INTRODUCTORY BANKING

Lecture and Tutorial 10 – Market risk

Magda Pečená, Jana Juhászová

Institute of Economic Studies, Faculty of Social Sciences,
Charles University in Prague, Czech Republic

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Short revision (1)

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Content

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

Market risk – definition

- 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 or an asset or a 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.

Market risk – definition (2)

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

Market risk measures

GAP analysis

for measuring interest rate risk, liquidity risk, FX risk via GAPs - open positions

Volatility

another instrument for measuring risk is the **sensitivity** to adverse movements in the value of a key variable.

First-order risk measures:

Beta	(β)
Duration	(D)
Delta	(δ)

Second-order risk measures (changes in sensitivities):

Convexity, Gamma, Vega and others

Models

e.g. Value at Risk, Expected Shortfall

Task 1 – GAP analysis

We have a universal bank with the following assets, liabilities and equity in its balance sheet as of 1.2.2019 (see next slide). The 6M Pribor is 0,6%.

1. Determine the values of the missing asset items.

2. Determine the „Registered capital“ item.

3. Determine the amounts in the highlighted time buckets.

Task 1 – GAP analysis (2)

Balance sheet of the bank as of 1.2.2019:

Loan A	6 year, 6 annual repayments, interest rate of 5 % p.a., issue date 1.4.2016, 4 300 000
Loan B	2 year, nominal value 5 200 000, bullet repayment, semi-annual interest payment, interest rate 6M PRIBOR + 3,2 % p.a., issuance 1.1. 2019
Cash	in the amount of 1 300 000
O/N Deposits	at ABC Bank @ 0,5 % p.a. in the amount of 800 000
Current accounts (clients)	@ 0% p.a. amounting to 7 500 000
Term deposits (clients)	3M deposits, interest rate 2,8% p.a., fixation 31.12. 2018, 31.3. 2019, 30.6.2019…., in the amount of 1 440 000
Retained earnings	in the amount of 650 000
Profit from current year	in the amount of 220 000
Registered capital	

Task 2 – Effect of an IRR shock on NII

GAP Analysis – floating vs. fixed rates and 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: the example is simplified i.e.:

- no differentiation among different short-term rates (e.g. PRIBORs - 1W, 1M, 3M, 6M, etc.),
- merely annual frequency of interest rate

Task 3 - 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 4Y fixed-rate asset of 100 paying fixed 3,5% p.a.
Asset B an operating asset with daily repricing (and 0% interest rate) of 120.

are funded with :
Liability A - floating deposit, with 1Y repricing of 80
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

Task 3 - Effect of shock on NPV and NII (2)

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 we assume parallel ± 200 bps shock) on NPV and NI, hence on market value of capital of the bank.

Task 2 - Effect of shock on NPV and NII (2)

Assumption:

	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%

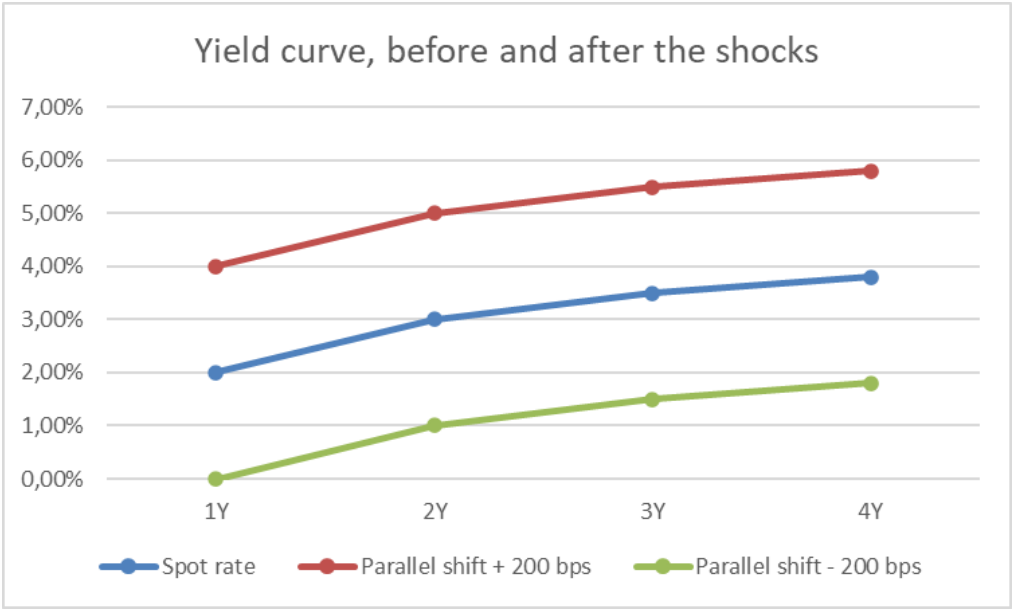
	Spot rate	Discount Factor	Fwd Rates
1	2%	0,9804	
2	3%	0,9426	4,01%
3	3,50%	0,9019	4,51%
4	3,80%	0,8614	4,71%

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%



Task 3 - Effect of shock on NPV and NII (3)

Before the shock - NPV

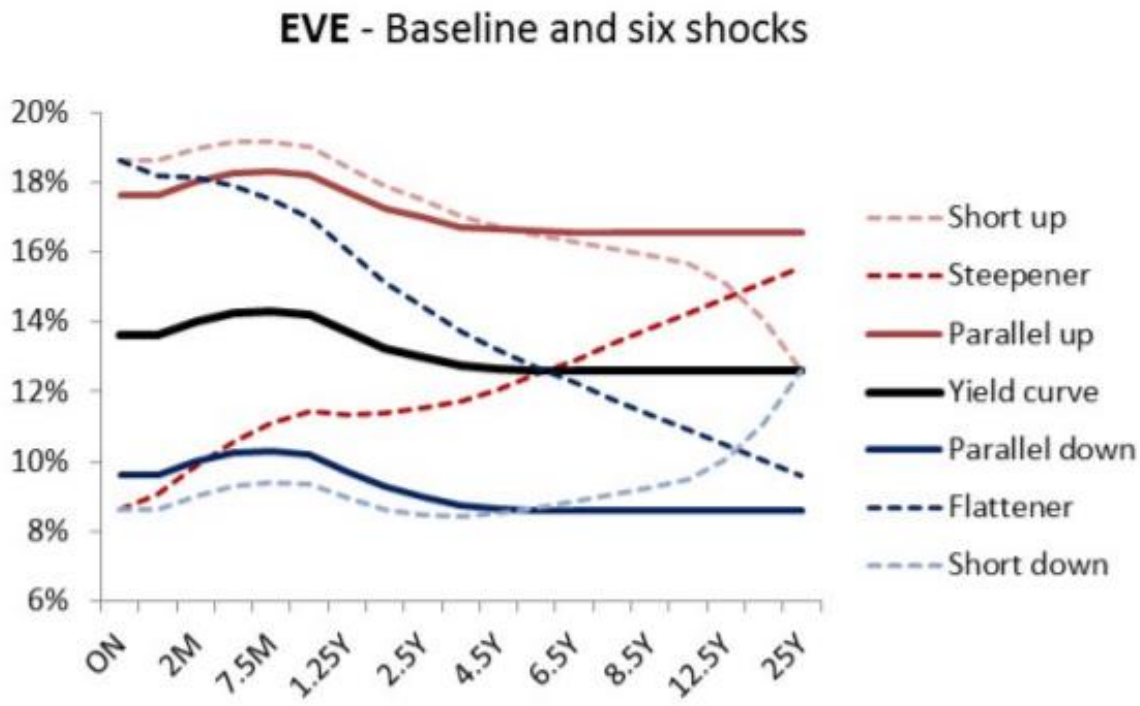
	Market value	Book value	Cash flow/Time buckets				
			CF0	*CF1*	*CF2*	*CF3*	*CF4*
			0/N	*1 year*	*2 years*	*3 years*	*4 years*
Asset A	99,04	100,00	0,00	3,50	3,50	3,50	103,50
Asset B	120,00	120,00	120,00				
Liability A	80,00	80,00	0,00	81,60			
Liability B	126,29	130,00	0,00	1,95	131,95		
Capital	**12,76**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

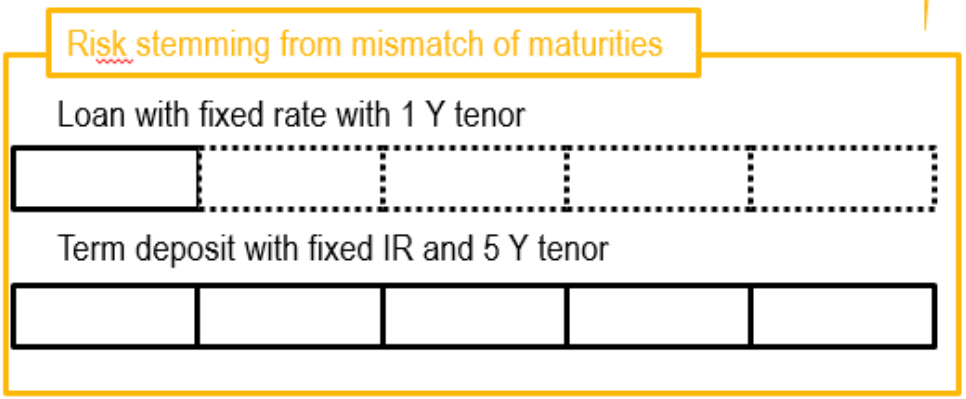
IRRBB risk measures – Economic Value of Equity

- There are 6 prescribed scenarios for stress-testing of IRRBB
- They consider both parallel and non-parallel shifts/twists of the yield curve



IRRBB risk measures – Net Interest Income

The bank does not know for what rate they will reinvest cash received as repayment of the loan



Solution of this mismatch?

A) Hedging using derivatives
B) Natural hedging – purchasing bonds etc.

There are following options:

a) IR decreases – income from interest is lower in 2-5Y compared to Year 1
b) IR stay on the same level – interest income is same
c) IR increase – profit for 2-5Y is higher than in Year 1

In case of a sharp decrease of NII the bank can realize a loss. This source of income is prominent for Czech banks.

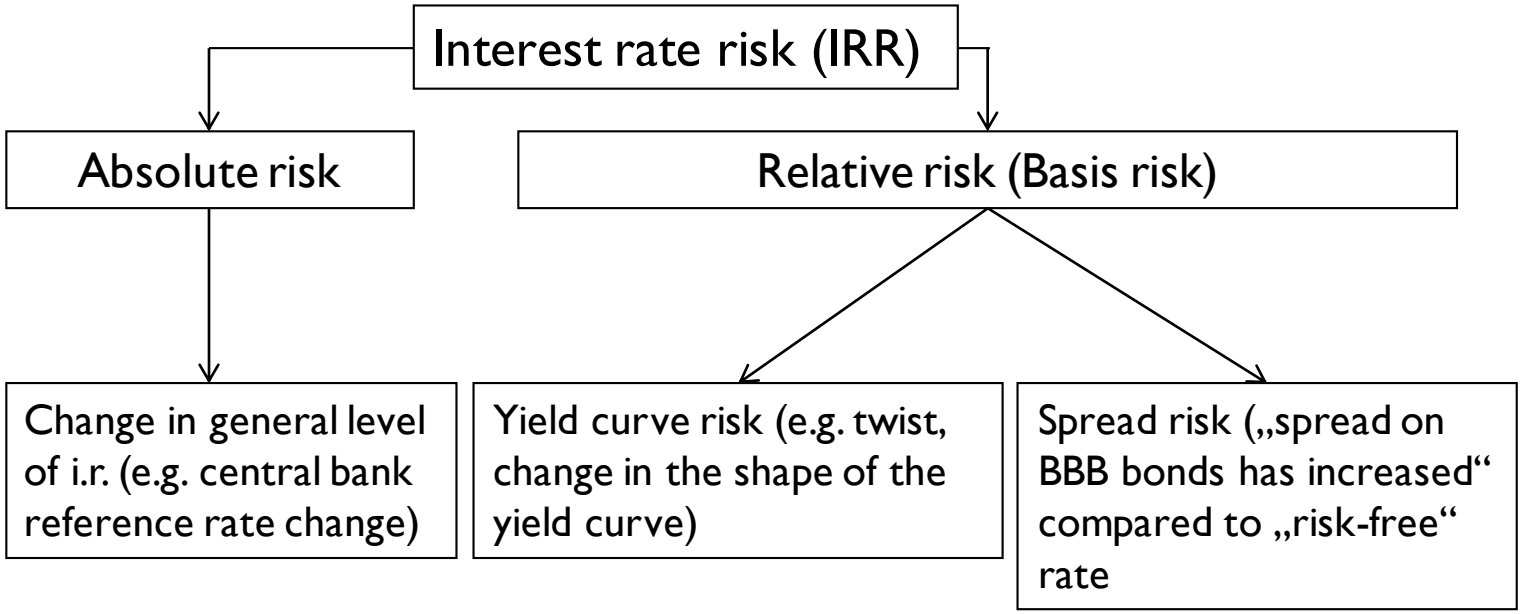
Conclusion

- Effect of interest rate shock on NII (Net Interest Income) in the indefinite horizon and on NPV (Net Present Value, equivalent to EVE – Economic Value of Equity) 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

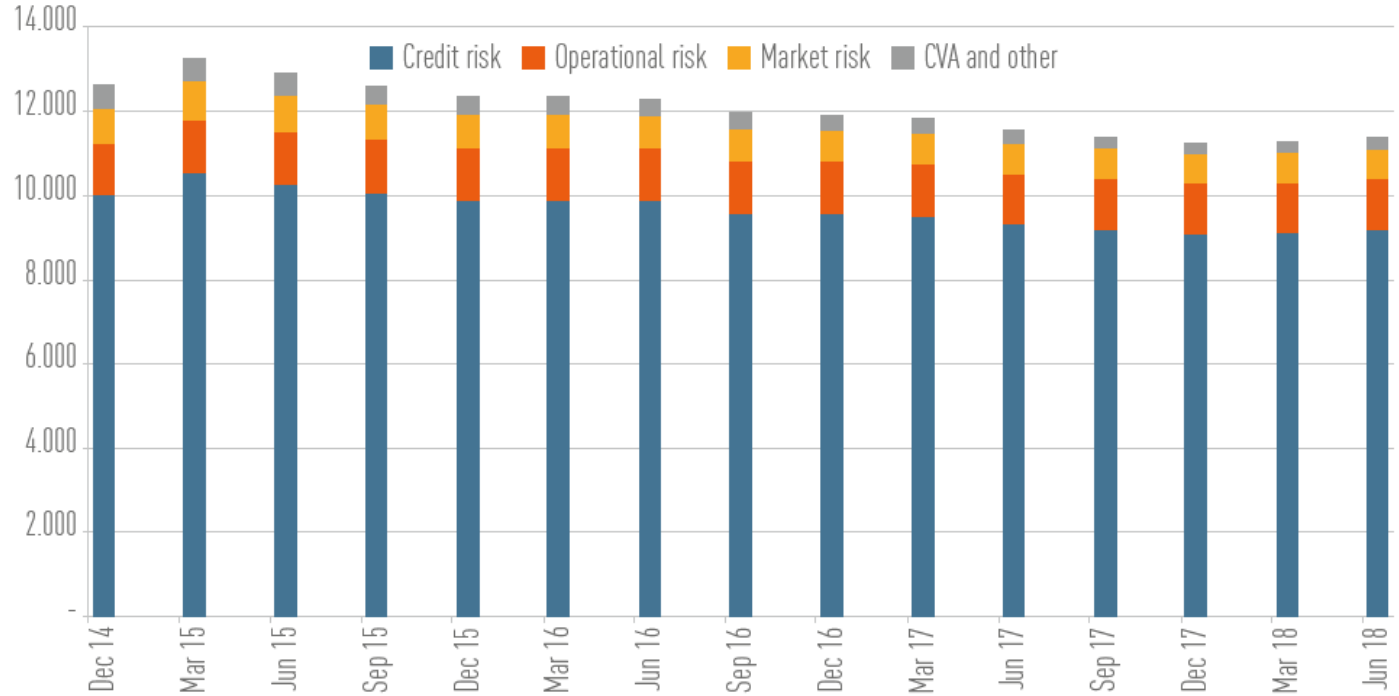
Out of the presented market risks, far most important is the **interest rate risk (IRR).**

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



Market risk in the context of other risks

Figure 53: Evolution of RWAs (EUR bn)
Source: EBA supervisory reporting data



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

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Duration

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

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

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 IR"

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 (2)

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.

Portfolio duration (D_P) is a weighted average of individual asset durations.

$$D_P = \frac{PV_1 xD_1 + PV_2 xD_2 + ... + PV_N xD_N}{PV_1 + PV_2 + ... + PV_N}$$

Duration and Convexity

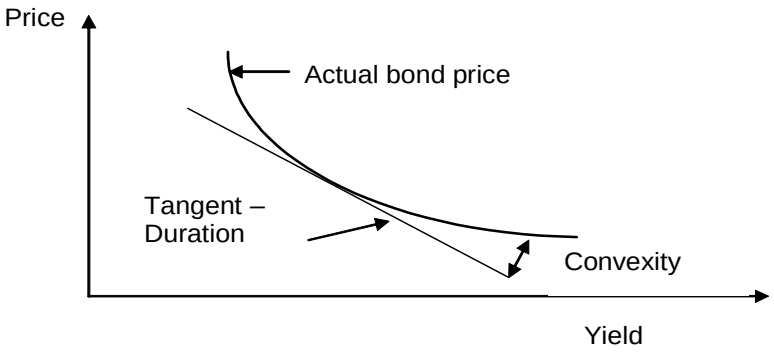
Macaulay duration $$Maculay\ duration = -\frac{\frac{\Delta P}{P}}{\frac{\Delta i}{(1+i)}}$$

Modified duration – Price sensitivity $$Modified\ duration = -\frac{\frac{\Delta P}{P}}{\Delta i}$$

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 and Convexity

Duration effect:

$$dP = -D\frac{P}{1+i}di = D_{\text{mod}}Pdi$$

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

$$dP = dPV = -D\frac{P}{(1+i)}di + \frac{1}{2}KPdi^2$$

Effective duration

$$D_{effective} = \frac{P_{-} - P_{+}}{2P_0(di)}$$

P_- = the price of the bond, when interest rate decrease

P_+ = the price of the bond, when interest rate decrease

P_0 = current price

di = change in the interest rate

Task 4 - Effective duration

A portfolio manager wants to estimate the interest rate risk of a bond using duration. The current price of the bond is 82. A valuation model found that if interest rates decline by 30 basis points, the price will increase to 83,5 and if interest rates increase by 30 basis points, the price will decline to 80,75.

What is the duration of this bond?

source: CFA Program, Level 1, Volume 5

Task 5 – Duration and Convexity

Assume that the current price of a bond is 108, modified duration is 4.5 and convexity is 87. Interpret this information in the case of a 0.8% decrease in the general level of interest rates.

source: CFA Program, Level 1, Volume 5

Task 6 – Duration

A bond portfolio manager gathered the following information about a bond issue:

Par value	USD 10 mil.
Current market value	USD 9,85 mil.
Duration	4,8

If yields are expected to decline by 75 basis points, which of the following would provide the most appropriate estimate of the price change for the bond issue:

A. 3,6 % of USD 9,85 mil.
B. 3,6 % of USD 10 mil.
C. 4,8 % of USD 9,85 mil.

source: CFA Program, Level 1, Volume 5

Task 7 – Duration

source: CFA Program, Level 1, Volume 5

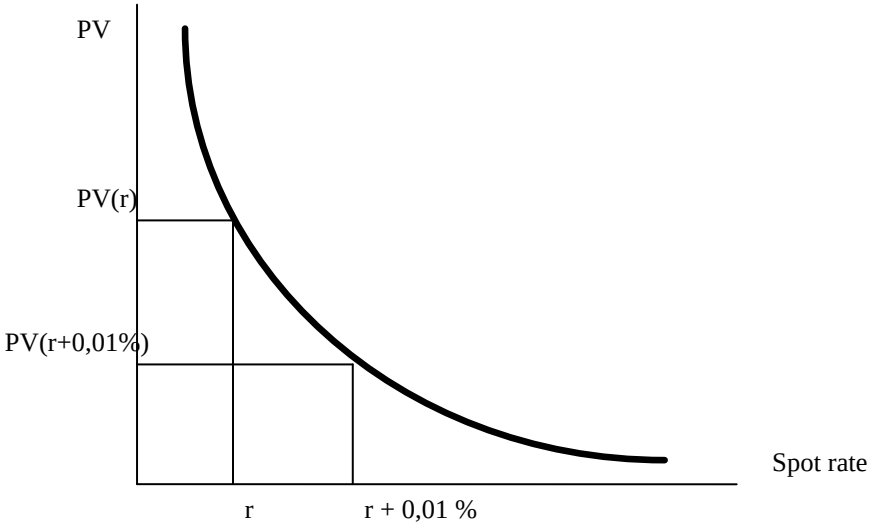
Interest rate measurement via BPV value

- 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 IR sensitive liabilities are divided into respective time buckets (according to their maturity or next (nearest) repricing, IR 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 relative (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.



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

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

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Value at Risk

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

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

VaR is the most widely and easily used model 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 and therefore is suitable for „normal times“ analysis, **fails in crisis time**…hence the **SVaR (stressed VaR) is used.**

Value at Risk (2) - 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. of 99 out of 100 trading dayson average , the maximum loss of CZK 1 million is expected.
- The second largest loss to occur in 100 trading days is expected to be of CZK 1 million at maximum.
- The CZK 1 million is the minimum loss to be expected for the worst 1% of days.

Value at Risk (3) - Method

1. Historical simulation
2. Monte Carlo simulation
3. Variance-covariance method (analytical method, delta normal method)

! Risk factors vs. positions weights !

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

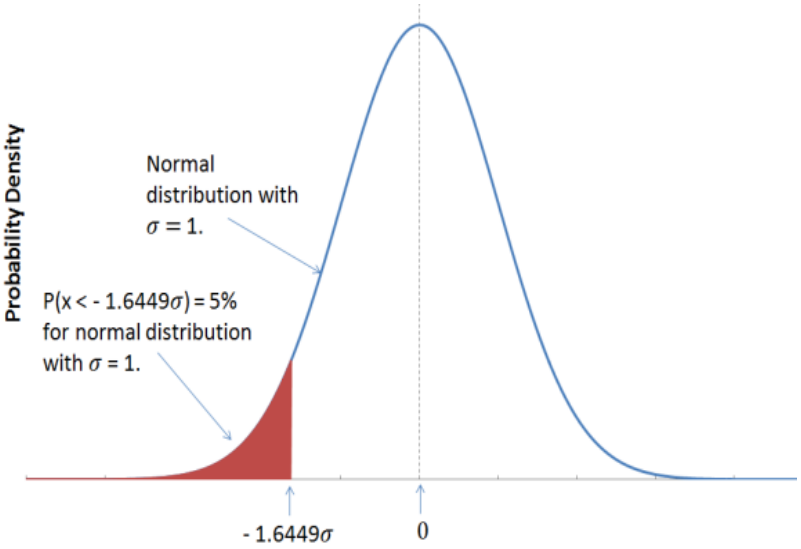
$$VaR_{t\text{-days}} = t^{1/2} * VaR_{1\text{-day}}$$

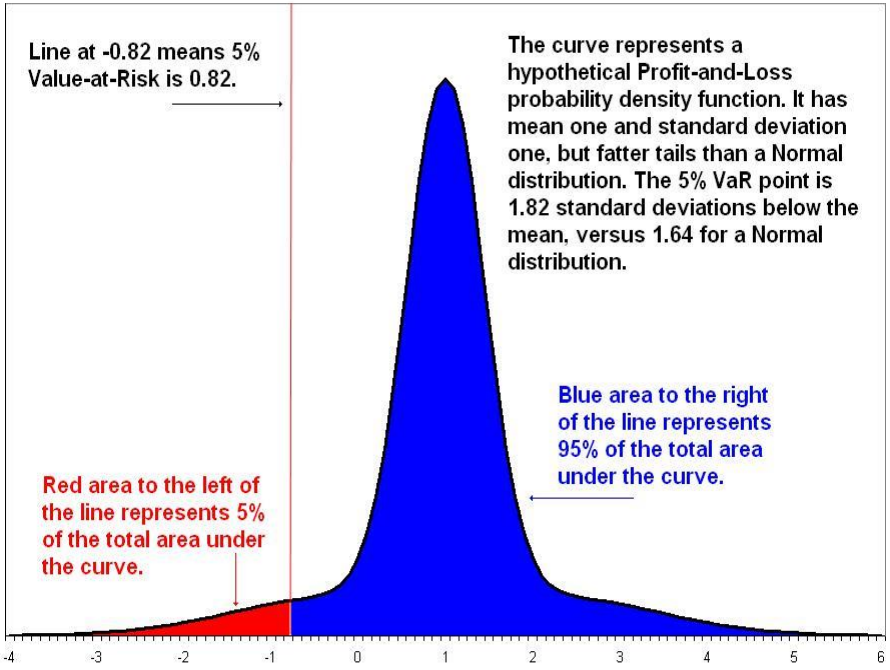
Numbers to be remembered:

95 % confidence level – 1,65 standard deviations

99 % confidence level – 2,33 standard deviations

Value at Risk (4) - Illustration





Probability Density Distribution of Normal Distribution

Value at Risk (5) - 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.	…	…
……		

Value at Risk (6) - Historical simulation

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 of VaR (corresponding to 1%) may exceed the VaR limit. So out Value at Risk is fourth in the sorted amounts.

Value at Risk (7) – Application

When we consider quantifying a VaR model, we must first consider these 4 steps:

1. Determine the time horizon, over which we will calculate VaR.
2. Determine the desired confidence level (most frequent are 95%, 99% and 99,9%).
3. Construct a probabilistic distribution of profits and losses
    1. Historical method
    2. Variance-covariance
    3. Monte Carlo simulation
4. Calculation of VaR

The choice of the time horizon is likely determined by the purpose of the model calculation (regulatory – 10-day risk management – according to market data available or model backtesting – 1 day).

Value at Risk (8) – Scaling

If we want to approximate a different time horizon or a different confidence level, we use the following formula:

a) Time horizon

$$VARt1 = VARt2 * \sqrt{\frac{t1}{t2}}$$

b) Confidence level

$$VAR\ 99\% = VAR\ 95\% * \frac{q\ 99\%}{q\ 95\%} = VAR\ 95\% * \frac{2{,}32}{1{,}645} = VAR\ 95\% * 1{,}41$$

Task 8 - Value at Risk

A US investor is holding a position of CZK 1 million (which translates into USD 40 000 at the exchange rate of 25 CZK/USD). The standard deviation (daily volatility) of the CZK/USD exchange rate is 0,7%.

a) What is the daily VaR at a 95% confidence level?
b) Determine the 10-day VaR on the same confidence level.

Task 9 - Value at Risk

We have a portfolio consisting of two shares:

Share	Market Value (mil CZK)	1-day volatility (in %)
A	12	1.44
B	10	0.87

Calculate the diversified and undiversified 1-day VaR using a 99% confidence level.

a) First, assume the correlation of - 0.23 between the two shares.
b) Then determine the diversified VaR for the limiting values of correlation coefficient (- 1 and 1).

Value at Risk (9) – Application in banks

As a consequence of the crisis (when VaR did not prove to be an effective measure of risk), following trends grew in popularity with banks:

- 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“ – provides rather supplementary information for risk management.

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 (2) - 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 FX 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 (3) - 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.

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Portfolio immunization – for managing IRR

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 ?

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Using derivatives in IR risk management

Hedging IR 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 in extreme conditions

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

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

- FX risk – x% depreciation or repreciation of FX rate,
- IR 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 in extreme conditions (2)

Alternatively,
applying macro scenarios (esp.ecially for Credit risk), defined by bank itself or CNB macro scenarios,

or

worst historical periods of stress (e.g. FX risk for CZK – currency exchange rate shocks caused by a crisis in 1997).

The main goal is to determine the effect of stress test on net income or capital ratios.

ICAAP (Pillar II)

ICAAP – Internal Capital Adequacy Assessment Process
Is a process to ensure that the management body adequately identifies, measures, agregates and monitors the institution´s risk and holds adequate internal capital with regards 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) – *IR risk of the banking book, business risk, reputational risk* etc. (differs a lot accross banks, also risk models used for assessing credit, market and operational risk may differ substantially under Pillar I and Pillar II)

Stress testing – is an integral part of ICAAP

Short revision (2)

Mentimeter

Please visit the following website and input the 8 digit code provided below.

Menti.com

55 36 62 14

Hint: You can also use your phone, there is no need to switch between browser windows, but the choice is entirely yours.

Thank you for your attention!