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Terascale Statistics School

Introduction to Financial Risk Management

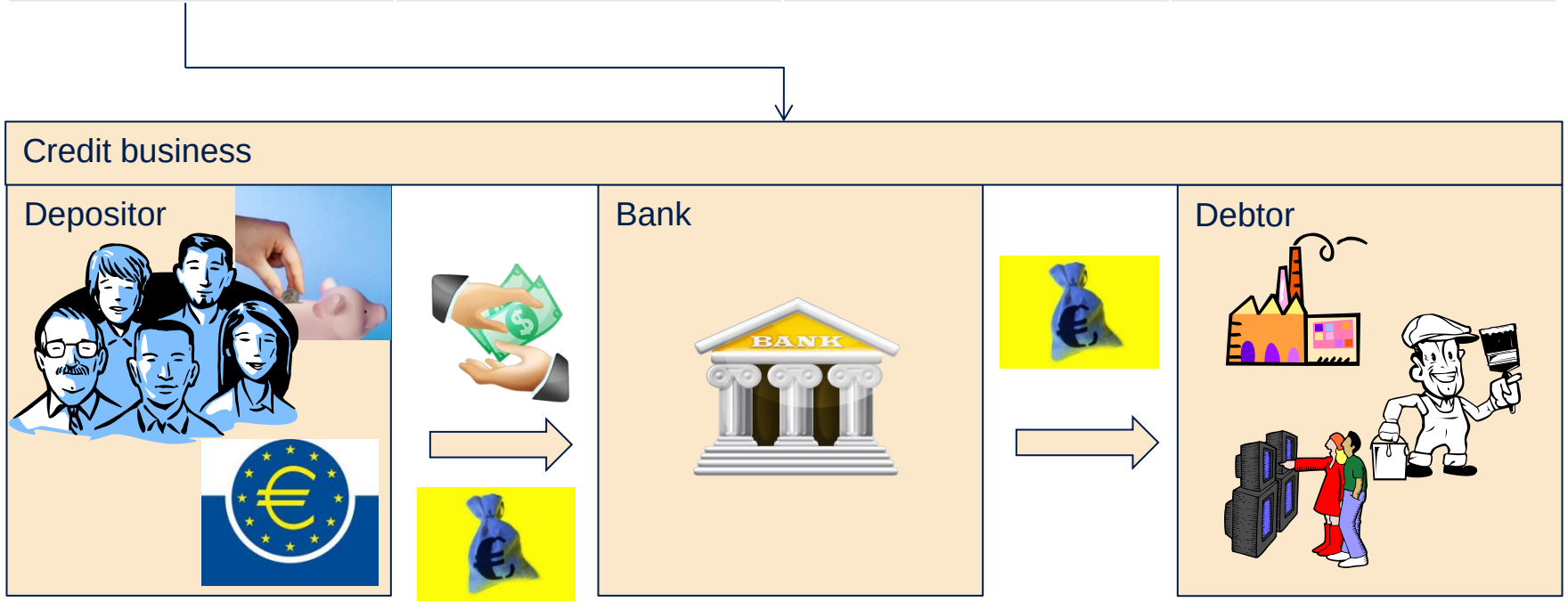
DESY, February 19th 2016

Content

- Introduction
  - What is a Bank good for?
  - Risk and Regulation
  - Risk Measure
- Estimation of confidence levels in finance

What's a Bank good for?

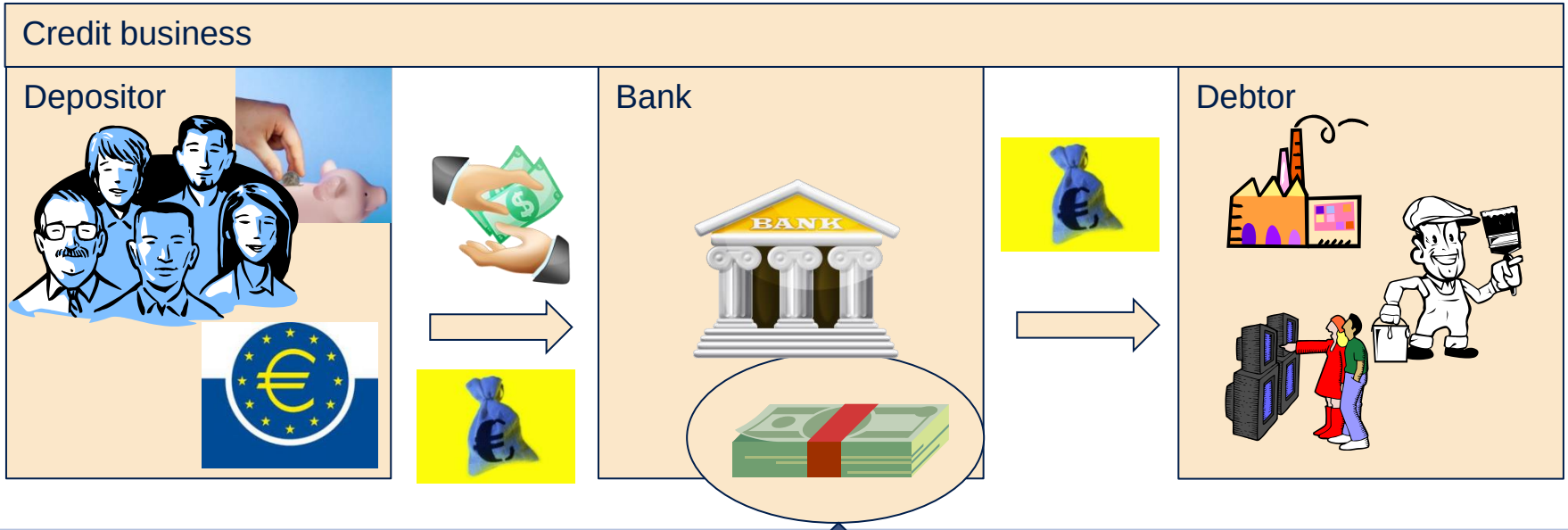
Credit business From simple retail credits to complex funding models	**Payment services**: Current accounts, all kinds of money transfer	**Investment services** Sales and management of investment products	**Corporate finance** Supporting corporates raising funds in capital markets (security issuance, equity,...)



What's a Bank good for?

Economic role of banks

- Transformation of maturities, e.g. short term deposits in long term loans
- Lot-size transformation, e.g. small deposits in larger loans
- Transformation of risk, e.g. risky loans in savings deposits
- Transfer of monetary policy (interest rates)



- Banks are essential for the economy
- Their business is not riskless
- They must have sufficient capital to cover their risks. But how much?

Risk and Regulation

Basel Committee on Banking Supervision (founded 1974)

- Members: Central banks and supervisors (founded by G10, **now global membership**)
- Goal: Development of high consistent standards for banking and supervision
- Activity: Quarterly meetings in Basel (Bank for International Settlements)
- Results: **Development of legally non-binding guidelines** and recommendations through discussions with banks and regulatory authorities

Supervision and Implementation Group
Foster the implementation of standards; improvements in banking supervision

Policy Development Group
Developing policies that promote a sound banking system and high supervisory standards

Macroprudential Supervision Group
Monitors systemic risk and global developments that relate to systemic important banks supervision policy

Accounting Experts Group
International accounting and auditing standards

Basel Consultative Group
Dialogue with non-membership authorities on supervisory issues and initiatives of the committee

Global banking regulation is strongly influenced by the Basel Committee

Risk and Regulation

» The regulatory requirements are detailed requirements

EU Capital Requirement Regulation (337 p)
law in all member states

REGULATIONS

REGULATION (EU) No 575/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 26 June 2013
on prudential requirements for credit institutions and investment firms and amending Regulation (EU) No 648/2012
(Text with EEA relevance)

EU Capital Requirement Directive (99 p)
to be implemented by countries

DIRECTIVES

DIRECTIVE 2013/36/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 26 June 2013
on access to the activity of credit institutions and the prudential supervision of credit institutions and investment firms, amending Directive 2002/87/EC and repealing Directives 2006/48/EC and 2006/49/EC
(Text with EEA relevance)

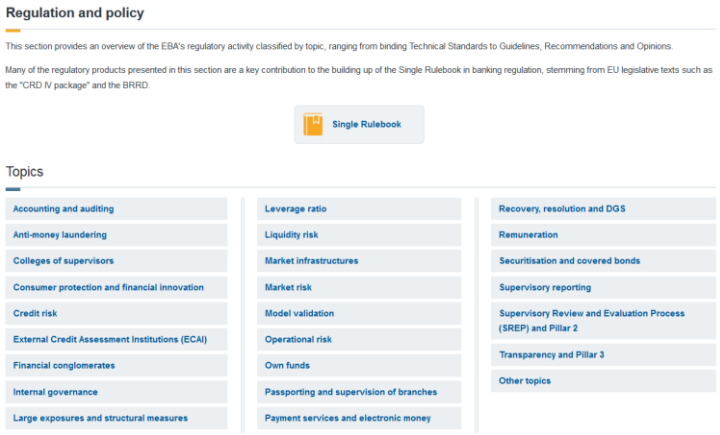
e.g. it defines the risk weight for a lending to an central governments and central banks depending on the rating

Credit quality step	1	2	3	4	5	6
Risk weight	0 %	20 %	50 %	100 %	100 %	150 %

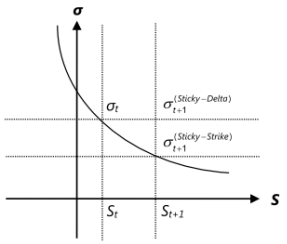
Roughly speaking the capital requirement (in the standardized approach) is:

capital requirement = 8% * risk weight * debt

» ... and there are many more guidelines by regulatory agencies (European Banking Authority, Bundesanstalt für Finanzdienstleistungsaufsicht, ..)



» detailed means for example that they tell you how to calculate derivatives



$$s_{k,r_t} = \frac{V_i(r_t + 0.0001, cs_t) - V_i(r_t, cs_t)}{0.0001}$$

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Risk and Regulation

Risk types to be covered

capital requirement by the regulator

Regulatory capital

credit risk
- losses due to defaults of counterparties

market risk
- losses due to changes in market prices

operational risk
- losses resulting from inadequate or failed internal processes, people and systems or from external events

Settlement/delivery risk
- losses due to default of a counterparty during settlement/delivery

Credit value adjustment risk
- losses due to changes in the market value of counterparty credit risk

... and requirements on the institutions liquidity and debt ratio

capital measure for the internal risk management

Economic capital

credit risk	market risk	operational risk

other risk categories	
participation risk	e.g. when owning an insurance company there is insurance risk
Sovereign risk	insolvency of the country in which the institution has an exposure.
Pension risk	Risk from the involved in their employees' old-age pension plans
Funding cost risk	Risk of changed cost when borrowing money
Risk concentrations	Concentration of risk in specific areas
Business and strategic risk	Lower profit, unsuccessful business plans

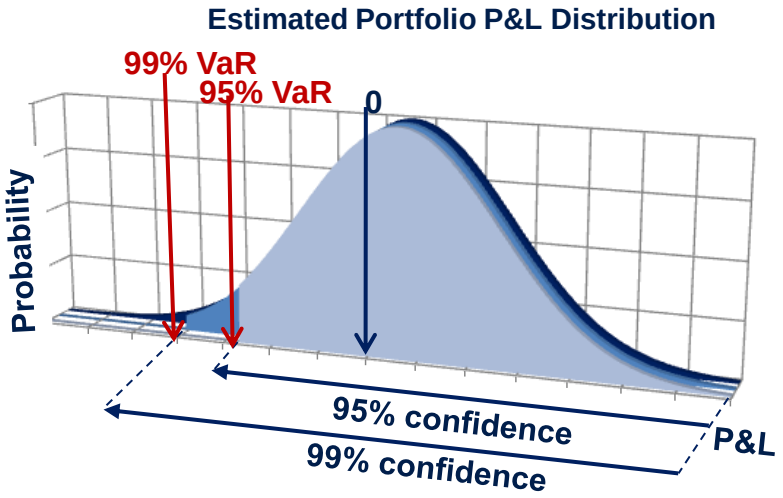
Includes all sources for potential unexpected losses

Market Risk Measure

Value-at-Risk (VaR)

The Value-at-Risk of a portfolio over a certain time horizon T is the maximum loss which will not be exceeded with a given probability (one sided confidence level).

- VaR is measured in monetary units (e.g. €).
- VaR is the risk measure mainly used in conjunction with regulatory and economic capital



... VaR quantifies potential portfolio losses based on historical data

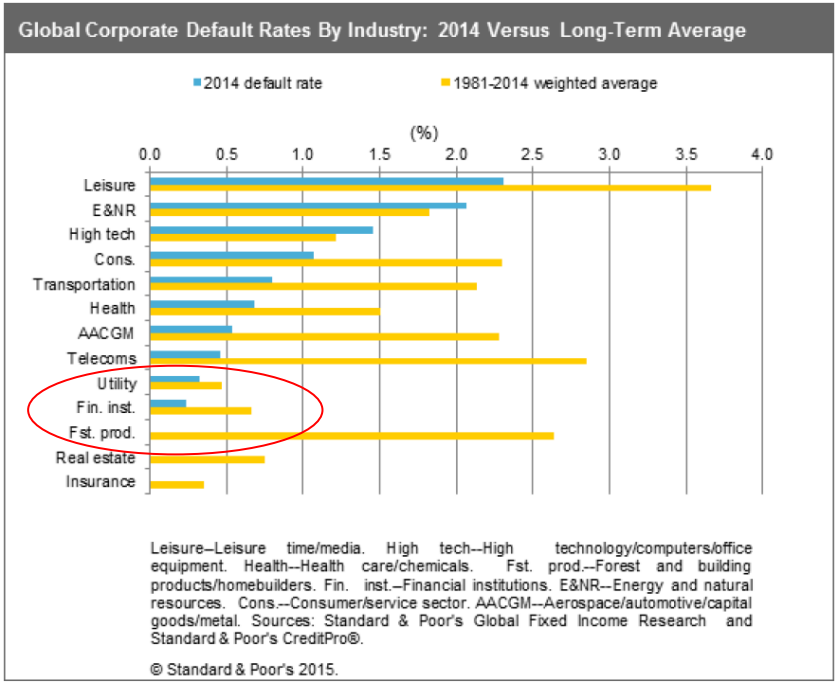
Market Risk Measure

Quantitative Requirements

	confidence level	holding period
Regulatory capital		
credit risk (IRB approach)	99,9 %	one year
operational risk (Advanced Measurement Approach)	99,9 %	one year
market risk (internal model)	99 %	10 day
Economic capital		
typical value	99,9 %	one year

corresponds to only one default per year per thousand banks

It is essential that the risk determination is done independently from the trading department



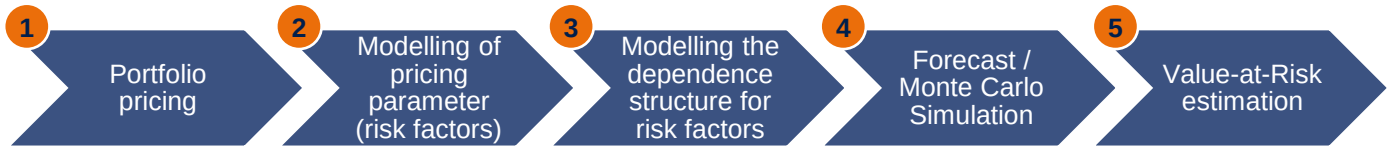
Modelling Market Risk

Use Case

Market Risk for a small Portfolio

- Suppose we have an investment (1 year horizon) of
  - 0.1 unit of a DAX Fund with current value of €8,967
  - 10 units of a MSCI Word Fund with current value of $67
  - 1 unit of gold with current value of €1,100
  - 1 unit of a bond with current value of €500 (approximated by an interest rate index)
- What is the risk I am exposed to?

- Our program to answer this question:



1 Pricing = What is the price of my investment under changed market conditions?

In our case:

$$V = 0.1 \cdot V_{DAX} + 10 \cdot V_{MSCI}/FX_{EUR\backslash \mathrm{USD}} + 1 \cdot V_{gold} + 1 \cdot V_{bond}$$

Risk factors modelled as stochastic parameter

1 Portfolio pricing is quite complicated because of a large variety of products

Financial Instruments

- There is no unique classification of financial instruments. Every classification depends on its purpose and may therefore refer to different aspects of the financial instruments (e.g. accounting categories, financial mathematics aspects).
- Here is an example of very simple classification according to the main market risk drivers:

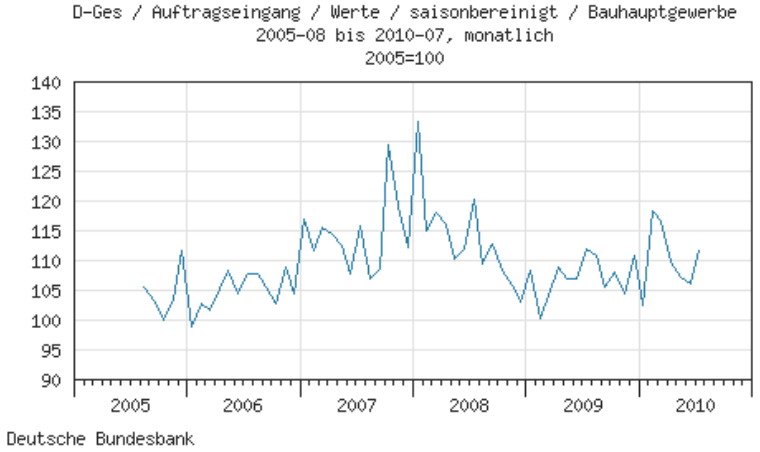
Interest rate products	Equity products	FX products	Commodity derivatives	Credit products
» Corporate Bonds » Government Bonds » Swaps » Loans » Bond Options » Swaptions » Caps/Floors » IR Futures » …	» Shares » Equity Options » Index Options » Equity Certificates » Basket Options » ...	» FX Cash » FX Forwards » FX Options	» Crude Oil » Gas Oil » Base Metals » Precious Metals » Coal » Power » …	» Credit Default Swaps » Credit Spread Options » Securitisations » Credit Index Products » Credit Basket Derivatives » ...

Different financial instruments are sensitive to different aspects of market risk.

Market Risk of Financial Instruments – Motivation

The **current (market) value** of a financial instrument is subject to the current **market conditions**. Therefore the **value** of any financial product will usually **fluctuate** from one day to another (and also during the day) due to changes in the market conditions.

Market conditions can be quantified by (or from) quantities that can be **observed** in the market, e.g., exchange rates or equity courses.



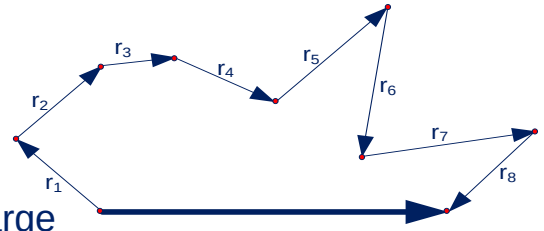
The quantities that quantify market conditions reflect the market's current opinion, which in turn depend on more or less unpredictable economic variables (e.g. unemployment rate, company news, GDPs, …) and psychology (the reactions of the market to any news are also more or less unpredictable).

Therefore the quantities quantifying the market conditions need to be modelled as stochastic variables.

Value of financial instruments depends on (stochastic) market conditions.

2 Modelling of Risk Factors

Risk Factors – Stochastic Processes (1/3)



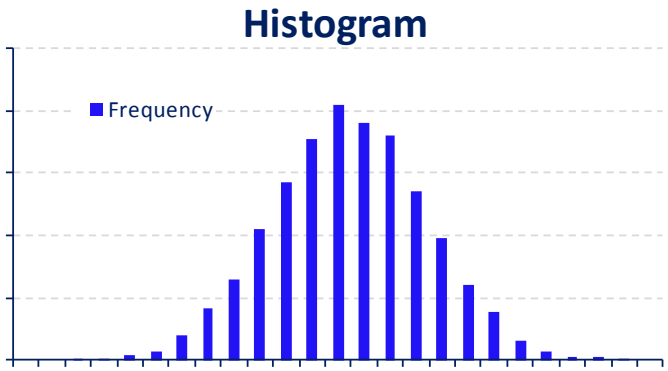
Random Walk

For the number of steps n (n=8 in figure) sufficiently large the distribution of r_{log} (end-to-end vector **r** in figure) follows a **normal distribution**:

$$p(r) = \frac{1}{\sqrt{2\pi \cdot \mathrm{var}(r)}} \cdot \exp\left[-\frac{(r - \langle r \rangle)}{2 \cdot \mathrm{var}(r)}\right]$$

The **number of steps** in the random walk n is proportional to the **time Δt** that passes during the random walk.

This also holds for **absolute returns** (relative returns do not follow a random walk but one can still assume that they are normally distributed).



Random walk is a popular process used to model risk factors

2 Modelling of Risk Factors

Risk Factors – Stochastic Processes (2/3)

general diffusion process

The simple process model can be generalized to a general diffusion process with drift and variance being functions of t and V:

$$d\log(V_t) = a(t, V_t) \cdot dt + b(t, V_t) \cdot dW$$

In this way the model can also be used for risk factors that show different (e.g. mean reverting) behavior like interest rates, commodity prices, or FX rates.

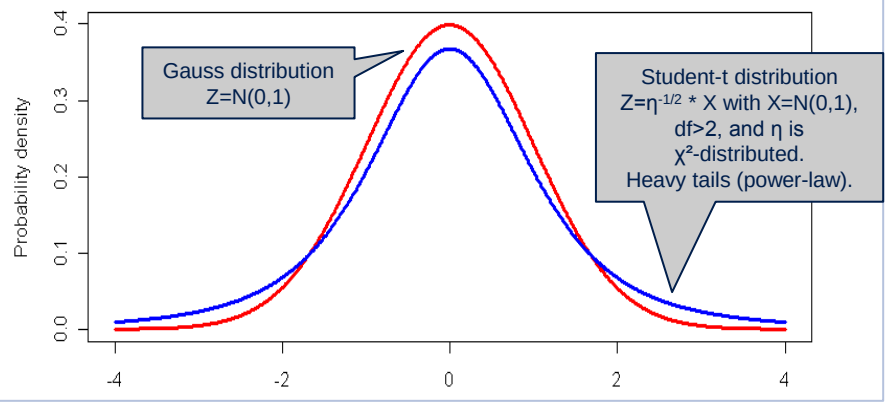
Example Vasiceck model (Ornstein-Uhlenbeck process):

$$d\log(V_t) = (\mu - \nu \cdot V_t) \cdot dt + \sigma \cdot dW$$

non-Gaussian distribution

Student-t distribution is an extension of Gauss distribution with additional parameter df.

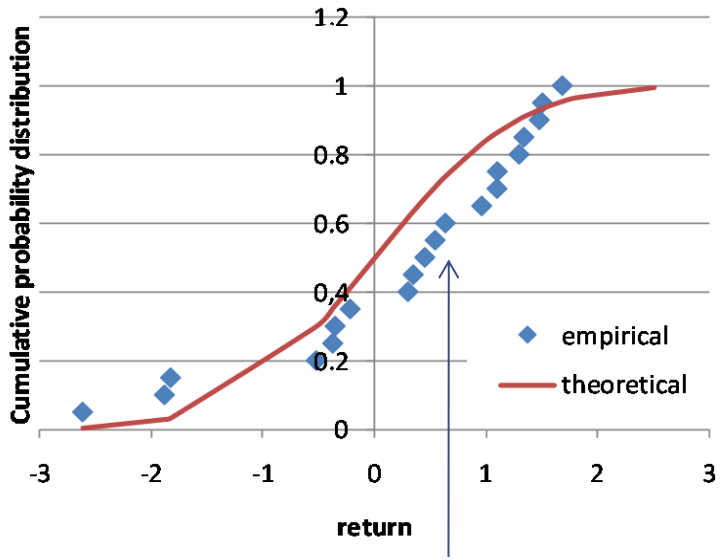
Keep in mind the two limits
df=∞: Gauss distribution recovered
df=2: Limit where tails become heaviest.



The simple diffusion model can be generalized to more complex processes

Risk Factors – Stochastic Processes (3/3)

Kolmogorov-Smirnov test



Test statistics is the largest difference of the cumulative distribution function ➔ P-value

- For any given cumulative probability value the number of observed values follows a binominal statistics independent of the distribution of the stochastic variable
- Thus, the test is universal and can be applied to any hypothetical probability distribution

Limitations of the calibration

- The estimation of the mean return value has large errors
- We cannot use the fit value for an estimate of the expected long-term return
- For the purpose of risk estimation we will set the drift of the process to 0

3 Modelling the dependence structure

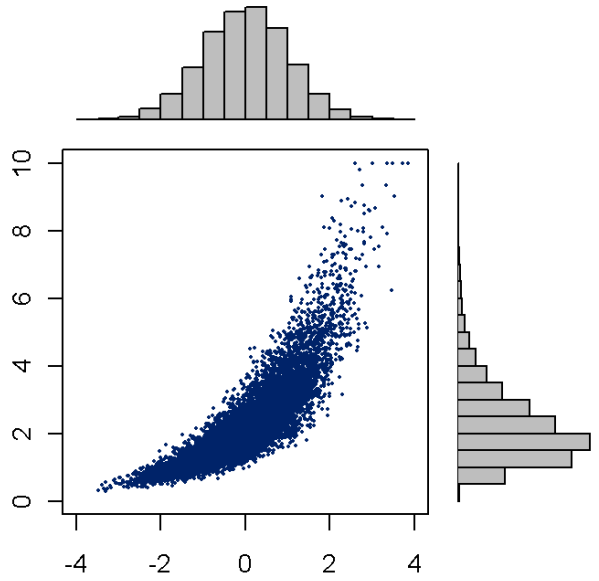
Modelling dependence structure with copulas is very popular.

» Given a n-dimensional multivariate cumulative probability distribution CPD(x1,…,xn) and the corresponding marginal distributions $CPD_1(x_1)$,…,$CPD_n(x_n)$ the (elliptical) copula $C:[0, 1]^n \rightarrow R$ describes the dependency structure of the random variables x_1,…,x_n according to

$$C(u_1,...,u_n) = CPD[x_1,...,x_n]$$

where $u_i = CPD_i(x_i)$ are uniformly distributed.

» The purpose of the copula concept is to model the full dependency structure of random variables beyond a correlation matrix approach.



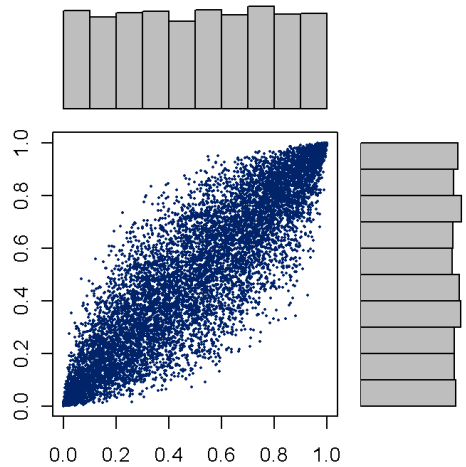
A copula approach decouples marginal distributions and dependence structure

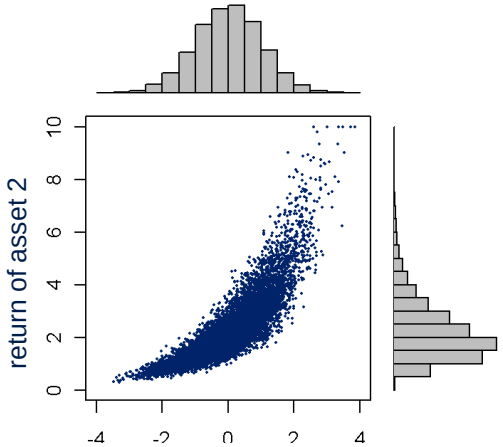
3 Modelling the dependence structure

Variables u_1 vs u_2

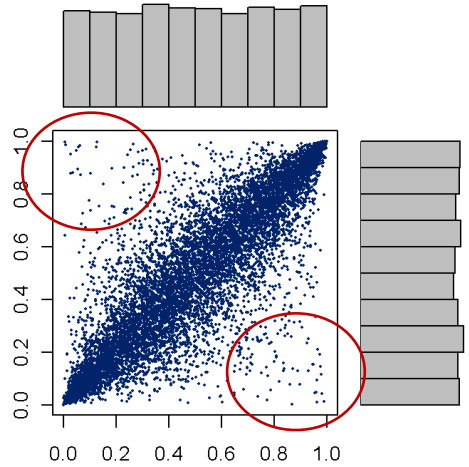
Variables x_1 vs x_2

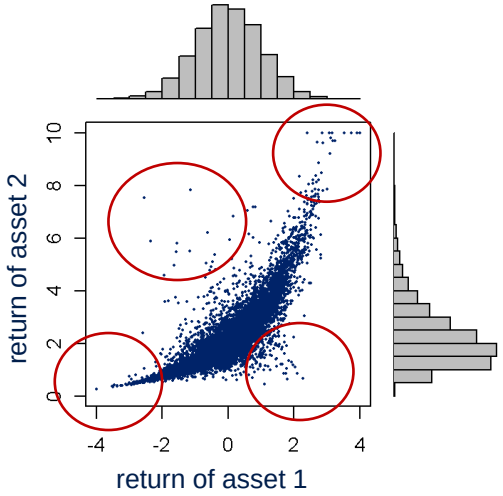
Gauss copula





Stdent-t copula



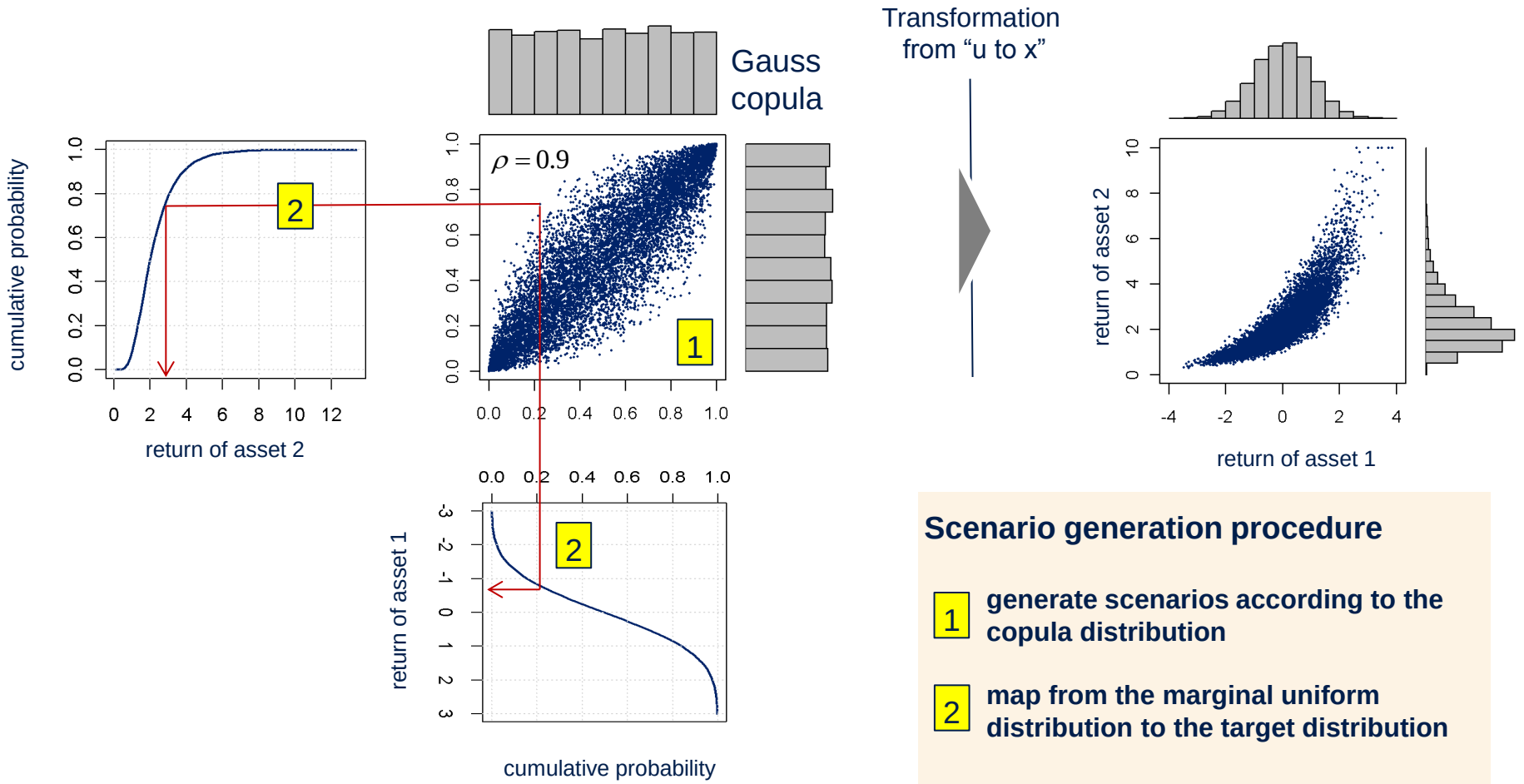


t copula vs. Gauss copula

- A Gauss copula with normal marginal distributions is multivariate normal distribution
- A t-copula has one extra parameter df. A Gauss copula is a t-copula with df $\rightarrow\infty$.
- A t-copula has a higher tail dependence, i.e. when losses are high correlation increase as observed in a crisis
- More extreme events with a t-copula

4 Forecast / Monte Carlo Simulation

The generation of Monte Carlo scenarios is a two step procedure.

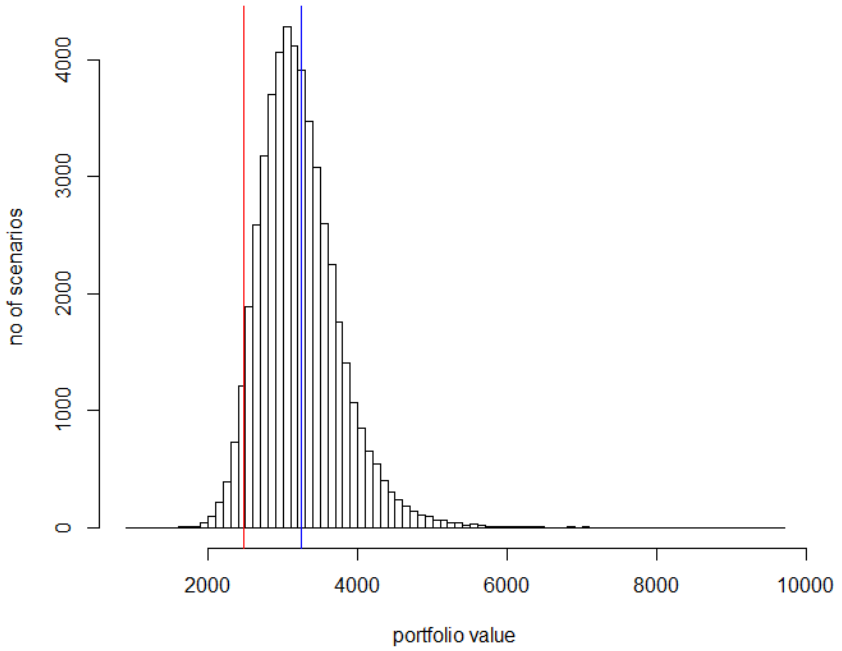


Scenario generation procedure

1. **generate scenarios according to the copula distribution**
2. **map from the marginal uniform distribution to the target distribution**

5 Value-at-Risk estimation

» Result of the Monte Carlo simulation is a forecast distribution from which the Value-at-risk can be deduced:

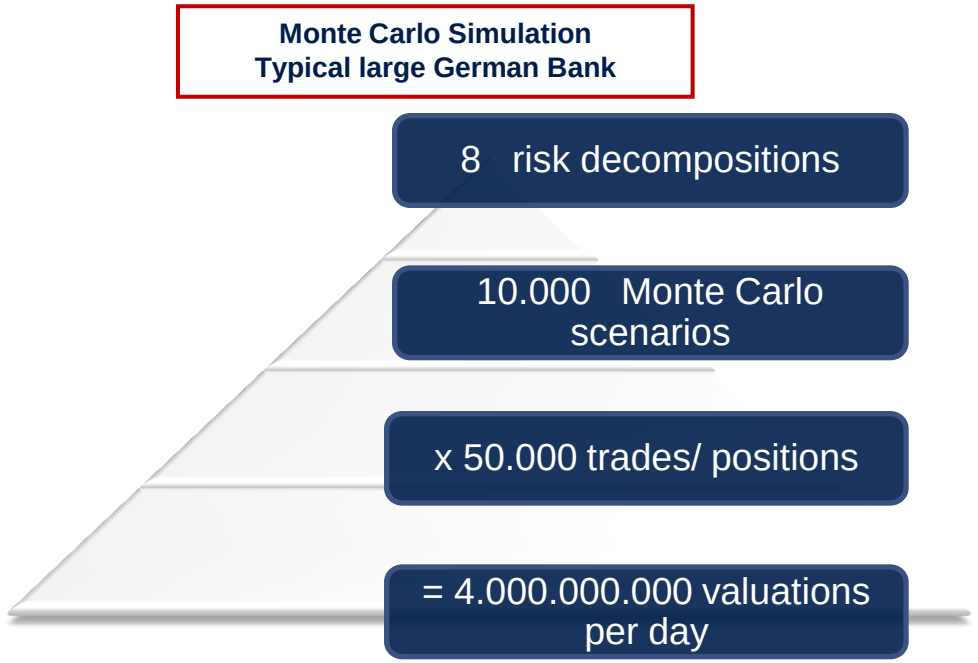


» In our case: $VaR_{95\%,1y} \approx 24\%$

» This one has to compare with the expected gain (which is much less)

For a bank it is much more complicated

- ... many and complex products
- ... much more parameter
- ... calibration is more difficult because of calculated market data
- ... more requirements than calculating only a “standard VaR”
- ... many more deals



... and Market Risk is only one topic where mathematical skills are required

Trading / Asset & Liability Management

- Pricing
- Asset liability management, Portfolio optimization, Hedging
- Risk adjusted returns
- .....

Financial Engineering

- Development of valuation models
- Calibration procedures
- ...

Risk Management

- Credit Risk
- **Market Risk**
- Operational Risk
- Insurance Risk
- Model validation, Backtesting
- ...

Market Data

- Cleaning of data
- Derived market data
- Imputation / missing data
- ...

Accounting / Transaction Management

- Pricing
- Value adjustments
- Hedge accounting
- ...

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