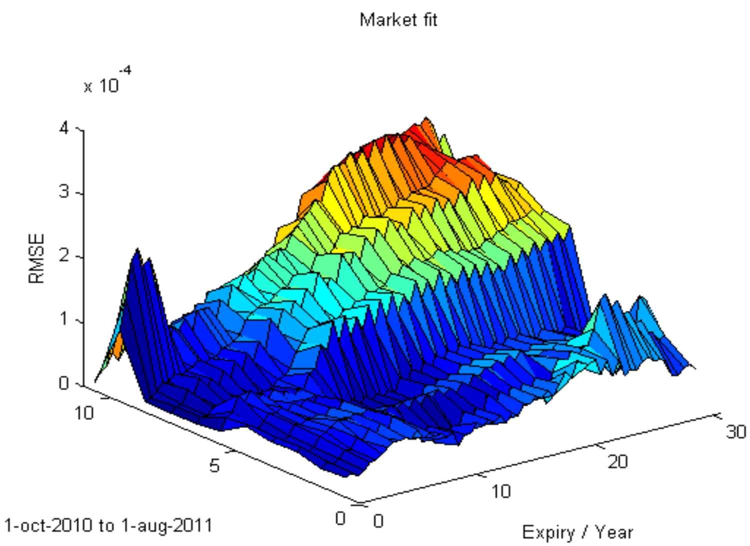
Nordea

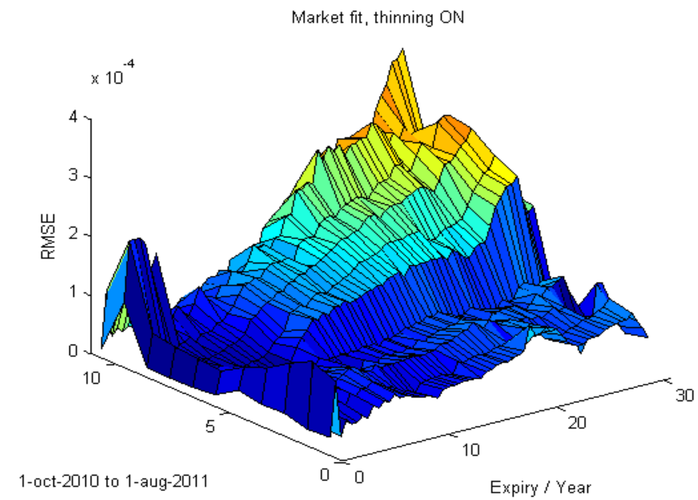
Model Risk Control: Calibration fit

Comparing two different calibration strategies for a Cheyette type IR model

- Model calibrates time-dependent parameters to a strip of swaption prices
- Analyze price deviations (fit to input)
- Left figure based on interpolating swaption prices *before* calibration (i.e. interpolating in input prices)
- Right figure based on interpolating swaption prices *after* calibration (i.e. interpolating in model parameters)

→ Fit quality seems reasonably unaffected



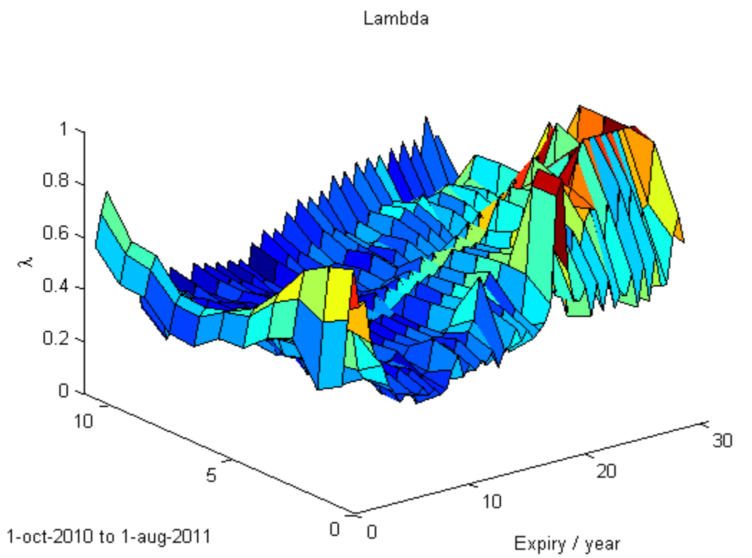


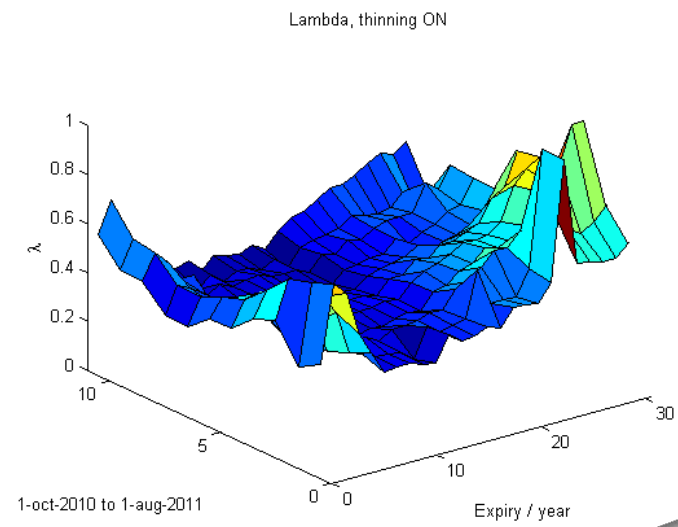
Model Risk Control: Calibration smoothness

Comparing two different calibration strategies for a Cheyette type IR model

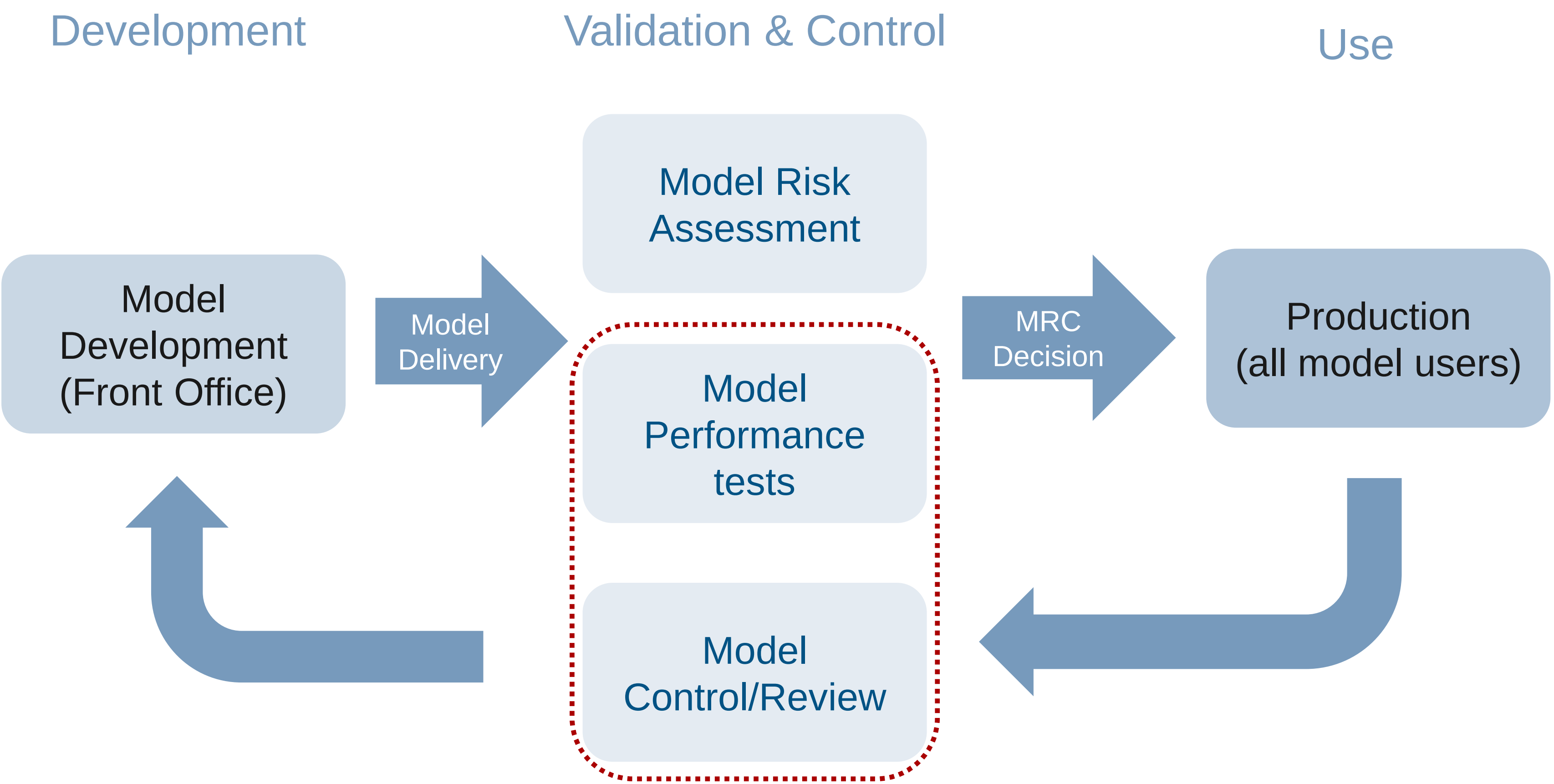
- Model calibrates time-dependent parameters to a strip of swaption prices
- Analyze behavior of internal model parameters (in this case parameter controlling the volatility level)
- Left figure based on interpolating swaption prices *before* calibration (i.e. interpolating in input prices)
- Left figure based on interpolating swaption prices *after* calibration (i.e. interpolating in model parameters)

→ Parameter smoothness very different. This may have significant effect on price and greeks of exotic structures





Model Risk Governance



Model **R**isk **C**ommittee decides on approval conditions and set action points to be completed before model deployment

Model Risk Governance: Roles & Responsibilities

Model Development:

- Develop and maintain models appropriate for business needs
- Documents and tests all new models and model changes
- Facilitate reviews of production models
- Assist model users (traders, risk managers, controllers)

- Profiles:
  - Math
  - Efficient coding
  - Micro perspective
  - → Quants

Model Risk Governance: Roles & Responsibilities

Group Model Validation:

- Independent validation and risk assessment of new and changed models
- Submit risk assessment report to senior management (MRC)
- Maintain records of all model validation documentation
- Develop and operate risk models (e.g. VaR)

- Profiles:
  - Math
  - Aggregation of risks
  - Macro perspective
  - → Quants/Risk Managers

Model Risk Governance: Roles & Responsibilities

Business Model Validation/Model Risk Control:

- Tests performance of new and changed models
- Design and operate frameworks for monitoring/controlling of model performance as well as methods for adjusting and reserving for model deficiencies and uncertainties
- Operational unit for model risk control
- Conduct regular reviews of production models

- Profiles:
  - Math
  - Effective data handling
  - Portfolio/market perspective (micro and macro)

  → Quants/Controllers: “Quantrollers”

Model Risk Governance: Roles & Responsibilities

Model Risk Committee (senior management):

- Approve the use of new and changed models within a specified scope (model risk appetite) and attendant control regime
- Set action points to be completed before model deployment
- Grant temporary exemptions to allow the use of unapproved models to allow model use beyond approved scope
- Escalation body for model risk control and review findings

- Profiles:
  - Senior management
  - *Not* experts on details

Model Risk Governance: The review cycle

A sound and sustainable management of model risk requires a dynamic *trough-the-life-cycle* monitoring of the models performance and the environment in which it is applied. In this respect the on-going model performance monitoring is supplemented by *model reviews*.

The aim of the model review is to ensure the transparency of the model and its use as well as giving and up-to-date recommendation as input to senior management (MRC) decisions about the model approval status and conditions.

The review cycle:

	Complexity	**Exposure**	**Reliance**	**Review frequency**
Tier 1	Complex	High	High	**Annual**
Tier 2	Complex	High	Low	**Every 2nd year**
	Complex	Low	High	
	Standard	High	High or Low	
Tier 3	Complex	Low	Low	**Every 3rd year**
	Standard	Low	High or Low	

Summary

- Many different sources of model risk
- Many different qualitative and quantitative tests can be applied
- Need for dynamic *through-the-life-cycle* model risk management
- A lot of simple tests can be applied in on-going model performance monitoring
- Strong governance is essential

Thank you.

Jens Jakob Baltzer Rasmussen,

Risk & Valuation Control, Model Validation

jens.rasmussen@nordea.com

Opinions expressed in this presentations are the views of the author and do not reflect the views and opinions of Nordea