LDA at Work: Deutsche Bank's Approach to Quantifying Operational Risk

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A Passion to Perform. Deutsche Bank

Agenda

For more information:

F. Aue and M. Kalkbrener (2006).
LDA at work: Deutsche Bank's approach to quantifying operational risk.
J. Operational Risk, 1(4), 49-93.

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AMA Model Development at Deutsche Bank

Timeline

1999 Systematic collection of loss data

2000 Economic capital with LDA

- Top-down model: loss distribution at Group level, capital allocation with risk indicators
- Internal and external loss data
- Qualitative adjustment with Incentive Scheme

2001 AMA project

2002 Development of AMA model

2003 Implementation of prototype

2004 EC test calculations with AMA model

2005 Official EC calculation with AMA model (starting Q2 05)

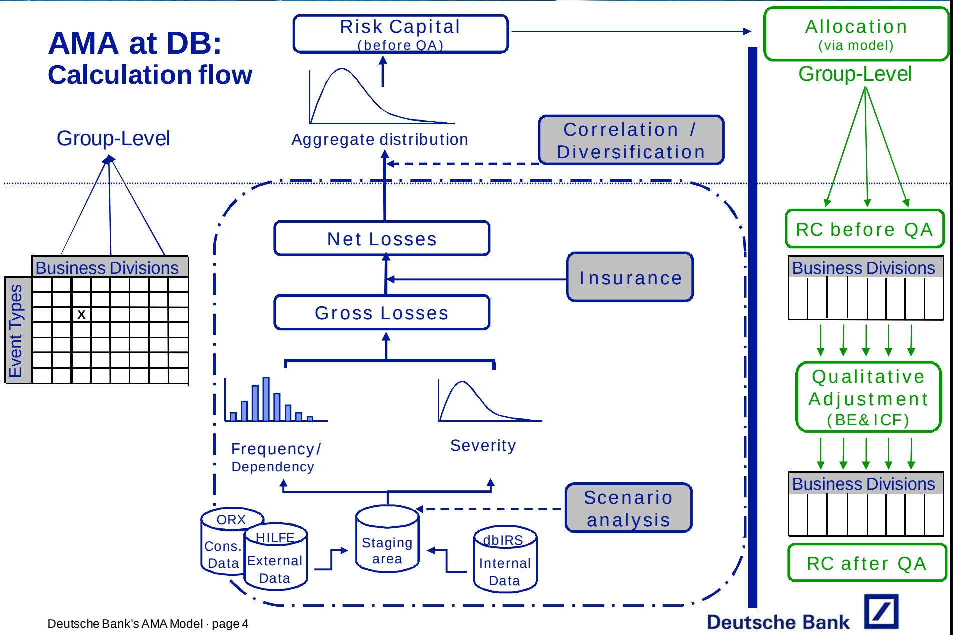
2006 Implementation of production engine

AMA application submitted in September

2007 Regulatory approval

2008 Joint EC and RC calculation with AMA model

AMA at DB:
Calculation flow



DB’s Business Line / Event Type Matrix

Basel Level 1	Internal Event Types	Business Lines						
		BL1	BL2	BL3	BL4	BL5	BL6	Group
Internal Fraud	Fraud							
External Fraud								
Damage to physical assets	Infrastructure							
Business disruption …								
Clients, Products, Business Practices	Clients, Products, Business Practices							
Execution, delivery, process management	Execution, delivery, process management							
Employment practices, workplace safety	Employment practices, workplace safety							

- Design criteria
  - comparable loss profile
  - same insurance type
  - same management responsibilities
  - availability of data
  - relative importance of cells
- Treatment of losses that cannot be assigned to a single cell
  - Group losses
  - Split losses

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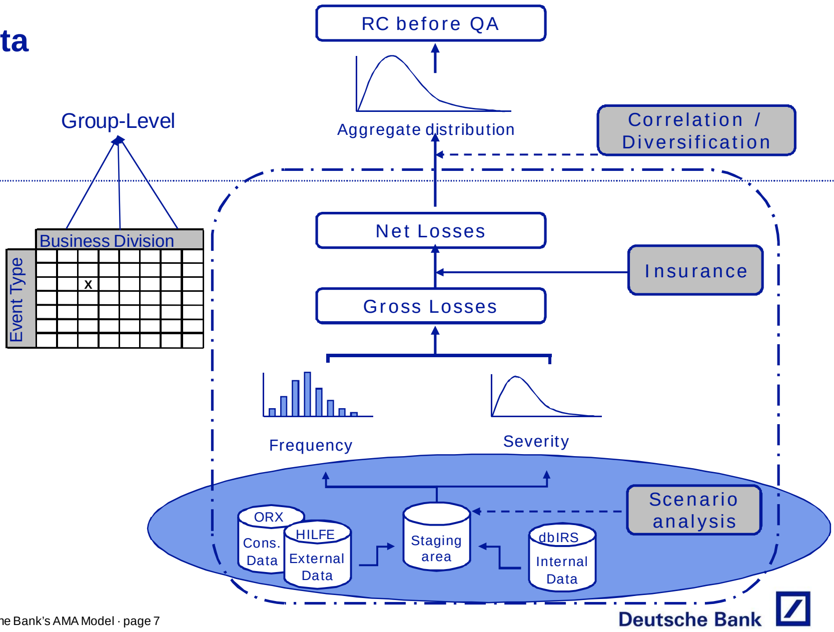
Data



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Data for Modelling Loss Distributions

Data sources

- Internal loss data
- Consortium data
- Commercial loss database
- Scenarios

Internal loss data is the most important data source

- Each firm's operational losses are a reflection of its underlying operational risk exposure
- Internal losses are used for
  - modelling frequencies (exclusively)
  - modelling severities
  - estimating correlations

Motivation for using external data and scenarios

- Additional information on severity profile, in particular on risk of unexpected losses (tails of severity distributions)

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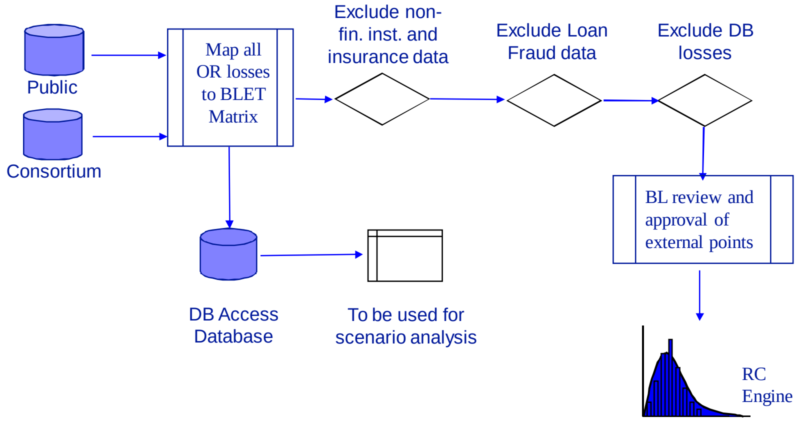
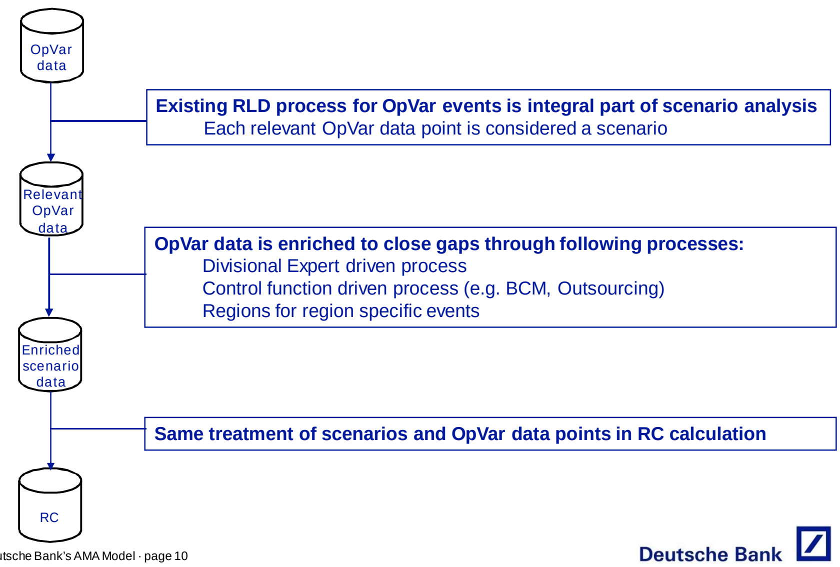
Creating a Relevant Loss Data Set



Scenarios are added as individual data points to relevant external losses

Scenario Analysis Process and Methodology



Biased External Loss Data

Scale Bias

- Operational risk is dependent on the size of the bank, i.e. the scale of operations
- The actual relationship between the size of the institution and the frequency and severity may be stronger or weaker depending on the particular OR category

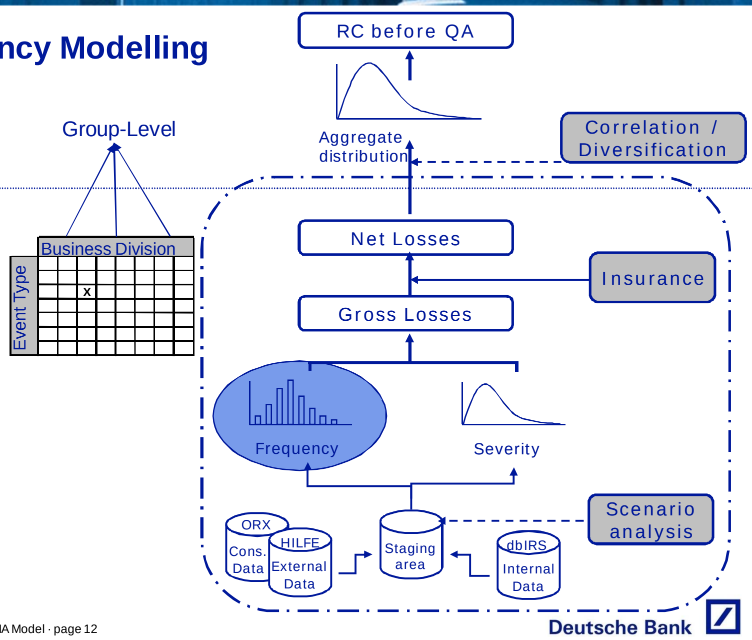
Truncation Bias and Data Capture Bias

- Collection thresholds are not uniform for different data sets
- Data is often captured with a systematic bias. This problem is particularly pronounced with publicly available data: there exists a positive relationship between the loss amount and the probability that the loss is reported
- The disproportionate number of large losses could lead to an estimate that overstates a bank's exposure to operational risk

Scaling in AMA at DB

- No correction of Scale Bias since it is considered less relevant for severity modeling
- Correction of Truncation Bias and Data Capture Bias

Frequency Modelling



Frequencies in AMA at DB

Data

Only internal loss data is used for calibrating frequency distributions:

- Internal loss data reflects DB's loss profile most accurately
- Difficult to ensure completeness of external data (essential for application in frequency calibration)
- Lower data requirements in frequency modeling (compared to severity modeling)

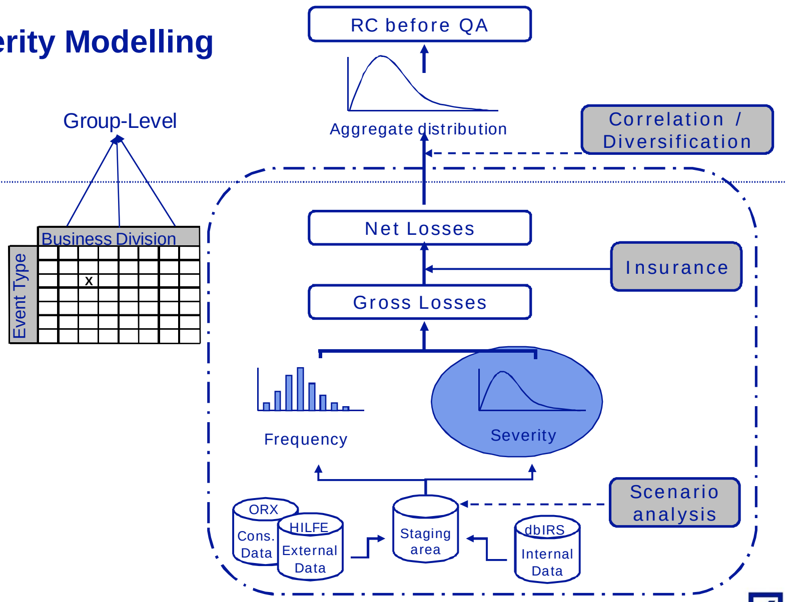
Implemented distributions

- Poisson (no dependence between occurrence of events in a cell)
- Negative Binomial (positive dependence)
- Selection algorithm based on statistical tests

Frequency distributions in official capital calculations

- Poisson in all cells
- Reason: negligible difference to combination of Poisson and Negative Binomial cells

Severity Modelling



Modelling Decisions

Range of distribution

- One distribution for the entire severity range
  or different distributions for small, medium and high losses?

Choice of distribution family

- Two-parametric distributions like lognormal, GPD
  or more flexible distribution families, i.e. three- or four-parametric,
  or even empirical distributions?
- One distribution family for all cells
  or selection of “best” distribution based on quality of fit?

Mixing internal and external data

- How much weight is given to internal and external data?
- How to combine internal and external data?

Severities in AMA at DB

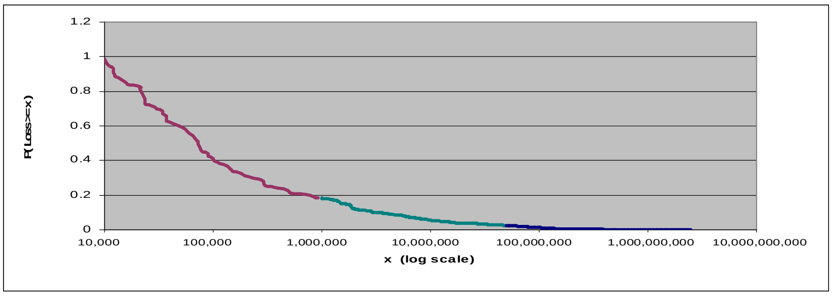
Range of distribution and choice of distribution family

- In many cells, data characteristics are different for small and big losses
- Different distributions for body and tail
  - Body: non-parametric (empirical) distribution
  - Tail: modified technique from Extreme Value Theory for tail modelling
- Empirical and parametric distributions are combined via a weighted sum applied to the cumulative distribution functions

Mixing internal and external data

- Internal data for calibrating body of distribution
- Internal and external data for calibrating tail

Core Idea: Piecewise Defined Severity Distributions



First section: given by empiric distribution of cell specific internal data

Mid section: given by weighted average of

- empiric distribution of cell specific internal data
- empiric distribution of cell specific external and scenario data

Tail section: given by weighted average of

- empiric distribution of cell specific internal data
- empiric distribution of cell specific external and scenario data
- parametric distribution calibrated on all data >= 50mn

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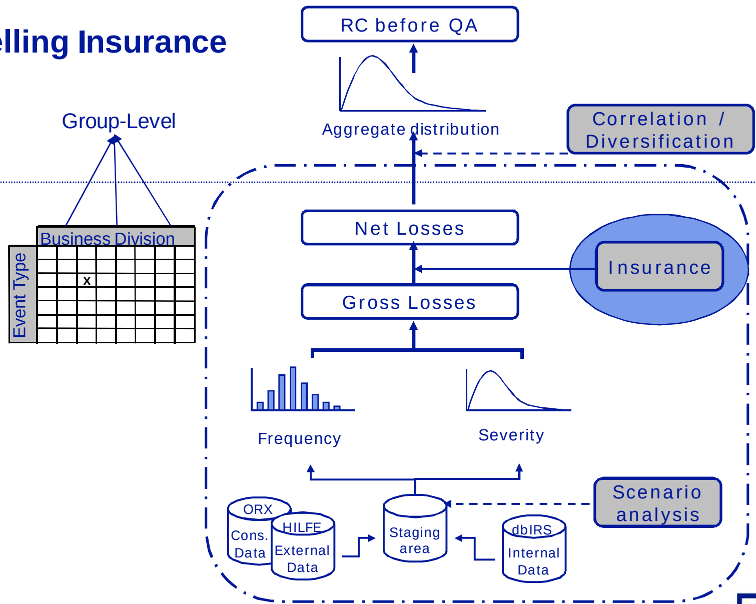
Modelling Insurance



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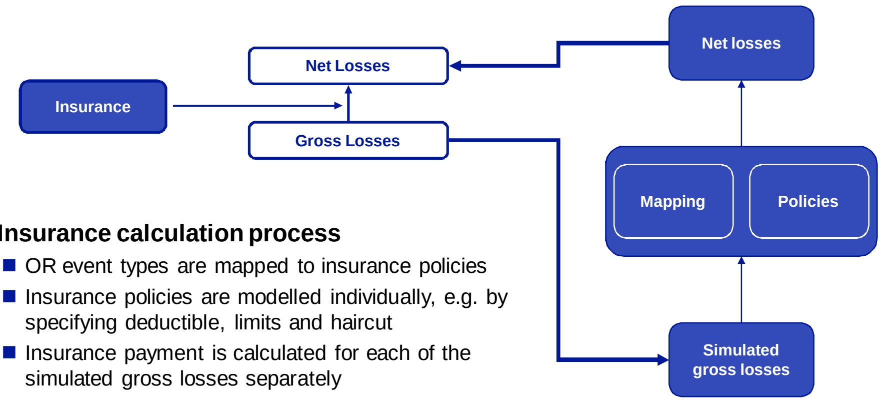
Insurance in AMA at DB



Insurance calculation process

- OR event types are mapped to insurance policies
- Insurance policies are modelled individually, e.g. by specifying deductible, limits and haircut
- Insurance payment is calculated for each of the simulated gross losses separately

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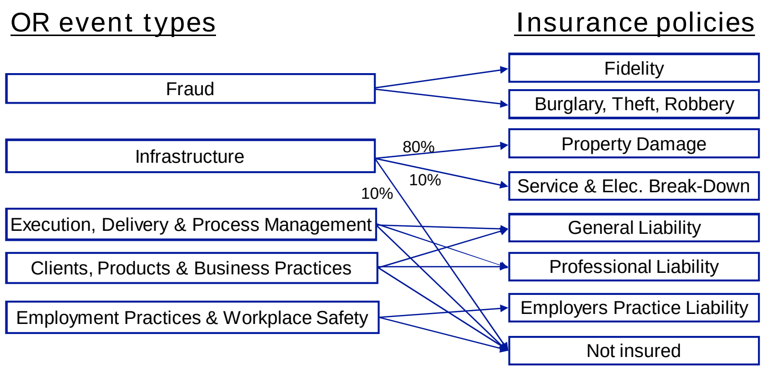
Insurance Mapping



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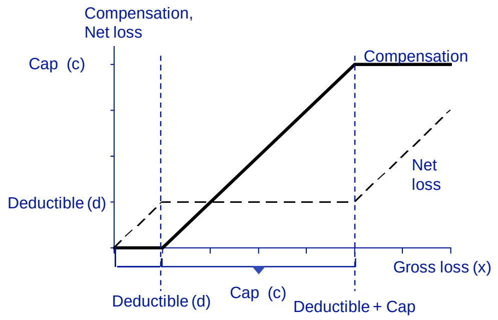
Modelling Insurance Contracts

- Deductible: amount the bank has to cover by itself
- Cap: maximum amount compensated by the insurer



$$\min(c, \max(x - d, 0))$$

Additional features

- Aggregate caps
- Haircuts (regulatory requirements)

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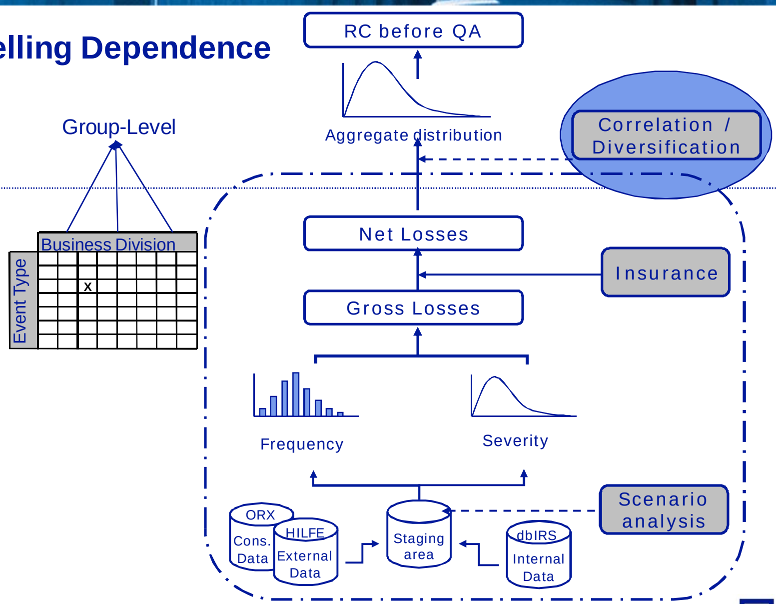
Modelling Dependence



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Analyzing Dependence

Dependence in a bottom-up LDA

- Within cells
  - Dependence between the occurrence of loss events
  - Dependence between the frequency distribution and the severity distribution
  - Dependence between the severity samples
- Between cells
  - Dependence between the frequency distributions
  - Dependence between the severity distributions

Statistical analyses performed at Deutsche Bank

- Based on internal loss data
- Identification of dependence between
  - occurrence of loss events within a cell => Frequency distribution not Poisson
  - frequency distributions in different cells => Copula applied to frequencies

Dependence in AMA at DB

Frequencies

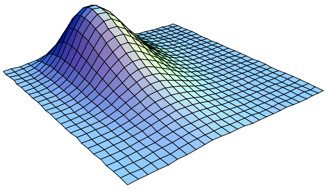
- Gaussian copula applied to frequency distributions

Severities

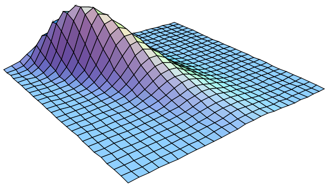
- Sum of split losses
- Severities of different loss events are independent

Example: Gaussian copula applied to a Poisson and a Negative Binomial distribution

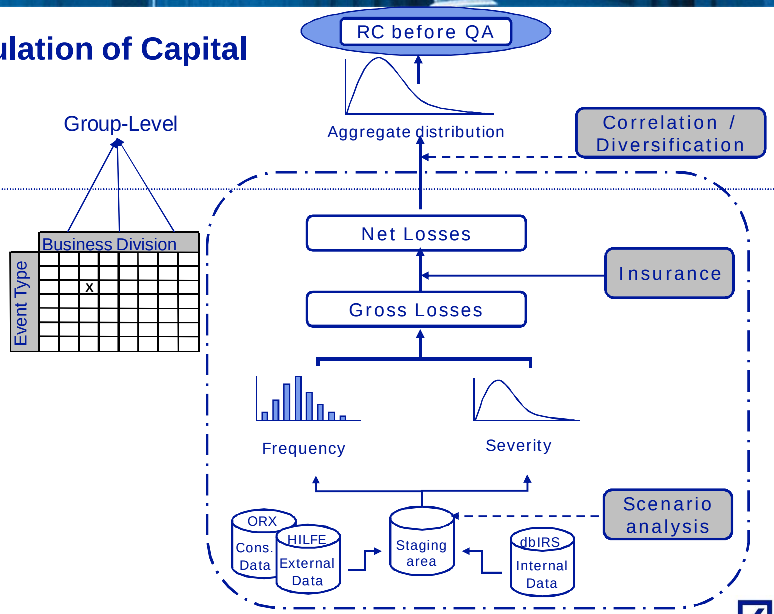
uncorrelated



Correlation factor $\sqrt{0.5}$ in Gaussian copula



Calculation of Capital



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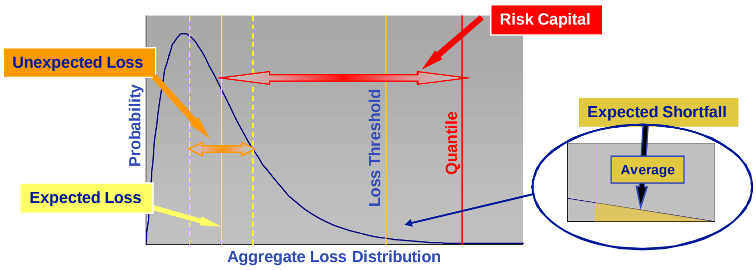
Calculation and Allocation of Risk Capital



Aggregate loss distribution:	Monte Carlo simulation
Economic Capital:	99.98% Quantile minus Expected Loss
Regulatory Capital:	99.9% Quantile minus Expected Loss

Capital allocation

- Cell level: Expected Shortfall allocation
- Divisional level: Aggregation of EC in divisional cells plus proportional contributions of Group cells

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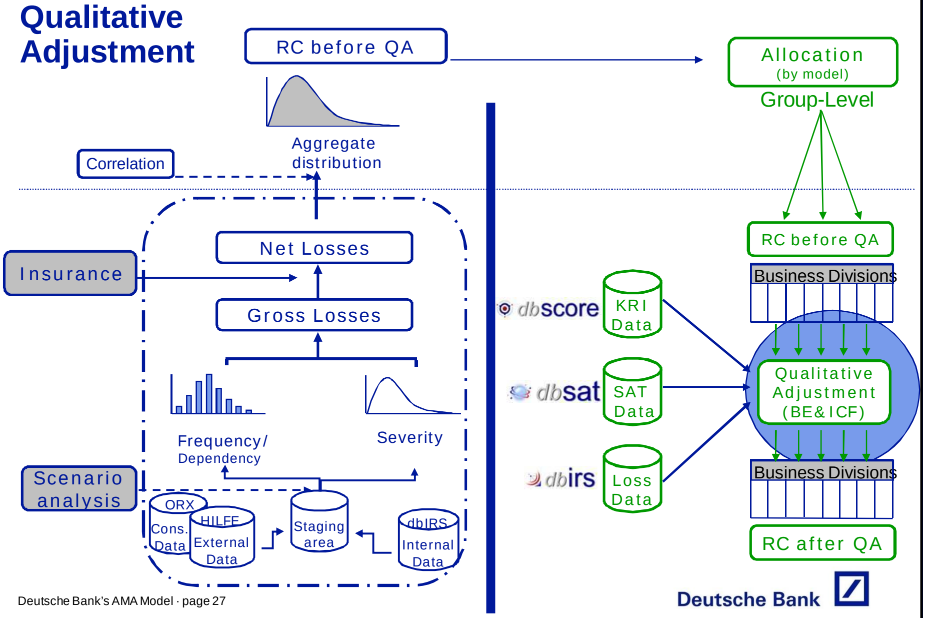
Qualitative Adjustment



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Qualitative Adjustment in DB's OR Model

- Qualitative adjustment applied to contributory capital of business lines
  - QA is separated from the quantitative capital calculation
  - Simple and transparent but difficult to justify with statistical means
- Main facts on QA
  - Risk indicators and self assessment are main components
  - QA score (applied on BL /ET level) plus penalty component (inappropriate loss data collection, KRI/SAT minimum standards, etc.)
  - Insurance OR capital may be adjusted by +40% to -40%
  - Measurement of risk sensitivity and coverage determines range
- Key risk indicators
  - Global KRIs: HR, BCM, open issues (Audit, SOX, db-Track), NPA, Technology Risk
  - Business specific KRIs, e.g. nostro reconciliations, outstanding confirmations, average processing time of customer complaints

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Validation

Basic properties of LDA model

- Variance analysis
- Loss distributions for heavy-tailed severities

Sensitivity analysis of basic components of LDA models

- Frequencies
- Severities
- Dependence
- Insurance

Impact analysis of stress scenarios

Backtesting and benchmarking

- Benchmarking the tail of the aggregate loss distribution against individual data points

Variance Analysis
Cell level

- Variance analysis
  - does not provide information on quantiles of loss distribution
  - but: quantifies impact of frequencies and severities on volatility of aggregate losses
  - is independent of specific distribution assumptions
- Variance of aggregate losses (*F* and *S*: frequency and severity distribution):

$$E(F)\cdot Var(S)+Var(F)\cdot E(S)^2$$

Conclusion

- Importance of frequency distribution depends on relationship of $Var(F)/E(F)$ (frequency vol) and $Var(S)/E(S)^2$ (severity vol)
- In high impact cells, the volatility of severities dominates and the actual form of the frequency distribution is of minor importance:

$$E(F)\cdot Var(S)+Var(F)\cdot E(S)^2$$

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Variance Analysis
Group level

Frequency correlations

- Variance of loss distribution at Group level

$$\sum_{j=1}^{m} E(F_j)\cdot Var(S_j)+Var(F_j)\cdot E(S_j)^2+\sum_{j,k=1,j\neq k}^{m} Cov(F_j,F_k)\cdot E(S_j)\cdot E(S_k)$$

- Variance in the homogeneous model (*c:* homogeneous correlation coefficient)

$$m\cdot(E(F)\cdot Var(S)+Var(F)\cdot E(S)^2\cdot(c\cdot(m-1)+1))$$

Impact of frequency correlations depends on

- number of (relevant) cells *m* and
- relationship of $Var(F)/E(F)$ (frequency vol) and $Var(S)/E(S)^2$ (severity vol)

In general, the impact of frequency correlations is rather limited and less significant than the impact of correlations of severities or loss distributions

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Loss Distributions for Heavy-Tailed Severities

Subexponential distributions

- Heavy-tailed: tail decays to 0 slower than any exponential Exp[a*x], a<0
- Tail of the sum of subexponential variables has the same order of magnitude as tail of the maximum:

$$\lim_{x\to\infty}\frac{P(X_1+\ldots+X_n>x)}{P(\max(X_1,\ldots,X_n)>x)}=1$$

Aggregate loss distributions of subexponential severities

- Let *F* be a frequency distribution
- *S* the distribution function of a subexponential severity
- *G* the distribution function of the aggregate loss distribution
- Under general conditions on *F* (satisfied by Poisson and Negative Binomial):

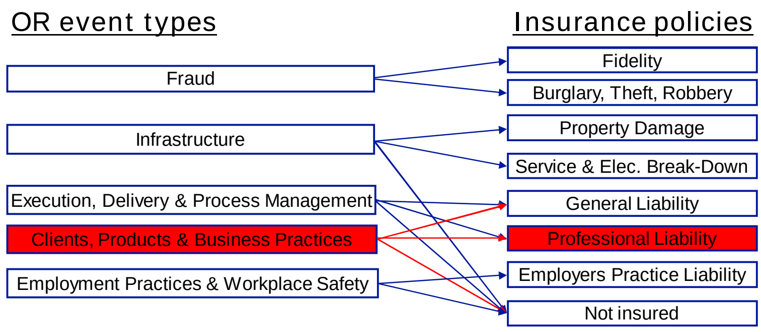
$$\lim_{x\to\infty}\frac{\overline{G}(x)}{\overline{S}(x)}=E(F),\qquad \text{where } \overline{S}(x):=1-S(x)$$

Sensitivity Analysis of Basic LDA Components

Based on theoretical results and experience with Deutsche Bank's LDA model

- Frequency distributions
  - Mean of frequency distribution is important
  - Shape has limited impact on capital in cells with fat-tailed severities
  - Shape has limited impact on Group capital
- Severity distributions
  - Weights and techniques for combining different data sources are important
  - Significant impact of distribution assumptions for severity tails and tail probabilities
- Dependence
  - Impact depends on the level where dependence is modelled, e.g. frequencies, severities or aggregate losses
  - Limited impact of frequency correlations

Sensitivity Analysis of Insurance Model



- Clients, Products & Business Practices consumes most of the capital
  - Impact of mapping percentages to insurance contracts
  - Most severe losses fall under Professional Liability: single limit of PL is particularly important
- Higher reduction (in percentage) for median (EL) than for high quantiles (EC and RC)
- Insurance may cause reallocation of capital between different event types

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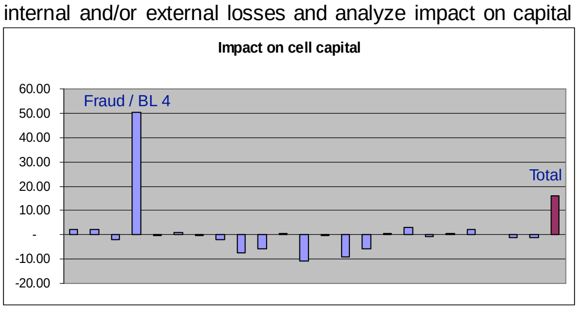
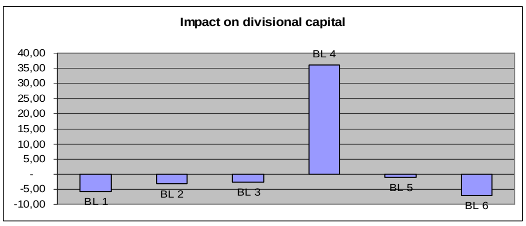
Stressing Loss Data

Methodology: Add (remove) internal and/or external losses and analyze impact on capital

Stress Scenario
Add 200mn loss in a Fraud cell

Impact on capital
Fraud / BL 4: +50mn
BL 4: +35mn
Group: +15mn





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Backtesting and Benchmarking

- Backtesting
  - Sequential testing of a model against reality to check the accuracy of the predictions
  - Backtesting is frequently used for the validation of market risk models
  - In credit and operational risk, the inherent shortage of loss data severely restricts the application of backtesting techniques to capital models

- Benchmarking
  - Comparison of a bank's operational risk capital charge against a bank's close peers
  - Comparison of the AMA capital charge against the BIA or TSA capital charges
  - Comparison of the LDA model outputs against adverse extreme, but realistic, scenarios

These tests help to provide assurance over the appropriateness of the level of capital but there are obvious limitations

Benchmarking
Tail of aggregate loss distribution versus individual data points

- Based on assumption that these tails have the same order of magnitude:
  - Tail of aggregate loss distribution calculated in a bottom-up LDA model
  - Tail of loss distribution directly specified at Group level

- Loss distribution specified at Group level:
  - Take all losses (across business lines and event types) above a high threshold, say 1m, for the specification of a severity distribution *S*
  - Calculate the bank's average annual loss frequency *n* above 1m

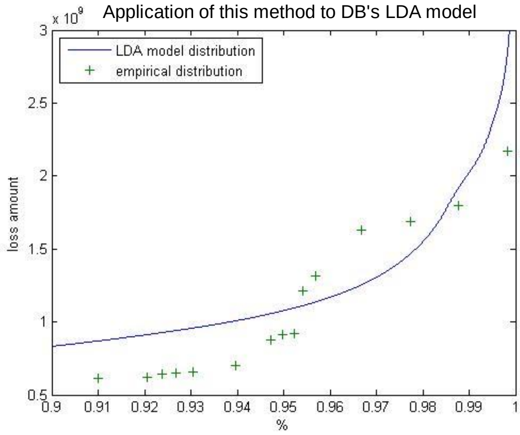
- Under the assumption that *S* is subexponential, identify

$$\alpha - quantiles \text{ of loss distribution } S_1 + \ldots + S_n \text{ with}$$
$$\alpha - quantiles \text{ of maximum distribution } \max(S_1, \ldots, S_n) \text{ with}$$
$$1 - ((1-\alpha)/n) - quantiles \text{ of severity distribution } S$$

Benchmarking Result

- 1-((1-alpha)/n) – quantiles of the severity distribution correspond to individual losses for appropriate alpha and n
- The amount of loss data provides a limit for the confidence level that can be derived directly from the data

Application of this method to DB's LDA model



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