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Risikosensitive Allokation von Ökonomischem Kapital

Schlüssel zum Profitabilitätsmanagement

Effizientes Kreditportfoliomanagement

19.9.2007, Mainz

Dr. Georg Stapper

Contents

- Motivation

> Target of the risk & capital management of a bank is to **assign adequate capital** to those transactions, which continuously provide **earnings exceeding capital costs**. This way each transaction supports the increase of shareholders' value.
>
> Detlef Bindert, Group Treasurer Deutsche Bank AG, in Gabler 2004

- Profitability- and Exposuremanagement
- Factor Model and Correlations
- Efficient Monte Carlo Sampling Methods
- Stress Testing

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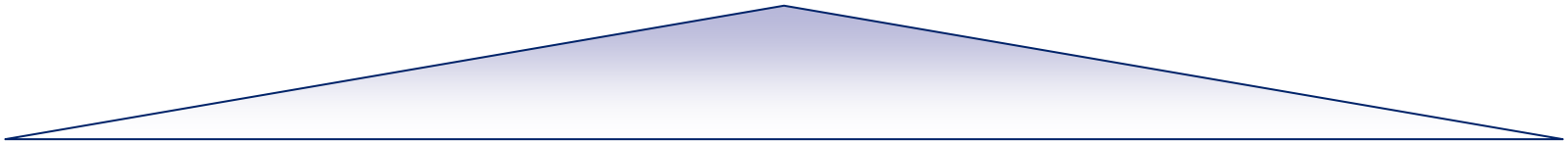
Requirements

- portfolio model for group wide capital assessment
- risk sensitive capital allocation techniques down to transaction level
- group wide integration and allocation of capital for different risk types
- risk adjusted pricing tool
  (forward looking steering/backward looking measurement)
- manage Basel II capital point in time through the economic cycle
- further tools for Active Portfolio-Management
  (capital impact study, risk transfer pricing)



Basel II implementation standards

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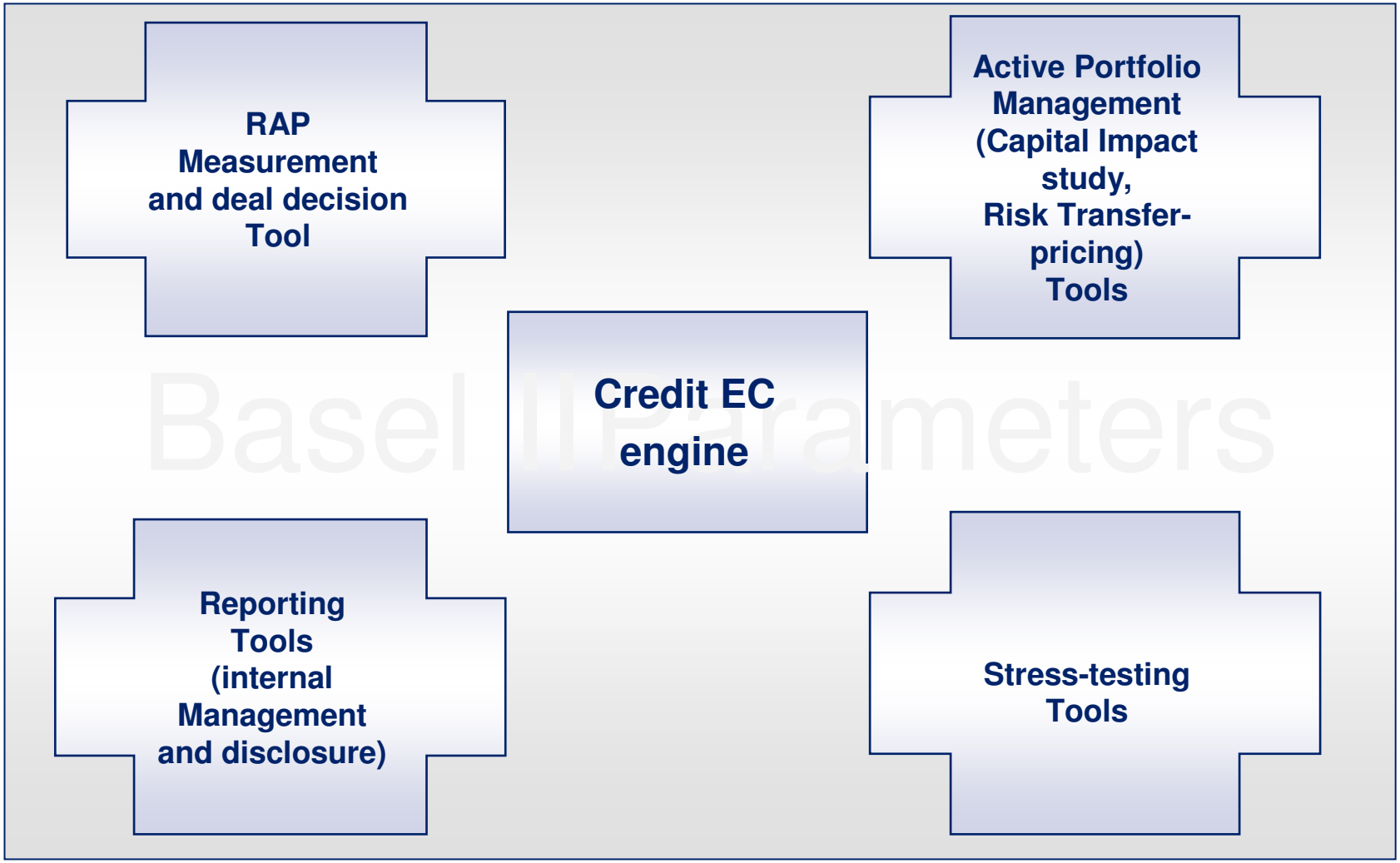
Applications and intelligent steering tools



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Economic Capital and profitability measure RAROC

Risk-based transaction pricing
Steer the bank based on economic profitability

$$RAROC = \frac{(Revenues - Costs - EL + Capital\ Benefit)}{Contributory\ EC} = RAR$$

Economic Profit = RAR - Hurdle Rate • EC

< 0 reject transaction

Hurdle Rate : Minimum return on equity expected from shareholders

Capital Benefit:
1.) Estimate contributory EC
2.) Calculate Book Capital = EC * Capital Allocation Factor (α)
3.) Investment of Book Capital at Capital Market by Treasury
4.) Give back the accrued interest (e.g. 4.9% of book capital)

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Bank steering based on RAROC: Examples

Be careful with:

- ❑ Capital allocation method
- ❑ Cost function break-down
- ❑ Consideration of Capital Benefit
- ❑ etc.

Small changes due to pitfalls or inadequate calculation of constituents of the RAROC formula can lead to completely wrong steering signals!!!

Example: Pitfall due to incorrect capital benefit figures

Influence of Capital Benefit		
	Customer X including capital benefit	Customer X without capital benefit
Customer Rating	A	A
Exposure	10,000,000	10,000,000
Margin	0.62%	0.62%
+ Revenue	62,000	62,000
- Administrative Expenses	30,000	30,000
- Product Expenses	10,000	10,000
- Expected Loss	5,400	5,400
+ Capital Benefit @ 4.9%	4,498	0
/ Economic Capital	91,800	91,800
RAROC	23.0%	18.1%
Risk adjusted Return (RaR)	21,098	16,600
Cost of Capital (hurdle rate = 20%)	18,360	18,360
= Economic Profit (€)	2,738	-1,760

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RAROC steering: Regulatory vs. Economic view

2 customers with **same** Rating but **different industries**

Regulatory view

	Customer A	Customer B
Industry	Telecomunication	Construction
Customer Rating	A-	A-
PD	0.10%	0.10%
LGD	77.00%	77.00%
Exposure	10,000,000	10,000,000
Margin	0.62%	0.62%
+ Revenue	62,000	62,000
- Administrative Expenses	30,000	30,000
- Product Expenses	10,000	10,000
- Expected Loss	7,700	7,700
+ Capital Benefit @ 4.9%	12,495	12,495
/ Regulatory Capital	255,000	255,000
RaR/Regulatory Capital	10.5%	10.5%
Risk adjusted Return (RaR)	26,795	26,795
Cost of Capital (hurdle rate = 20%)	51,000	51,000
= Economic Profit (€)	-24,205	-24,205

Economic view: ESF allocation

	Customer A	Customer B
Industry	Telecomunication	Construction
Customer Rating	A-	A-
	0.10%	0.10%
	77.00%	77.00%
Exposure	10,000,000	10,000,000
Margin	0.62%	0.62%
+ Revenue	62,000	62,000
- Administrative Expenses	30,000	30,000
- Product Expenses	10,000	10,000
- Expected Loss	7,700	7,700
+ Capital Benefit @ 4.9%	2,940	3,920
/ Economic Capital	60,000	80,000
RAROC	28.7%	22.8%
Risk adjusted Return (RaR)	17,240	18,220
Cost of Capital (hurdle rate = 20%)	12,000	16,000
= Economic Profit (€)	5,240	2,220

Risk sensitive allocation of capital can turn non profitable business to a highly profitable. Here Basel II capital is dumb

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RAROC steering: Economic view: Var/Covar vs. ESF-allocation

2 customers with **same** Rating but **different industries**

Economic view: Var/Covar allocation

	Customer A	Customer B
Industry	Telecomunication	Construction
Customer Rating	A-	A-
	0.10%	0.10%
	77.00%	77.00%
Exposure	10,000,000	10,000,000
Margin	0.62%	0.62%
+ Revenue	62,000	62,000
- Administrative Expenses	30,000	30,000
- Product Expenses	10,000	10,000
- Expected Loss	7,700	7,700
+ Capital Benefit @ 4.9%	2,940	5,390
/ Economic Capital	60,000	110,000
RAROC	28.7%	17.9%
Risk adjusted Return (RaR)	17,240	19,690
Cost of Capital (hurdle rate = 20%)	12,000	22,000
= Economic Profit (€)	5,240	-2,310

Economic view: ESF allocation

	Customer A	Customer B
Industry	Telecomunication	Construction
Customer Rating	A-	A-
	0.10%	0.10%
	77.00%	77.00%
Exposure	10,000,000	10,000,000
Margin	0.62%	0.62%
+ Revenue	62,000	62,000
- Administrative Expenses	30,000	30,000
- Product Expenses	10,000	10,000
- Expected Loss	7,700	7,700
+ Capital Benefit @ 4.9%	2,940	3,920
/ Economic Capital	60,000	80,000
RAROC	28.7%	22.8%
Risk adjusted Return (RaR)	17,240	18,220
Cost of Capital (hurdle rate = 20%)	12,000	16,000
= Economic Profit (€)	5,240	2,220

Risk sensitive allocation of capital can turn non profitable business to a highly profitable.

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Profitability: RoE on the basis of RAROC

RAROC =

Steering

Revenues – Costs – Expected Loss + Capital Benefit

Allocated Economic Capital

RAROC

Customer X

Customer Rating	A
Exposure	10,000,000
Margin	0.62%
+ Revenue	62,000
- Administrative Expenses	30,000
- Product Expenses	10,000
- Expected Loss	5,400
+ Capital Benefit @ 4.9%	4,498
/ Economic Capital	91,800
RAROC	**23.0%**

RoE =

Measurement

Revenues–Costs– (Write Offs + Provisions) + Capital Benefit

~~Book Equity~~ Allocated EC * α

RoE

Customer X

Customer Rating	A
Exposure	10,000,000
Margin	0.62%
+ Revenue	62,000
- Administrative Expenses	30,000
- Product Expenses	10,000
- Expected Loss	5,400
+ Capital Benefit @ 4.9%	4,498
/ (Economic Capital * α)	137,700
RoE	**15.3%**

$$\text{If Provisions} = \text{Expected Loss} \Rightarrow \text{RoE} = \frac{\text{RAROC}}{\alpha}$$

α in this example = 1.5

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RAROC measurement (backward looking)

Backward-looking profitability measure with respect to a fixed time horizon:

- for performance measurement and accounting
- to support business decisions with up to date results

Methodology:

RAROC ex-post calculation needs all input information on customer level

- Available data source feed for EL and EC for Credit Risk
- Time horizon is the past twelve months from the calculation date
- Breakdown to lowest aggregation level, e.g. to business areas
- Global ratios are taken to estimate all quantities which are not yet available on customer level, e.g. Costs, EL and EC for Operational Risk, and EC for Market Risk
- Time averages over all quantities are to be taken

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Reporting of aggregated risk figures and steering based on economic capital

- RAROC Calculation (retrospective):
  - Portfolio level
  - Transaction
- RAROC estimation for single transactions (forward looking)
- Reporting capital adequacy:
  - Comparison of economic capital
- In depth portfolio analysis:
  - Identification of concentrations
- Scenarios and stress tests

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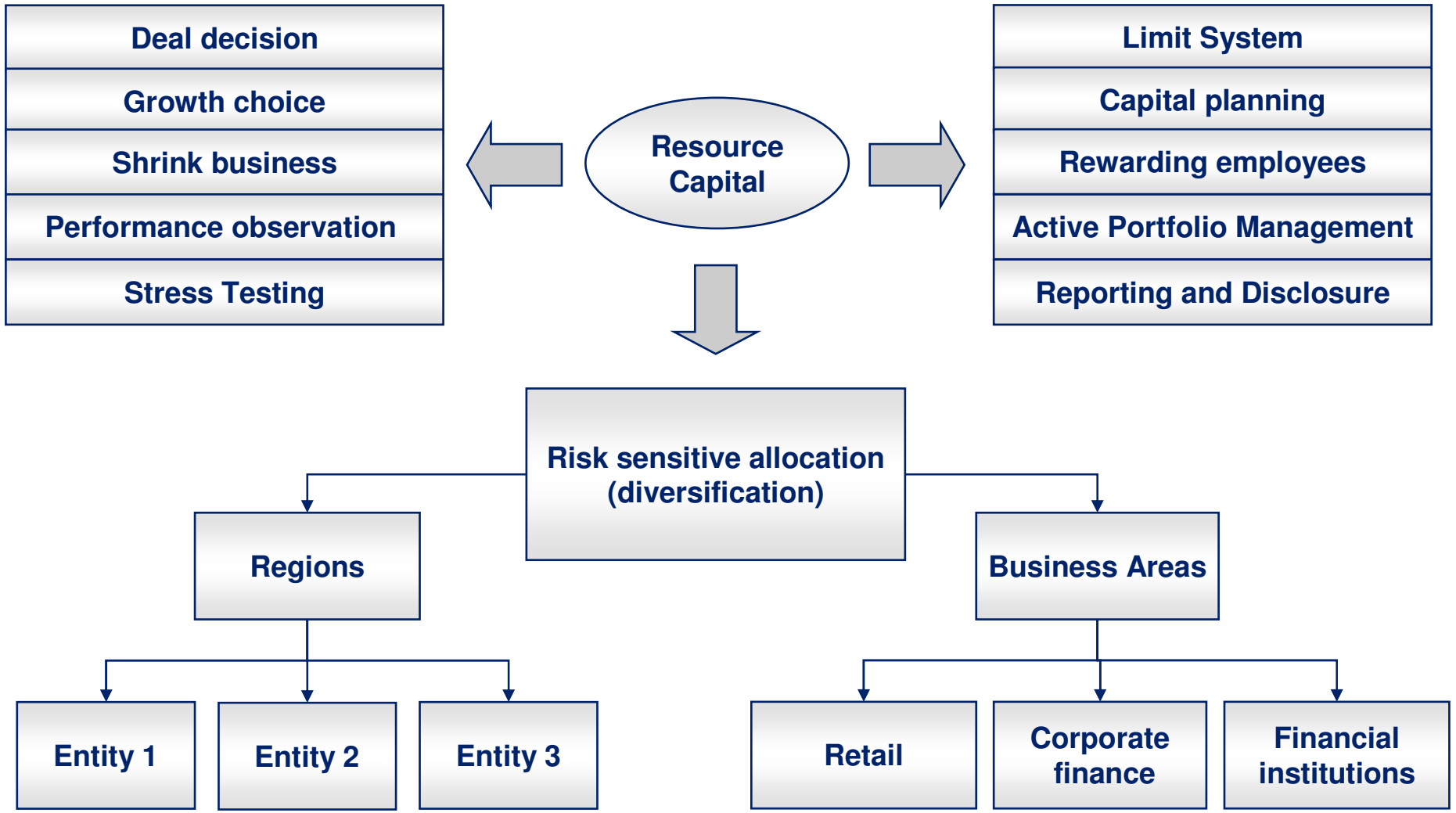
Benefits of an EC based allocation approach



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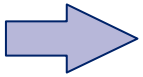
An capital allocation method has to fulfill a number of requirements …

- General requirements for sound capital allocation schemes
  - **Linearity** – Contributory EC of subportfolios sums up to total EC
  - **Diversification** – contributory EC of a subportfolio P does not exceed its standalone Economic Capital EC(P)
  - **Continuity** - Small changes to a portfolio only have a limited effect on the contributory EC of its subportfolios
  - Stable and efficient calculation method
- Special requirements for Credit Risk
  - Contributory EC scales with the credit "riskiness" of the transaction - Transactions with lower credit quality should consume more capital and transactions with higher correlations/concentration risk should consume more capital



Fulfilled by Coherent Risk Measure Expected Shortfall

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EC Allocation methods

Expected Shortfall:

- EC contribution of a transaction is the average loss of the transaction in the "extreme loss scenarios" of the portfolio:

  $ES(transaction) = E[L_{trans} \mid L_{portfolio} > quantile_{\alpha}] - E[L_{trans}]$

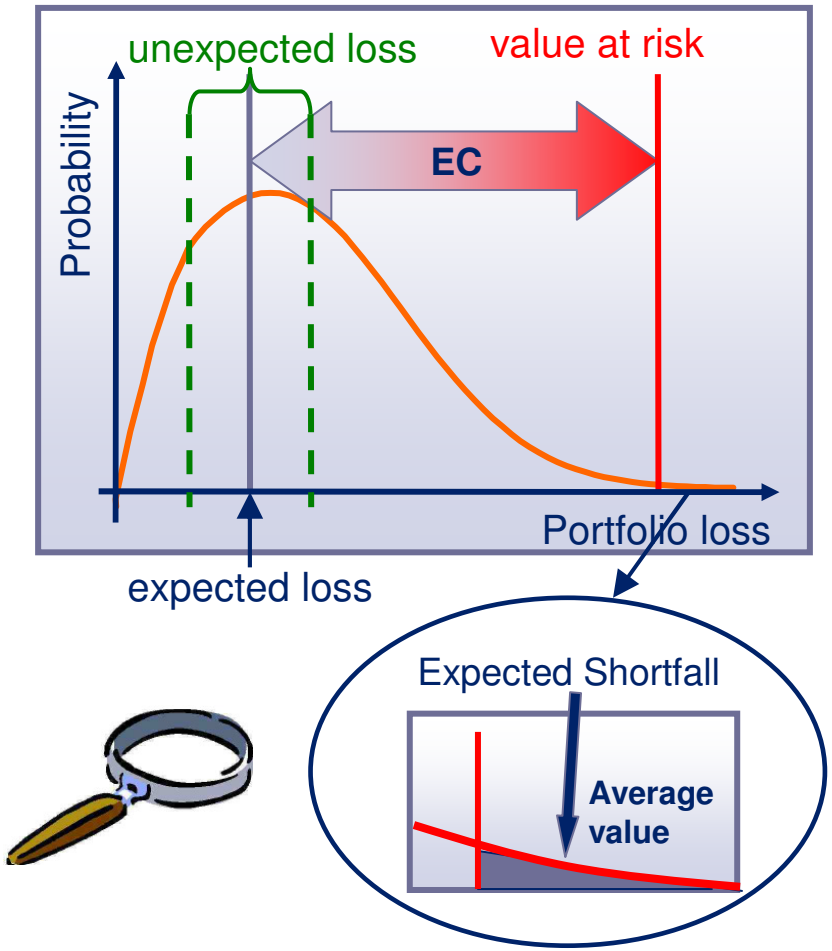
- distributes extreme losses

Unexpected Loss (stdev):

- Covariance Allocation:

  $Cov[L_{trans}, L_{portfolio}] / Var[L_{portfolio}]$

- distributes loss volatility



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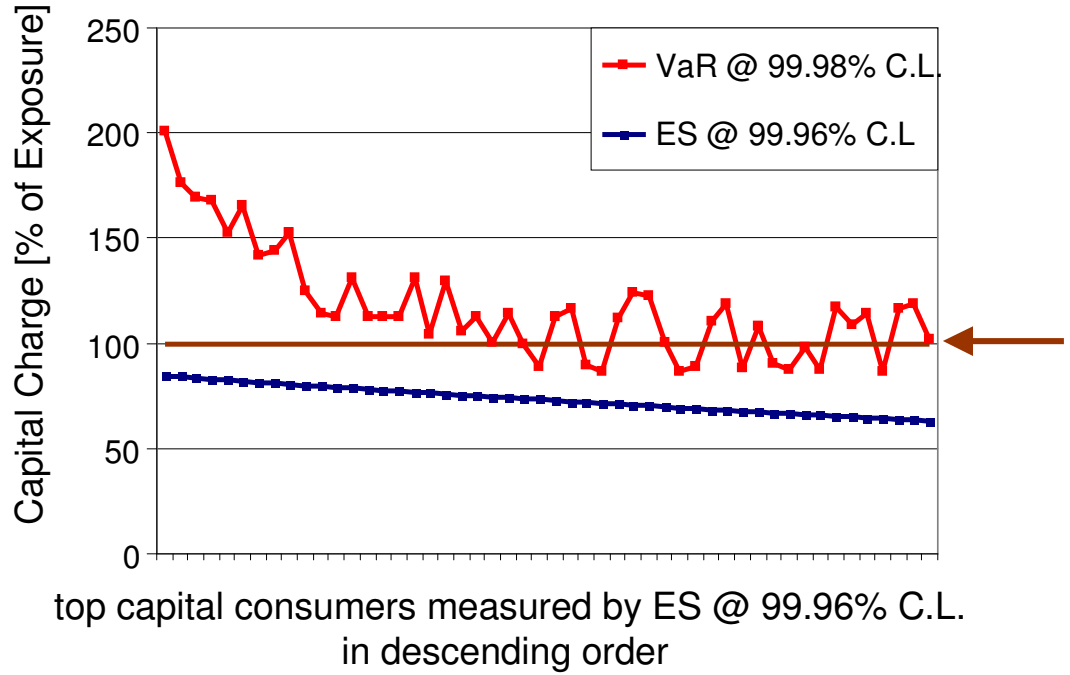
Comparison Expected shortfall vs. Var/Covar (1)

Capital charge of top capital consumers



Capital charge 100%: Economic capital equals exposure

- Var/Covar Allocation: Capital charge > Exposure
- Related to non-normality of the credit loss distribution

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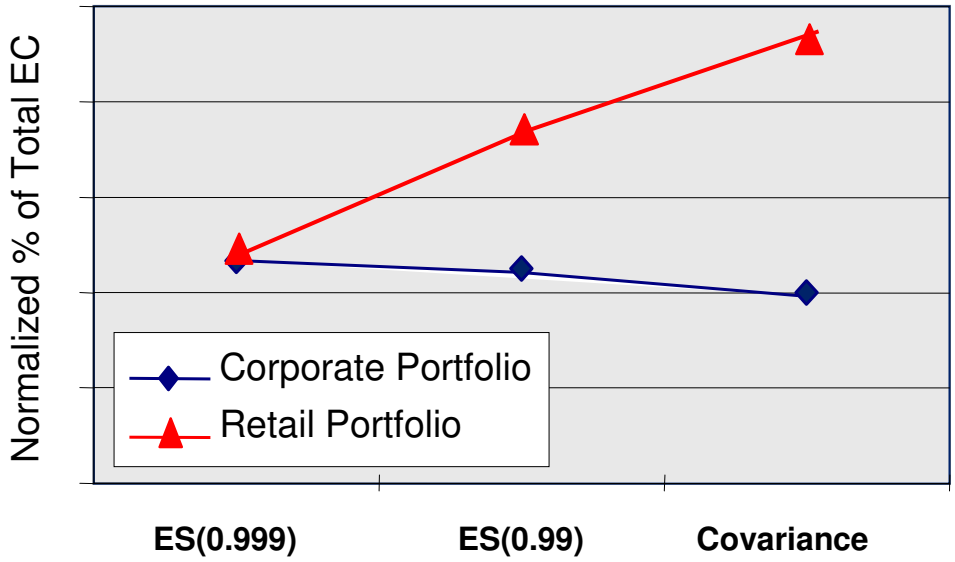
EC Impact Study

typical financial institution, typical portfolios



Concentration risk estimated by ES

- EC increase in more risky trading portfolios (higher concentration risk)
- EC reduction in diversified retail banking
- Not just a technical issue: impact of management input – e.g. choice of threshold

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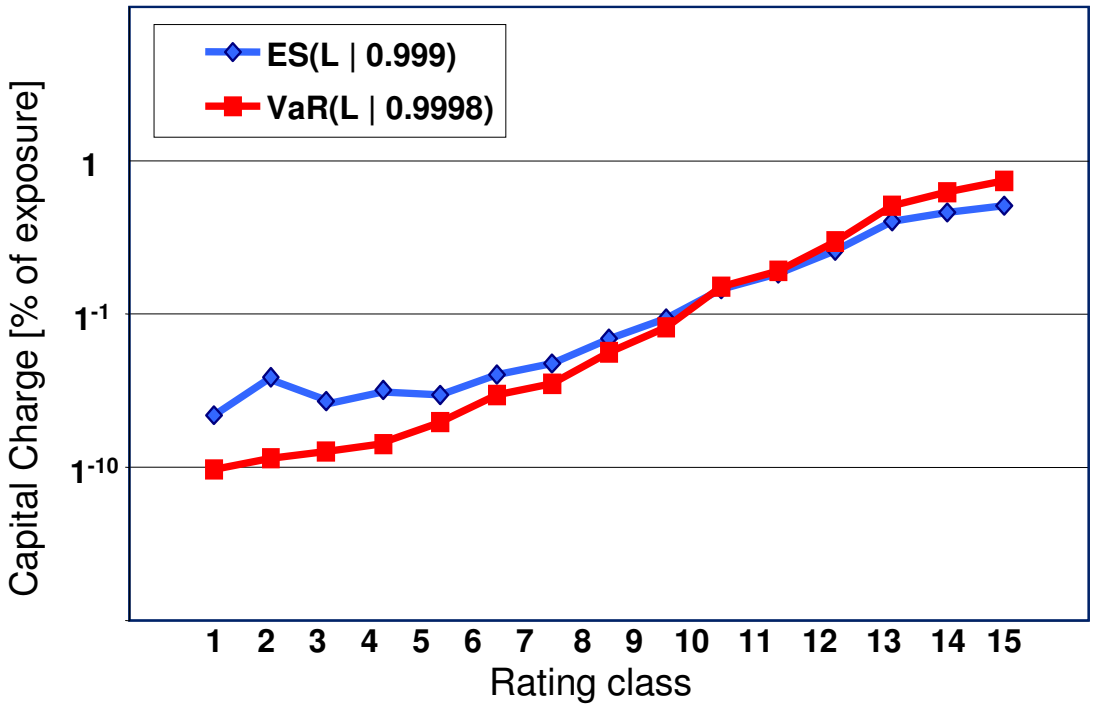
Sensitivity of the capital charge to the creditworthiness of a customer (Rating) for different allocation methods



Normalised capital charge here means:
The distributed capital of the test portfolio has been normalised to a common value for each method

- Expected Shortfall Allocation compared to Covariance Allocation:
  - higher amount of capital allocated to high rating classes
  - lower amount of capital allocated to low rating classes

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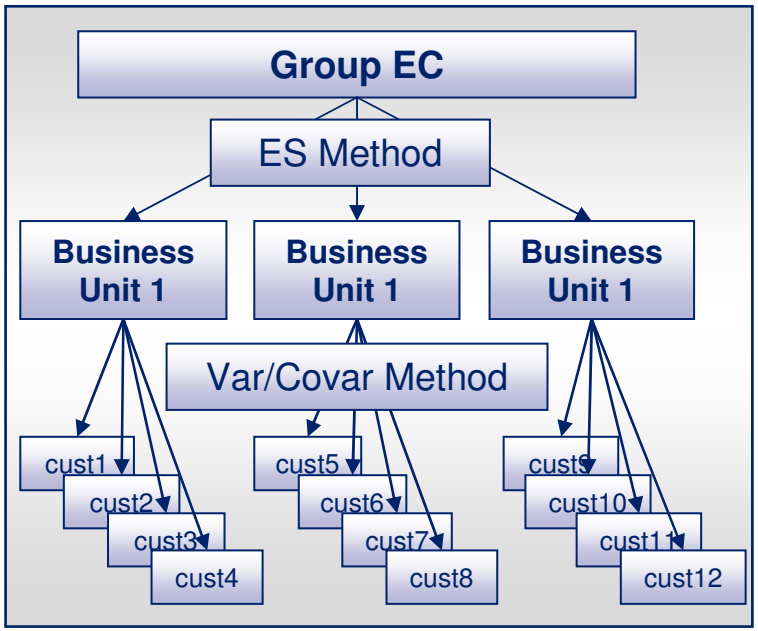
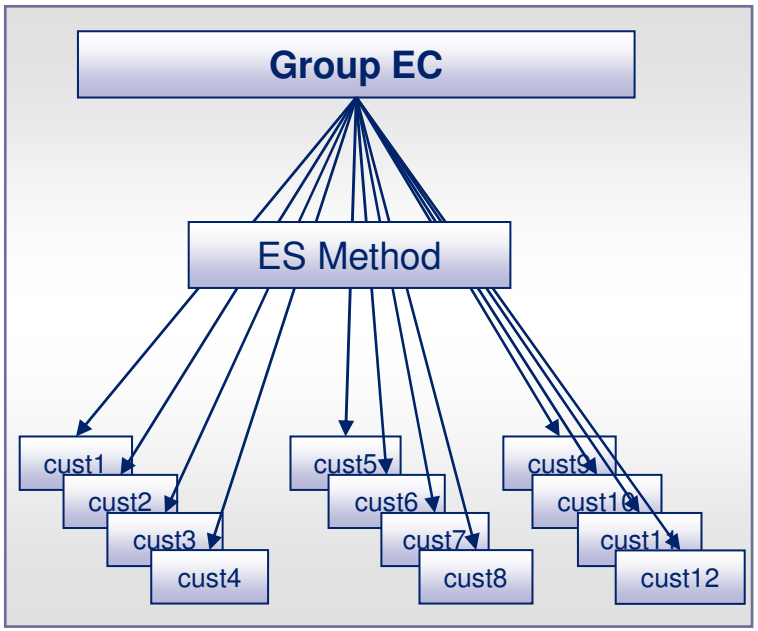
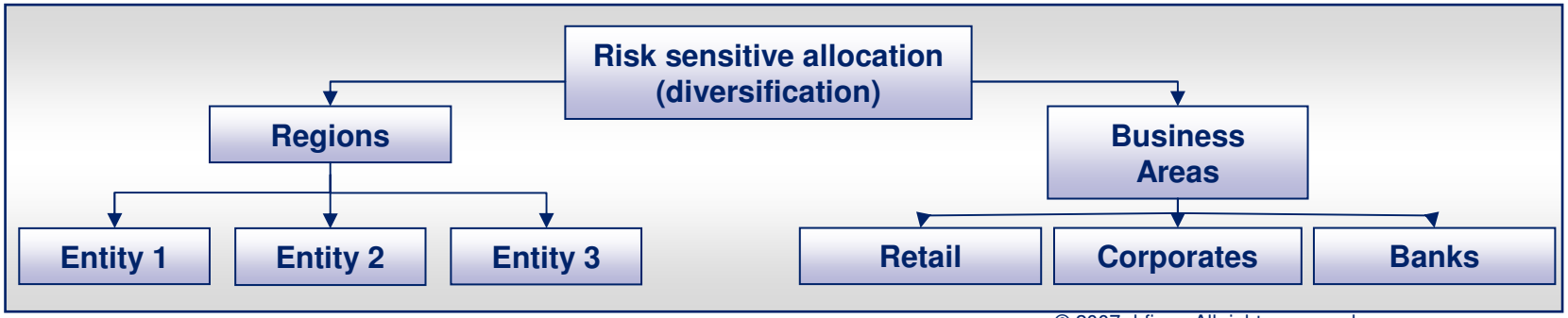
Goal: EC allocation down to transaction level

Mixture allocation technique



Pure Expected Shortfall allocation





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Estimation of Default Correlations

Directly from defaults or rating migrations

- Problem: too few joint default or migration events
- Really long history required, no relation to current economic cycle

Structural approach (Merton type model)

- Equity values widely available
- No linear relationship between equity and asset values
- Apart from credit risk several other factors influence the equity values which are not directly related to asset values

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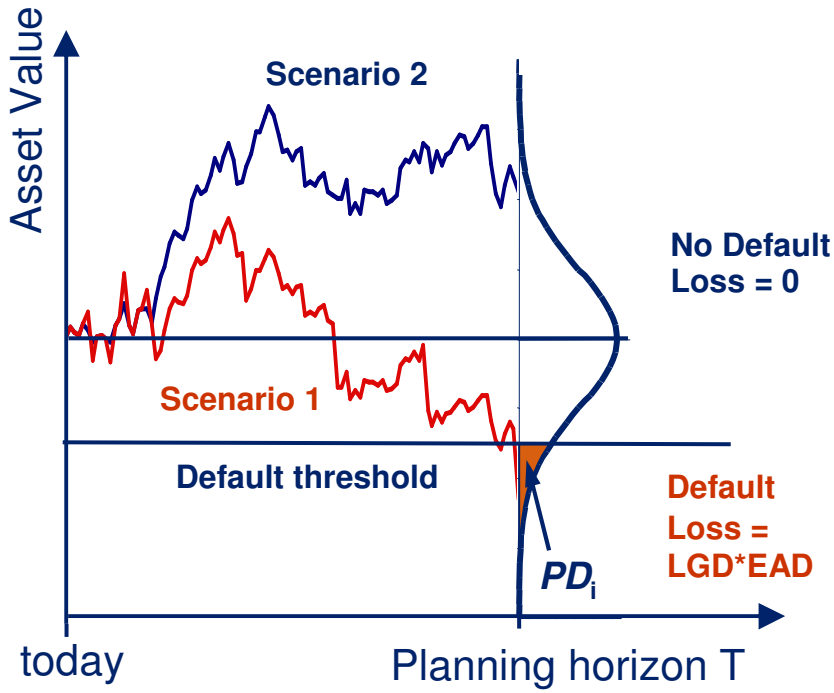
Merton, Default and Monte Carlo



Merton Model

- Default occurs when value A_i of firm's *i* assets falls below the value of its liabilities D_i
- Asset value modelled as Brownian Motion process (log returns normally distributed: $r \sim N(\mu, \Gamma)$
- Value of liabilities fixed over time

Normalised Asset log Return Process

- Normalisation, discretisation → $\tilde{r}_i$ standard normally distributed, N(0,1)
- Value of liabilities calibrated such that

$$PD_i = \Pr\left[\tilde{r}_{i,T} < \tilde{D}_i\right] = N\left[D_i\right]$$

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Default Correlation: Factor Model

Factor Model: $\tilde{r}_i = \underbrace{R_i \cdot \sum_{j=1}^{K} w_{ij} \cdot f_j}_{\text{systematic risk (country \& industry)}} + \underbrace{\sqrt{1-R_i^2} \cdot \varepsilon_i}_{\text{Specific (idiosyncratic) risk}}, \qquad \tilde{r}_i, f_j, \varepsilon_i \sim \mathrm{N}(0,1)$

Decompose Firm's risk:

- Systematic Risk: Country & industry risk factors f_j. R quantifies to which extent the firms risk is explained by the factor model
- Specific Risk: independent part of firm value (ε_l), not correlated with creditworthiness of other counterparties
- Definition of Loss of a transaction: $L_{\text{trans}} = LGD_{trans} \cdot EAD_{\text{trans}} \cdot \mathbf{1}_{(\tilde{r}_{i,T} < \tilde{D}_i)}$
- Definition of Portfolio Loss: $L_{\text{Portfolio}} = \sum_{i=1}^{N} LGD_i^{\text{trans}} \cdot EAD_i^{\text{trans}} \cdot \mathbf{1}_{(\tilde{r}_{i,T} < \tilde{D}_i)}$

Normalised asset return Correlation ρ_{ij}: m Counterparties: m(m-1)/2 Correlations

Data Reduction in Factor Model: m ~ 25-100 factors

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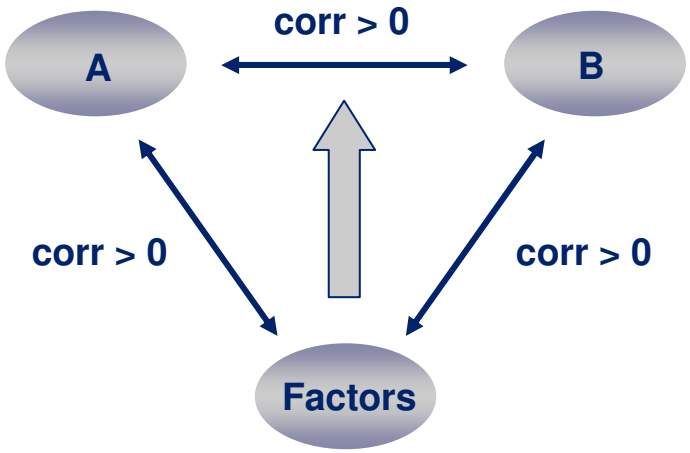
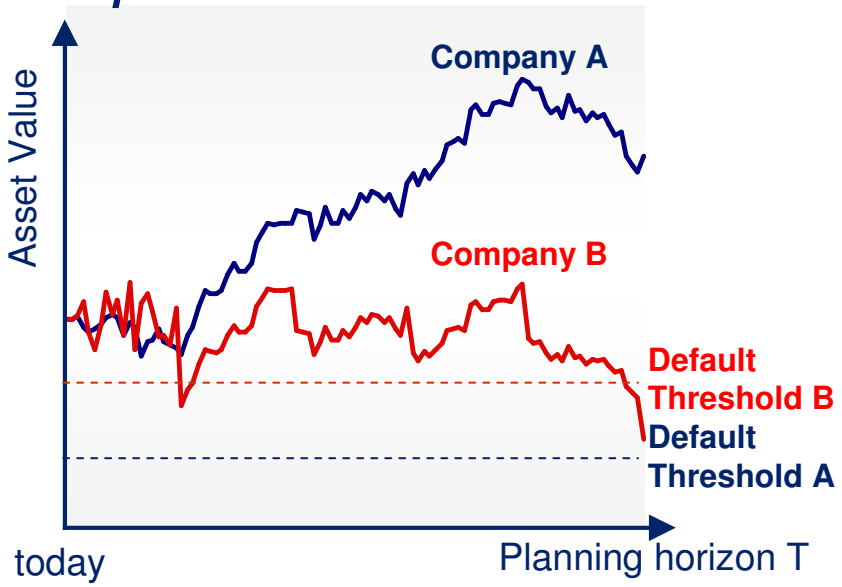
Factor Model Correlation: Example





assets (A) = 0.8 Germany + 0.2 US
+ 0.9 utility + 0.1 x finance
+ specific risk (A)

assets (B) = 0.6 US + 0.4 Japan
+ 0.3 utility + 0.6 x finance
+ 0.1 aerospace
+ specific risk (B)

Joint **D**efault **P**robability: JDP_{ij} :

$$JDP_{ij} := \Pr[\tilde{r}_{i,T} < \tilde{D}_i, \tilde{r}_{i,T} < \tilde{D}_j]$$

$$= N_2[N^{-1}(PD_i), N^{-1}(PD_j), \rho_{ij}]$$

Correlation of Asset return processes

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Default Correlations

Asset return correlations

joint probability distribution model (binary Gaussian copula) for asset log returns (σ_i, σ_j = 1):

$$\mathrm{JPD}_{ij} = \Pr(\tilde{r}_{i,T} < \tilde{D}_i, \tilde{r}_{j,T} < \tilde{D}_j) = \frac{1}{2\pi\sqrt{1-\rho_{ij}^2}} \int_{-\infty}^{\tilde{D}_i} dx \int_{-\infty}^{\tilde{D}_j} dy \exp\left\{ -\frac{1}{2(1-\rho_{ij}^{\ 2})} \left[\tilde{r}_{i,T} + \tilde{r}_{j,T} - 2\rho_{ij}\tilde{r}_{i,T}\tilde{r}_{j,T} \right] \right\}$$

default correlation (PD_i, PD_j Bernoulli distributed):

$$\hat{\rho}_{ij} = \frac{\mathrm{JPD}_{ij} - \mathrm{PD}_i \mathrm{PD}_j}{\sqrt{\mathrm{PD}_i(1-\mathrm{PD}_i)}\sqrt{\mathrm{PD}_j(1-\mathrm{PD}_j)}}$$

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R^2 estimation for public and private companies

Asset log return process:

$$r = \beta \cdot X + \sigma \cdot \varepsilon$$

Goodness of fit of regression between asset log return and composite factor X:

$$R^2 = \frac{\beta^2 \cdot Var(X)}{Var(r)}$$

Normalize asset log return processs to standard normal:

$$\underbrace{Var(r)}_{\text{firm's total risk}} = \underbrace{\beta^2 \cdot Var(X)}_{\text{systematic risk}} + \underbrace{\sigma^2 \cdot Var(\varepsilon)}_{\text{specific risk}} = 1$$

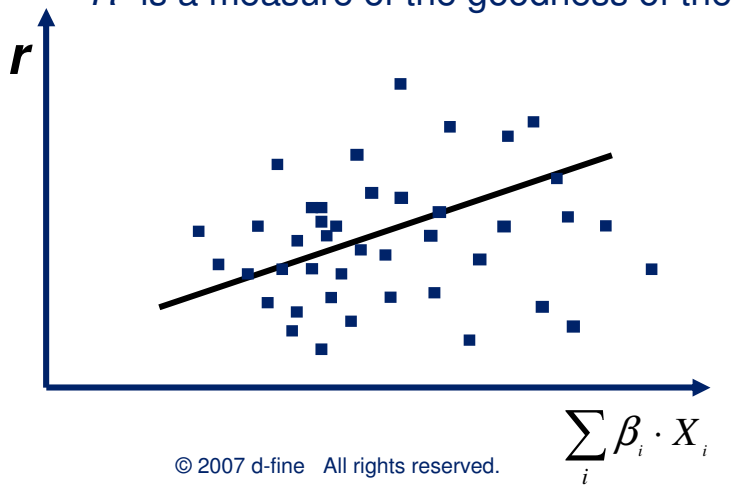
$$\Rightarrow \sigma = \sqrt{1 - \beta^2 \cdot Var(X)} = \sqrt{1 - R^2}$$

Approach 1: Take rough best practice values

Approach 2: Regression analysis

- Public firms
  - Regression between equity return value and factor model representation.
- Private firms
  - Regression between size and R^2 from above
  - Mapping to available public firms

R^2 is a measure of the goodness of the fit



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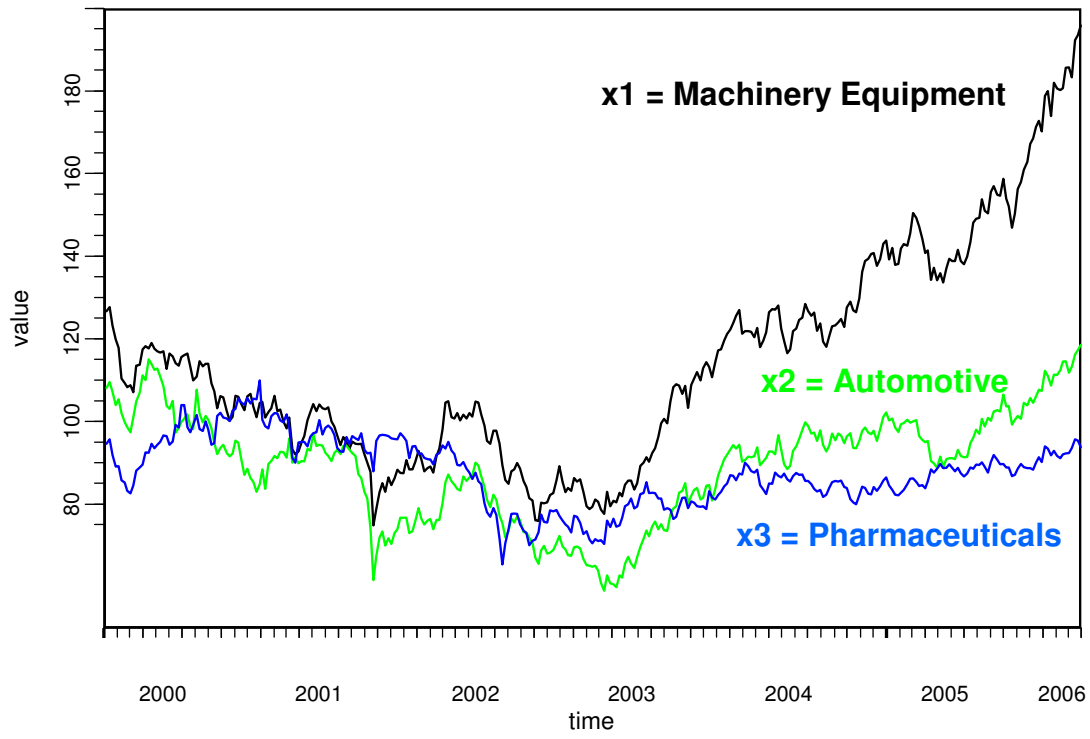
Estimation of covariance matrix of a factor model

Illustrative example



Correlation Matrix

	x1	x2	x3
x1	1	0.76	0.43
x2		1	0.38
x3			1

Covariance Matrix (weekly)

	x1	x2	x3
x1	0.0007	0.0006	0.0003
x2	0.0006	0.0008	0.0003
x3	0.0003	0.0003	0.0005

x 52 weeks

Covariance Matrix (yearly)

	x1	x2	x3
x1	0.0351	0.0293	0.0134
x2	0.0293	0.0427	0.0130
x3	0.0134	0.0130	0.0280

Estimate Covariance Matrix for the factors and scale with t=52 to get annualized values

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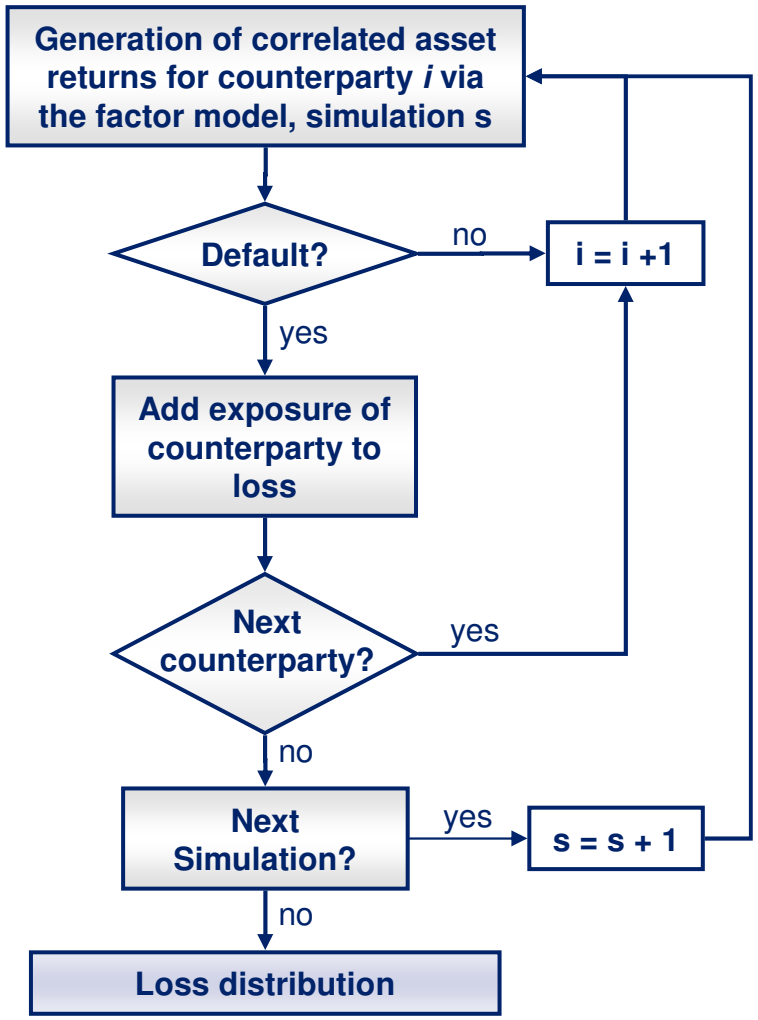
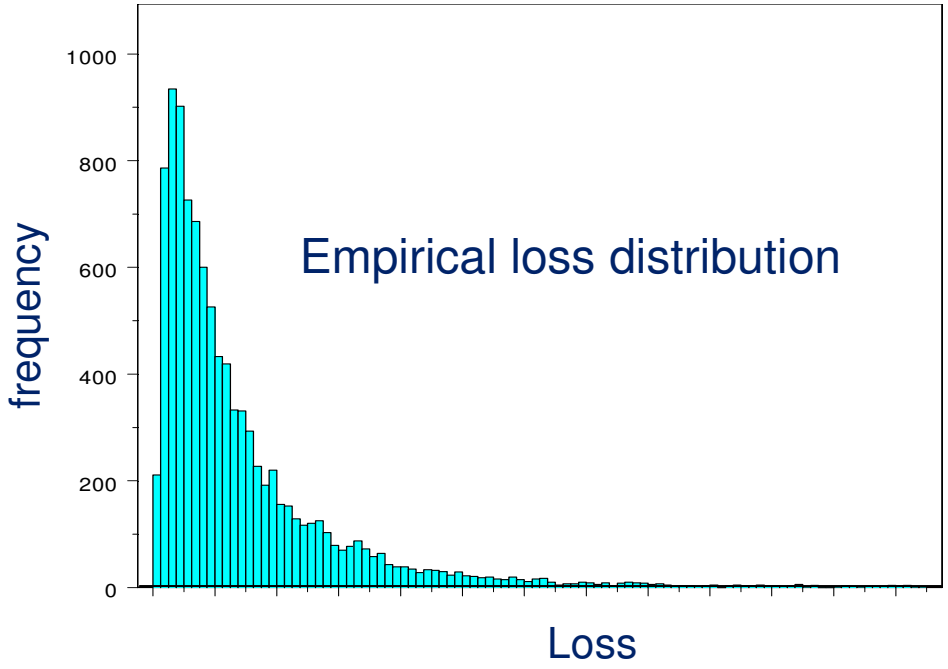
MC Simulation of Loss Distribution for a credit portfolio





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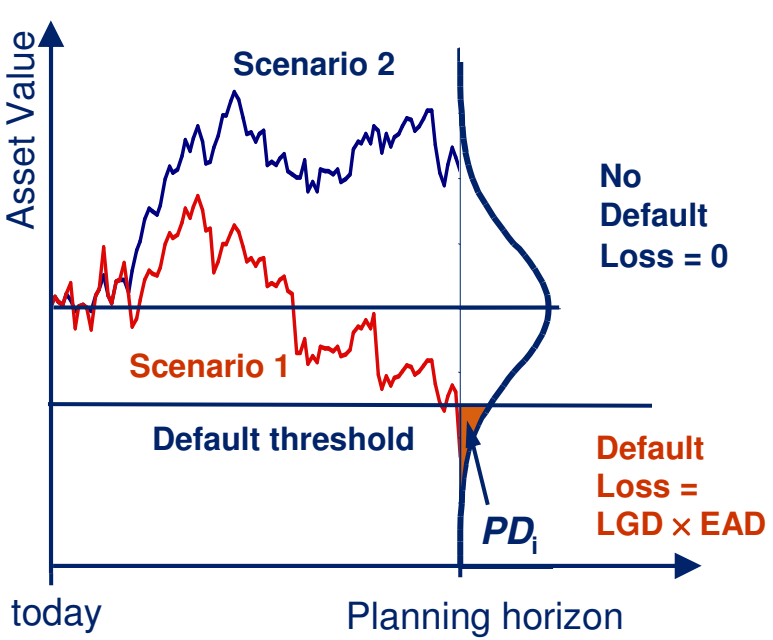
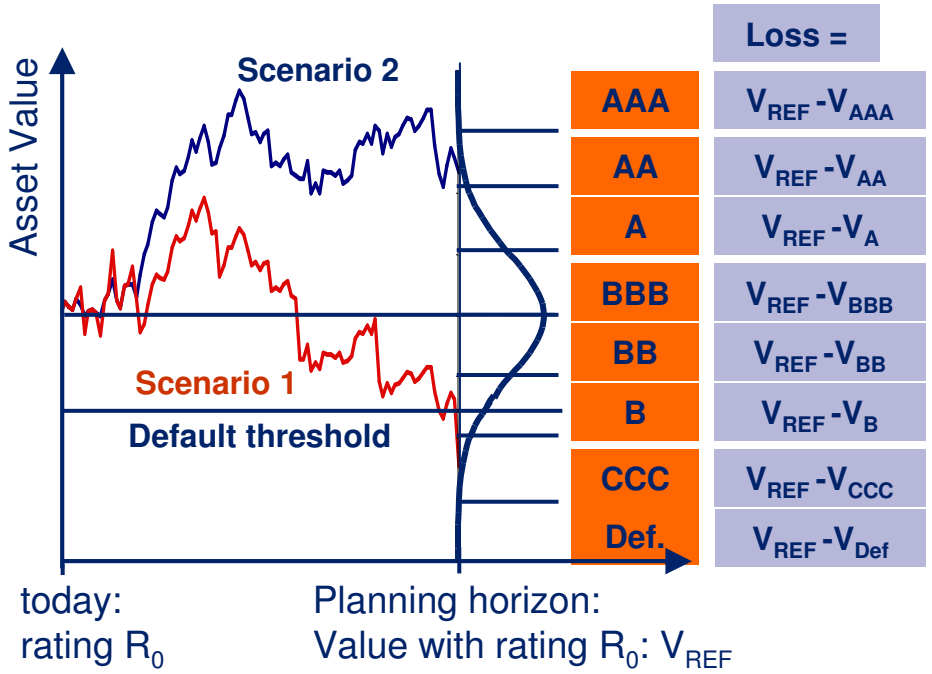
Model Extension (mark to model)

Default Mode



- Event = defaulted / not defaulted
- Loss value depends only on EAD and LGD

Multi-State Mode



- Event = Rating change at horizon
- Cash flow valuation: additional dependence on maturity, interest rates etc

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Expected Shortfall

Expected shortfall of loss L at level $\alpha \in (0,1)$:

$$\mathrm{ES}_\alpha(L) = \mathrm{E}(L \mid L > \mathrm{VaR}_\alpha(L)) \approx (1-\alpha)^{-1}\,\mathrm{E}(L \cdot 1_{\{L>\mathrm{VaR}(L)\}})$$
$$= (1-\alpha)^{-1} \int L \cdot 1_{\{L>\mathrm{VaR}_\alpha(L)\}}\,\mathrm{dP}$$

Expected shortfall contribution of the i-th loan:

$$\mathrm{ESC}_\alpha(L_i) = \mathrm{E}(L_i \mid L > \mathrm{VaR}_\alpha(L)) \approx (1-\alpha)^{-1}\,\mathrm{E}(L_i \cdot 1_{\{L>\mathrm{VaR}(L)\}})$$

Example: α = 99.98% quantile, compute n =100000 MC samples s_i

s1 ≥ s2 ≥ … ≥ sn

$$\mathrm{ES}_\alpha(L) = (1-\alpha)^{-1}\,\mathrm{E}(L \cdot 1_{\{L>\mathrm{VaR}_\alpha(L)\}}) = (1-\alpha)^{-1} \int L \cdot 1_{[L<\mathrm{VaR}_\alpha(L)\}}\,\mathrm{dP} = \sum_{i=1}^{20} s_i / 20$$

⇒ Only 20 samples fullfil the requirement for the total portfolio, but the contribution of the i-th loan is usually 0!

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MC Acceleration Methods

- Parallel and multi-threading computing
  - Distributed memory
  - Message passing
- Variance reduction techniques
  - Antithetic variates
  - Importance sampling
  - Conditioning
  - others
- Quasi Monte Carlo

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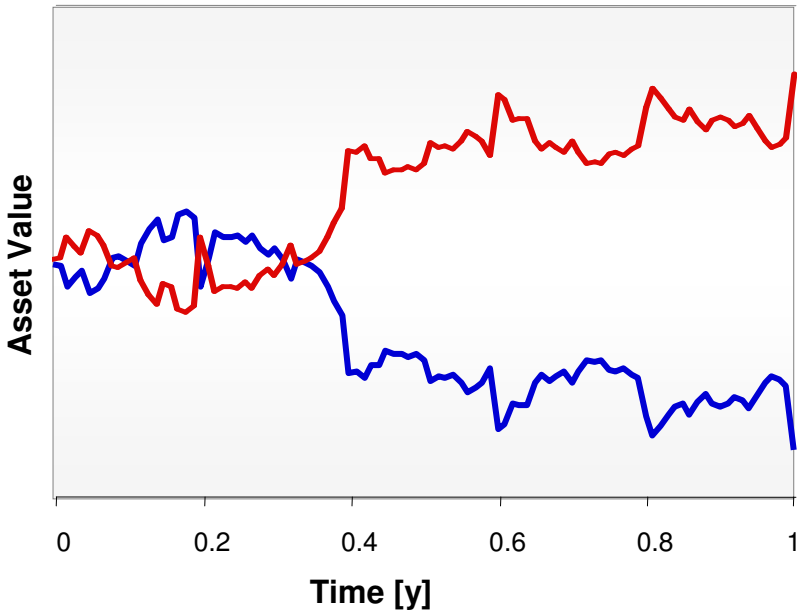
Antithetic variables

The principle of this simple technique is to add the factor scenario $-x^{(j+1)}$ as a new scenario of the simulation for every scenario x^j drawn from the simulation engine. We get one scenario for free !



Acceleration factor compared to crude Monte Carlo: ~ 2

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Importance Sampling: Shifting the systematic mean

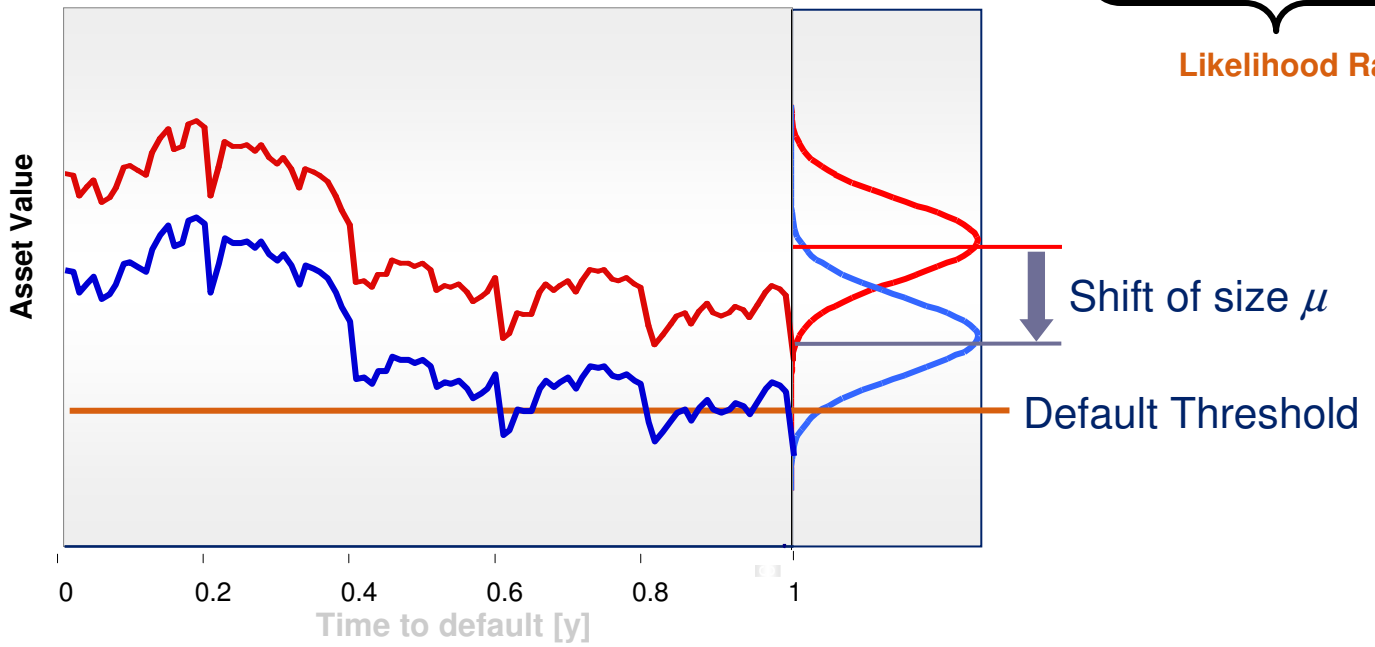
Generate asset returns using N[-μ,σ] instead of N[0, σ] for the systematic factors. Amend Monte-Carlo estimate accordingly:

$$\mathrm{EL} \approx \frac{1}{m} \sum_{j=1}^{m} L^{(\text{scenario } j)}$$

Change of measure

$$\mathrm{EL} \approx \frac{1}{m} \sum_{j=1}^{m} \left\{ \frac{\mathrm{N}[0,\sigma]\left(\tilde{r}^{(\text{scenario } j)}\right)}{\mathrm{N}[\mu,\sigma]\left(\tilde{r}^{(\text{scenario } j)}\right)} \right\} L^{(\text{scenario } j)}$$

Likelihood Ratio



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Monte Carlo Acceleration combined

Crude Monte Carlo

+ Antithetic variable:	factor	2
+ Importance sampling:	factor	100 - 350
+ Quasi MC, conditioning and others	factor	~ 40

- => Together (Ant.Var.* Imp.Sampl.*(Cond. and others))
- acceleration factor ~ 3000 - 20000
- Variance reduction: ~ $N^{1/2}$ = 55 - 140
  std error typically from 40% down to => 0.8% - 0.3%
- For stable ES allocation, a crude Monte Carlo run would need
  750 mio simulations (run time ~ 15000 h for one EC run) instead of
  100000 simulations (run time ~ 2h for one EC run)
- => ES is a stable allocation method!
- Depends on portfolio contributors and risk concentrations, i.e. for high risk concentration the acceleration factor gets bigger, for low concentration it gets lower

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Motivation and Business perspective of Stress Testing

Objectives

- Impact on credit reserve / expected loss and economic capital (EL, EC)
- Identification of concentration risk in sub portfolios (or other aggregation level)
- Identification of major capital consumers under stress

- Basel II: notes
  - Use of scenarios like economic or industry downturn, market risk events, liquidity shortage
  - Recession scenarios, not necessarily worst case scenarios
  - Banks should use their own data for rating migrations and integrate the insight of external ratings
  - Smaller deteriorations should also be considered

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Stress testing framework

Rare but reasonable scenarios (e.g. 1 in 10 year stress event)

- All EC relevant risk types must enter into the regular stress testing framework
- Macroeconomic, business related and quantitative aspects to be considered with respect to risk profile implications
- Change of risk profile and its impact on capital requirements (incl. regulatory capital) should be analyzed
- Regular reporting to senior management and the business to act accordingly is the focus
- Stress testing report for group and sub-portfolios of special risk distinction are required on a daily, weekly and monthly basis

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Common Practice & typical Problems

- Observed singular stress event
  - "Worst annual internal experience"
  - Broad default rate movements
  - Equity market crash
  - Widening of credit spreads
- Arbitrary shocks
  - e.g. impose a two-grade downward migration across the portfolio.
- Stress key parameters
  - e.g. increase all PD, LGD, EAD or correlations by 10%, 25%, 50% or 100%.
- Relevant data often not incorporated
  - e.g. internal transition matrices, internal economic projections, historical parameter behaviour
  - correlations between LGD and PD
  - volatilities of LGD, EAD
- Missing
  - Portfolio Dynamics
  - Economic Dynamics; multi sector correlations
  - Scenario probabilities

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Example: Stress Transition Matrix

Historical event: e.g. Changes in transition matrices from 2000 to 2002

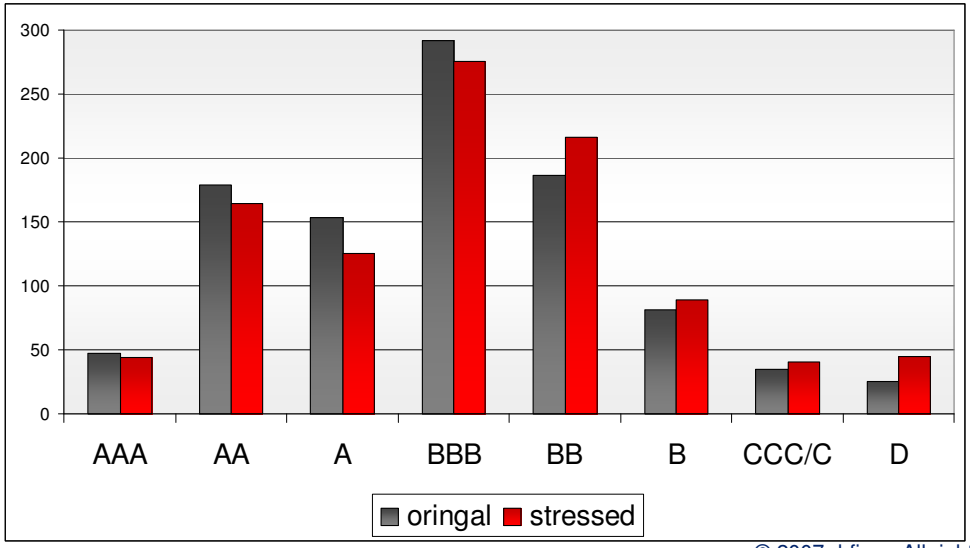
Original transition matrix

1 year	AAA	AA	A	BBB	BB	B	CCC	D
AAA	68.19	23.04	5.20	1.43	1.44	0.60	0.07	0.03
AA	6.29	72.00	13.13	6.60	1.27	0.30	0.32	0.09
A	1.31	22.85	42.70	25.72	5.83	0.71	0.30	0.58
BBB	0.27	4.25	13.17	62.06	18.25	0.67	0.41	0.92
BB	0.02	0.53	3.12	21.89	59.06	12.03	1.49	1.86
B	0.10	0.32	0.97	9.21	26.55	50.91	2.89	9.05
CCC	0.10	0.19	1.10	2.02	4.99	16.90	55.06	19.65
D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

stressed transition matrix

1 year	AAA	AA	A	BBB	BB	B	CCC	D
AAA	62.00	27.40	5.74	2.68	1.44	0.60	0.07	0.07
AA	6.29	63.27	7.07	12.65	7.44	2.24	0.52	0.52
A	1.23	21.24	37.46	29.47	7.78	1.37	0.36	1.09
BBB	0.19	4.17	10.64	51.36	26.07	2.12	1.71	3.74
BB	0.02	0.30	3.00	21.60	54.80	13.54	2.58	4.16
B	0.10	0.32	0.66	8.72	26.35	47.57	5.61	10.68
CCC	0.10	0.19	0.52	2.02	3.83	16.88	49.27	27.20
D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

Expected Rating distribution



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Constraints on sampling space

- Specify economic stress scenario determined by economists
  Example: decline of 20% in the utility index.
- Translate scenario into stress of systematic factor (restriction of factor space)
- Concentrate on a small number of relevant systematic risk factors
  (preserve probability of scenario occurrence)
- Other factors are impacted through correlations to the stressed factors.
- Restrict Monte Carlo sample according to the stress scenario

  ⇨ consistent set of stressed PDs for all loans in the portfolio,
  change in PD depends on the loan's correlation to the stressed factors

  ⇨ estimate for the probability of the simulated scenario (probability of occurrence)
- Determine impact of stress scenario by calculating expected loss conditioned on the scenario and other statistics of the portfolio.
  e.g.: $PD_{i,stress} = EL_{i,stress}$/ LGD /EAD

Bonti, Kalkbrener, Lotz and Stahl: Credit Risk Concentrations under Stress, working paper, 2005

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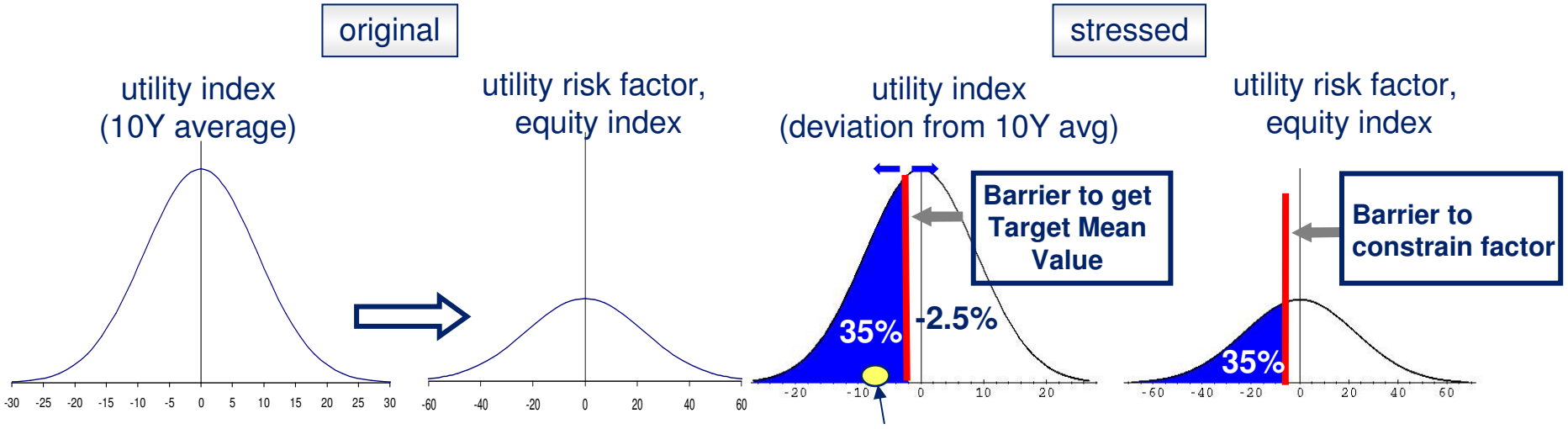
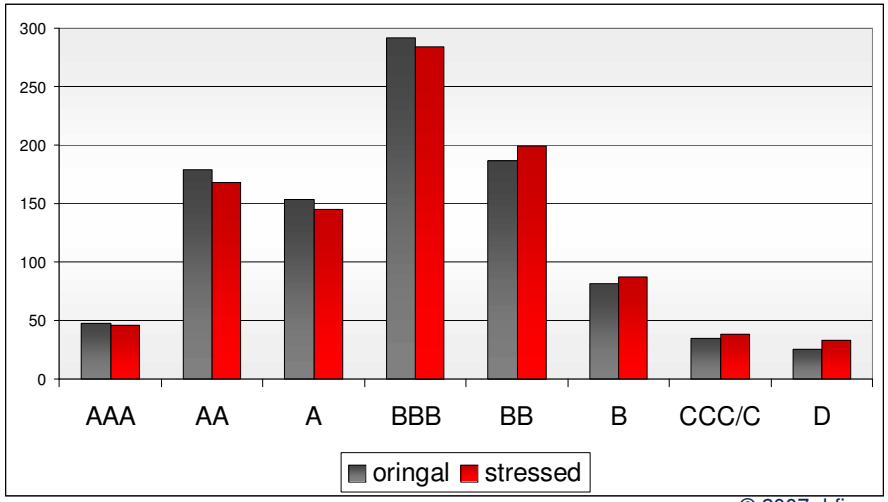
Link between Macroeconomic Outlook and Credit EC



Utility Index Forecast = -7.3% = Target Mean value



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