Market risk modeling in a new era of finance

XXXIX Heidelberg Physics Graduate Days

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Agenda

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Introduction to (Market) Risk

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What is Market Risk?

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Market risk of financial instruments – motivation

» **Market Risk is defined as potential losses in the value of financial instruments and other assets due to (stochastic) changes in the market conditions.**

A financial instrument is any contract that gives rise to a financial asset of one entity and a financial liability or equity instrument of another entity. (definition according to **IAS 39.8)**

Simple **classification** of financial instruments according to the **main market risk drivers**:

Interest rate products
- Corporate Bonds
- Government Bonds
- Swaps
- Loans
- Bond Options
- Swaptions
- Caps/Floors
- IR Futures
- …

Equity products
- Shares
- Equity Options
- Index Options
- Equity Certificates
- Basket Options
- ...

FX products
- FX Cash
- FX Forwards
- FX Options

Commodity Futures/ Forwards
- Crude Oil
- Gas Oil
- Base Metals
- Precious Metals
- Coal
- Power
- …

Credit products
- Credit Default Swaps
- Securitisations
- Credit Index Products
- Credit Basket Derivatives
- ...

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

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Market risk of financial instruments – motivation

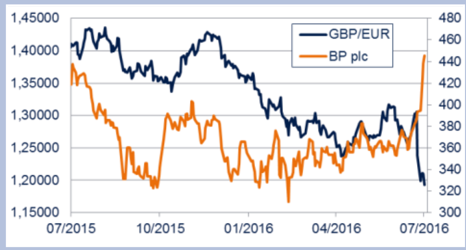
» The **market value** of financial instruments is driven by various **more or less observable** but most of all **unpredictable** entities

European stock option quotes

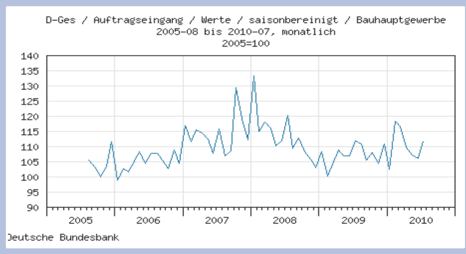
COMMODITY NAME	CONTRACT MONTH				SETTLE	
	MONTH	STRIKE	P/C	DELTA	PRICE	CHANGE
BP	Dec16	430	C	0.5930	31.500	4.500
BP	Dec16	440	C	0.5269	25.750	3.750
BP	Dec16	450	C	0.4609	21.000	0.000
BP	Dec16	460	C	0.3970	16.750	3.000
BP	Dec16	480	C	0.2850	10.500	2.250

» As a consequence, the market value itself should be considered a **stochastic entity** subject to **(market) risk**.

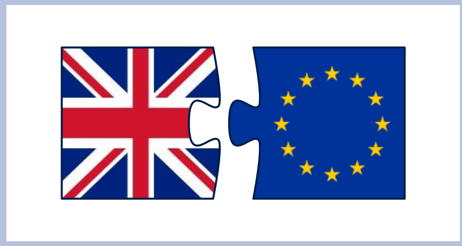
Current market conditions and opinions of market participants



explicit market variables (e.g. FX rates)



implicit market variables (e. g. order situation)



unobservable variables (e. g. psychology)

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

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Classification of Market Risk

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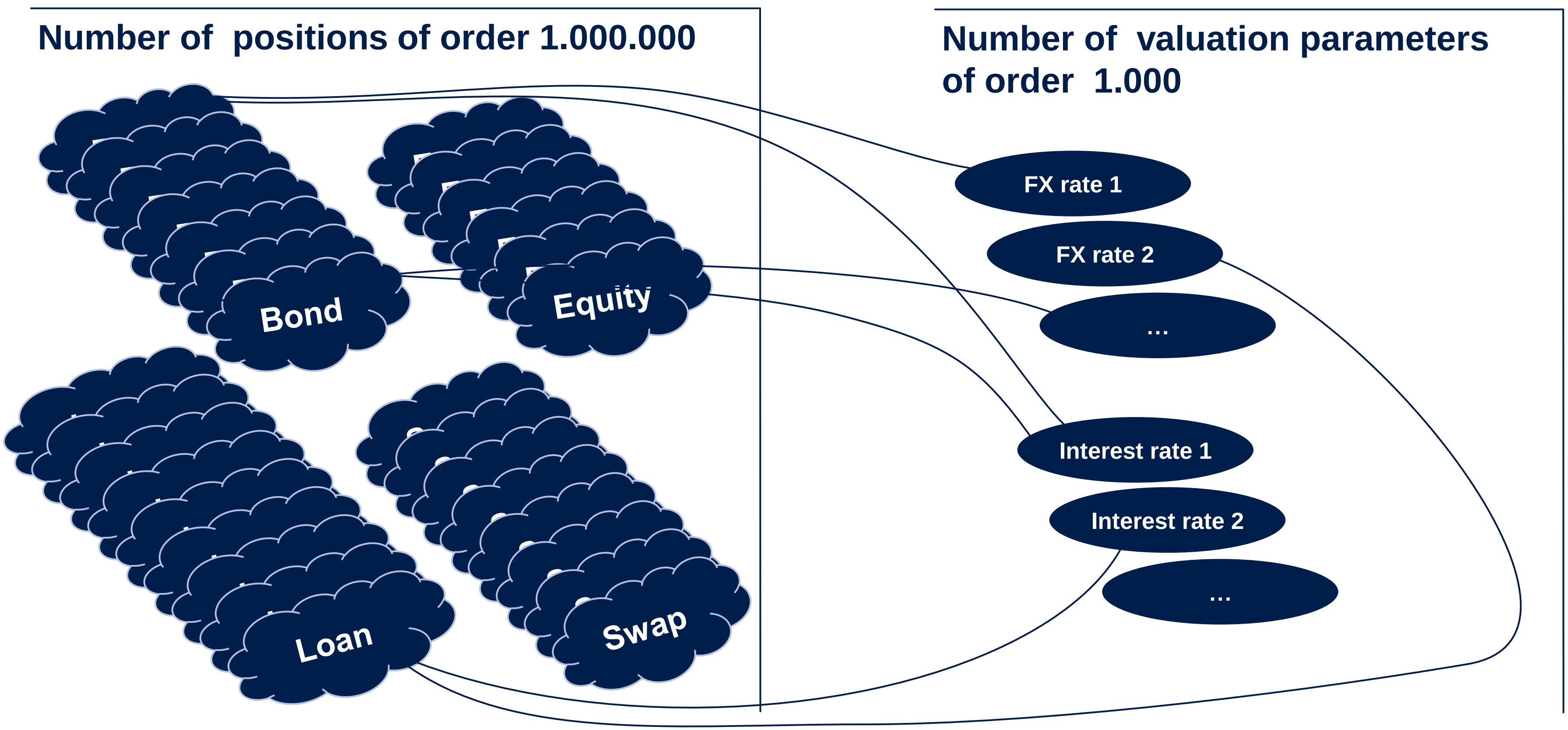
Quantification of market conditions – risk factors (1/3)

» **Why not consider the price of each financial instrument as a risk factor?**



Modelling valuation parameters instead of each financial instrument separately reduces dimensionality.

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Quantification of market conditions – risk factors (2/3)

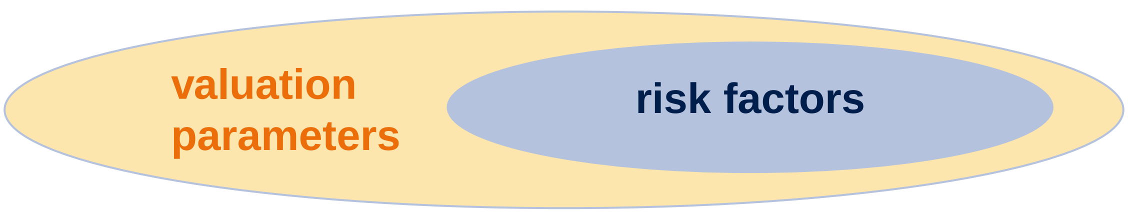
» For given market conditions, the **current (market) value** of a financial instrument is fixed.

» It is given by a deterministic **pricing function** of market conditions.

› **Example**: Portfolio of 10 Intel Corp. stocks

- › Intel stock price: 19.42 USD
- › EUR/USD exchange rate: 1 EUR = 1.3442 USD
- › Portfolio-Value:
  10·19.42 USD / 1.3442 USD/EUR = 144.47 EUR

› $\mathbf{value} = \boldsymbol{f}(\mathbf{stock\ price}; \mathbf{FX\ rate})$



Risk factors quantify market conditions and are the sources of market risk.

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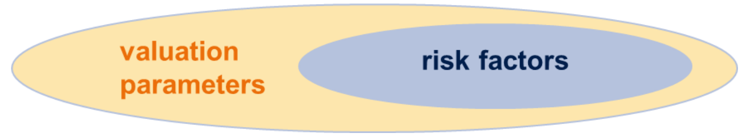
Quantification of market conditions – risk factors (3/3)

For **measurement** of market risk of a financial instrument, the stochastic behaviour of its value needs to be described mathematically.



» $\textbf{market value} = f(\textbf{valuation parameters}) \approx f(\textbf{risk factors}),$

» observe risk factors in **the market → time series**

» **Idea: Statistical inference** based on historical data

Examples:

» Equity prices: BASF, E.on, Toyota, Pfizer, …

» Exchange rates: EUR/XAU, EUR/GBP, …

» Equity Indices: Dax, MDax, Nikkei 225, …

» Commodity spot prices: Brent, WTI, XAG, …

Stochastic properties of risk factors can be determined from historical data.

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Risk factors – risk factor categories

Risk factors can be divided into groups according to their market risk category:

Interest Rate	(Credit) Spread	FX
Commodity	Equity	Volatility (Option Prices)

Within these categories there are still different kinds of risk factors:

- 0-dimensional structures: prices, indices, FX rates
- 1-dimensional structures: interest rate curves, spread curves, commodity forward curves
- 2- or 3-dimensional structures: equity volatility surfaces, FX volatility surfaces, interest rate volatility surfaces (cap/floor 2-dim, swaption 3-dim)

There are different categories and types of risk factors.

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Risk factors – return types

Usually it is not the risk factors themselves but their **returns** that are **used for market risk calculations** (therefore sometimes the returns are called risk factors). This is because the returns can **usually be better described by basic stochastic processes** than the risk factors themselves and in risk management one is more interested in the changes of quantities than in their absolute values.

A risk factor return r describes the change in a risk factor ρ between two points in time. There are three kinds of returns used for the different risk factors:

» absolute return: $$r_{abs} = \rho_t - \rho_{t_0}$$

» relative return: $$r_{rel} = \left(\rho_t - \rho_{t_0}\right) / \rho_{t_0}$$

» logarithmic return: $$r_{\log} = \ln\left(\rho_t / \rho_{t_0} \right)$$

The **choice** of the return type depends on **characteristics** of the respective risk factor.

Market risk is measured via absolute, relative or logarithmic risk factor returns.

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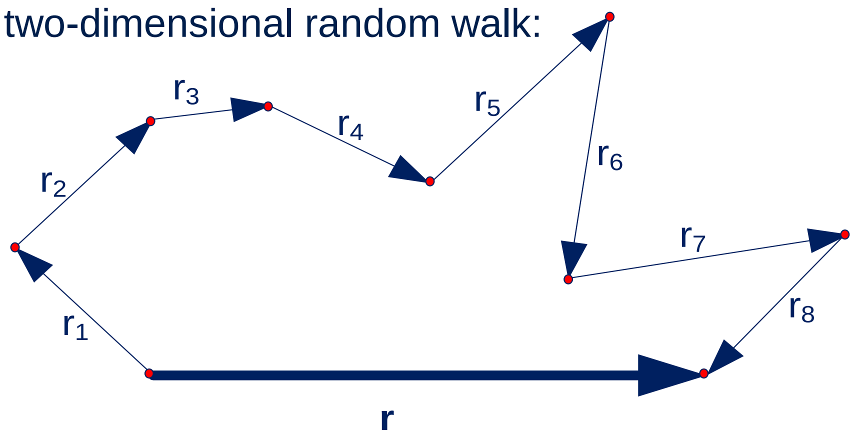
Risk factors – assumption of stochastic processes

For risk management calculations one has to **assume stochastic process models** for the risk factor returns or make **direct distribution assumptions** for them.

» **Market risk measurement is based on phenomenology.**

A widely used assumption especially in the equity market is the assumption that logarithmic returns of equity prices follow a one-dimensional **random walk**: each incremental price movement is **independent** and **identically distributed**.

End-to-end vector of two-dimensional random walk:



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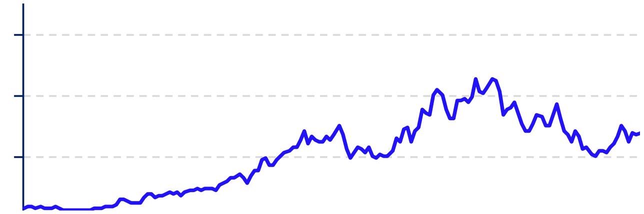
Risk factors – stochastic processes (1/4)

Central Limit Theorem: The sum of identically distributed random variables that are "independent enough" converges towards a **normal distribution.**
("Independent enough" for example in the sense of "strong mixing processes" or the Lindeberg condition)

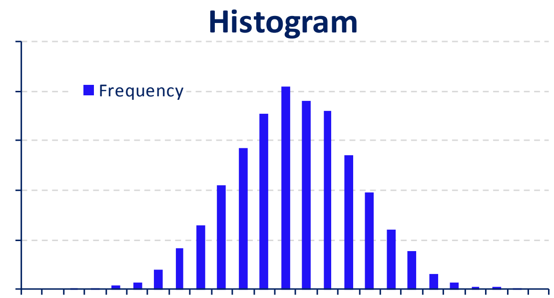
➔ The well known **Wiener process** $\boldsymbol{W(t), t \geq 0}$, is a natural model for the risk factor development over time:

- $W(0) = 0$
- $W(t) - W(s)$ is normally distributed with mean 0 and variance $t - s$
- increments are independent



The latter two properties imply self-similarity of the process, i.e., for infinitesimal time intervals:

$dW \sim X\sqrt{dt}$ with $X \sim N(0,1)$, $\operatorname{var}(dW) = dt$



Wiener processes are standard stochastic processes, commonly used for modelling market conditions.

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Risk factors – stochastic processes (2/4)

Usually not the risk factor itself, but a suitable transformation is modelled as a Wiener process.

For equity prices, usually log prices are used, i.e.

$$\ln(\rho_t) = \ln(\rho_0) + \sigma \cdot W_t$$

To reflect the expected rate of return in the process model we add a deterministic drift term:

$$d\ln(\rho_t) = \mu \cdot dt + \sigma \cdot dW$$

i.e., the **discounted price process** is a **martingale**.

Because the **drift** term is deterministic, the increments of the process are still normally distributed with variance $\sigma^2(t-t_0)$ but now the expectation value is $\mu(t-t_0)$.

Drift components in diffusion processes allow to account for expected rates of return.

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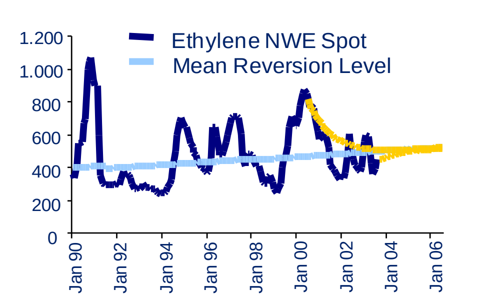
Risk factors – stochastic processes (3/4)

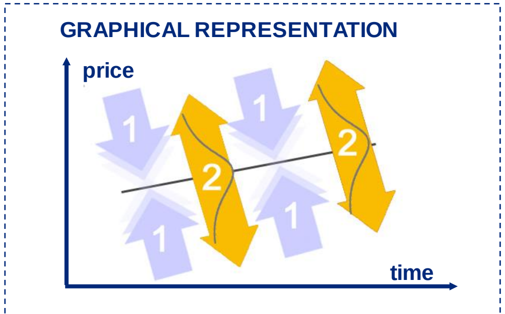
The simple process model can be generalized to a **general diffusion process** with drift and variance being functions of t and ρ:

$$d\ln(\rho_t) = a(t,\rho_t)\cdot dt + b(t,\rho_t)\cdot dW$$

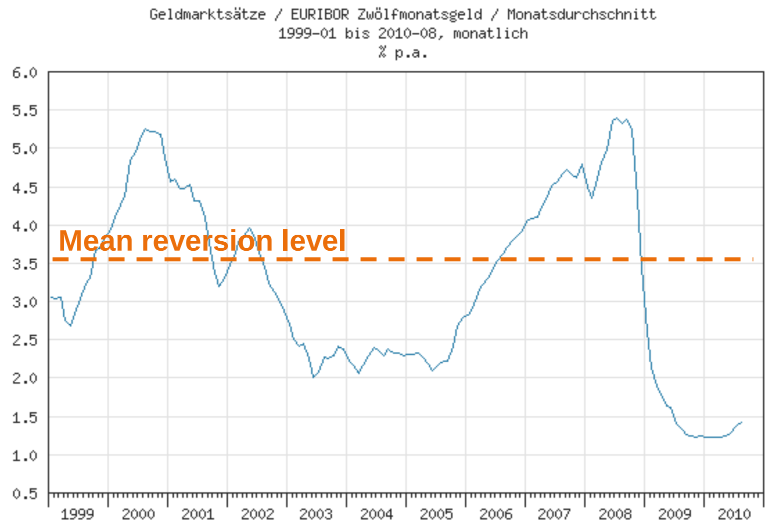
(**lognormal model**)

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





Example **Vasicek model**:
(Ornstein-Uhlenbeck process)



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

(**normal model**)

Mean reversion force

The simple diffusion model can be generalized to more complex processes.

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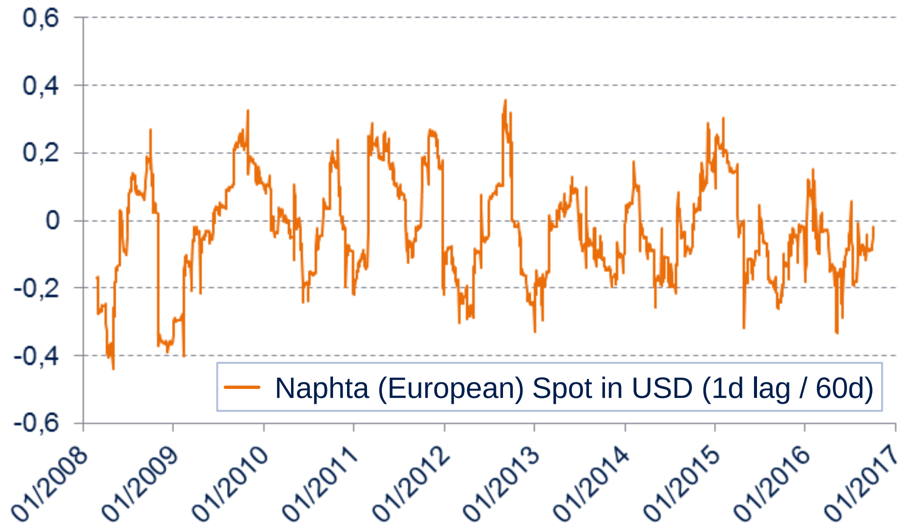
Risk factors – stochastic processes (4/4)

Assumption in random walk model:

Assuming that the **current value** of a risk factor, such as a stock price or an interest rate, **contains all the information** about its historical development (this is called weak market efficiency), it follows that the subsequent values taken on by such a risk factor **depend** only on the current price and other external effects, such as politics, but **not on the past prices** or rates. Market prices can then assumed to be **Markov processes**.

Naphta (European) autocorrelation



This assumption is not always suitable. **Autoregressive process models** (e.g. AR, GARCH models) might be suitable generalisations of the random walk model.

Example AR(1) model: $X_t = \phi X_{t-1} + \varepsilon_t$ with $\varepsilon_t \sim N(0, \sigma^2)$

Risk factors are usually modelled as Markov processes.

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Risk factors – model simplification for market risk calculations

Most **market risk calculations** in banks are performed on **short time horizons** of only a few days. As we will see later this is also connected to regulatory requirements. For these purposes the **restriction** of modelling risk factors as simple processes containing only a **constant drift** and a **stationary diffusion** term is usually sufficient:

» lognormal model

$$d\ln(\rho_t) = \mu \cdot dt + \sigma \cdot dW$$

drift   volatility

» normal model

$$d\rho_t = \mu \cdot dt + \sigma \cdot dW$$

In the following we will therefore concentrate on these processes. However, for **pricing purposes** (e.g. for interest rate models) or **for more sophisticated risk calculations** (e.g. on longer time horizons) **more complex processes** are required.

The next step is to calibrate the model by determining the process parameters drift and volatility from available (historical) market data.

Market risk: risk factors are usually modelled as simple diffusion processes.

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Risk factors – determining process parameters from time series

Process Parameters

Based on the assumption of **stationary markets, drift and volatility** of the stochastic process can be estimated from time series.

$$d\ln(\rho_t) = \mu \cdot dt + \sigma \cdot dW$$

Mean StdDev

date	Dax	r_{log}
24. Sep 10	6.298,30	0,0182
23. Sep 10	6.184,71	-0,00381
22. Sep 10	6.208,33	-0,01084
21. Sep 10	6.275,98	-0,00296
20. Sep 10	6.294,58	0,013567
17. Sep 10	6.209,76	-0,0064
16. Sep 10	6.249,65	-0,00195
15. Sep 10	6.261,87	-0,00216
14. Sep 10	6.275,41	?
13. Sep 10	?	?
10. Sep 10	6.214,77	-0,00109
09. Sep 10	6.221,52	0,009217
08. Sep 10	6.164,44	0,00758
...	...	...

Practical Difficulties – Data Quality

» **Missing data**
- › small gaps: constant/linear interpolation; proxy time series return
- › larger gaps: Brownian Bridge or EM algorithm

» **Products without available data history**
- › map on suitable existing time series (related product)
- › create synthetic time series with desired volatility and correlation

Market risk calculations are based on historical data.

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Risk factors – volatility surfaces

Historical volatility

» extracted from time series of risk factors

» used for market risk calculations.

Implied volatility

» volatility that has to be used in a certain model to hit the observed option price (solving the pricing function for the volatility)

» for pricing of volatility dependent instruments the historical volatility is not adequate

Volatility surfaces are 2- or 3-dimensional objects: Volatility as a function of time to maturity and strike of the option (for swaptions also maturity of swap)

Examples:

» **IR:** caplet-, swaption-, bond option-surfaces

» **EQ:** stocks, indices

» **FX:** major currency pairs

Black-Scholes

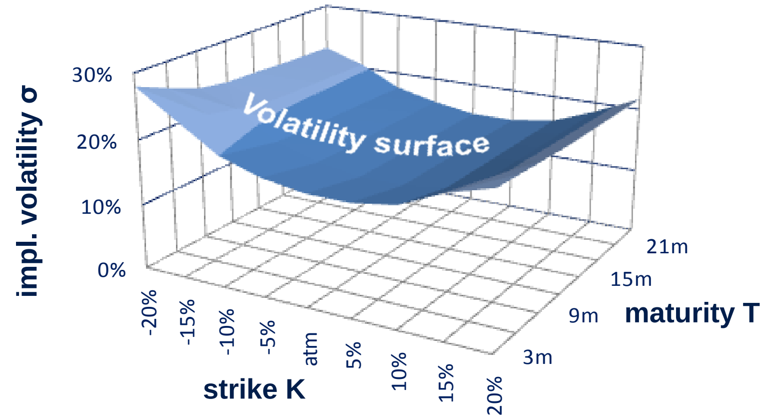
European Call option

$$C(S,t) = S\Phi(d_1) - Ke^{-r(T-t)}\Phi(d_2)$$

$$d_1 = \frac{\ln(S/K) + (r + \sigma^2/2)(T-t)}{\sigma\sqrt{T-t}} \qquad d_2 = d_1 - \sigma\sqrt{T-t}$$

$$\Phi(x) = \int_{-\infty}^{x} \frac{1}{\sqrt{2\pi}} \exp\frac{-z^2}{2}\,dz$$

cumul. density function of normal distribution



Volatility Surface Risk Factors

The risk factors are given by fixed grid points on the maturity-strike grid. Time series for risk factors are generated from daily observations of volatility surface.

Implied volatilities are used as risk factors.

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Risk factors – dynamics of risk – part I: volatility smile

On October 19th, 1987, stock exchanges were struck by "Black Monday", the first market crash after the 2nd World War

Implied volatility for equity options changed

- » until then, risk calculations did not distinguish between options of different moneyness and maturity
- » since then, options started smiling

Black-Scholes

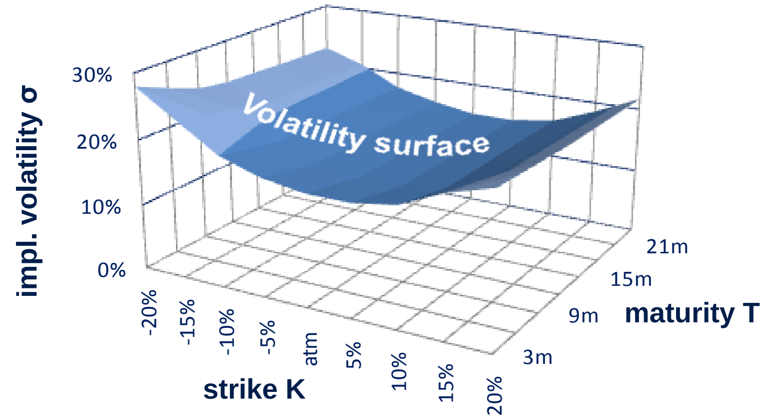
European Call option

$$C(S,t) = S\Phi(d_1) - Ke^{-r(T-t)}\Phi(d_2)$$

$$d_1 = \frac{\ln(S/K) + (r + \sigma^2/2)(T-t)}{\sigma\sqrt{T-t}} \qquad d_2 = d_1 - \sigma\sqrt{T-t}$$

$$\Phi(x) = \int_{-\infty}^{x} \frac{1}{\sqrt{2\pi}} \exp\frac{-z^2}{2} dz$$

cumul. density function of normal distribution



Volatility Surface Risk Factors

The risk factors are given by fixed grid points on the maturity-strike grid. Time series for risk factors are generated from daily observations of volatility surface.

Lessons learnt: Moneyness and maturity are relevant risk factor dimensions.

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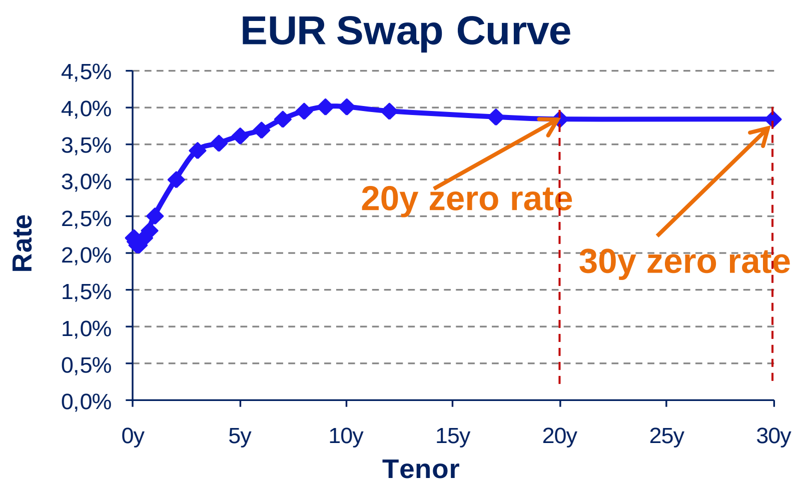
Risk factors – Interest rate curves (1/2)

The interest rate determines the interest one receives when depositing money in a bank. The rate depends on the time the money is deposited, therefore interest rates have a **term structure**. Another way to look at it is the **time value of money**. One euro today is worth more than one euro received in a year.



Specification requires:

- **Interpolation method**: e.g., linear on DF, ...
- **Day count convention**: A/360, Act/Act, ...
- **Business Day Convention**: preceding, ...
- **Compounding**: continuous, 3m, 6m, ...

There are different kinds of interest rate curves depending on the referenced entity:

- **Government curves**: Germany, France, UK, US, …
- **Swap curves**: EUR, USD, GBP, JPY, …

Depending on the properties of the financial instruments they are constructed from, Government and Swap curves can be further differentiated (see next slide).

Risk factors

Interest rate curves are usually defined as array of zero rates (marker on diagram curve) for a fixed grid of tenors. The zero rates per tenor can be used as risk factors for the rate curve (generate time series for each tenor from daily observation).

Interest rate curve: simple concept, complex in practice.

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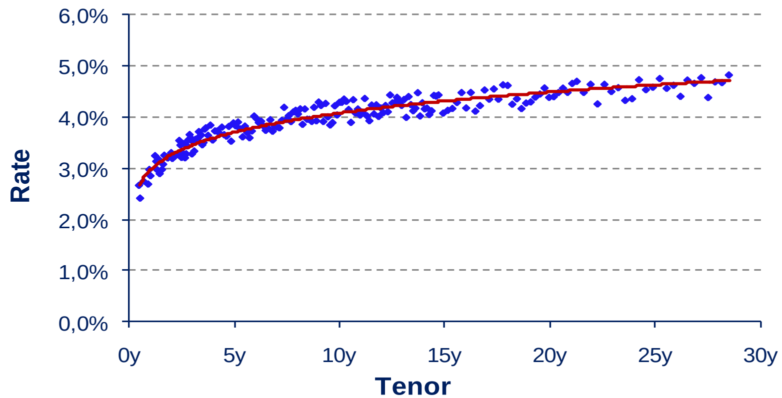
Risk factors – interest rate curves (2/2)

Construction of Interest Rate Curves

Government curves

A government curve is constructed from the prices of government bonds. It can be calculated as regression curve through the available data but often also parametric forms are used.

Government Curve



There are also special government curves that are constructed from government bond futures (Germany: Bund, Bobl, Schatz) only.

Swap curves

During the recent financial crisis the classification of swap curves has been further differentiated. Now banks use several swap curves for the same currency depending on the instruments they are constructed from.

Swap curves are constructed via **bootstrapping** from different instruments:

- short end: deposits, FRAs, futures, EONIAs
- long end: swaps

Today the **different degree of credit risk and liquidity** of the different instruments can no longer be neglected in the construction of rate curves. The same holds for basis risks between swap tenors.

Interest rate curve construction has become more complex during the financial crisis.

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Risk factors – spread curves (1/3)

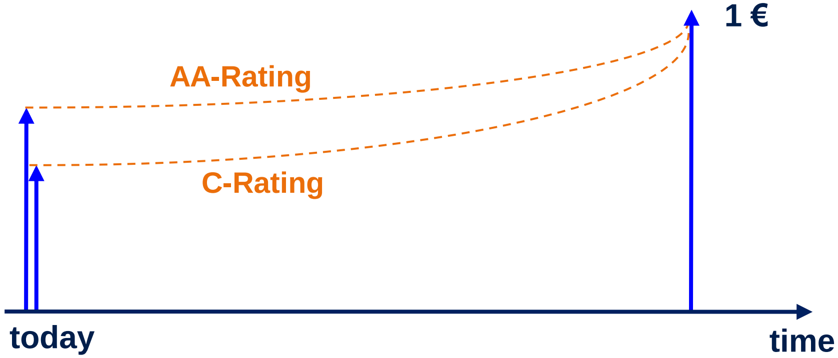
Creditworthiness and Spread Curves

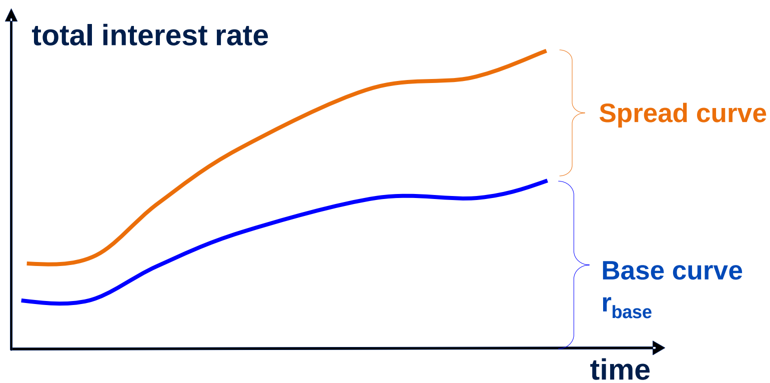
The value of financial instruments and contracts also depends on the **creditworthiness** of the issuer or counterparty. This is reflected in the time value of money. 1 euro due in one year from a AA-rated company is worth more than 1 euro due in one year from a C-rated company.

Creditworthiness is reflected in valuation and risk measurement of financial instruments through **individual rate curves**. Additionally, risk management usually wants to **separate risk contributions** of interest and creditworthiness.

→ **Spread curves** measure the spread between a common base curve (e.g. swap curve) and the issuer/counterparty specific curve.

Market risk accounts only for the **change in spread levels** but **not for defaults or rating migrations**!





Spread curves reflect the creditworthiness of the issuer/counterparty.

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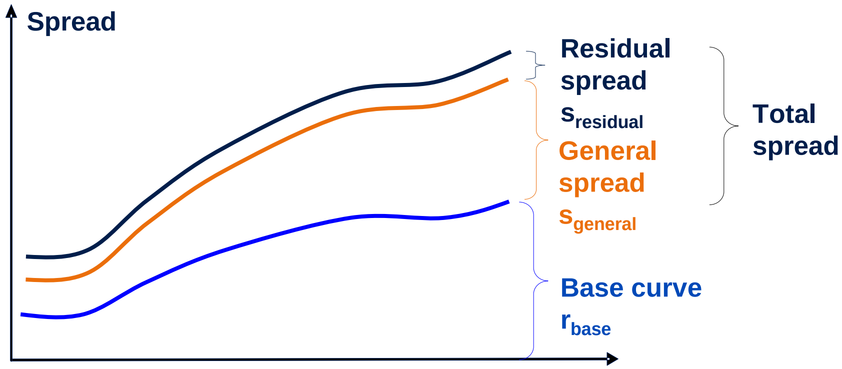
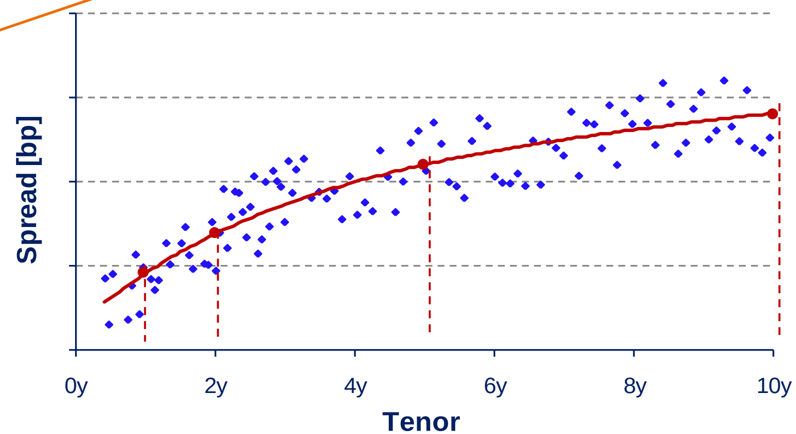
Risk factors – spread curves (2/3)

Spread Curve Construction (Bonds)

In **practice** one often **lacks** the **data** to generate individual spread curves for each address. Instead general spread curves (per sector/rating) with a residual spread are used.



$$r_{total} = \underbrace{r_{base} + s_{general}}_{\text{systematic}} + \underbrace{s_{residual}}_{\text{idiosyncratic}}$$



Spread Curve Risk Factors

» Similar to interest rate curves, spreads for individual tenors are used as risk factors for the general (sector/rating) spread curves.

» The residual spreads are usually modelled as single risk factor.

» For CDS, issuer specific spread curves are used.

Spread curves can be separated into systematic and idiosyncratic parts.

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Risk factors – spread curves (3/3)

Example of a corporate bond

Market risk (restricted to spread risk) does not account for defaults or rating migrations.

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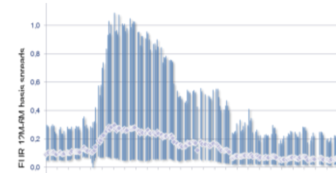
Risk factors – dynamics of risk – part II: basis risk



Basis Risk in a nutshell

» Basis risk is a financial entity related to imperfect hedging and has many facets, related losses usually reveal themselves during or in the aftermath of financial crises.

Tenor and FX Basis Risk (post Lehman)

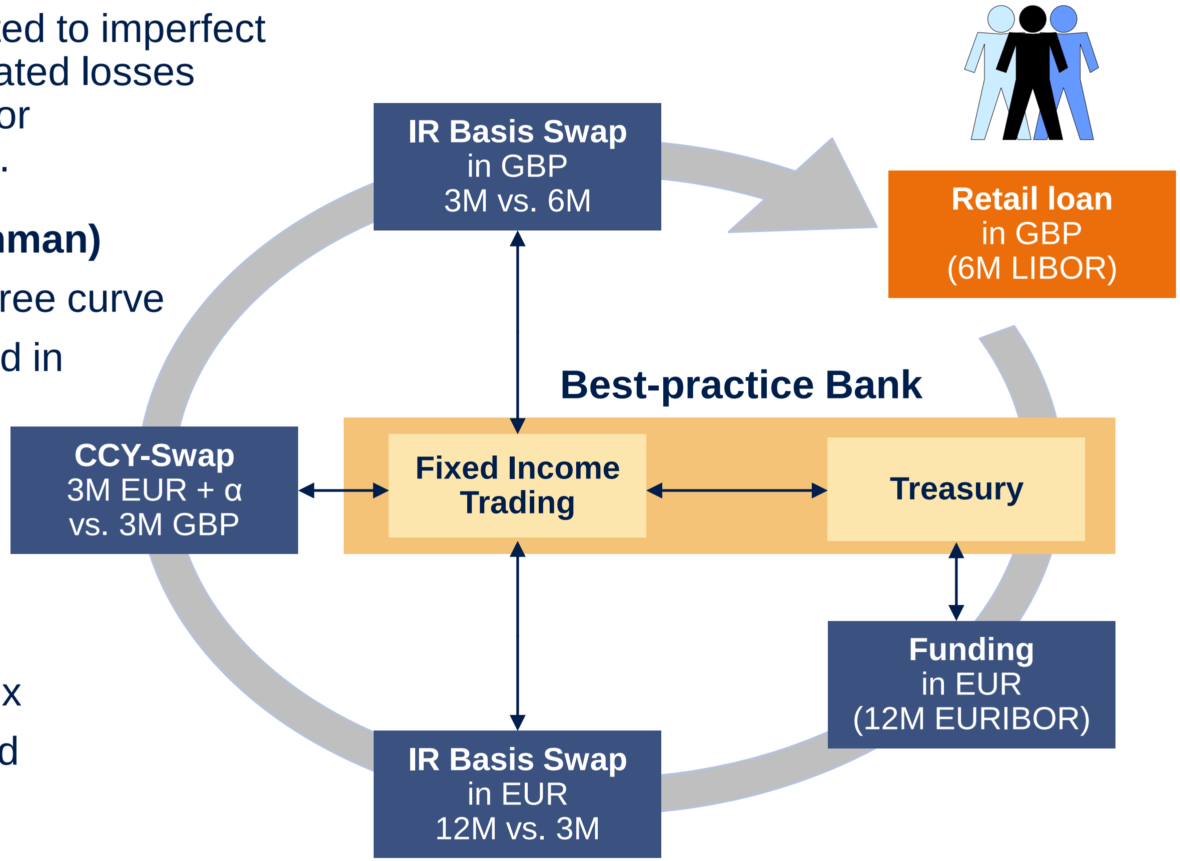
» Strictly speaking, there is no risk free curve

» Counterparty credit risk is reflected in tenor-dependent spreads (IR basis)

» Cross-currency financing yields another basis between funding rates (FX basis)

» As a consequence, offering a credit has become quite complex

» It involves external refinancing and sophisticated risk management



Lessons learnt: Risk modeling and management need to be sensitive to new types of (basis) risk.

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Risk Factors – portfolio level

Market Risk Factors on Portfolio Level

» The trading book of big banks contains all kinds of risk factors that easily amount to **several thousand risk factors**. Risk measurement has to take all (relevant) risk factors into account.

» Risk factors usually are not independent of each other but are **correlated**. Risk measurements must take these correlations into account.

» Risk factors continuously vary while markets are open. Therefore risk factor **observations** to generate time series for risk measurement **must be simultaneous** to preserve correlations.

» Portfolios are often hedged to eliminate risks. This might result in risks that can be neglected on instrument level to be dominant on portfolio level.

Adequate risk measures, tools and processes are needed to manage market risk.

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Measurement of Market Risk

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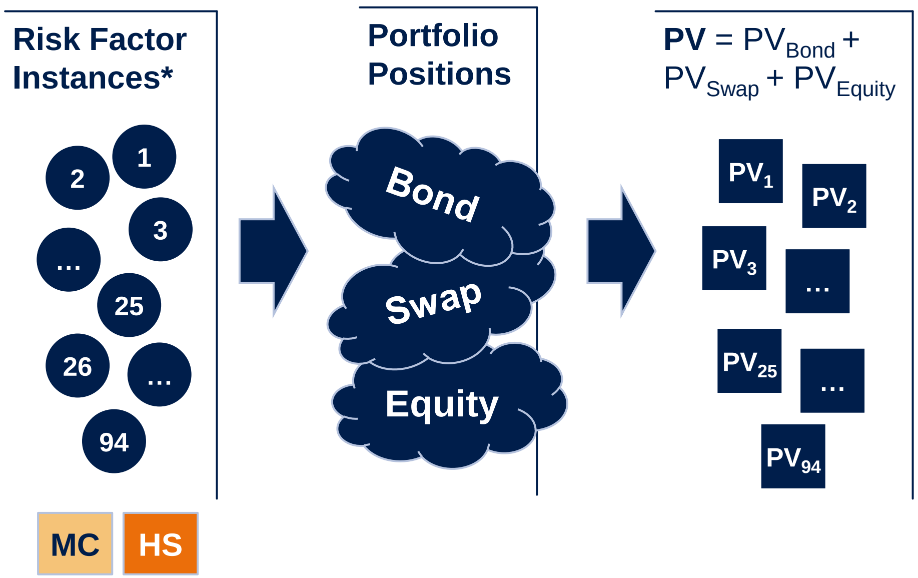
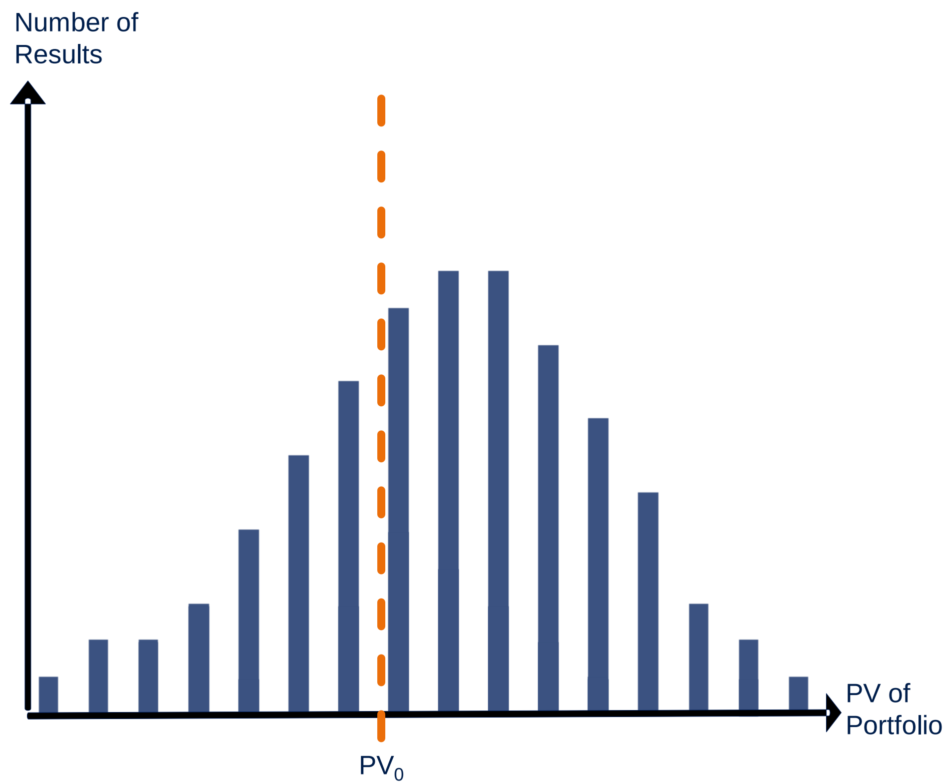
Market risk valuation – portfolio level

Random Change of Risk Factors

Going forward in time risk factors change. The Profit-and-Loss (P&L) is derived as the difference between the new (PV_i) and old present values (PV_0), first for single portfolio positions and subsequently for the portfolio.





The Profit-and-Loss distribution derives from the (common) distributions of risk factor changes.

* e. g. simulated by Monte Carlo (MC) or Historical Simulation (HS)

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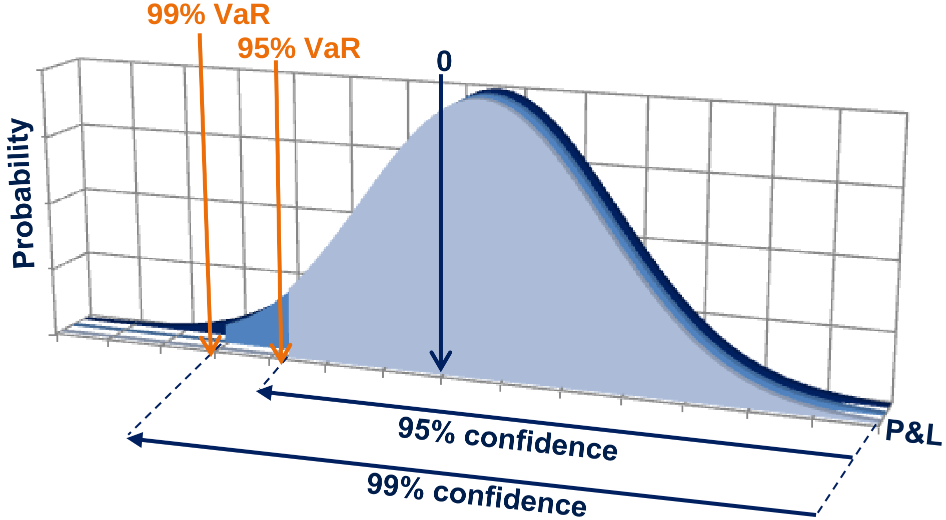
Introduction of market risk measures – Value-at-Risk (VaR)

Market Risk of Portfolios

Financial instruments and therefore portfolios of financial instruments are subject to market risk.

Market risk management requires adequate measure to quantify market risk of portfolios that are sensitive to thousands of risk factors.

Estimated Portfolio P&L Distribution



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 can be calculated for arbitrary quantiles.
- VaR is usually calculated on short time horizons (e.g. 1 or 10 days).
- VaR is based on historical risk factor time series from which the estimated portfolio P&L distribution is calculated (assumption of stationary market).

VaR quantifies potential portfolio loss based on historical data.

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Introduction of market risk measures – Expected Shortfall

Expected Shortfall (Expected Tail Loss)

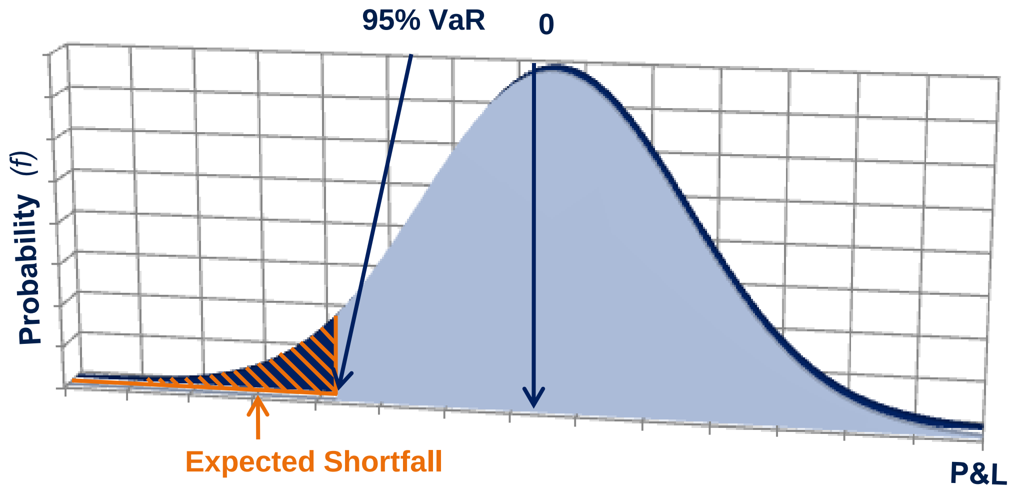
The expected shortfall (ES) is also called expected tail loss or conditional VaR.

It is related to VaR and measures the expectation value of losses (as a positive number) that exceed the VaR.

- ES is measured in monetary units (e.g. €).
- ES can be calculated for arbitrary quantiles
- ES is usually calculated on short time horizons (e.g. 1 or 10 days)
- ES is based on historical risk factor time series.
- In contrast to VaR ES is a coherent risk measure and therefore is sub-additive: for two sub-portfolio *A* and *B* holds:

$$ES(A+B) \leq ES(A) + ES(B)$$

Estimated Portfolio P&L Distribution



$$ES(\alpha) = \frac{\int_{-\infty}^{VaR(\alpha)} PL \cdot f(PL) dPL}{\int_{-\infty}^{VaR(\alpha)} f(PL) dPL}$$

Expected Shortfall is coherent risk measure that is related to VaR.

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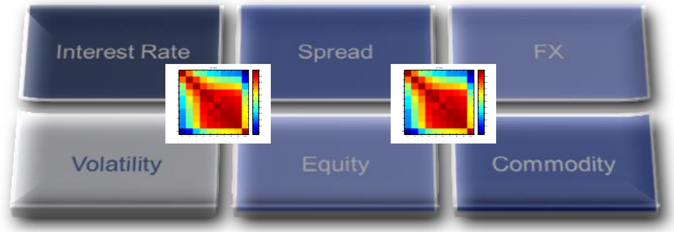
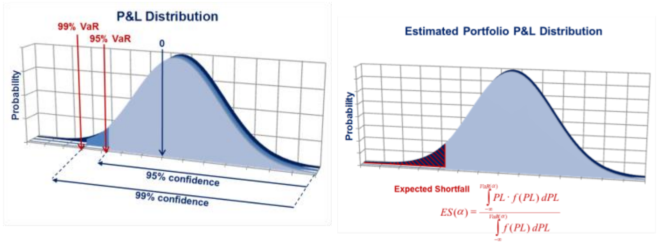
(Market) Risk modeling in a nutshell

- » Identify risk position (portfolios, desks, institute)
- » Classify and model risk factors (EQ, IR, Vol, FX)



- » Derive Profit & Loss distribution (scenario-wise)
- » Choose Risk Measure (VaR, Expected Shortfall)



- » Analyse and understand risk structure
- » Report comprehensive risk assessment

The understanding of risk is essential to grasp the necessity for regulation and recent evolutions.

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Regulation of (Market) Risk

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Goals and Structure of Regulation

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Goals of regulation – enforcing good reason

Pillar 1	Pillar 2	Pillar 3
Ensure minimum capital buffers to balance risks.	Banks shall analyse, understand and manage risks inherent in their business.	Market disclosure and discipline
Regulatory Capital	**Economic Capital**	**no capital req.**

different implications

Bank Portfolio

Banking Book:
» long term investments
» “held to maturity”

Trading Book:
» positions held for trading
» short term horizon

Main goals of regulation

» Preservation of financial industry

» Protection of creditors

Regulation takes into account the different nature of banking book and trading book.

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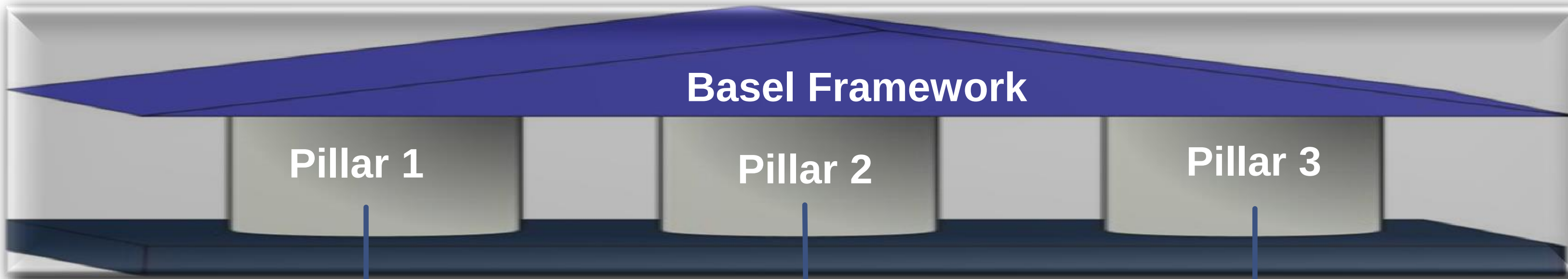
Regulatory requirements – German regulatory documents



CRR: Capital Requirements Regulation

directly applies to national institutes

CRD IV: Capital Requirements Directive

directly applies to national institutes

Kreditwesengesetz (KWG) + CRD IV Umsetzungsgesetz

KWG § 24
KWG § 25a

BaFin 10/2012: MaRisk

Basel III is incorporated into German regulations by CRR and MaRisk 2012/2017*.

* MaRisk will soon by updated by its 5th amendment in 2017.

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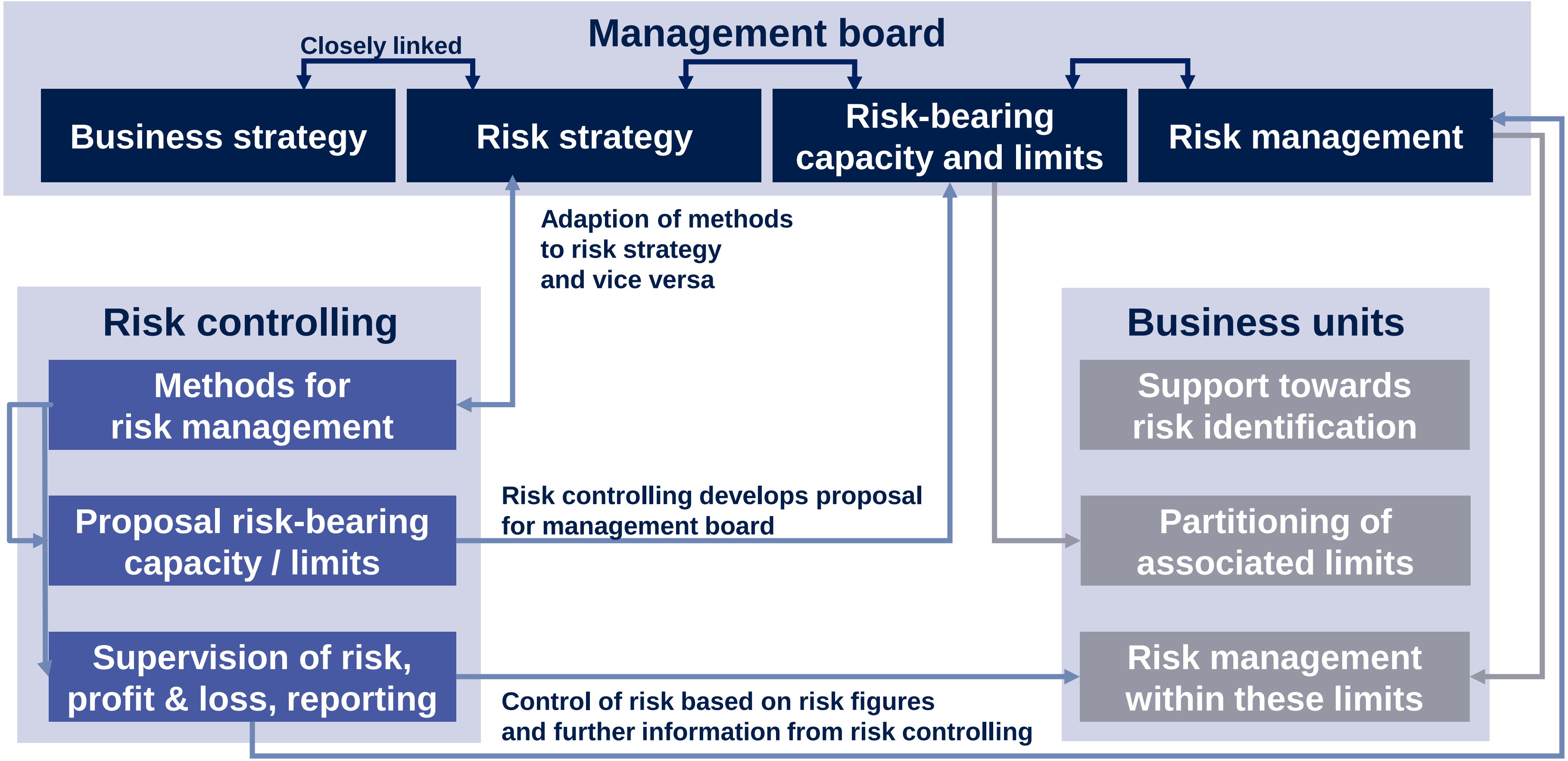
Organisation of risk management in line with the MaRisk



Possible real-world organisation of Risk Management.

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Pillar 1 – Regulatory Capital

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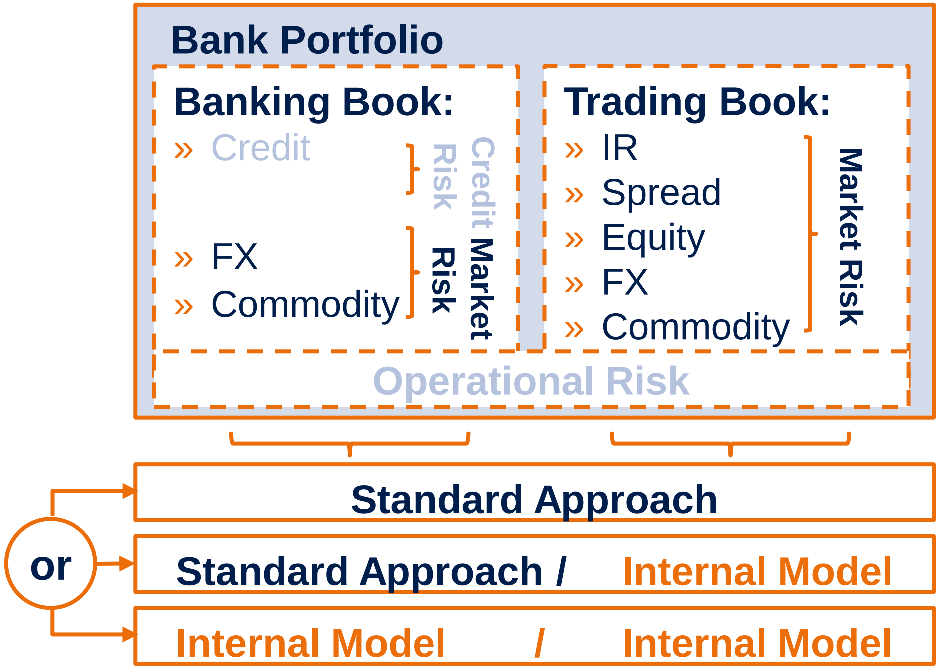
CRR defines requirements for Regulatory Capital (pillar 1)

Managing Market Risk – Regulatory Capital Requirements

- Regulation requires capital buffers for positions subject to **market risk (CRR)**:



Standard Approach

In the standard approach, minimum capital requirements are basically defined by weighted exposures.

- Definition of exposure measures
- “god-given” weight factors

Internal Model Approach

Internal models are usually based on a VaR-model. Constraints for the model:

- one-sided confidence interval of 99%; 10 day holding period
- Effective historical observation period ≥1y
- Extended requirements for specific interest rate risk (since after the financial crisis)

Partial Use

Combination of both with internal model used only for selected market risk categories.

Banks must use the standard approach or an internal model.

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The (current) market risk modelling framework (pillar 1)

Novations since crisis

Internal Market Risk Models

Value-at-Risk, 10 day risk horizon, risk factor time series 1y+, 99% confidence level, factor 3+x+y

Stressed Value-at-Risk, as above, but parameterised in stress period (e. g. 2007/08), factor 3+z

General Market Risk

EQ, EQ vol

FX, FX vol

IR(1), IR vol

Specific Market Risk

Residual Risk

Issuer spreads, equities

Event Risk

Equities (M&A, jumps, etc.)

+

Exceptions Outside

Incremental Risks

1 year risk horizon + ≤1 year liquidity horizon(2), 99,9% confidence level, factor 1, default and migration risk (at least specific IR)

+

Fallback model Stand. Approach

Comprehensive Risk

for the „Correlation Trading Portfolio“ (CDO tranches, n-th-to-default credit derivatives with sufficient liquidity), all relevant price risks, factor 1, floor w.r.t. modified standardised approach

(1) IR = base curve + sector-by-rating spreads; (2) Assumption: constant level of risk

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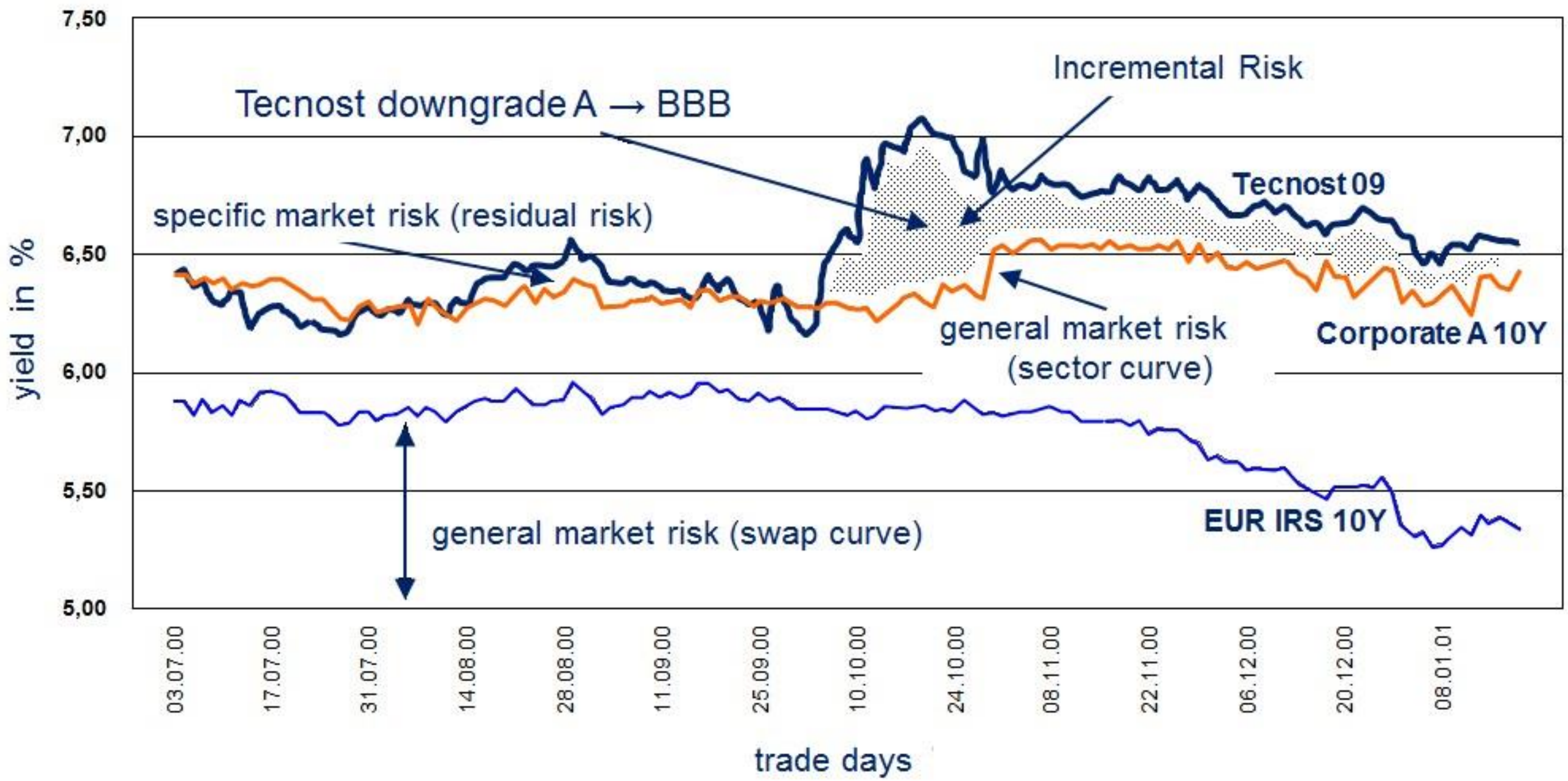
Market risk categories of Internal Models (pillar 1)

Example of a corporate bond



Basel II.5 requirements cover relevant market risk dynamics.

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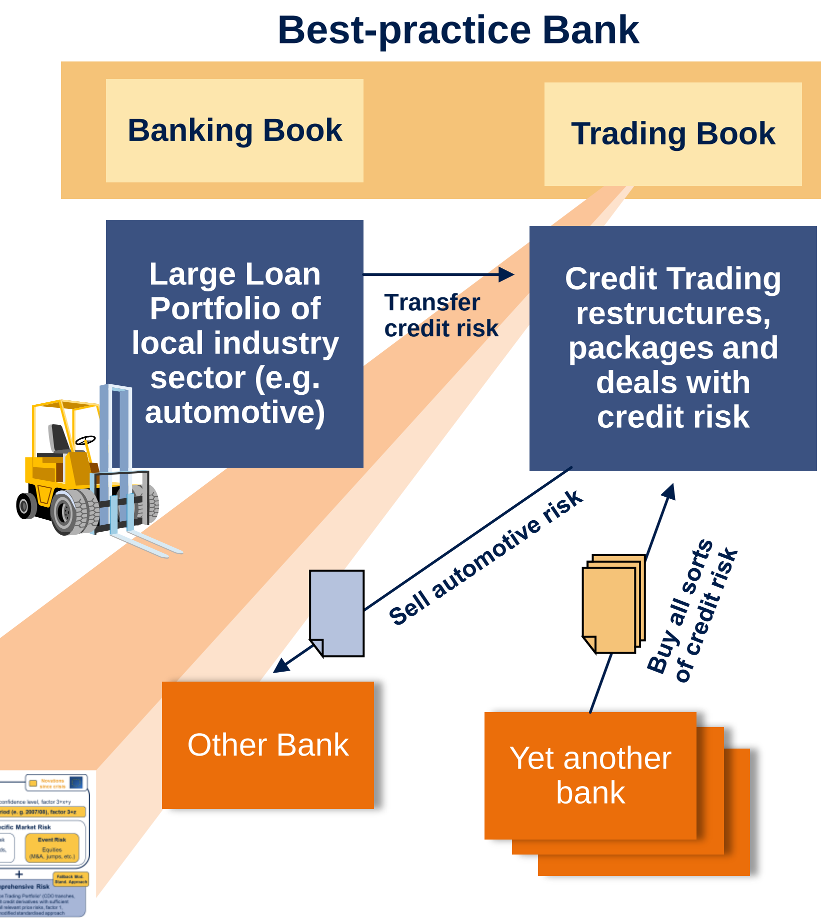
Dynamics of regulation: regulatory arbitrage (part I)

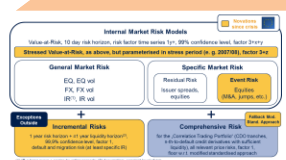
Regulatory arbitrage of credit risk in a nutshell

- » Requirements on risk management and capital need to keep up with the markets in scope of regulation
- » New products (e. g. CDS) allowed to trade and diversify credit risk, which is in general a very good idea
- » Even better, credit risk in the trading book used to be a lot cheaper when it comes to capital requirements (99% / 10d vs. 99,9% / 1y)

Arbitrage as a door to speculation on another “basis”

- » Leveraged buying/selling of credit risk (e. g. spread deals like JPM “London Whale” 2012), i. e. speculation on the tendency of markets (widening / tightening of basis spreads, here CDS vs. Bond/LIBOR)
- » Unknown risks (true correlations, market liquidity)
- » Regulators remedied arbitrage and addressed deficiencies by introducing ad-hoc measures making credit risk in the trading book in fact more costly (by incl. migrations)





Lessons learnt: Design of efficient and risk-adequate regulation is a challenging task.

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Pillar 2 – Economic Capital

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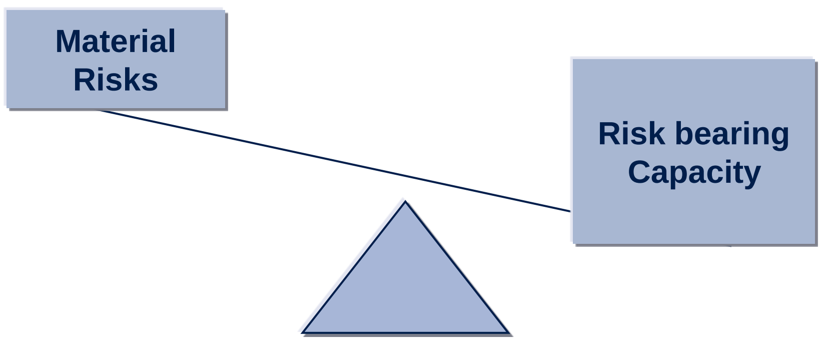
MaRisk (2012) contains requirements for Economic Capital (pillar 2)

Internal Capital Adequacy Assessment Process (ICAAP)
Idea: compare material risks to economic capital (risk bearing capacity) over a long time horizon (1y)



Methodological freedom for calculation of risks and risk bearing capacity

Proportionality Principle: regulations are adjusted based on the size and complexity of the institute

Bank Portfolio

Banking Book and Trading Book:

- Credit Risk
- FX
- Commodity
- IR (IRRBB)
- Spread
- Equity

(FX, Commodity, IR (IRRBB), Spread, Equity: **Market Risk**)

Operational Risk

- all relevant (material) types of risk need to be considered
- particularly for the Gone concern perspective: IR risk in the banking book

Both requirements for regulatory and economic capital need to be fulfilled for regulatory compliance.

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Different measures for different purposes

	Pillar I	Pillar II	Internal Steering	…
	Regulatory Capital	**Economic Capital**	**Internal Limit System**	
Idea	**Short term steering:** Measurement and steering of „current“ risk	**Risk bearing capacity:** Stable risk measure / stable capital requirements based on complete economic cycle	**Allocation of risk budgets** to departments and desks **Meeting the risk appetite**	…
Risk Measurement	**Standardised approach:** » Exposure based measure **Internal model approach:** » Risk based measure like VaR or ES	**Internal (Model) Approach:** » VaR / ES or Stressed VaR » Stress Tests » Going / gone concern approach (or both) » Balance sheet or value based	**Sensitivity based** **Internal (Model) Approach:** » VaR or ES	…
Model Parameterisation	Regulatory risk horizon of 10 days for internal model » Time series used in model: typically 1-2 years » Backtesting of 1 day model » Confidence level: 99%	Risk bearing capacity » Risk horizon: 1 year » Time series: several years » Confidence level › Gone Concern: 99,9x% › Going Concern: 95%+	Management of market risks usually short term (trading book) » Risk horizon: usually 1 day » Time series: typically 0.5-2 years, weighted	…

There are different purposes in a bank that require market risk measurements

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Ever-changing Markets

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The Future of (Market) Risk Regulation

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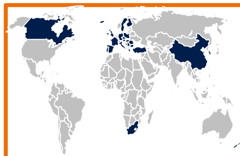
A tsunami still rolling – timeline of new requirements

Major upcoming regulatory projects

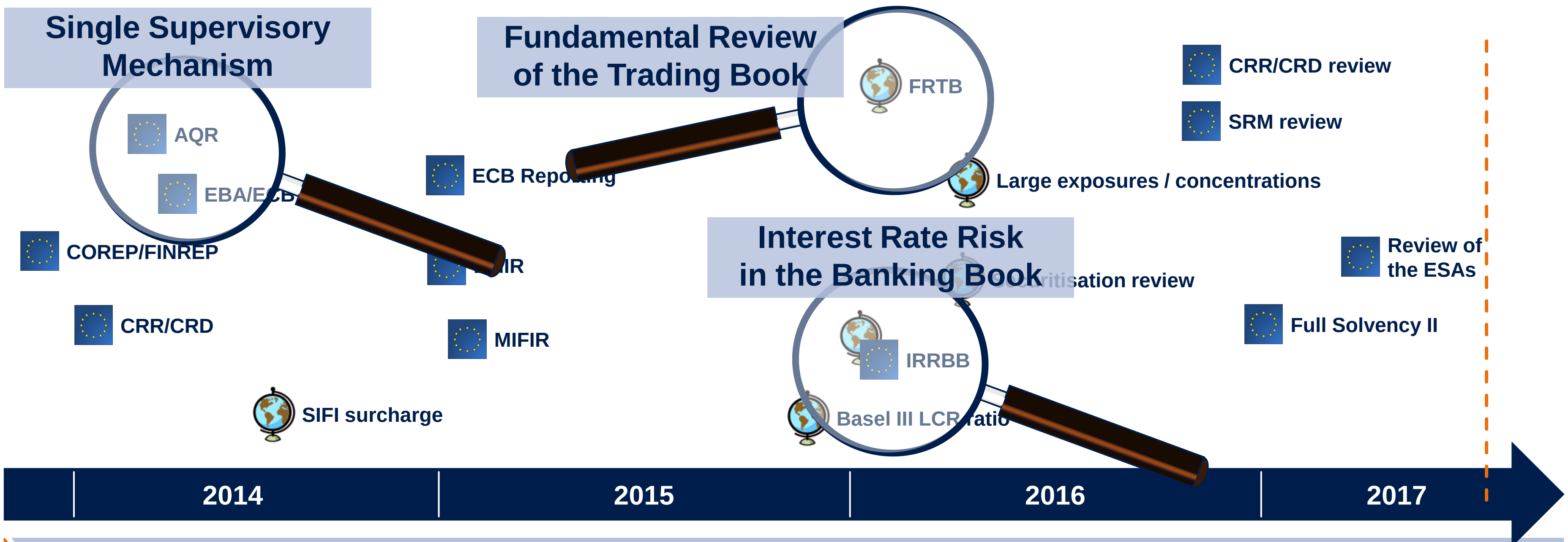


- Basel IV
- Update SA-CR
- CVA risk

- CRR review
- CRD review
- ...& a lot more

- IRRBB
- AML/TF

Selected regulatory project activities (EU / BCBS)



The timeline of regulatory requirements to be implemented by financial institutions severely stresses the industry in a literal and business sense and continues to do so.

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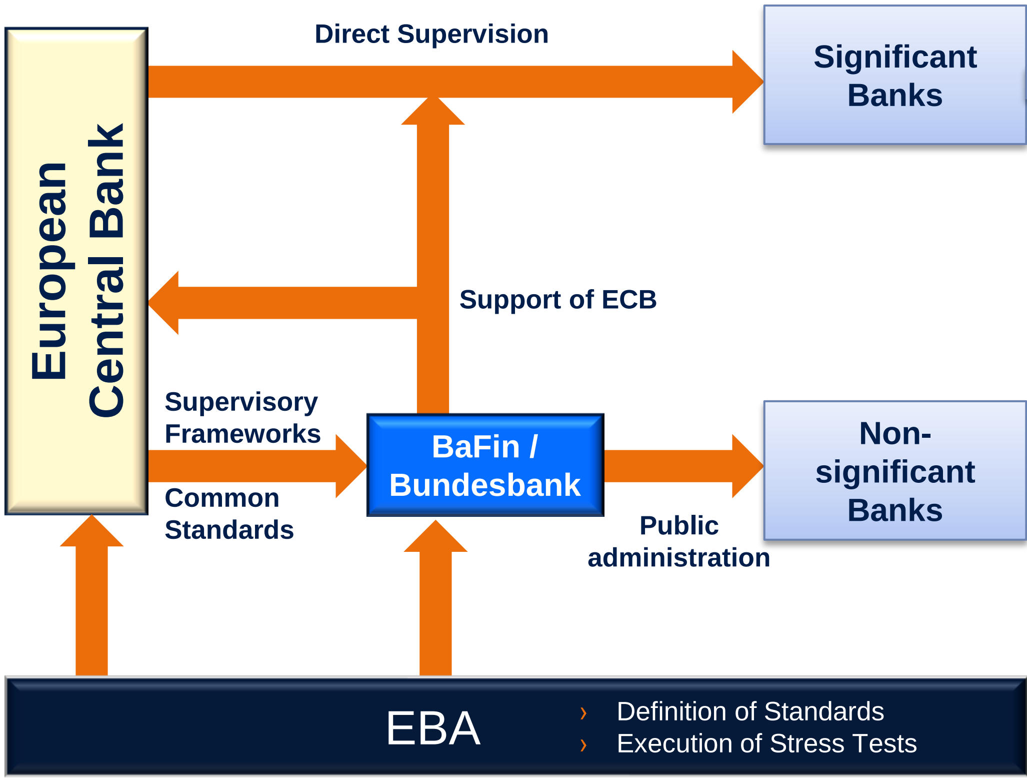
Stabilising the Eurozone – Single Supervisory Mechanism (SSM)



Significant Banks (SIBs)

Bank fulfils at least one criterion

Total assets > 30 bill. EUR	Total assets > 20% of GDP and Total assets > 5 bill. EUR	One of the three largest banks of the member state

Additional Criteria:

- Bank financially supported by EFSF/ESM
- ECB defines an international bank as SIB
- Bank voluntarily seeks supervision by ECB
- Voluntary participation in SSM from countries outside the Banking Union (Opt-in)

Euro zone supervision is organised as a Single Supervisory Mechanism (SSM) coordinated by the ECB.
Its counterpart, the Single Resolution Mechanism (SRM) addresses the “Too Big to Fail” problem.

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Ongoing paradigm shift – Fundamental Review of the Trading Book (1/2)

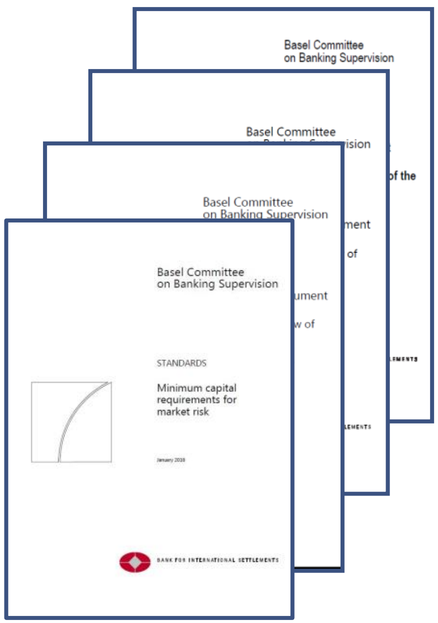
- **10/2010 FSA FR DP** ✓
- **05/2012 BCBS 219 CP1** ✓
- **10/2013 BCBS 265 CP2** ✓
- **12/2014 BCBS 305 CP3** ✓
- **01/2016 Final text** ✓
- **01/2019 National legislation**
- **12/2019 1st reporting date**

2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020

BCBS QIS 1-4

Banks: FRTB design & implementation

BCBS: Basel III Monitoring
(semi-annually/ad-hoc, parallel to implementation)



Open issues and dependencies

- » **Calibration**: adjustments possible due to **monitoring results** and/or by parallel modifications of the other pillar 1 contributions (credit, operational, and counterparty risk)
- » Interdependency with regulation of **securitisations** (BCBS 343)
- » Integration of the **CVA Risk Charge** into the FRTB text (BCBS 325)
- » Modification due to regulation for **capital deductions** (market making, TLAC regime)
- » For internal models: details on **P&L attribution test**
- » Incentives for internal models – role of **floor** between SA-TB and IMA-TB (BCBS 306)
- » Comprehensive revision of **disclosure requirements** (pillar 3, e.g. BCBS 356)
- » Modifications or de minimis regulation for small banks

The first official reporting date set by FRTB rules is December 31st 2019. The complexity of requirements in combination with other ongoing regulatory initiatives requires a timely start of FRTB projects.

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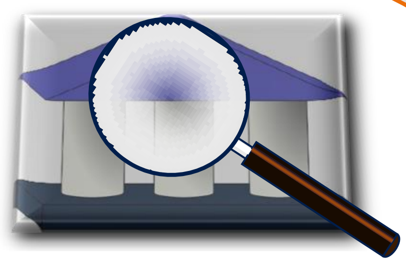
Ongoing paradigm shift – Fundamental Review of the Trading Book (2/2)

New criteria for the Trading / Banking Book Boundary

Moving to Expected Shortfall instead of Value-at-Risk
(Based on period of significant financial stress)



Desk-wise Model Approvals

Revised Standard-Approach
(portfolio model light)

Final document of Basel Committee on Banking Supervision (published on 14.01.2016) proposes several material changes to existing regulatory framework.

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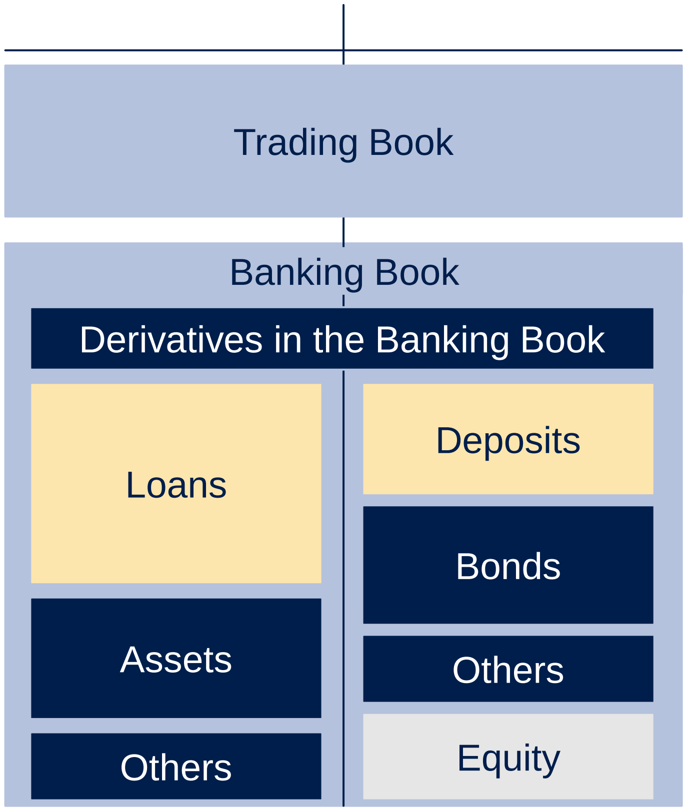
Dynamics of regulation – regulatory arbitrage (part II)

IRRBB (Interest Rate Risk in the Banking Book) = “The current or prospective risk to both the earnings and capital of institutions, in respect of the banking book only, arising from adverse movements in interest rates.“



Interest rate risk in the trading book

- Available-for-sale position; Fair-Value (FV) accounting
- Market values observable
- Near-market Valuation; objective valuation

IRRBB

- Held-to-maturity investments instead of FV positions.
- Consideration of both present value (PV) and Net Interest Income (NII)
- Non-existing market values (e.g. for loans).
  Valuation (and risk assessment) hardly objective.
- Risk measurement is highly individualized by banks, e.g.
  - Treatment of positions with behavioural options or non-maturing instruments (e.g. deposits)
  - Treatment of accruals and deferrals and equity

IRRBB regulation accounts for the extensive modelling needs in the banking book and the way market risk for banking book positions is usually managed and limited.

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New IRRBB requirements affect all three pillars

Regulation	valid from	Pillar 1 (Reg. Capital)	Pillar 2 (ICAAP)	Pillar 3 (Disclosure)
SREP Guidelines (EBA)	1.1.2016	Introduction of **Pillar 1+** (Minimum capital requirements)	Principles for supervisors IRRBB vs. market risk model risk	
IRRBB Guidelines (EBA)	1.1.2016	**SREP-Add-on** for Pillar 1+	Refinement of IRRBB Pillar 2 requirements methodological guidelines **200bp interest rate shift**	
IRRBB Consultation (Basel)	2018 (expected)	**Pillar 1 Capital Requirements** are put up for discussion. **Standardized** hybrid approach: intersection between Pillar 1 and 2 Earnings-based measures and modelling of customer behaviour	In addition to EBA reqs: **Fallback** standardized measurement approach Credit Spread Risk in the Banking Book (**CSRBB**) Principles for supervisors	Standardized **disclosure of banks' IRRBB exposures** (Qualitative such as behavioural assumptions and quantitative such as economic value and earnings measures)

Regulation aims at stronger capital basis, limited incentives for capital arbitrage, more transparency and better comparability between different banks concerning IRRBB.

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The Future of (Market) Risk Modelling

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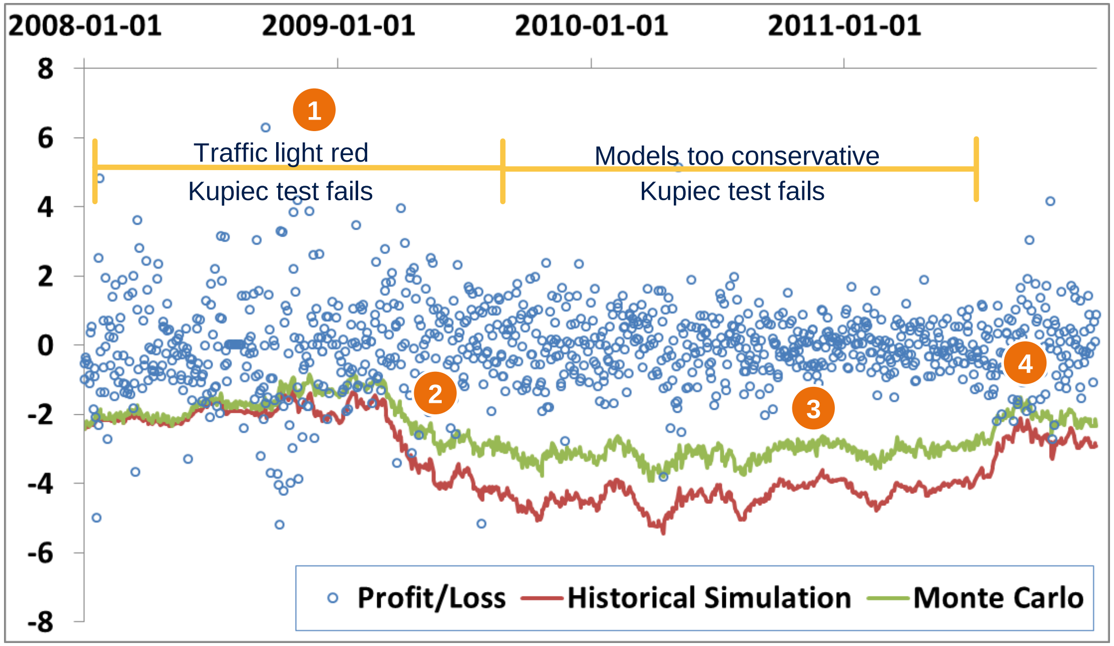
Model weaknesses of standard Historical Simulation and Monte Carlo

» Back testing of example Portfolio 1 from 2008 to 2011:



» **Setup:**

- Historical Simulation with 1000 scenarios (i.e. 4 years moving window)
- Monte Carlo with 2000 scenarios and 4 years calibration window
- Confidence Level equals 99%

» Kupiec proportion of failures (POF) test during the crisis (Jan 2008 – Aug 2009) fails (for *p = 95%)* because models have too many outliers. Basel traffic lights are also red.

» Kupiec test for the time period Aug 2009 to June 2011 fails because model is too conservative

1. Market volatility increases (Lehman-crisis). Large returns enter the moving time window, but the Value-at-Risk does not 'see' them yet
2. Sufficiently many large returns have entered the moving time window leading to increasing risk figures
3. Although markets have calmed down, large returns still dominate the moving scenario time window, so risk figures remain on a high level
4. Large returns start dropping out of the moving time window and risk figures decrease

Standard Historical Simulation and Monte Carlo suffer from low reactivity to changing market conditions.

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Filtered Historical Simulation – general idea

- A basic assumption of standard historical simulation is stationarity of scenarios, i.e. each scenario "has the same probability", which in reality is violated more often than not
- Filtered historical simulation(1) tries to heal this by introducing a suitable model for the historical volatility σ_j^t (could be EWMA, GARCH …) and possibly the drift μ_j^t which are then used to normalise the returns(2) r_j^t before they are further processed.
- **Simplest version:** (Univariate) filtered historical simulation with EWMA – volatilities:

1. Compute historical (EWMA-) volatility for each risk factor over time (this can be done recursively). There is one additional parameter $\lambda \in [0,1]$ (per risk factor), a typical value is $\lambda = 0.97$

$$\mu_j^t = (1-\lambda) \cdot \sum_{i=0}^{\infty} \lambda^i \cdot r_j^{t-i} \qquad \sigma_j^t = (1-\lambda) \cdot \sum_{i=0}^{\infty} \lambda^i \cdot \left(r_j^{t-i} - \mu_j^{t-i}\right)^2$$

2. Compute residuals by dividing each return by its volatility at the same point in time

$$\xi_j^t = \frac{r_j^t}{\sigma_j^t}$$

3. At the valuation date T, compute shifts $R_j^{T,k}$ by upscaling all residuals with the volatility at time T

$$R_j^{T,k} = {\sigma_j}^T \cdot \xi_j^{T-k} \qquad (k = 1, \dots, n)$$

4. Use these shifts instead of the original returns in the historical simulation algorithm

(1) Barone-Adesi, G., Bourgoin, F. and K. Giannopoulos, 1998, *Don't Look Back*, Risk, 11, August
Hull, J. and A. White, 1998, *Incorporating Volatility Updating into the Historical Simulation Method for VaR*, Journal of Risk 1
(2) from now on "returns" will always mean "log-returns" unless stated otherwise, that is $r_j^t = r_j^{t,log}$.

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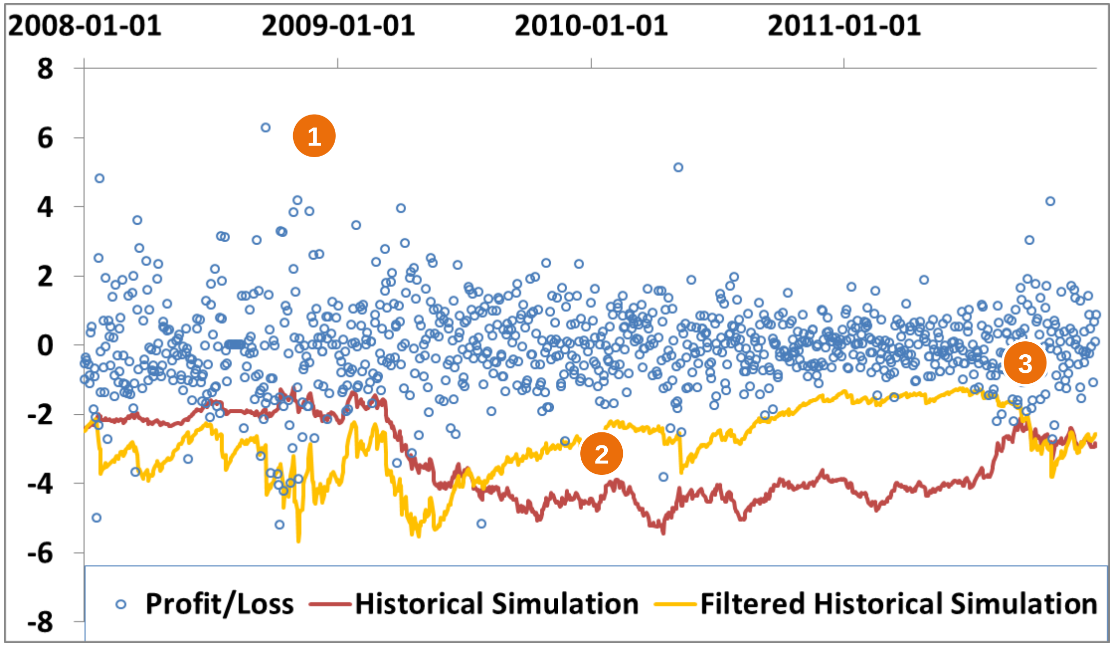
Filtered Historical Simulation – back testing

» Back testing of example Portfolio 1 from 2008 to 2011:



» **Setup:**
- › Historical Simulation with 1000 scenarios (i.e. 4 years moving window)
- › Filtered Historical Simulation with 1000 scenarios and decay factor $\lambda = 0.97$
- › Confidence Level equals 99%

» Kupiec test during the crisis (Jan 2008 – Aug 2009) for *p = 95%* passes for Filtered Historical Simulation

» Kupiec test for the time period Aug - 2009 to June 2011 passes as well for Filtered Historical Simulation

1 Market volatility increases (Lehman-crisis). The EWMA – volatility in the FHS picks up, shifts in the simulation become larger and VaR increases

2 Market volatility decreases. Due to the lower upscaling factor shifts in the FHS become smaller and VaR decreases

3 The Euro-crisis leads again to increasing volatility in the market to which the FHS reacts swiftly again.

Filtered Historical Simulation leads to improved reactivity to changing market conditions and provides excellent back testing statistics.

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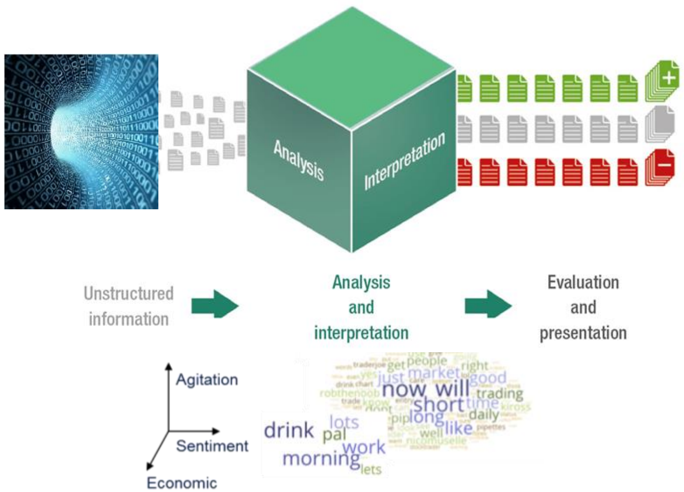
Seize information towards improvement of risk management

Company news can be analysed in a systematic fashion

- » Semi-automated processing of big data may be used to quantify information by NLP and machine-learning techniques
- » Impact of positive and negative news as well as disagreement can be analyzed and projected to target variables
- » Model needs to be calibrated towards expected results for abnormally large returns, i. e. market reactions to positive and negative news
- » Results can be applied to automated trading strategies, but may also be facilitated for risk management purposes by e. g. improving volatility estimators



Pooled Analysis	$s\hat{\varepsilon}$	sT	$s\Delta V$	sO	$s\Delta C$
$s\hat{\varepsilon}_{-1}$	−0.0005	0.0079^c	−0.0028	0.0054	0.0155^a
sT_{-1}	0.0239^a	0.5475^a	−0.0548^a	0.0910^a	−0.0044
$s\Delta V_{-1}$	0.0347^a	0.0751^a	−0.1605^a	0.0187^a	0.1224^a
sO_{-1}	−0.0182^a	0.0350^a	0.0033	0.2749^a	−0.0147^a
$s\Delta C_{-1}$	−0.0081	0.0272^a	0.0041	−0.0022	0.0871^a
sP_{-1}	0.0105^a	0.0093^b	−0.0058	0.0043	−0.0011
sN_{-1}	−0.0042	−0.0027	0.0149^a	0.0070	0.0074
sD^{std}_{-1}	−0.0163^a	−0.0248^a	0.0097^c	−0.0104^a	0.0071

Big Data, data engineering & data science as well as machine learning are taking off to explore new regimes of risk and finance.

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