Quantitative and Qualitative Methods in Risk Management

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Agenda

Part I. Qualitative and Quantitative Methods to Assess and Manage Risks

1. Overview
   - What is risk?
   - Basic mathematical concepts about risk measurement
2. Types of Risks
   - Underwriting, Credit, Market and Operational risk
   - Qualitative description
   - One quantitative method for each(?) type

Agenda

Part II. Integrated Risk Management

3. Enterprise Risk Management
   - COSO Framework
4. Aggregation of Risks
   - Methods
   - Sensitivity
5. Risk Diversification
   - Capital Allocation
   - Dynamic Portfolio Management

1. Overview

What is risk?

Basic mathematical concepts

What is Risk?

- Concept from real life and inherent in all human endeavor
- Risk describes the uncertainty of the future outcome of a current decision or situation.
- Risk is the business of insurance companies
  - Pricing risk
    - Calculation of insurance premium first application of risk measurement
  - Measuring risk
  - Managing risk
- There are many different definitions of risk
  - As there are many, may be there is no completely satisfying one….

➔ Risk is extremely difficult if not impossible to define

- **Measurement of risk**
  - Mathematical concept
  - Well defined

Refer to F. Delbaen [1] for an excellent overview

Fundamental mathematical concepts for measuring risk (1)

Concept

- Future states
  - Set of states $\omega_1, \omega_2, \omega_3, \ldots$
- Probability P for each state
- Random variable X defined on the set of states:
  - For each scenario ω a quantifiable outcome $X(\omega)$.
- Cumulative Probability Distribution

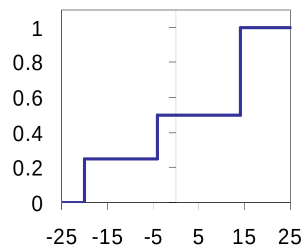
$$F_X(x) = P(X \le x)$$

  - Describes the probability of possible outcomes. $F_X(x)$ is the probability that the outcome of X is not bigger than a given value x.

Example: Flipping two coins

- Each coin shows head or tail
  - hh, tt, ht, th
- P(hh)=P(tt)= P(ht)=P(th)= 1/4
- X = €-amount you win as a result of a bet whose outcome depends on the flipping of the coins.
  - X(hh)=-20, X(tt)=-4, X(ht)=X(th)=14
- Tabular and graphical illustration

x	F(x)
-25	0
-20.01	0
-20	0.25
-4.01	0.25
-4	0.5
0	0.5
19.99	0.5
14	1
15	1



Fundamental mathematical concepts for measuring risk (2)

Concept

- Expected Value

$$EX = \sum_k X(\omega_k) \cdot P(\omega_k)$$

- Risk measure Value-at-Risk

$$\mathrm{VaR}_\theta(X) = -F_X^{-1}(\theta)$$

  - confidence level 1-θ
  - Solvency: 1-$\theta \approx$ 99%

- Risk Measure Tail-Value-at-Risk

$$\mathrm{TVaR}_\theta(X) = \frac{1}{\theta} \cdot \int_0^\theta \mathrm{VaR}_t(X)\,dt$$

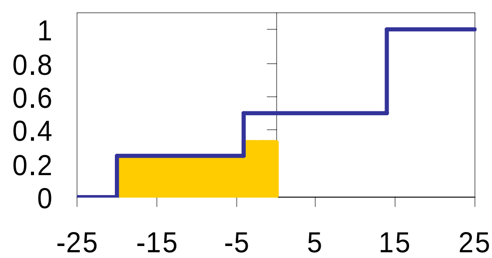
  - Average of all VaR's with confidence level better than 1-$\boldsymbol{\theta}$
  - Considers the *entire* tail

Example: Flipping two coins

- Expected Profit

$$EX = -20€ \cdot 0.25 - 4€ \cdot 0.25 + 14€ \cdot 0.25 + 14€ \cdot 0.25 \\ = 1€$$

- $\mathrm{VaR}_{35\%}(X)$ = 4€
- $\mathrm{TVaR}_{35\%}(X)$ = 15.43€



Fundamental mathematical concepts for measuring risk (3)

- We saw that risk can be described by random variables
- For practical reasons, such as
  - Pricing
  - Accepting / rejecting
- We need to associate a single number $\rho(X)$ to a risk described by a random variable X
- A risk measure should have the following properties (coherence):

X,Y random variables where "the risk" is in the negative outcomes, a,b constants.

1. Scalable: $\rho(aX) = a\rho(X)$
2. Ranks risks correctly: If $X(\omega) \leq Y(\omega)$ for each scenario ω, then $\rho(X) \geq \rho(Y)$
3. Allows for diversification: $\rho(X+Y) \leq \rho(X) + \rho(Y)$
4. Translation invariance (proper treatment of riskfree cashflows): $\rho(X+b) = \rho(X) - b$

- TVaR has all these properties, VaR does not have property 3.

Stochastic Simulation (1)

We want to have a computer based algorithm which produces plenty of independent random samples of a random variable

Concept

- Scenario based simulation
  - Draw randomly a scenario ω and compute $X(\omega)$. The probability for drawing a certain ω is $P(\omega)$. Repeat this process as often as you wish and record the results.

Example

- Scenario based simulation
  - Say, h corresponds to 0 and t to 1.
  - Draw two consecutive random bits, each time 50% probability for 0 and 50% probability for 1.
  - Read the result for this stochastic sample in the following table:

scenario	Result
00	-20
01	14
10	14
11	-4

Stochastic Simulation (2)

Concept

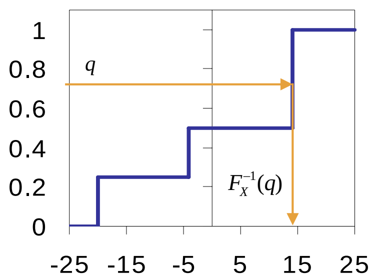
- Based on the distribution F_X
  - Sample a random number q between 0 and 1, each with equal probability
  - The stochastic sample x of is the inverse of the distribution F_X with respect to q, i.e.

$$x = F_X^{-1}(q)$$

  - Repeat this process as often as you wish and record the results.

Example

- Based on the distribution F_X
  - Sample a random number q between 0 and 1, each with equal probability
  - The inverse of F_X with respect to q can be read off from the graph of F_X:



  - E.g.: $F_X^{-1}(0.7) = 14, F_X^{-1}(0.11) = -20,$
    $F_X^{-1}(0.42) = -4, F_X^{-1}(0.05) = -20$

Scenario based simulation vs. distribution based simulation

Scenario based

Pro

- Risk is modeled at it source
- If modeling more random variables on the same scenarios, their dependence is recorded automatically
  - E.g., economic scenarios with impact on random variables “asset value *A*” and “value of liabilities *L*”

Con

- For many risks, the random variable cannot be modeled or it is extremely difficult to calibrate the models.

Distribution based

Con

- The source of the risk is forgotten
- Appropriate dependencies more difficult/ impossible to incorporate
  - In the example above, the different scenarios “ht” and “th” cannot be distinguished anymore. The dependence of another risk (with different outcomes for ht and th) with “flipping our coins” cannot be recorded properly in this way.

Pro

- For many risks the random variable may be difficult or impossible to model, but the distribution can be estimated using statistics.

Example: Windstorm

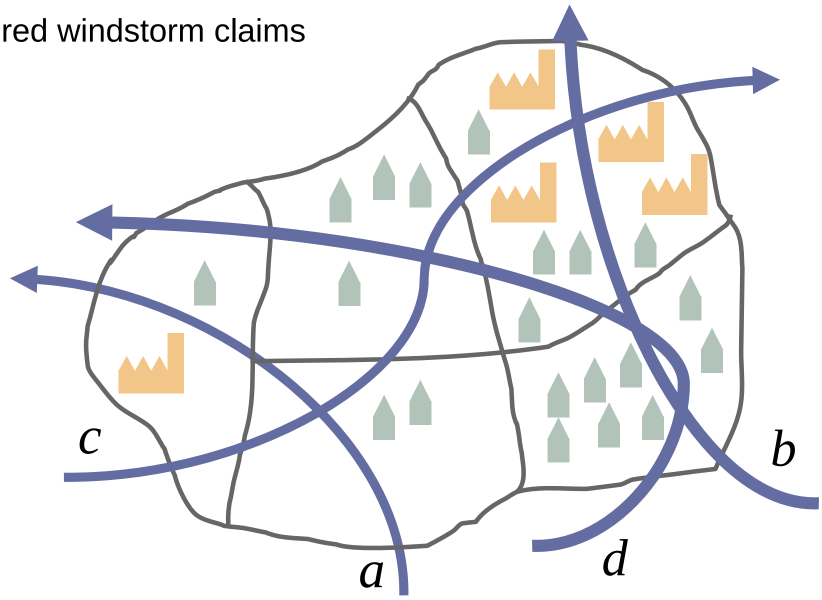
Collect the exposures from all policies per zip-code area in an accumulation control system

- Here: Private homes and industrial plants

- Scenarios = Windstorms
- Random Variable = insured windstorm claims

Stochastic Simulation

Scenario	Insured Loss
a	3
b	27
c	11
d	8



There are commercial models of this type available for major peril regions.

Internal model

- The variable to be modeled is the company's net asset value at a future point in time
- "Ideal world": Entirely scenario based
  - Each scenario represents *a possible* future state of the world
    - i.e. the collection of "all" events between now and 1 year in the future
  - The underlying set of scenarios is "complete"
  - The probabilities of the scenarios are known
  - Given an ω, the internal model calculates the net asset value for this scenario
  - ➔ Needless to say that such a model does not and cannot exist….
- However, there are scenario based components (e.g. natural perils)
  - Some are provided by commercial organizations
- Other components may be of statistical nature
  - i.e. based on probability distributions rather than on random variables based on concrete scenarios
- Combination of the various components is challenging

2. Types of Risks

Qualitative description

One quantitative method for each(?) type

Underwriting Risk

Associated with perils covered in insurance contracts and processes associated with the conduct of the insurance business.

- Underwriting process risk
- Pricing risk
- Product design risk
- Claims risk
- Economic environment risk
- Net retention risk
- Policyholder behavior risk
- Reserving risk

Source: IAA Report on Insurer Solvency [2]

Collective model for insurance claims: Frequency and Severity

- Model assumptions
  - The number N of claims arriving in a certain period (say next year) is random
  - The losses $X_1, X_2, X_3, \ldots, X_N$ arriving in that period are independent and have the same probability distribution F_X.
  - N and $X_1, X_2, X_3, \ldots, X_N$ are independent.
- Commonly used distributions
  - Poisson distribution for N: Probability for k losses is $P(N=k) = \frac{\lambda^k}{k!} e^{-\lambda}$
  - This is the frequency appropriate model if the expected waiting time for the next loss is always the same, i.e., 1/λ. The expected number of claims per year is λ
  - Pareto distribution for the severity if we are only considering big losses, i.e., N is only counting those losses greater than a certain threshold t.

$$F_X(x) = 1 - \left(\frac{x}{t}\right)^{-\alpha}$$

Refer to [3], Chapter 2, for a comprehensive introduction and for various types of distributions

From the data to the model (1) *

Example: Poisson-Pareto-Model for big fire claim

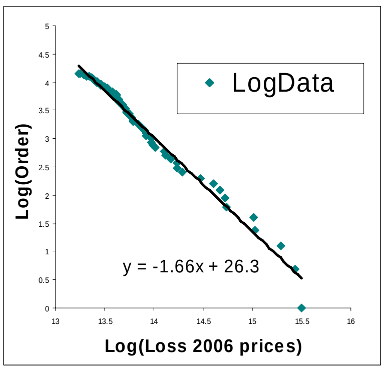
- Data: All fire loss data greater than 500’000€ data since 1997

De-trending claims inflation: house prices, … → Sorting in descending order → Regression of Log(Losses) vs. Log(Order) → Slope of tail is an estimate for -α

Year	Loss in orig. prices
1997	661'289
1997	1'117'902
1998	1'077'621
1999	669'028
1999	570'178
1999	773'689
2000	889'877
2000	1'335'845
2000	533'134
2000	2'802'269
2000	2'058'730
2001	825'156
2001	880'003
2001	996'343
:	:

Year	Loss in 2006 prices
1997	1'211'457
1997	840'507
1998	1'420'868
1999	1'344'114
1999	820'720
1999	699'457
2000	949'111
2000	1'069'032
2000	1'604'785
2000	640'468
2000	3'366'439
2001	2'473'206
2001	965'213
2001	1'029'369
:	:

Loss in 2006 prices	Order
5'385'524	1
5'055'507	2
4'367'570	3
3'366'439	4
3'322'110	5
2'524'164	6
2'473'206	7
2'360'333	8
2'202'225	9
1'940'777	10
1'604'785	11
1'527'702	12
1'516'810	13
1'420'868	14
:	:



Choosing the “right” threshold is not easy
Refer to [4] on Extreme Value Theory

* Illustrative and simplified.

From the data to the model* (2)

- The starting point s of the regression needs to be selected with care
  - Needs to be greater than 2007-price of the reporting threshold 500'000€ in 1997.
  - Threshold for severity is $t=\mathrm{Exp}(s)$, say $t=700'000$€.
  - Pareto-α is estimated to be $\alpha=1.66$ (see trendline in LogLog-graph)
- Frequency
  - Count number of losses n_i in year i ($i=1997,1998,\ldots$) and measure the volume v_i of the underlying business in year i, say v_i = number of policies in year i with sum insured greater than t. The claims intensity for the threshold t is n_i/v_i.
  - An estimate for the expected claims intensity γ in 2007 is the volume-weighted average of the intensities over the past*:

$$\gamma = \left. \sum_{i=1997}^{2006} v_i \cdot \frac{n_i}{v_i} \middle/ \sum_{i=1997}^{2006} v_i \right.$$

  - The assumption of the Poisson-model (expected waiting time for the next claim…) is probably a good one (provided natural hazard losses are excluded). We estimate:

$$\lambda = v_{2007} \cdot \gamma$$

20-year event loss for this fire portfolio?

- The frequency λ_u for losses greater than u (where $u > t$) is

$$\lambda_u = \lambda \cdot (1 - F_X(u)) = \lambda \cdot \left(\frac{u}{t}\right)^{-\alpha}$$

since N and $X_1, X_2, X_3, \ldots, X_N$ are assumed to be independent.
- Example: $\lambda=3$, $\alpha=1.66$, $t=700'000$€
  - Setting $\lambda_u=1/20$, we can solve this for u. We obtain u= 8.25 mio €.
  - The biggest loss observed in the data was around 5.4 mio €
  - The further one extrapolates beyond the range of observed losses, the less reliable the estimate gets.

Interpretation of Pareto-α

- Looking at the formula

$$\lambda_u = \lambda \cdot (1 - F_X(u)) = \lambda \cdot \left(\frac{u}{t}\right)^{-\alpha}$$

  we can see that
  - twice as big claims have a 2^α -times as big retrun-period.

- Some rough rule of thumb*:

Type	α
Earthquake / storm	≈ 1
Fire	≈ 2
Fire in industry	≈ 1.5
Motor Liability	≈ 2.5
General Liability	≈ 1.8
Occupational injury	≈ 2

* Source: Peter Antal, Swiss Re [3]

Understanding the underlying model assumptions is crucial

- Example: Modeling Hurricane loss frequency with Poisson-model?
  - Estimate for the expected return period of a 3.6 bn USD industry loss from a hurricane in South East US is 3.4 years.
  - Poisson model: N number of industry losses per year greater than 3.6 bn USD
    - $\lambda=1/3.4$
    - P(N >3)=1-P(N=0)-P(N=1)-P(N=2)-P(N=3)=1/4053
  - Insured losses for hurricanes in 2004 in bn USD:

Hurrican	Insured loss
Charley	7.475
Frances	4.595
Jeanne	3.656
Ivan	7.110

Estimates as at June 23, 2005 by US Property Claims Service
www.iso.com/products/2800/prod2801.html

  - Pitfall: Seasonality effects. Expected waiting time for a hurricane is not constant throughout the hurricane season and not the same in each season.
  - At least there are other frequency distributions required (e.g. Negative binomial)
  - Can the variables N and $X_1,X_2,X_3,\ldots,X_N$ assumed to be independent in this case?

Is the past experience reliable for modeling the future?

- In the above fire example, we corrected for a changing environment
  - By simply applying claims inflation
- Are all effects of a changing environment quantified adequately?
  - Higher concentration of values (e.g., coasts)
  - Changes in mortality
  - Medical cost inflation
  - Changes in legal environment
  - Climate change
  - Terrorism
  - …
  - The longer the time horizon, the more difficult it is to quantify these effects
    - ➔ Longer tail lines of business
      - Life & Pension
      - Liability
      - …

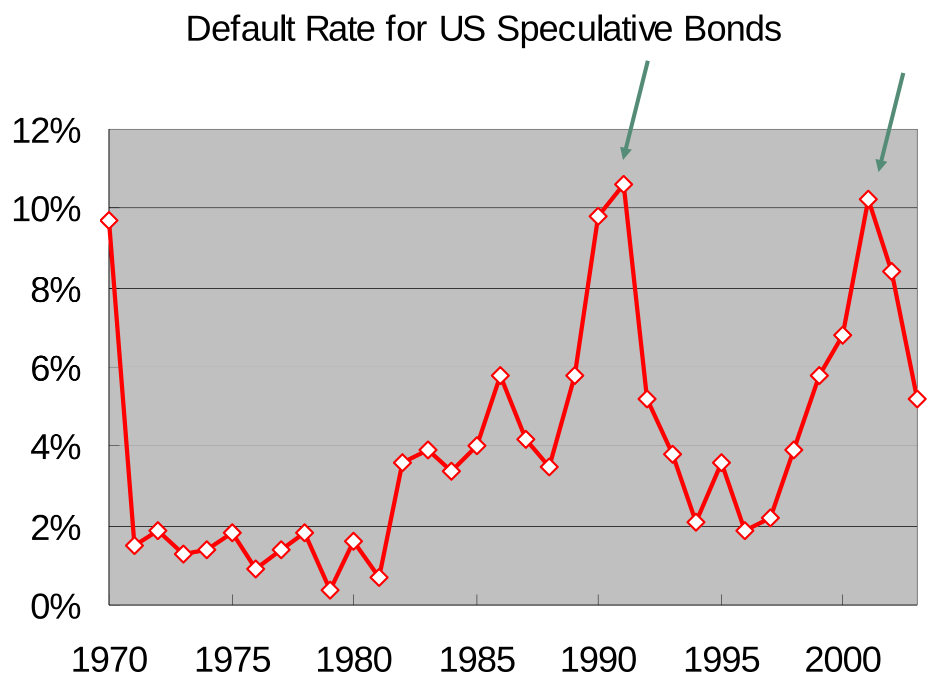
Credit Risk

Risk of default or change in credit quality of counterparties and intermediaries to whom the company has an exposure.

- Default risk
- Downgrade or migration risk
- Spread risk
- Settlement risk
- Sovereign risk
- Concentration risk
- Counterparty Risk

Source: IAA Report on Insurer Solvency [5]

Credit Risk Can Run High



Source Moody's

Credit Risk Enters the Balance Sheet in Many Places

- The first essential piece of measuring credit risk is to identify where those risks are on the balance sheet.
- Premium receivables, depends on the credit risk of the buyers.
- Reinsurance receivables, depends on the credit risk of the sellers.
- Corporate bond and equity holdings, this is related to the investments.
- On the liability side, credit and bond insurance is also related to credit risk.

The Traditional Approach of Measuring Credit Risk

- Traditionally assessing corporate risk was based on:
  - ✓ Rating agencies (S&P, Moody's, Fitch, AM Best, …).
  - ✓ Credit information agencies (Dunn & Bradstreet, …).
  - ✓ Analysis of annual accounts.
  - ✓ Information agencies (Reuters Business Briefing, …).
- The assessment is done qualitatively supported by some scoring mechanism of business and financial ratios.
- It is updated relatively infrequently (yearly, sometimes quarterly).

Measuring the Risk Using Credit Risk Models

- Recently quantitative credit risk models have become commercially available and banks have been using them quite successfully for managing their credit risk portfolio.
- Most of these models use "option pricing technology" to value the companies.
- Two main strands of models have emerged:
  - ✓ *Structural models:* essentially look at the balance sheet of a company and try to evaluate its strength (e.g. Moody's KMV, CreditMetrics®).
  - ✓ *Default intensity models*: actuarial type of model where the default originates from exogenous shocks (e.g. CreditRisk+®).

Valuation Theory: Structural Models

- Default is determined by the relation between the value of the firm and its liabilities.
- Black/Scholes (1973) pointed out that corporate debt can be seen in terms of an option position on firm‘s assets.
- Based on this idea it is possible to deduce the asset value of a firm from its equity price.
- Default occurs when the value of the firm falls below some boundary related to its liabilities.
- The probability of default is thus related to the distance between the asset value and the liabilities payable.

The Main Ingredients

- For measuring credit risk with a structural model, we need to model three elements:
  1. The probability of default of a certain firm (Expected Default Frequency, Rating, …),
  2. The loss given default (the recovery rate),
  3. The dependence between defaults to evaluate the portfolio of risks.
- The first is often provided by commercial organizations
  - either through quantitative models:
    - Moody’s KMV Credit Monitor®, CreditMetrics®, …
  - or through ratings by rating agencies.
- The others are essentially provided by quantitative models based on statistical studies.

The Kealhofer, McQuown and Vasicek (KMV) Model*

- The model estimates the probability of default: Expected Default Frequency (EDF).
- Steps in estimating EDF:
  - ✓ Determine the market value of assets.
  - ✓ Measure the volatility of asset value.
  - ✓ Determine the liabilities and the capital structure from the balance sheet.
  - ✓ Determine the default point.

*) refer to: Moody's KMV, www.moodyskmv.com/research/whitepaper/ModelingDefaultRisk.pdf

Market Value of Assets

- Following Merton's model that the equity value, V_E, is the price of an option on the *asset value,* V_A, by means of derivative asset pricing, we can write the following relations:

$$\begin{cases} V_E = & F(V_A, \sigma_A, K, c, r) \\ \sigma_E = & G(V_A, \sigma_A, K, c, r) \end{cases}$$

  where $\boldsymbol{K}$ denotes the leverage ratio in the capital structure, $\boldsymbol{c}$ is the average coupon paid on the long-term debt and $\boldsymbol{r}$ the risk-free interest rate.
- In blue, we have the two variables to be determined: the asset value, V_A, and its volatility, σ_A.

Computing the Market Value of Assets

- Since only V_E is directly observable,we can back out V_A from the equation before:

$$V_A = H(V_E, \sigma_E, K, c, r)$$

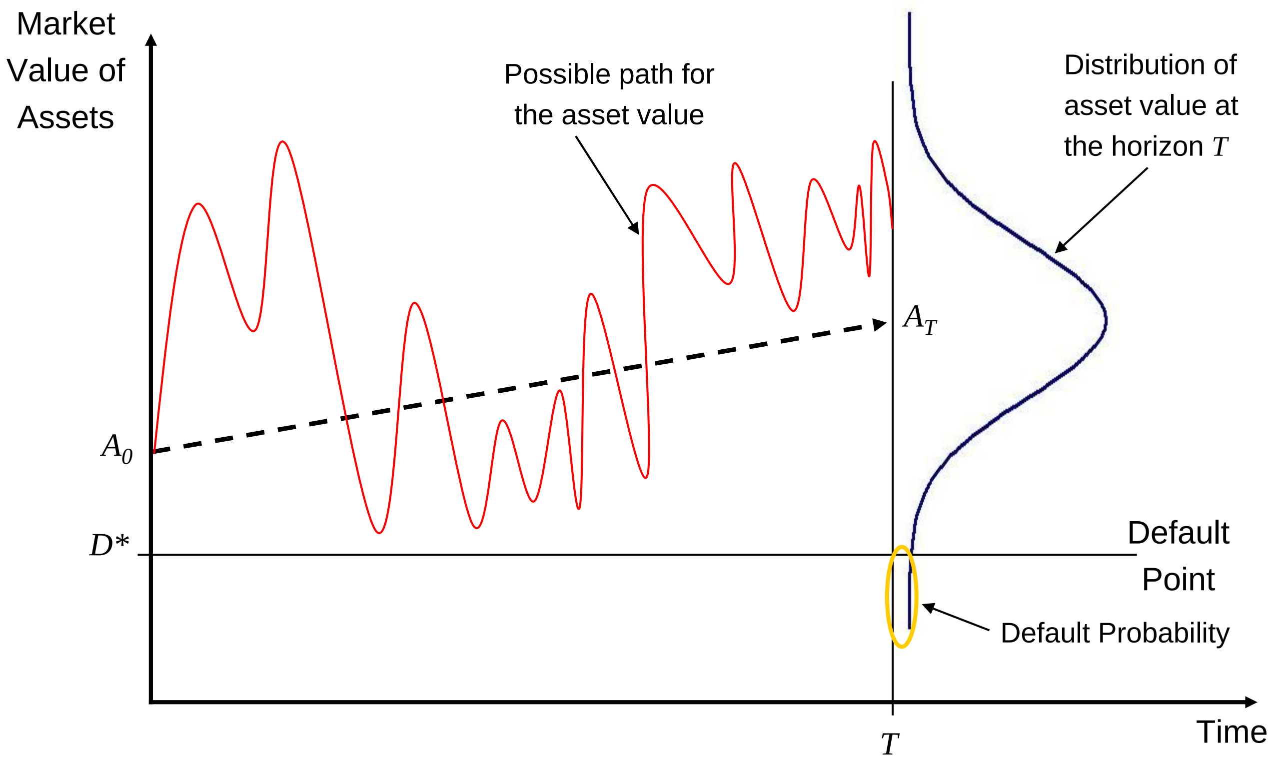
- From the equity price history we can compute the price volatility, σ_E, (the size of the movements).
- We also need to know the leverage ratio (debt / equity), K, the structure of the liabilities: average coupon paid on the debts, c, from balance sheet information and the risk free rate, r.
- To calibrate the model for σ_A, one can use an iterative technique

Distance to Default

- The default point, D^*, is defined as the point where the cumulative amount of obligations payable within the time frame, T, is higher than the asset value of the company.
- The distance to default, Z, is thus computed from the asset value to the default point:
- The probability of default (EDF) is then $p=\mathcal{N}(-Z)$.

$$Z = \frac{\log V_A - \log D^* + \mu T - \frac{1}{2}\sigma_A^2 T}{\sigma_A \sqrt{T}}$$

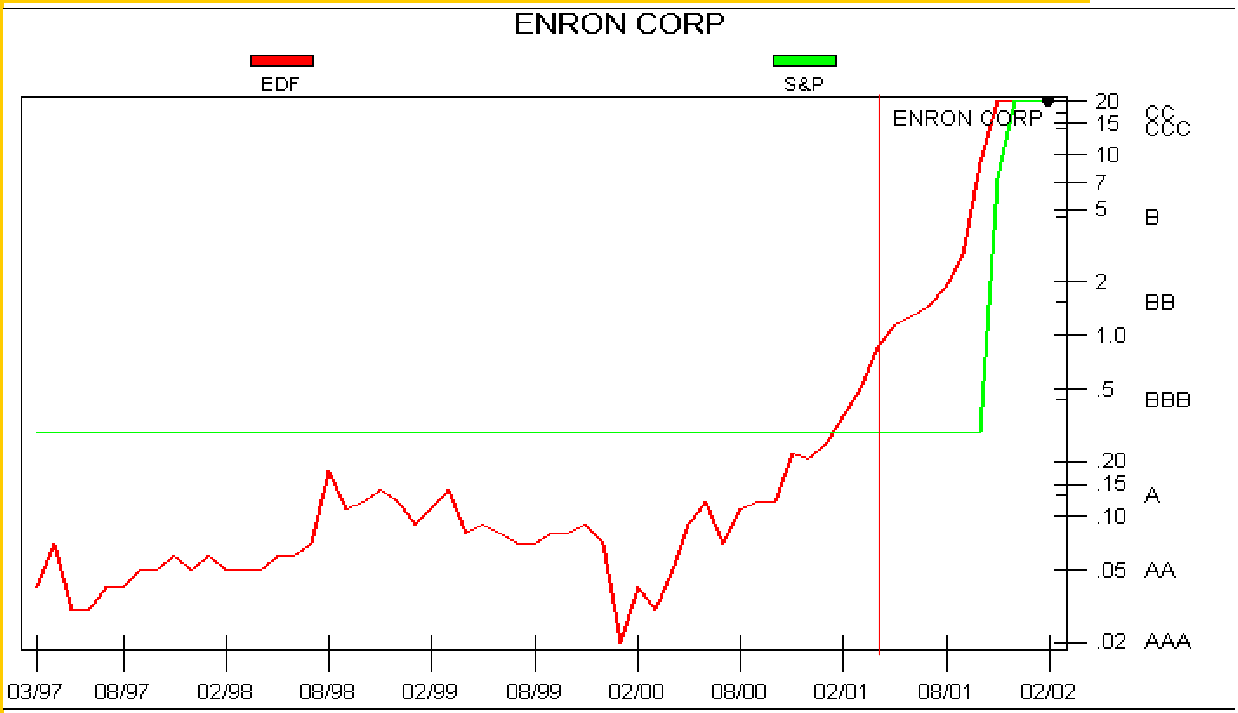
Estimating EDFs



Movements in EDFs

- The main drivers in the model for changes of an EDF are:
  - ✓ Variations in the stock prices.
  - ✓ The debt level (leverage ratio).
  - ✓ The asset volatility.
- The EDF varies *much faster* than the rating agencies.
- Because the distribution of EDFs is very skewed and fat-tailed there is a difference between *average* and *median*.

Example of Early Warning: Enron



- Source Credit Monitor® (see www.mkmv.com)

Limitations of KMV-model

- Although Moody's KMV offers a private firm model, the firm must be listed to get the full power of the model.
- The portfolio part uses a variance/covariance approach, which might not be appropriate for default distributions.
- The EDF is an unconditional measure, thus the multi-year evaluation of the portfolio is fully determined and does not allow for migration and non-linear effects due to the economic environment.

Keeping Track of The Exposure

- The credit exposure is at different places of the balance sheet.
- Each exposure needs to be monitored and properly aggregated.
- In our company, there are four places where this is particularly important:
  1. Our credit & surety reinsurance business,
  2. Our investment portfolio,
  3. Reinsurance recoverables,
  4. (Premiums).
- For each of them we need to build an accumulation control system.

Incorporating Credit Risk

- With the current level of credit default, this risk cannot be neglected.
- It enters in the balance sheet in many places:
  - Premium receivables,
  - Reinsurance receivables,
  - Corporate bond holdings,
  - Credit and Surety insurance.
- Rating agencies or commercial software make available *expected default probabilities* for corporations.
- These can be used to evaluate the credit risk of a bond portfolio or the credit risk of a set of reinsurers or other counterparties.

Market Risk

Arises from the level of market prices of assets

- Interest rate risk
- Equity and property risk
- Currency risk
- Basis risk
- Reinvestment risk
- Concentration risk
- Asset/Liability Management (ALM) risk
- Off-balance sheet risk
- Liquidity risk

Source: IAA Report on Insurer Solvency [2]

Assessing the Evolution of the Economy at Converium

- For a realistic internal model we need to assess the future of the economy and its implications to the company.
- Modeling the world economy is a rather ambitious goal.
- We just look at key variables that describe the economy: interest rates (yield curves), FX rates, equity indices, inflation, GDP, …
- We model only five currency zones (USD, EUR, GBP, JPY, CHF).
- All the key variables have to be modeled for all currency zones. We end up with more than 100 variables.

Realistic Economic Scenarios

- Usual economic scenario generators underestimate the risk of extreme movements in financial markets.
- The yield curve models must reproduce the empirical features (percentage of inverted yield curves, term structure of volatility) to a satisfactory accuracy.
- It is difficult to produce consistent scenarios between the major economic indicators: yield curves and stock market indices, inflation and GDP.
- The relations between the economy and the insurance liabilities are difficult to assess.

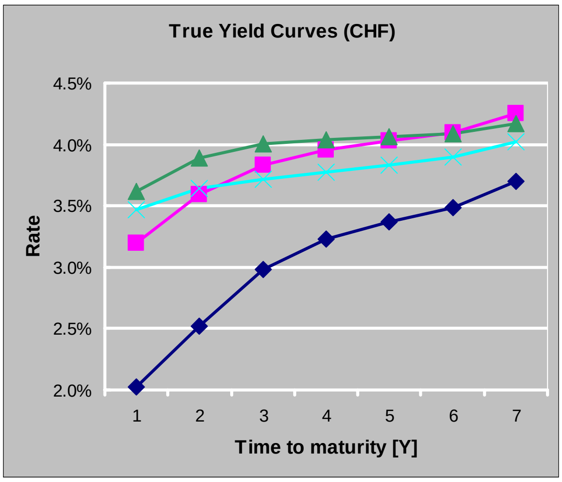
Extreme Daily FX-Returns and their "Normal" Probability

Rate	Historical Max.	One in # years event	Historical Min.	One in # years event
EUR/USD	5.05%	10'838'489	-3.86%	1'243
JPY/USD	3.98%	1'519'105	-7.20%	$>10^{12}$
GBP/USD	4.05%	24'533'626	-4.70%	3'269'448'288
CHF/USD	3.76%	21'157	-4.51%	1'543'769

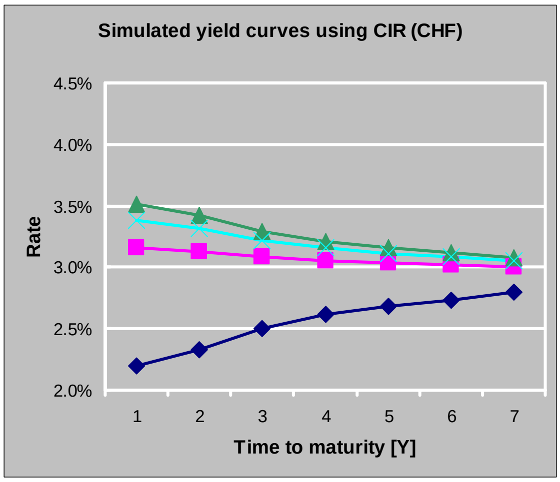
Model estimated over 21(EUR:13) years of daily Foreign Exchange Rates *Returns*

Inappropriate Economic Models: Illustration Yield Curves

Quarterly Behavior of the Yield Curve



Real Behavior



Cox Ingersoll Ross

Blue curve is the initial yield curve. **Pink** is one, **turquoise** two and **green** three quarters later, resp.

Economic Scenarios, Generated by Re-Sampling Past Data

- How will the economy of five main currencies behave in the next few years: GDP, interest rates, FX rates, equity indices, ...?
- Resampling idea: generate scenarios from random *re-sampling of historical economic data.*
- Method: re-sample *returns* rather than raw values; mapping of yield curve; heavy tails of distribution; …. Finance know-how is required.
- Advantage: by picking a whole set of economic indicators at the same date, we preserve the contemporaneous *dependence structure.*
- Problem: short relevant history, use other knowledge about the behavior of the tails of the distribution to correct for the lack of data and current forward rates to stay consistent with the market.

“Everything Else” → Operational Risk

The risk of loss resulting from inadequate or failed internal processes, people, systems or external events

- People risk
  - Incompetency
  - fraud
- Process risk
  - Model/methodology risk
  - transaction risk
  - control risk
- System risks
  - System failure
  - programming error
  - information risk
  - telecommunication error

Quantifying operational risk?

- Insufficient data of the right type
  - Short history
  - Confidentiality is an issue
  - Banks track small to moderate losses, which occur frequently
- Characteristics of available data
  - Structural changes over time
    - due to business and economic cycle, management interaction, regulation
    - Losses may tend to occur in clusters
  - Severe tails
    - One loss may cause ruin (e.g. Baring Bank, 1995)
  - Some losses do not obey a repetitive pattern
    - E.g. incompetency, fraud

➔ Currently available model may not be adequate
  - Think e.g. about the assumptions of the collective model

Reference: Embrechts et al [5]

Summary

- Random variables, scenarios, probability distributions are the quantitative tools to describe risk
- We discussed various quantitative methods
  - Statistical methods (e.g. Pareto-Poisson-Model, tail estimates)
  - Scenario based models (e.g. for windstorm)
  - Structural model (e.g. Moody's KMV)
  - Re-sampling method (e.g. Converium model for market risk)
- We should remember that
  - Understanding the assumptions of a model is crucial
  - Models can be abused
  - Not all risks can be quantified
  - Accumulation control systems are required in order to keep track of exposures
    - basis to estimate the impact of certain scenarios onto the company
  - Dealing with a changing environment is very challenging

➔ *Qualitative methods are essential and described in the next part*

3. Enterprise Risk Management

COSO Framework
ERM at Converium

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Enterprise Risk Management (ERM)

Definitions

- In its "Overview of Enterprise Risk Management" [6], the Casualty Actuarial Society describes Enterprise Risk Management as:

  "… the discipline by which an organization in any industry assesses, controls, exploits, finances and monitors risk from all sources for the purposes of increasing the organization's short- and long-term value to its stakeholders."

- In its "Enterprise Risk Management – Integrated Framework" [7], COSO defines ERM as:

  "… a process, effected by an entity's board of directors, management and other personnel, applied in strategy setting and across the enterprise, designed to identify potential events that may affect the entity, and manage risks to be within its risk appetite, to provide reasonable assurance regarding the achievement of entity objectives."

COSO's ERM Framework

- COSO (Committee of Sponsoring Organizations of the Treadway Commission)
  - COSO is a private sector organization dedicated to improving the quality of financial reporting through business ethics, effective internal controls and corporate governance
  - COSO includes representatives from industry, public accounting, investment firms and the NYSE
  - "Enterprise Risk Management – Integrated Framework" 1 (2004) defines essential components, suggests a common language and provides clear direction and guidance for ERM
  - Webpage: www.coso.org

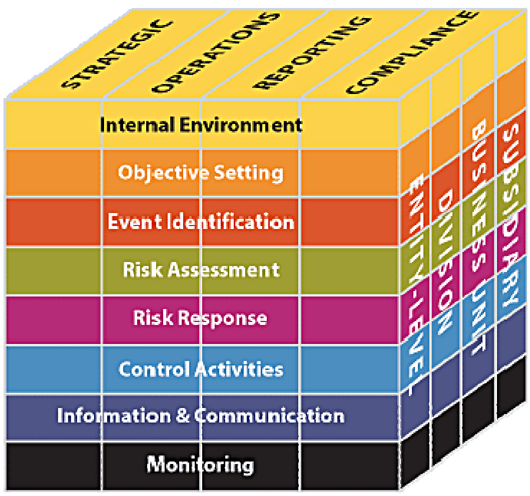
COSO ERM Framework

- Underlying principles:
  - Every entity, whether for-profit or not, exists to realize value for its stakeholders.
  - Value is created, preserved, or eroded by management decisions in all activities, from setting strategy to operating the enterprise day-to-day.
- ERM supports value creation by enabling management to:
  - Deal effectively with potential future events that create uncertainty.
  - Respond in a manner that reduces the likelihood of downside outcomes and increases the upside.
- *ERM requires an entity to take a portfolio view of risk*

Source: www.coso.org/Publications/ERM/COSO_ERM.ppt

COSO ERM Framework

- Entity objectives can be viewed in the context of four categories:
  - Strategic
  - Operations
  - Reporting
  - Compliance
- ERM considers activities at all levels of the organization:
  - Enterprise-level
  - Division or subsidiary
  - Business unit
  - processes
- The eight components of the framework are interrelated …



Source: www.coso.org/Publications/ERM/COSO_ERM.ppt

COSO ERM Framework

Internal Environment

- Establishes a philosophy regarding risk management. It recognizes that unexpected as well as expected events may occur.
- Establishes the entity's risk culture.
- Considers all other aspects of how the organization's actions may affect its risk culture.

Source: www.coso.org/Publications/ERM/COSO_ERM.ppt

COSO ERM Framework

Objective Setting

- Is applied when management considers risks strategy in the setting of objectives.
- Forms the risk appetite of the entity — a high-level view of how much risk management and the board are willing to accept.
- Risk tolerance, the acceptable level of variation around objectives, is aligned with risk appetite.

Source: www.coso.org/Publications/ERM/COSO_ERM.ppt

COSO ERM Framework

Event Identification

- Differentiates risks and opportunities.
- Events that may have a negative impact represent risks.
- Events that may have a positive impact represent natural offsets (opportunities), which management channels back to strategy setting.
- Involves identifying those incidents, occurring internally or externally, that could affect strategy and achievement of objectives.
- Addresses how internal and external factors combine and interact to influence the risk profile.

Source: www.coso.org/Publications/ERM/COSO_ERM.ppt

COSO ERM Framework

Risk Assessment

- Allows an entity to understand the extent to which potential events might impact objectives.
- Assesses risks from two perspectives:
  - Likelihood and Impact
- Is used to assess risks and is normally also used to measure the related objectives.
- Employs a combination of both qualitative and quantitative risk assessment methodologies.
- Relates time horizons to objective horizons.
- Assesses risk on both an inherent and a residual basis.

Source: www.coso.org/Publications/ERM/COSO_ERM.ppt

COSO ERM Framework

Risk Response

- Identifies and evaluates possible responses to risk.
- Evaluates options in relation to entity's risk appetite, cost vs. benefit of potential risk responses, and degree to which a response will reduce impact and/or likelihood.
- Selects and executes response based on evaluation of the portfolio of risks and responses.

Source: www.coso.org/Publications/ERM/COSO_ERM.ppt

COSO ERM Framework

Control Activities

- Policies and procedures that help ensure that the risk responses, as well as other entity directives, are carried out.
- Occur throughout the organization, at all levels and in all functions.
- Include application and general information technology controls.

Source: www.coso.org/Publications/ERM/COSO_ERM.ppt

COSO ERM Framework

Information & Communication

- Management identifies, captures, and communicates pertinent information in a form and timeframe that enables people to carry out their responsibilities.
- Communication occurs in a broader sense, flowing down, across, and up the organization.

Source: www.coso.org/Publications/ERM/COSO_ERM.ppt

COSO ERM Framework

Monitoring

- Effectiveness of the other ERM components is monitored through:
  - Ongoing monitoring activities.
  - Separate evaluations.
  - A combination of the two.

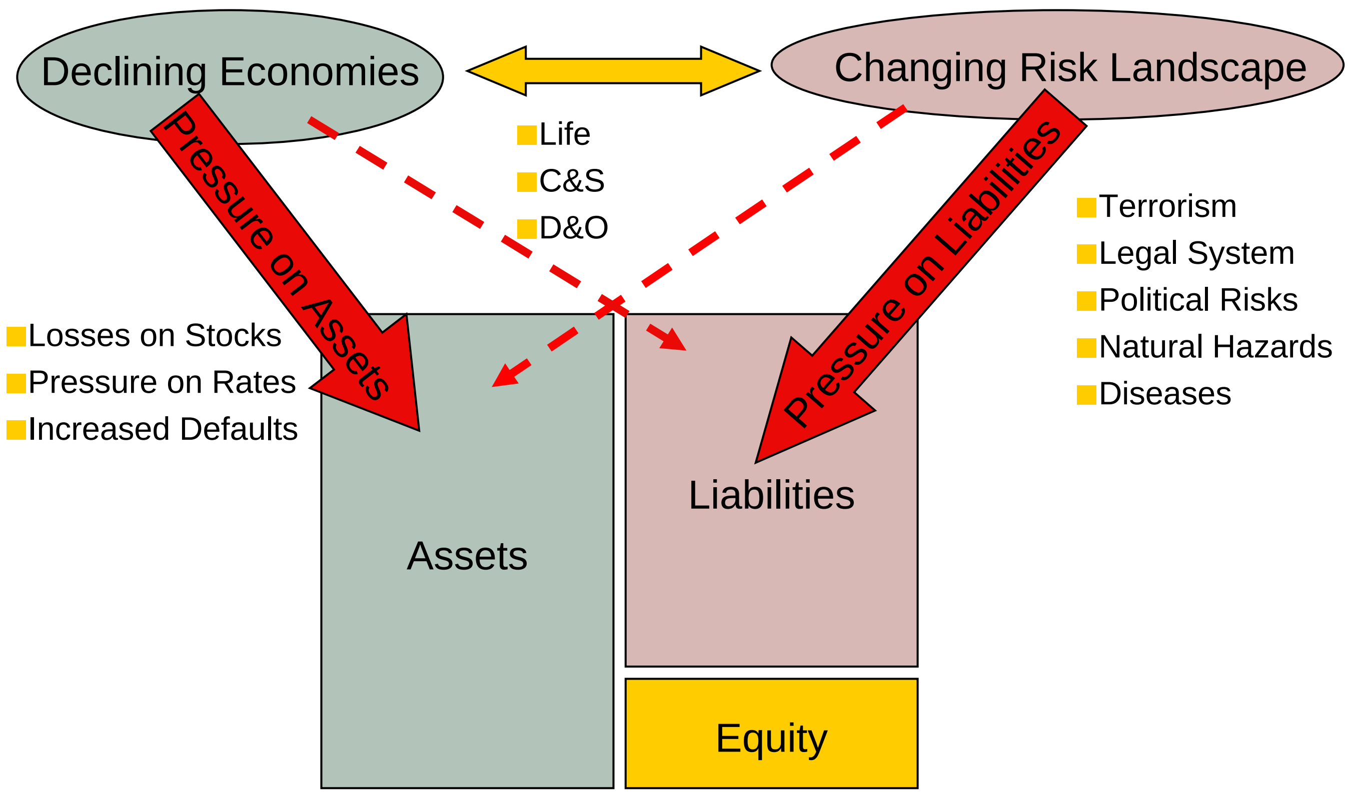
Source: www.coso.org/Publications/ERM/COSO_ERM.ppt

4. Aggregation of Risks

Methods

Sensitivity

The Challenging Environment



What needs to be considered for risk aggregation?

- Insurance claims (per line of business)
- Economic basics: GDP, inflation, interest rates, etc.
- Development of historical losses (reserves)
- Financial markets: equity, bonds, real estate, etc.
- Miscellaneous: business cycles, operational risks (?), changes in legislation etc. (often very hard or impossible to model)

➔ **In principle, all types of risk**

How to model?

- For most risk factors: component models from actuarial science, finance or economics are available, but moreover...
- Must model dependencies
- Must take into account extreme values (particularly when tail-based risk measures or non-proportional reinsurance are present)!
- Another issue: finding the right level of aggregation:
  - What variables to include and how detailed to model them?
  - Strong repercussions to dependence models?

The whole model is (considerably) more than the sum of its parts!

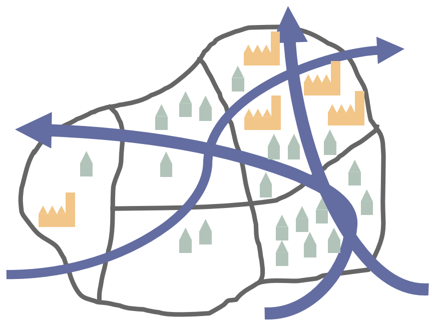
Keep it simple

- Typical settings naturally lead to integrated models with many variables and complicated relations between them.
- Hence: Do not make it more complicated than absolutely necessary.
- **Parsimony**: Use models with low numbers of parameters (makes calibration easier, see afterwards).
- **Transparency**: Models should allow for an intuitive interpretation.
  - Increased acceptance from customers / stakeholders
  - Possibility to make judgemental adjustments.

➔ As the process of risk aggregation usually involve several departments and also senior management, it is important that the models gain acceptance by all involved parties.

Describing dependencies

- Scenario based simulation
  - Dependencies between random variables modeled on the same scenarios is incorporated automatically
  - Example: Dependency in "our" windstorm model between losses on industrial risks and on private home owners
  - Building a realistic model of that type is challenging

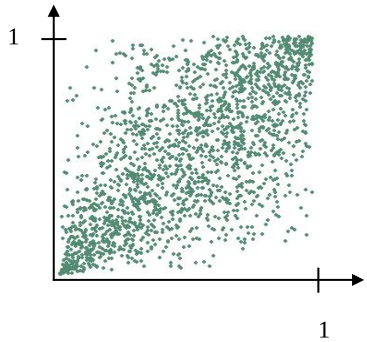


- Distribution based simulation
  - Via joint simulations of the individual distribution
  - Dependent sampling of the joint uniform random numbers
    ➔ copula
  - Calibration is an issue

Describing dependencies with distribution based simulations

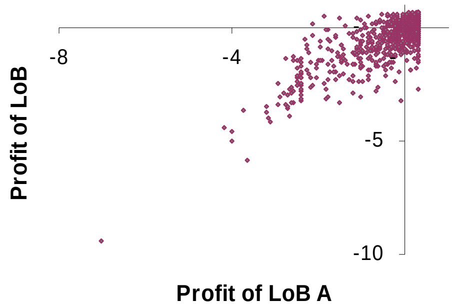
- A copula C is a rule how to simulate joint pairs (u,v) of random number between 0 and 1, where u and v are not independent.
- Assume we have two distributions F_X, F_Y for the future profits X,Y of line of business A and B, resp.
- $F_X^{-1}(u)$, $F_Y^{-1}(v)$ is a joint sample for (X,Y) with copula C

Samples from Copula



$$(F_X^{-1}, F_Y^{-1}) \longrightarrow$$

Joint samples of X and Y



Refer to [8] for a a discussion on correlations and copulas

How to estimate dependencies?

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- Dependencies can hardly be described by one number such as a correlation.
- We just saw that it is possible to use the ***copulas*** to model dependencies.
- In insurance, there is often not enough liability data to estimate the copulas.
- Nevertheless, copulas can be used to translate an opinion about dependences in the portfolio into a model:
  - Select a copula with an appropriate shape
    - increased dependencies in the tail
      - this feature is observable in historic insurance loss data
  - Try to estimate conditional probabilities by asking questions such as “What if a particular risk turned very bad?”
    - Think about adverse scenarios in the portfolio
    - Look at causal relations between risks

A stylised example (1): Model description

- A simple and stylized insurance structure consisting of two LoBs (***Motor Accident and Motor Liability***) is implemented in ReMetrica©, together with an XL reinsurance program.
- This structure is examined under ***different conditions of dependence*** between losses generated by the two LoBs.
- The goal is to detect the effects of these dependences on the aggregate loss distribution and in particular on the RBC of the insurer.
- RBC is calculated with TVaR for various risk tolerance levels. We summarize the results for the ***1/100 TVaR*****.**
- The results presented here are based on 100’000 simulations.

A stylised example (2): The input parameters

- For the sake of simplicity, we limit our model to the liabilities.
- We use discounted cash flows to account for the difference in payout patterns between MA and ML. Discounting w.r.t. the risk free rate.
- The premiums are 370 mEUR for MA and 560 mEUR for ML.
- Both LoBs are modelled with attritional and large loss models, generating a nominal gross loss ratio of *73.8%* (MA) and *78.9%* (ML).
- Both lines are protected by an XL layer:
  - ✓ MA: 15 xs 5 mEUR
  - ✓ ML: unlimited xs 10 mEUR.

A stylised example (3): Modelling Dependence

- In addition to the fully diversified model (no dependence), three dependence models were constructed, each with a different copula.
- All models with dependence present ***approximately the same rank correlation*** between MA and ML:

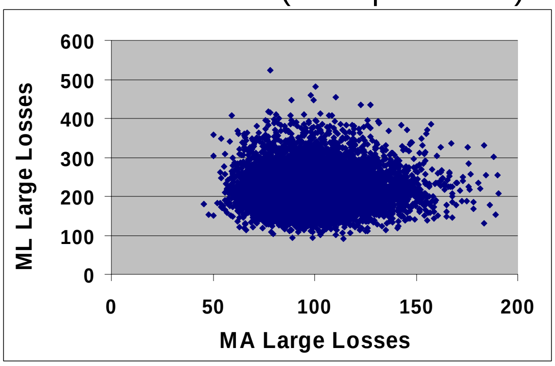
	Rank Correlation
No Dependence	0%
Gauss Copula	41%
T Copula	39%
Clayton Copula	38%

- Gaussian copula is derived from linear correlation in the Gaussian setting.

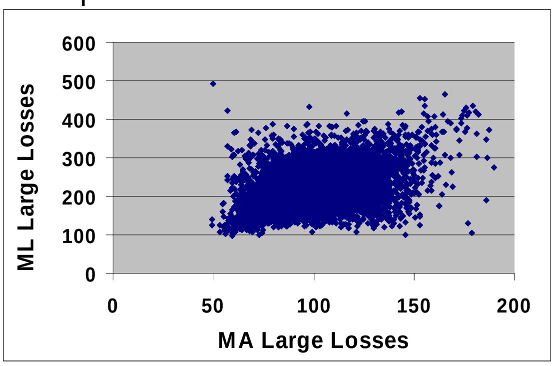
➔ **Stress testing**: Test the sensitivity of the model w.r.t. the various assumption

A stylised example (4): The Various Dependence Models

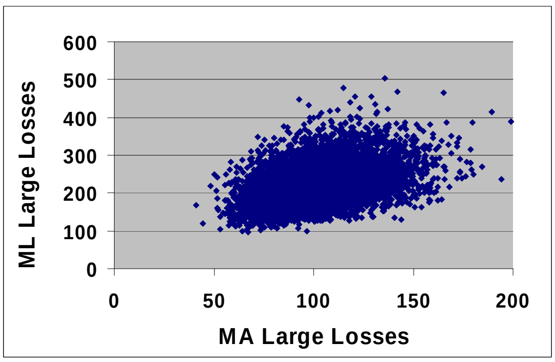
- Full Diversification (no dependence)



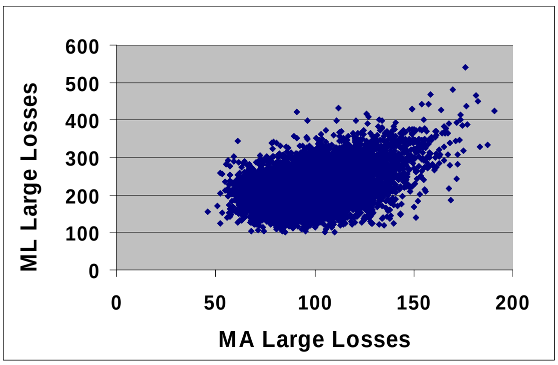
- T-Copula



- Gauss Copula

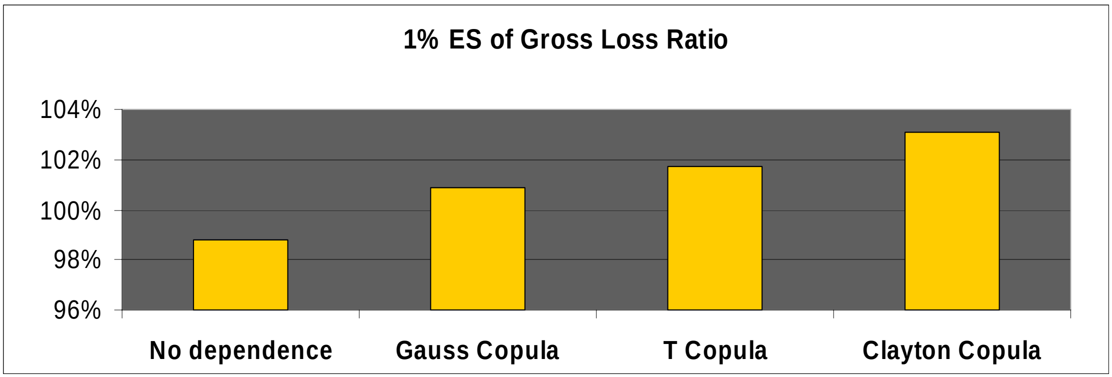


- Clayton Copula



A stylised example (5): Influence on the risk based capital

- Influence of various dependence models on nominal gross loss ratios (99% confidence level) and risk based capital (RBC).



RBC (discounted) and diversification gain
RBC relative to Expected UW Result

Model	RBC (Group) gross	Diversification gain	RBC (Group) net	Diversification gain
No dependence	170	29%	108	32%
Gauss Copula	188	22%	108	32%
T Copula	195	19%	97	32%
Clayton Copula	205	15%	97	32%

Figures for the 1% Risk Tolerance Level

5. Risk Diversification

Capital Allocation
Dynamic Portfolio Management

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Capital allocation

- The company needs a risk based capital K to run its business
  - Assume the company determines K using the risk measure TVaR.
- A minimum annual return h has to be generated on K.
- Decomposition of portfolio into profit generating units:
  - Unit 1, Unit 2, Unit 3,…, Unit n
  - Their profits $X_1, X_2, X_3, \ldots, X_n$ at the end of the year
- Allocation of capital $K_1, K_2, K_3, \ldots, K_n$ for $X_1, X_2, X_3, \ldots, X_n$ such that

$$\mathrm{TVaR}(X_1 + X_2 + \cdots + X_n) = K = K_1 + K_2 + \cdots + K_n$$

- Diversification benefit of Unit i:

$$\mathrm{TVaR}(X_i) - K_i$$

- Unit i is ***sufficiently profitable***, if its expected profit satisfies

$$EX_i \geq h \cdot K_i$$

Risk Based Capital via simulations

- The risk based capital (RBC) allocated for Unit i is the expected contribution of X_i to the TVaR of the company for a given of the portfolio
  - Consider 1 million stochastic samples of the portfolio's profit S ay θ =1/100:
  - The average of the worst 10'000 results gives the RBC K for the company.
  - The average of X_i on ***these*** 10'000 iterations gives the RBC K_i of Unit i
  - The sum of the K_i is equal to K.

➔ This algorithm satisfies the *Principle for a sound capital allocation*:

The higher the unit's downside risk and the higher its dependence with the portfolio*, the higher its allocated capital.

* *Higher* dependence with portfolio means:
The probability of bad results of the unit and simultaneously very bad results of the portfolio is *higher*.

Benefits of capital allocation according to risk contribution

- Measuring the performance of company's units
- Steering the portfolio towards more efficient risk/return-profiles
  - by reducing and increasing exposures based on their return on capital
  - ➔ Incentive to a dynamic management of
    - Underwriting risk
    - Credit risk
    - Market risk
- Enables the development of a risk management culture
  - The simple fact, that an amount of money is assigned facilitates discussions among the various stakeholders
  - In this way capital allocation contributes to the reduction of operational risk although there is no explicit charge for operational risk
- Capital allocation for operational risk?
  - Can this be done in such a way that it gives an incentive to the company to reduce its operational risk?

TVaR or VaR?

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- Model uncertainty of current models far out in the tail is relatively high
  - ➔ *From a regulator's perspective the discussion about VaR- or TVaR-measurement for Pillar I is not that relevant.*
- However, things look different from within the company…

Allocation for TVaR

- Principle for sound capital allocation
- sets the right incentives
- Calculated with internal model

➔ facilitates dynamic risk management

Allocation for VaR

- not possible in a consistent fashion
  - Adding a risk to the portfolio "beyond" the confidence level gets less capital the higher it is correlated with the portfolio and ultimately (for total dependence) zero capital
- Does not always set the right incentives

Summary and conclusions

- Portfolio view of risk
  - Integrated and holistic approach is needed
  - 8 components of COSO's ERM framework
- Dependence models are difficult to calibrate
  - Dependence can not be captured in one number such as a linear correlation
  - Scenarios and copulas can capture various aspects of the dependencies
  - Sensitivity w.r.t. various dependence models
  - Stress testing is indispensable
    - Not only for dependence models but for all other parameters as well
- Risk based capital allocation
  - Facilitates the development of a risk management culture
  - Key success factor for forward looking companies

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