BANKING

Tutorial 5 – Market risk

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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

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)

for solutions see excel

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	

For solutions see excel sheet

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Duration + convexity - recap

Macaulay duration (negative value)

$$\text{Maculay Duration} = \frac{\frac{\Delta P}{P}}{\frac{\Delta i}{(1+i)}}$$

Modified duration (negative value)

$$\text{Modified Duration (Price sensitivity)} = \frac{\frac{\Delta P}{P}}{\Delta i}$$

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.**

Portfolio duration

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

$$D_P = \frac{PV_1 x D_1 + PV_2 x D_2 + \ldots + PV_N x D_N}{PV_1 + PV_2 + \ldots + PV_N}$$

Duration and convexity effects

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 2 (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 3 (comparison calculation)

Assume 6-year loan, 4 300 000 nominal (from the Task 1), coupon of 5% with annuity repayments that originated on 1.4.2016. Today it is 1.4.2019 (3 more repayments left). You assume the following structure of interest rates:

Interest rates	
2019-20	4,00%
2020-20	4,50%
2021-20	4,80%

Calculate:

a) forward rate ${}_0f_3$

b) installment (calculated in Task 1)

c) duration and modified duration (and compare them)

d) effective duration

For solutions see the excel sheet

Task 4 (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.

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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.

- Price change (in %) due to duration = (– 4.5) * (– 0.8%) = 3.6%
- Interest rates decreased => due to duration the price increased
- New price due to duration effect

  $$108 * (1 + 0.036) = 111.89$$
- Price change due to convexity effect

  $$0{,}5 * 87 * 108 * 0.008^2 = 0.300672$$

- **New price (both effects) = 111.89 + 0.30 = 112.19**

Duration and convexity

Task 5 (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.

CFA Program, Level I, Volume 5

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Value at Risk – 4 steps

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 – 10D day risk management- according to market data available or model backtesting – 1day).

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, the maximum loss of CZK 1 million is expected.
- The second largest loss to occur in 100 trading days is expected to be the maximum of CZK 1 million.
- The CZK 1 million is the minimum loss to be expected for the worst 1% of days.

VaR – example (1)

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

If we want to approximate a different time horizon we use the following formula:

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

VaR – example (I)

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

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

VaR – example (I) solution

σ = 0,7%
t = 1 day
P = 40 000
95% confidence level → 1,65 standard deviations

a) daily VaR$_{95\%}$ = $40\,000 * 0.007 * 1{,}65 = 462\ USD\ or\ 11\,550\ CZK$

or equivalently the value of the position will not fall with a probability of 95% under **USD 39 538** $(P - 1{,}65 * \sigma)$

b) 10 day VaR$_{95\%}$ **=** $11\,550 * \sqrt{10} = 36\,524\ CZK$

VaR – example (II)

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

$(P - 1,65 * \sigma)$

VaR – example (II) solution

- Undiversified VaR:

$$VaR_{Total,undiv} = VaR_A + VaR_B = 12 * 0.0144 * 2.33 + 10 * 0.0087 * 2.33 = 0.4020 + 0.2024 = 0.604$$

- Diversified VaR (correlation - 0,23):

$$VaR_{Total,div} = \sqrt{0.4020^2 + 0.2024^2 + 2 * -0.23 * 0.4020 * 0.2024} = 0.4064$$

- Diversified VaR (correlation - 1):

$$VaR_{Total,div}^{\rho AB=-1} = VaR_A - VaR_B = 0.1996$$

Value at risk (III)

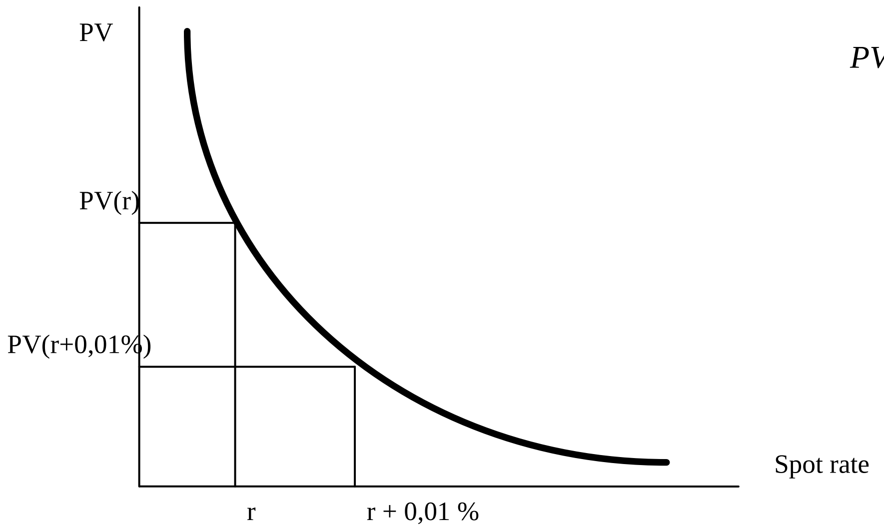
A. We have a position worth CZK 15 mil in ČEZ shares. Calculate the VaR at a confidence level of 99% if the holding period is 10 days. The daily volatility of ČEZ shares is 0,5%.

B. Now, determine the VaR from the point of view of an German investor (so VaR in EUR). The CZK/EUR expected FX rate is 24,6, the daily volatility of the FX rate is 0,8% and the correlation between FX risk and Czech equity risk is 0,2.

C. Assume, the German investor made a portfolio of his ČEZ shares (in CZK) and EUR 2 mil of German government bonds, with a daily volatility of 0,2%. Determine (all on the confidence level of 99 %) the total VaR his portfolio is exposed to. The correlation between the interest rate of the government bond and his position in Czech shares is - 0,1.

VaR – interest rate risk

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 are already taken into account.



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

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

VaR – interest rate risk

There is a zero coupon bond with a PVBP of EUR 47,500 and a 1-day volatility estimate of 0.02% (2 bps). Calculate the daily VaR at a confidence level of 95%.

VaR = 47 500 * 2 * 1,65 = EUR **156 750**

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Portfolio immunization – for managing interest rate risk

Immunization is a process in 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**.

Example - Portfolio Immunization

The portfolio manager´s or bank´s investment horizon is 8 years and the current yield is 8% (the investors are expected to receive $(1.08)^8 = 1.85$ at the end of the investment horizon. The portfolio manager may use:

(A) a maturity strategy, where the manager would acquire a bond with a term to maturity of eight years, or

(B) a duration strategy, where the portfolio manager sets the duration of the portfolio at eight years.

For the maturity strategy, portfolio manager acquires an eight-year, 8% bond; for the duration strategy, the manager acquires a 10-year, 8% bond that has approximately an eight-year duration, assuming an 8% yield to maturity. We assume a single shock to the interest rate structure at the end of Year 4, when interest rates change from 8% to:

a) to 6% and stay there,

b) to 9% and stay there.

Show which strategy is more profitable and why. Initial investment is 1,000 and the bonds have a face value of 1,000.

Maturity matching vs. Duration matching

Results with maturity strategy / **Results with duration strategy**

Cash flow	Reinvestment rate	End value		Cash flow	Reinvestment rate	End value	Year
80	0,08	**80,00**		80	0,08	**80,00**	1
80	0,08	**166,40**		80	0,08	**166,40**	2
80	0,08	**259,71**		80	0,08	**259,71**	3
80	0,08	**360,49**		80	0,08	**360,49**	4
80	0,06	**462,12**		80	0,06	**462,12**	5
80	0,06	**569,85**		80	0,06	**569,85**	6
80	0,06	**684,04**		80	0,06	**684,04**	7
1080	0,06	**1 805,08**		1117	0,06	**1 841,75**	8

The bond could be sold at its approximate value of 1,037, resp. 1,117 = 1,037 + 80

Results with maturity strategy / **Results with duration strategy**

Cash flow	Reinvestment rate	End value		Cash flow	Reinvestment rate	End value	Year
80	0,08	**80,00**		80	0,08	**80,00**	1
80	0,08	**166,40**		80	0,08	**166,40**	2
80	0,08	**259,71**		80	0,08	**259,71**	3
80	0,08	**360,49**		80	0,08	**360,49**	4
80	0,09	**472,93**		80	0,09	**472,93**	5
80	0,09	**595,50**		80	0,09	**595,50**	6
80	0,09	**729,09**		80	0,09	**729,09**	7
1080	0,09	**1 874,71**		1062	0,09	**1 857,12**	8

The bond could be sold at its approximate value of 982, resp. 1,062 = 982 + 80

Reading for the this seminar

- ✓ **Chapter IX.S – Market risk measurement**