BANKING

Lecture 5 – Market risk

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Key terms of Lecture 4

- Corporate governance
- Executive and non-executive management body members
- Segregation of conflicting duties

- Credit risk as a key risk in banking
- Credit risk measurement tools and management
  - Credit rating
  - Credit scoring
  - PD (probability of default)
  - NPL (non-performing loans)
  - LGD (loss given default)
  - Models (combining all of this)
  - LTV (loan-to-value), in %
  - DTI (debt-to-income), in number of years
  - DSTI (debt-service-to-total-income), in %
- Credit registers
- Capital requirement quantification
- Provisions quantification, IFRS 9

Content

1.	Market risk – basic terms (and illustrations)
2.	Duration, convexity and BPV value
3.	Value at risk
4.	Portfolio immunization
5.	Others: Hedging, Stress testing, ICAAP

Market risk – definition

Market risk

- is an umbrella term for risks to the bank that are a result of changes in prices, exchange rates (**FX risk**), interest rates (**IR risk**), stocks (**Equity risk**) and commodities (**Commodity risk**) and other risks associated with movements in prices on the financial markets.
- is representing a potential loss of a portfolio/asset/derivative due to changes in the markets,
- potential change in the value of an asset or derivative in response to a change in some basic source of market uncertainty,
- uncertainty of future earnings resulting from changes in market conditions.

Assets	Liabilities and Equity
Assets sensitive to interest rates, FX movements, stocks	**Liabilities sensitive to interest rate and FX movements**
Assets non-sensitive to interest rate and FX movements	Liabilities sensitive to interest rate and FX movements
	Equity
Off-balance sheet assets sensitive to market risk	Off-balance sheet liabilities sensitive to market risk

Quiz: Find all types of risks involved for a Czech investor investing in a US bond

GAP Analysis – Basic risk management model

GAP analysis for ALM purposes

- for measuring liquidity risk (Lecture 03),
- for measuring FX risk - „GAP analysis“ for FX positions – long and short position in a currency, (covered position = zero gaps)
- for measuring interest rate risk
  - The interest rate GAP analysis divides an institution’s interest rate sensitive assets **(RSA)** and liabilities **(RSL)** into different time buckets. It measures the risk that arises from interest rate mismatch (repricing mismatch)
  - GAP analysis measures the effect of potential interest rate changes on
    - 1. net interest income (limited horizon, usually 1 – 3 years)
    - 2. net present value (NPV) (indefinite horizon)

Example 1 - GAP Analysis – floating vs. fixed rates – effect of shock on NII

Given the balance sheet and the information on interest bearing assets and liabilities, calculate the:

1. Interest income and interest cost over a one year horizon (PRIBOR 0,2%)
2. Recalculate the income when short term interest rates are changing/rising (here PRIBOR)

Note, that the example is simplified (no differenciation among different short term rates (e.g. PRIBORs (1W, 1M, 3M, 6M…..)), only annual frequency of interest rate, etc…..

Solution: see the excel

Example 2 – effect of shock on NPV and NII

Illustration of an interest rate change effect on an institution's market value and/or market value of capital

The basic premise is that two assets : Asset A is a four-year fixed-rate asset of 100 paying fixed 3,5% p.a. and Asset B an operating asset with daily repricing (and 0% interest rate) of 220

are funded with :

Liability A - floating deposit, with 1 year repricing of 80 and Liability B - 2Y term deposit of 130 paying 1,5 % p.a.

Book value balance sheet

Asset - investment financing (4Y fixed rate at 3,5 %)	100	Deposit (floating rate, 1 year fixing)	80
Asset - operating financing (floating, O/N)	120	Term deposit (2Y fixed rate at 1,5 %)	130
		Equity	10
	220		220

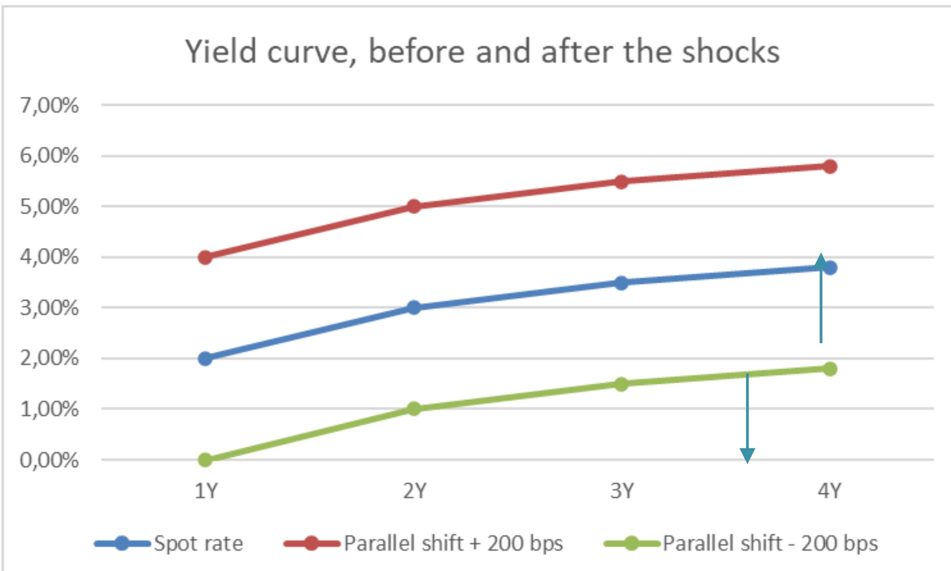
The shock is simulated as an interest rate change immediately after the assets is funded and 1Y floating liability A priced

Show the effect of a interest rate change (here parallel + and – 200 bps) on NPV and NI, hence on market value of capital of the bank

GAP Analysis – effect of shock on NPV and NII

Assumptions:

	1Y	2Y	3Y	4Y
Spot rate	2,00%	3,00%	3,50%	3,80%
Parallel shift + 200 bps	4,00%	5,00%	5,50%	5,80%
Parallel shift - 200 bps	0,00%	1,00%	1,50%	1,80%



	Spot rate	**Discount Factor**	**Fwd Rates**
1	2%	0,9804	
2	3%	0,9426	4,01%
3	3,50%	0,9019	4,51%
4	3,80%	0,8614	4,71%

shock **2%** **increase of rates**

	Spot rate	**Discount Factor**	**Fwd Rates**
1	4%	0,9615	
2	5%	0,9070	6,01%
3	5,50%	0,8516	6,51%
4	5,80%	0,7981	6,71%

shock **2%** **decrease of rates**

	Spot rate	**Discount Factor**	**Fwd Rates**
1	0%	1,0000	
2	1%	0,9803	2,01%
3	1,50%	0,9563	2,51%
4	1,80%	0,9311	2,71%

GAP Analysis – effect of shock on NPV and NII

Before the shock - NPV							
	Market value	**Book value**	**Cash flow/Time buckets**				
			CF0	*CF1*	*CF2*	*CF3*	*CF4*
			0/N	*1 year*	*2 years*	*3 years*	*4 years*
Asset A	99,04	100,00	0,00	3,50	3,50	3,50	103,50
Asset B	120,00	120,00	120,00				
Liability A	80,00	80,00	0,00	81,60			
Liability B	126,29	130,00	0,00	1,95	131,95		
Capital	**12,76**	10,00					

Before the shock - net income							
	Market value	**Book value**	**Cash flow/Time buckets**				
			CF0	*CF1*	*CF2*	*CF3*	*CF4*
			0/N	*1 year*	*2 years*	*3 years*	*4 years*
Asset A	99,04	100,00	0,00	3,50	3,50	3,50	103,50
Asset B	120,00	120,00	120,00	0,00	0,00	0,00	0,00
Liability A	80,00	80,00	0,00	1,60	3,21	3,6	83,8
Liability B	126,29	130,00	0,00	1,95	1,95	5,9	136,1
Capital	**12,76**	10,00					

Solution: see the excel

Conclusion

- Effect of interest rate shock on NII (net interest rate income) in the indefinite horizon and on NPV (net present value) shall be identical
- The more are the time buckets balanced, the smaller the total impact on NII or NPV
- The shorter the repricing (shorter time buckets) the less sensitive/the smaller is NPV and NII change

Market risk – interest rate decomposition

Out of the presented market risks, far most important is the **interest rate risk.**

Interest rate risk can be decomposed into several sub-risks:

Interest rate risk

- Absolute risk
  - Change in general level of i.r. (e.g. central bank reference rate change)
- Relative risk (Basis risk)
  - Yield curve risk (e.g. twist, change in the shape of the yield curve)
  - Spread risk („spread on BBB bonds has increased“… compared to „risk-free“ rate

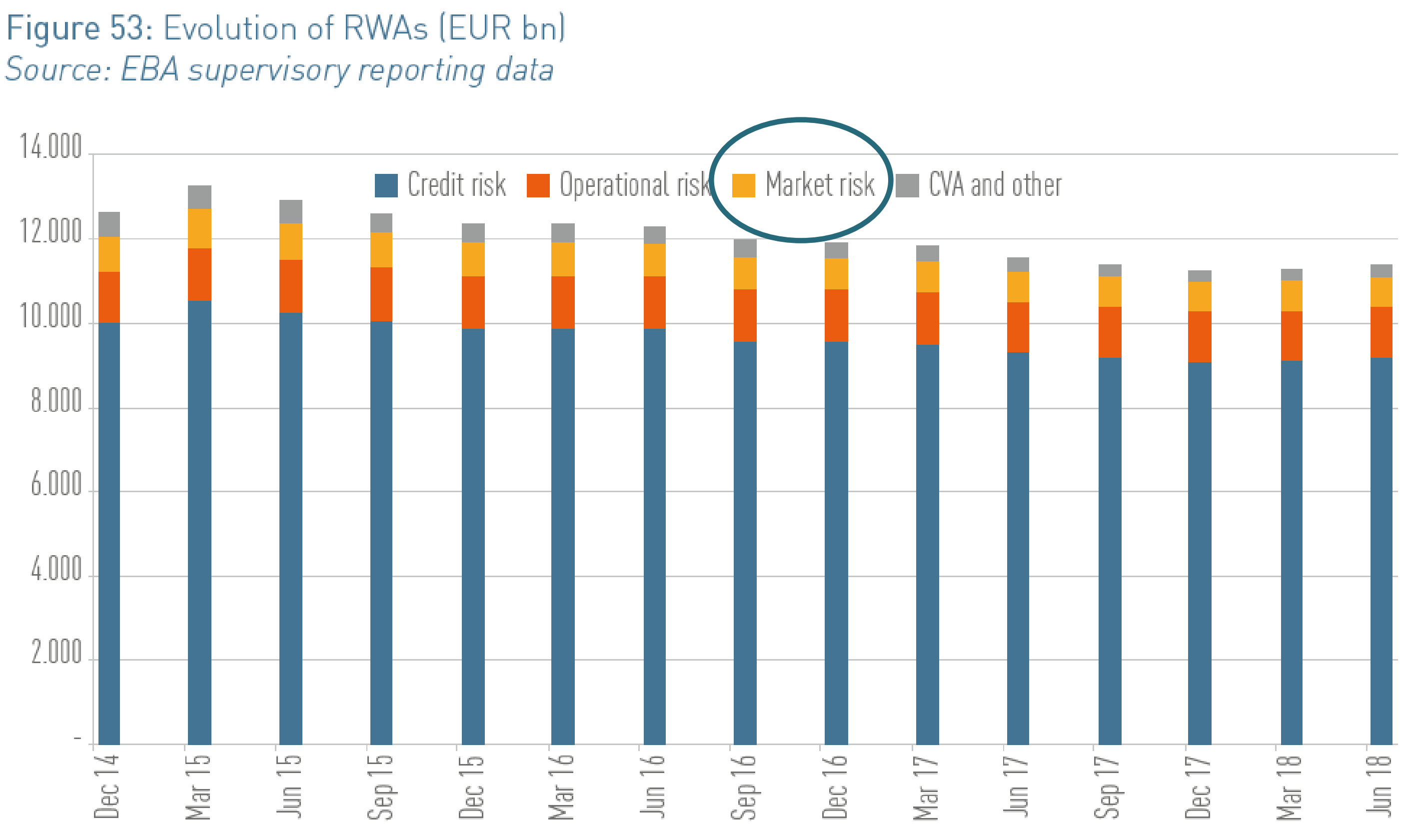
Market risk – CZEONIA and PRIBOR setting

CZEONIA - CZEch OverNight Index Average is a weighted average of interest rates paid on uncollateralized O/N deposits deposited by reference banks on interbank market, calculated and published by CNB since 2002

PRIBOR – calculated and published by the Czech Financial Benchmark Facility, since 24.7.2017, 1D – 1Y

- Historically
- Official Information of the Czech National Bank, April 1, 2015
- Reference banks (ČS, ČSOB, KB, Expobank CZ, Raiffeisenbank, UCB CZ)
- Calculation agents (organization assigned by The Financial Market Association of the Czech Republic (Czech Forex Club))
  - PRIBOR (Prague Interbank Offered Rate) – offer of deposits (prodej depozit)
  - PRIBID (Prague Interbank Bid Rate) – bid of interbank deposits (nákup deposit)

Market risk in the context of other risks



Source: EBA (2019). RISK ASSESSMENT OF THE EUROPEAN BANKING SYSTEM DECEMBER 2018

Content

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5. Others: Hedging, Stress testing, ICAAP

Duration

1. Calculate first derivation of *P* with respect to *i*
2. Then divide the outcome by *P*
3. Finally divide the outcome by *(1+i)*
4. You arrive at % change in Price divided by „% change in i.r.“

Technically, duration is the time-weighted present value of a financial instrument's cash flows.

$$P = \sum_{t=1}^{T} \frac{CF_t}{(1+i)^t} \longrightarrow \frac{\partial P/P}{\partial i/(1+i)} = D = -\frac{\sum_{t=1}^{T} \frac{t * CF_t}{(1+i)^t}}{\sum_{t=1}^{T} \frac{CF_t}{(1+i)^t}}$$

The Macaulay duration measures the "average" life of an asset in years (positive value of duration). It measures how long in years it takes for the price of a bond to be repaid by its internal cash flows (coupons).

Duration + convexity

In general, the higher the **duration**, the more a bond's price will drop as **interest rates** rise (and the greater the **interest rate** risk). As a general rule, for every 1% **change** in **interest rates** (increase or decrease), a bond's price will **change** approximately 1% in the opposite direction, for every year of **duration**.

Macaulay duration (negative value)

(ΔP/P)/(Δi/(1+i))

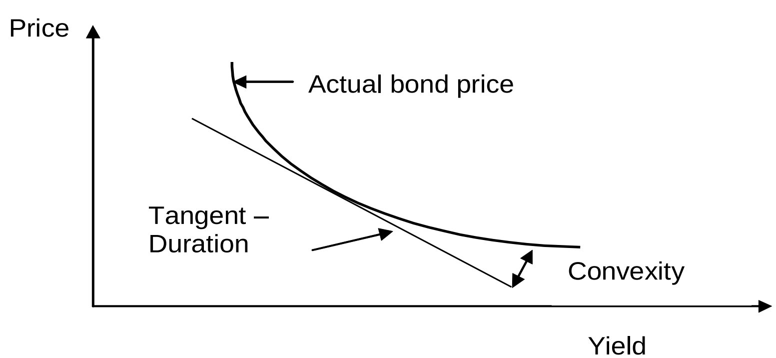
Modified duration – Price sensitivity (negative value)

(ΔP/P)/Δi

Effective duration is the same as modified duration, but can be applied to callable bonds also, i.e. bonds with option features (it takes into account changes in cash flows when the call feature becomes effective)

Convexity measures the relative curvature of a bond's price/yield curve.

$$K = \frac{1}{P}\left(\sum_{t=1}^{T}\frac{t(t+1)C}{(1+i)^{t+2}} + \frac{T(T+1)M}{(1+i)^{T+2}}\right)$$



The change in bond price is given by the sum of **duration effect** and **convexity effect**

Duration

Important features of duration

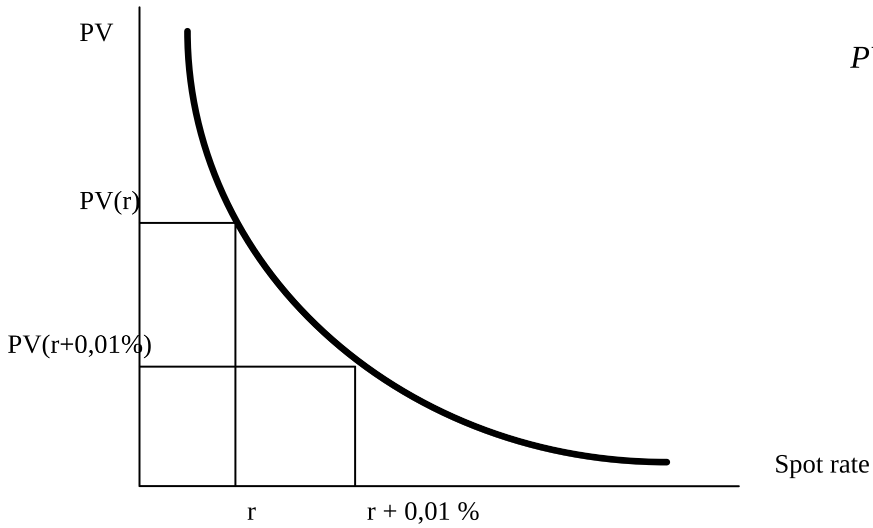
- Duration can never be greater than the remaining time to maturity of a fixed-interest bearing instrument when repaid at maturity.
- The duration of a zero-coupon bond is exactly equivalent to the bond's remaining time to maturity.
- The higher (lower) the market interest rate, the smaller (greater) the duration since the invested capital will be paid back earlier (later).
- The longer the time to maturity of a fixed-interest bearing security, the greater the duration.

Interest rate measurement via BPV value

- Widely used method for measuring interest rate risk
- Duration of every single instrument in the portfolio is calculated or
- …. may combine GAP analysis and duration
  - Interest rate sensitive assets and i.r. sensitive liabilities are divided into respective time buckets (according to their maturity or next (nearest) repricing, i.r. GAP analysis)
  - For each time bucket a BPV value is calculated (basis point value). BPV: if interest rates change by 1 basis point (1 bp), what is the effect on the present value of the gap in the respective time bucket……*see the duration in this ?*
  - Interest rate risk measurement – via **BPV limits** in respective time buckets.

BPV (or PVBP)

Present value of a basis point - Unlike the modified duration, the PVBP measures the absolute – and not the percentage – change in the current market price of a fixed-yield security when the market interest rate has changed by one basis point (0.01%), so the size and value of the position is already taken into account.



$$PVBP = \frac{D_{mod}}{100 * 100} * PV$$

$$PVBP(r) = PV(r) - PV(r + 0{,}01\%)$$

Content

Value at risk

Value at risk is still a widely applied risk management technique (but exposed to number of issues as illustrated within recent crisis).

Value at risk (VaR) is the maximum expected portfolio (asset) depreciation at a specified confidence level over a specified holding period subject to simplifying assumptions.

VaR is most widely and easily used to measure the loss from market risk (interest rate risk, FX risk, equity risk), but it can also be used to measure the loss from credit.

Main drawback – VaR has short-term focus, suits for „normal times" analysis**, fails in crisis time**….
….hence the **SVaR (stressed VaR)**

Value at risk - Interpretation

VaR = CZK 1 million at a confidence level of 99% over a 1-day holding period. (VaR is expressed in absolute numbers, amounts).

Interpretation:

- In 99% of cases, i.e. on an average of 99 out of 100 trading days, a maximum loss of CZK 1 million is expected.
- The second largest loss to occur in 100 trading days is expected to be a maximum of CZK 1 million.
- The CZK 1 million is the minimum loss to be expected for the worst 1% of days.

Value at risk - approaches

- Historical simulation
- Monte Carlo simulation
- Variance-covariance method (analytical method, delta normal method)

$$VaR = (z\text{-value}) * \sigma * P$$

$$VaR_{t\text{-days}} = t^{1/2} * VaR_{1\text{-day}}$$

Portfolio VaR

! Risk factors vs. positions weights !

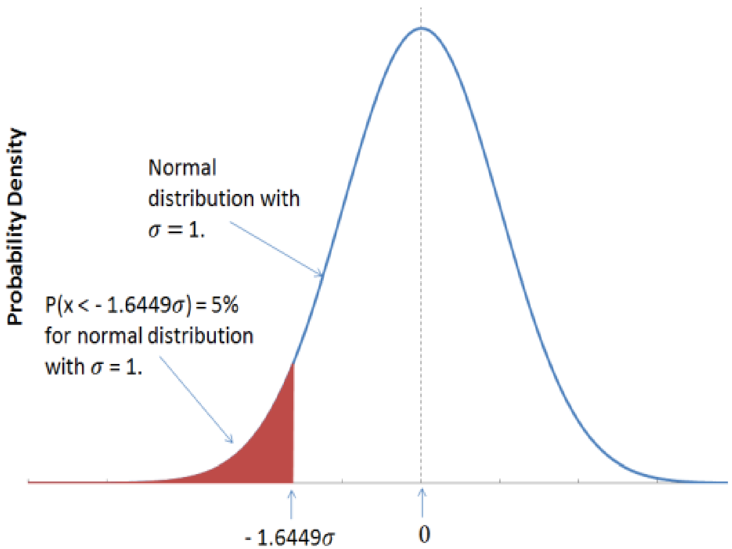
$$VaR_P = \sqrt{VaR_1^{\,2} + VaR_2^{\,2} + 2 * \rho * VaR_1 * VaR_2}$$

Numbers to be remembered:

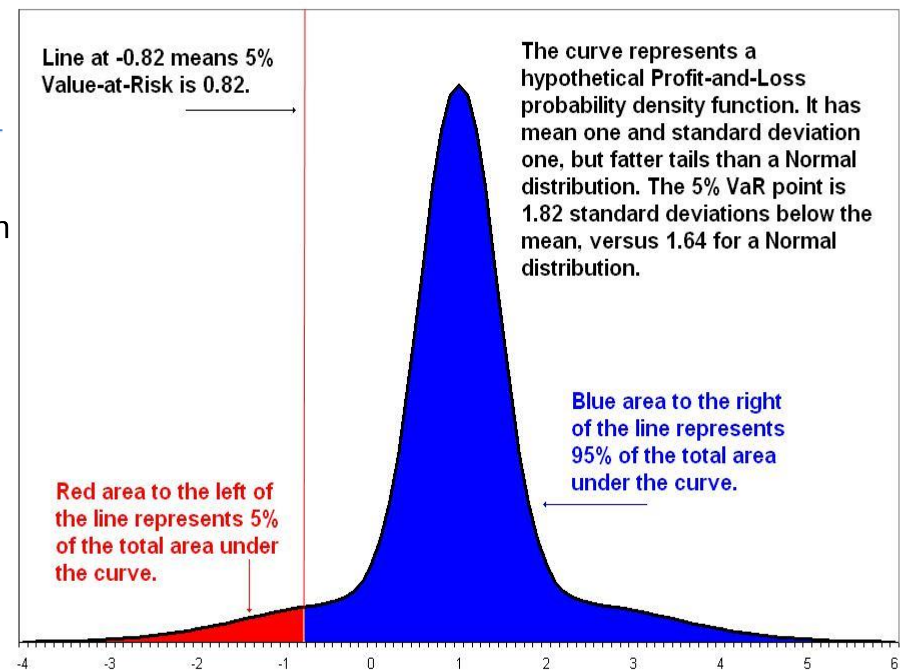
95 % confidence level – 1,65 standard deviations

99 % confidence level – 2,33 standard deviations

Value at risk - Illustration



Probability Density Distribution of Normal Distribution



Wikipedia

VaR – Historical simulation

Determination of the VaR on the confidence level of 99% using the historical simulation approach. You have the historical information on portfolio value changes available. Additionally, you have the price changes sorted by their size. The current value of the portfolio is CZK 20,440.

Datum/Date	***Tržní hodnota portfolia/ Market value of portfolio***	***1-denní změna v % (skutečné historické změny)/ 1 day change in % (real historical changes)***
2.1.	20 428	
3.1.	20 328	$(P_1 – P_0)/P_0$ = (20 328 – 20 428) / 20 428 = - 0,48952 %
4.1.	20 401	…
5.1.	20 425	…
6.1.	…	…
……		

VaR – Historical simulation cont.

1-denní změna v %, dle velikosti/ 1-day change in % in order of the size	*Pořadí/ Rank*
-0,8325 %	1.
-0,6568 %	2.
-0,5542 %	3.
-0,48952 %	4.
-0,35215 %	5.
-0,33524 %	6.
-0,2965 %	7.
…..	…..
+0,9581 %	299.
+1,2698 %	300.

A 99% confidence level means that only 3 out of 300 values (1%) may exceed the VaR number/limit. So the VaR number is the fourth in the rank.

Application of VaR in banks

… as a consequence of the crisis (when VaR did not prove to be effective), these trends grow stronger:

- back to basic risk management techniques (open position limits, GAP limits, BPV limits)
- product restrictions ((exotic) derivatives), speculation restrictions
- „Stressed VaR“ calculation – modelling extreme conditions in the market
- ……„Normal VaR“ – rather supplementary information

RAROC

- Risk adjusted return on capital (RAROC) is the risk-adjusted profitability measure where the volatility of losses is taken into account. RAROC provides a consistent view of profitability across businesses (business units, divisions). It allows the comparison of two businesses with different risk profiles, and with different volatility of returns.

- The pricing of a loan/product is derived from the fact that the manager must meet certain RAROC requirements (benchmark RAROC).
- RAROC is based on Value at risk methodology

RAROC - Example

Consider the following situation:

We have two traders, each of whom makes a profit of CZK 10 million, one in short-term treasuries, the other in foreign exchange (CZK/EUR). Which trader performed better? (Based on Jorion, 1997).

The face value of the treasury position **(Position A)** is CZK 200 million, the risk (price volatility) is 4%.

The face value of the foreign exchange position **(Position B)** is CZK 100 million, the risk (foreign exchange volatility) is 12%.

A normal distribution of returns is assumed for these transactions.

RAROC – Example (solution)

- The firm needs to hold enough capital to cover 99% of possible losses because 1% of normal distribution is a 2.33 standard deviation below the mean, and so the worst possible loss is:
- **position A**:
- 2.33 * 0.04 * 200 million = CZK 19 million
- **position B:**
- 2.33 * 0.12 * 100 million = CZK 28 million

- This is also called value at risk (VaR) and can be interpreted as capital needed to cover the position.

- **RAROC for position A:**
- 10 million/19 million = 54%
-
- **RAROC for position B:**
- 10 million/28 million = 28%
- Thus, when adjusted for capital resources the Treasuries trader performed much better even though he needed much more money to invest at the beginning.

Content

Portfolio immunization – for managing interest rate risk

Immunization is a process by which a bond portfolio is created to have an assured return for a specific time horizon irrespective of interest rate changes, i.e. under each interest rate change scenario the reinvestment risk and the price risk compensate each other.

Simplified conditions that must be met in order to have the portfolio immunized:

- **portfolio's (assets) duration is equal to the liability's (effective) duration**,
- **initial present value of the projected cash flows from the asset portfolio equals the present value of the future liabilities**.

Duration Gap Model

Durations are „additive“ – duration of a portfolio is the sum of the duration of respective items weighted by their proportions

Duration Gap measures the sensitivity of an institution´s equity value to changes in interest rates (it measures how well matched are the timings of cash inflows (from assets) and cash outflows (from liabilities)).

$D_{GAP} = D_A - wD_L$

$D_{Equity} = D_{GAP} \times (A/(A-L))$,

where w = ratio of total liabilities to total assets, D = duration

$D_{GAP} > 0$, interest rates increase ---> effect on MV_E ?

$D_{GAP} < 0$, interest rates increase ---> effect on MV_E ?

$D_{GAP} = 0$, interest rates increase ---> effect on MV_E ?

Content

Using derivatives in market risk management

OTC or standardized (listed) products/derivatives

Interest rate risk

- Interest rate swaps
- FRA
- Futures
- Interest rate options

FX risk

- Currency forwards
- Cross currency swaps
- Currency futures
- FX options

Using derivatives in interest rate risk management

Hedging i.r. risk of a credit portfolio – float or fixed priced loans – usually via interest rate swap (IRS)

FVH (fair value hedge) ⇒ fixed to float
CFH (cash flow hedge) ⇒ float to fixed

Related topics

- Macro hedging
- Hedge accounting

Stress testing – assessing risk under (more or less) extreme conditions

Stress testing is a form of deliberately intense or thorough testing used to determine the stability of a given system or entity under stress conditions.

Examples of risk stress testing (single risk stress testing):

- FX risk – x % depreciation or repreciation of FX rate
- i.r. risk – parallel shift of the yield curve (often 200 bps), other changes in the shape of the yield curve
- Equity risk - % drop in equity prices
- Credit risk (increased PD, increased LGD, increased EAD, increased correlations)

Or

Stressed VaR, Expected shortfall model etc.

Or

Increased confidence level (often with compliance with the target rating of the bank (1-PD))

Stress testing – assessing risk under (more or less) extreme conditions

Alternatively
applying macroscenarios (esp. for credit risk), defined by bank itself or CNB macroscenarios
or
Worst historical periods (e.g. FX risk (for CZK) – currency turbulation in 1997)

Goal: to determine the effect of stress test on NI or capital ratio

ICAAP (Pillar II)

ICAAP – internal capital adequacy assessment process

It is a process to ensure that the management body adequately identify, measure, agregate and monitor the institution´s risk and hold adequate internal capital in relation to the institution´s risk profile

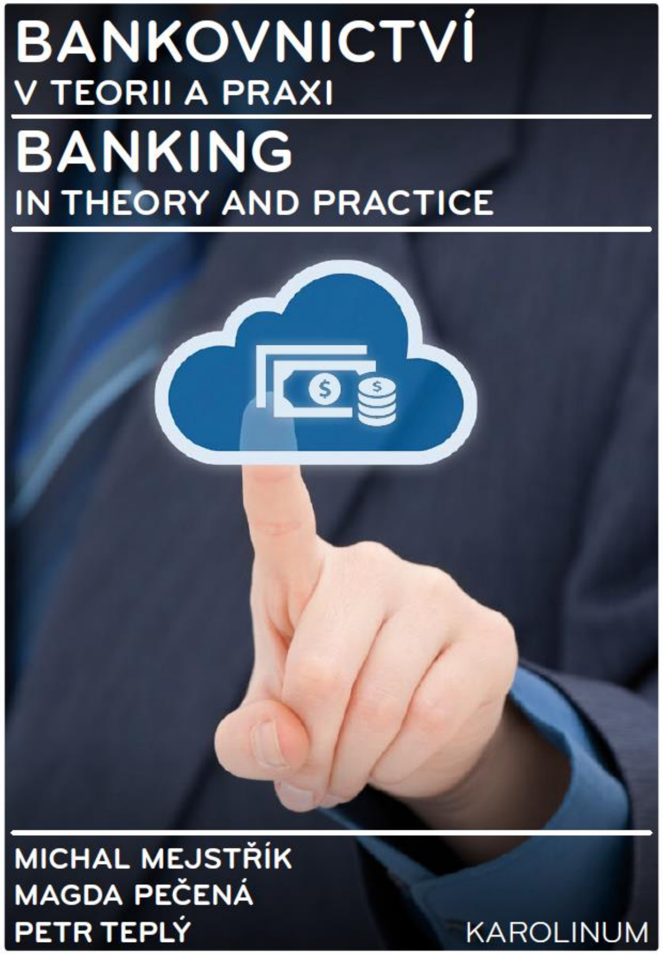
Pillar II – shall be more „forward looking"

Capital adequacy under Pillar I and Pillar II - differences

- Capital definition under Pillar I and Pillar II
- Risks included in Pillar II (other than under Pillar I) – *i.r. risk of the banking book, business risk, reputational risk* etc. (very differs accross banks, also risk models used for assessing credit, market and operational risk may differ substantially under Pillar I and Pillar II)

Stress testing – integral part of ICAAP

Reading for the this lecture



- ✓ **Chapter 9 – Market risk**