BANKING

Tutorial 09 – Money market instruments, interest rates and central banks

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

9 December 2020

Contents

Money market instruments - examples

Money market = securities with maturity up to 1 year

Instruments quoted on the yield basis

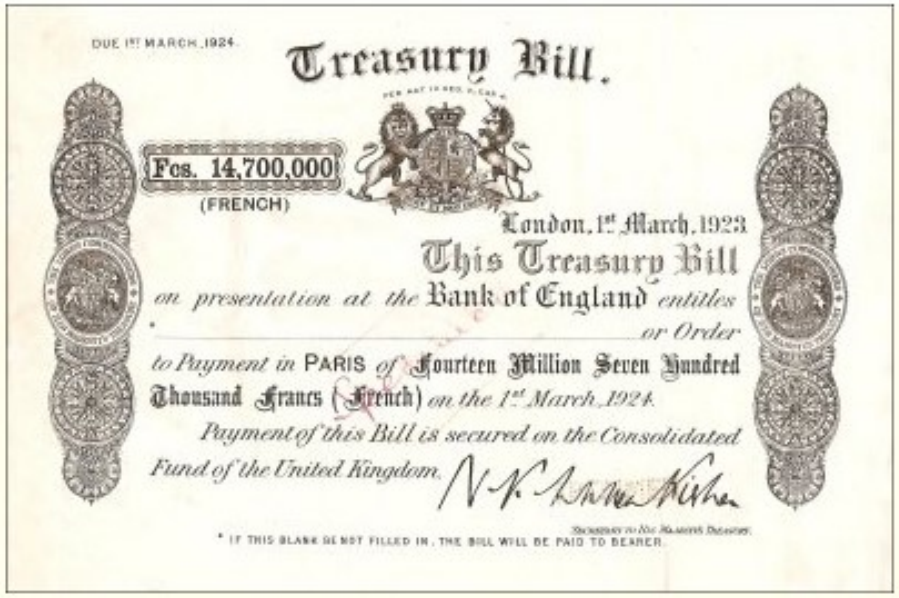
- Money Market Deposits (MMD)
- Certificates of Deposits (CD)

Instruments quoted on the discount basis

- Treasury bills
- Bills of exchange, commercial papers

Treasury bills

- Treasury bills (T-bills) are government bonds with maturity up to 1 year
- Traded on discount basis (i.e. under its par value)
- Simple interest and the ACT/360 method


DUE 1ST MARCH, 1924.

Treasury Bill.

Fcs. 14,700,000
(FRENCH)

London, 1st March, 1923

This Treasury Bill on presentation at the Bank of England entitles _____ or Order to Payment in PARIS of Fourteen Million Seven Hundred Thousand Francs (French) on the 1st March 1924.

Payment of this Bill is secured on the Consolidated Fund of the United Kingdom.

* IF THIS BLANK BE NOT FILLED IN, THE BILL WILL BE PAID TO BEARER.

Treasury bills

Average yield (r_{nom}) measures the rate of return on the T-bill

$$FV = PV\left(1 + \frac{t}{360} r_{nom}\right) \quad \Rightarrow \quad r_{nom} = \frac{FV - PV}{PV \times t/360}$$

FV - Future Value (par value or selling price) of the bond
PV - Present Value of the bond (issue price)
r_{nom} - Average yield
t - Holding period of the T-bill

Bond equivalent yield (r_{eq}) enables comparability among various instruments with different day conventions (ACT/360 and ACT/365).

$$r_{eq} = \frac{FV - PV}{PV \times t \,/ 365}$$

FV - Future Value (par value or selling price) of the Bond
PV - Present Value of the Bond
r_{eq} - Bond equivalent yield
t - Holding period of the T-bill

Day count conventions

$$\frac{\text{number of days between dates}}{\text{number of days in reference period}} \times \text{interest earned in reference period}$$

Standard	Method	Security
ACT/365	English	English securities (gilts etc.)
ACT/360	French (International)	Czech Treasury Bills, French T-bills, U.S. T-bills
30E/360	German (Trading)	Accrued Interest, Czech Government Coupon Bonds
ACT/ACT		U.S. Treasury Bonds

Task 1: Treasury bill

On March 1, 2015 the Ministry of Finance issued a 270-day, CZK 1-million par T-bill priced at CZK 980,000.

a) Compute an average yield of the T-bill.
b) Calculate the selling price of the T-bill if an investor sells the T-bill after 90 days with an average yield of 3%.

Task 1: Treasury bill (solution)

On March 1, 2015 the Ministry of Finance issued a 270-day, CZK 1-million par T-bill priced at CZK 980,000.

a) Compute an average yield of the T-bill.

b) Calculate the selling price of the T-bill if an investor sells the T-bill after 90 days with an average yield of 3%.

Solution:

a)

Par value	1 000 000 CZK
Maturity	270
Issue price (March 1, 2015)	980 000 CZK
Average yield (March 1, 2015)	2,72%

$$r_{nom} = \frac{FV - PV}{PV \times t/360} = \frac{1000000 - 980000}{980000 \times 270/360} = 2.72\%$$

b)

Holding period	90
Average yield (May 30, 2015)	3,00%
Selling price (May 30, 2015)	987 350 CZK

$$FV = PV \times (1 + \frac{t}{360} r_{nom}) = 980{,}000 \times (1 + \frac{90}{360} \times 3\%) = 987{,}350$$

Task 2: Money market deposit

As of March 1, 2015 JP Morgan placed a EUR 100-million deposit with a 30-day maturity and the current market rate of 2%. How much did JP Morgan receive on April 1, 2015?

Contents

Interest rates basics

Interest rate = “rental” price of money; price paid for the use of money for a period of time

Money loaned → the lender defers consumption to the future in exchange for an expected increase in future income

Real interest rate = expected increase in real income (relative to the amount loaned)

Real vs. vs. Nominal interest rate

- Fisher‘s equation: $i_r = i_n - \pi^e$ ← Expected inflation
- Adjustment for premium: $i_n = i_r + \pi^e + CRP + MP + LP + OP$

i_n – nominal interest rate
i_r – real interest rate
π^e – expected inflation
CRP – credit risk premium
MP – maturity premium
LP – liquidity premium
OP – optionality premium

Types of interest rates: ČNB announced rates

Discount rate … paid by the ČNB to commercial banks for making their deposits

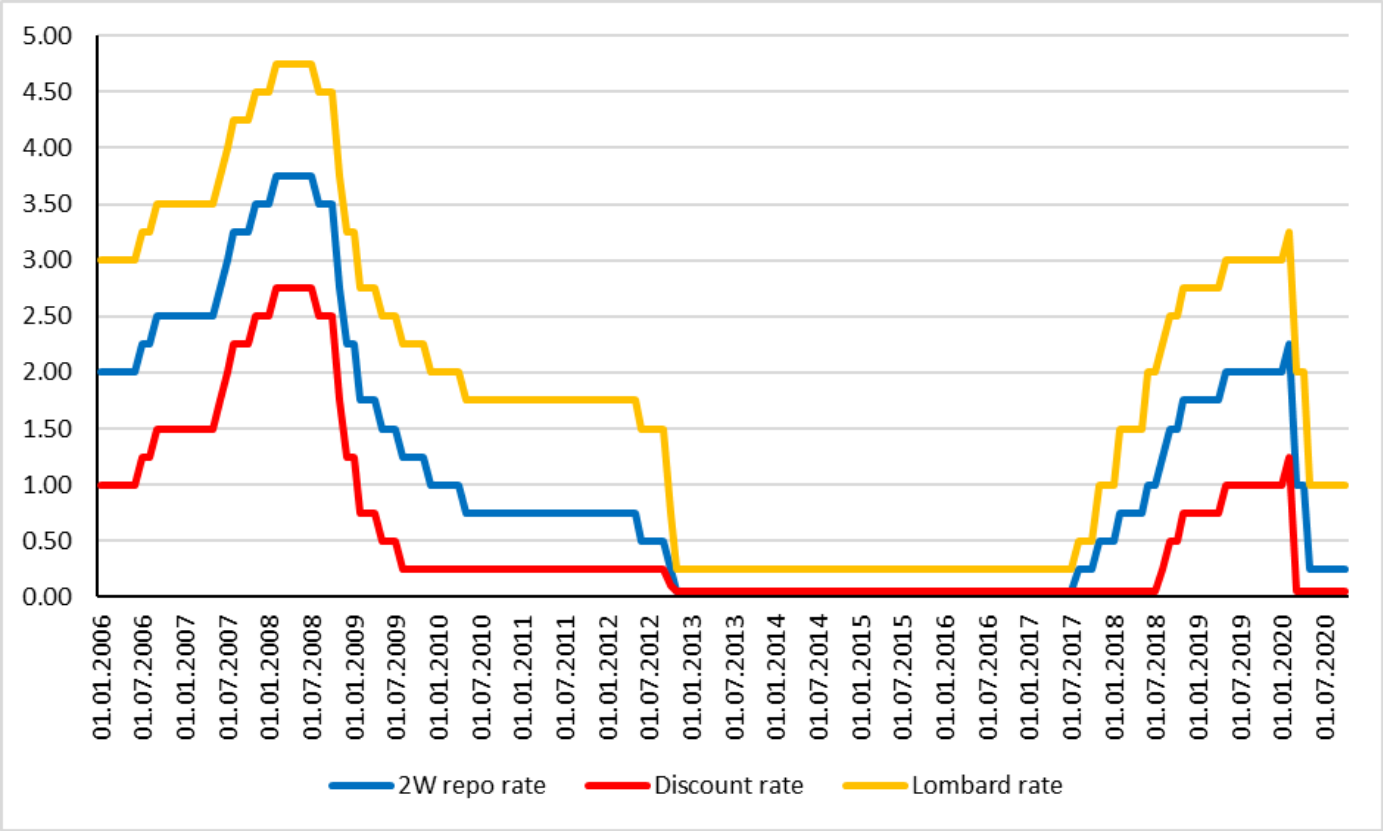
Repo rate … rate for which the ČNB provides repurchase agreements with commercial banks.

Lombard rate … the rate charged by the ČNB for granting loans to commercial banks against a pledge for securities

Q: What are current ČNB/ECB policy rates?

Interest rates

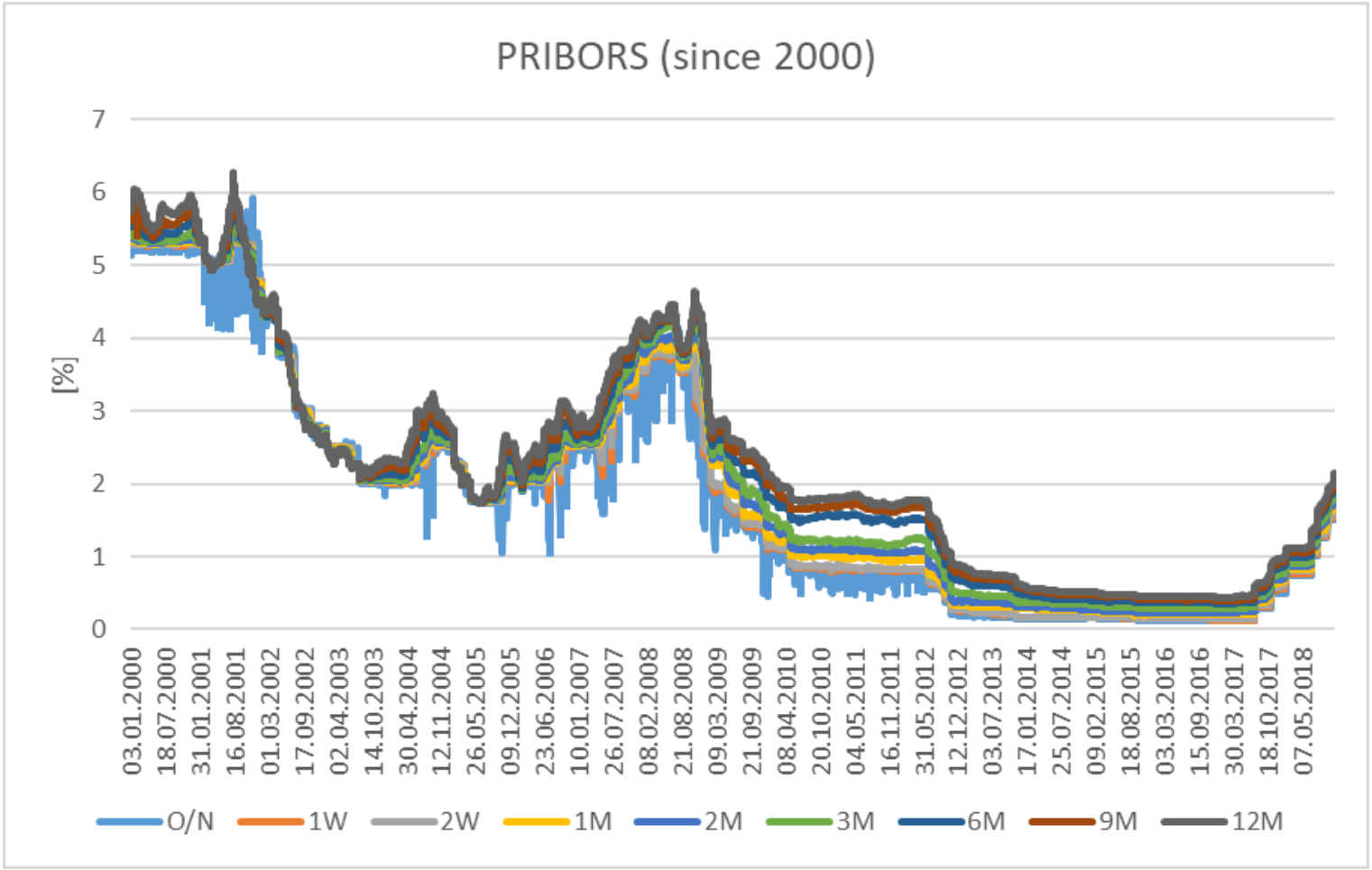
ČNB rates



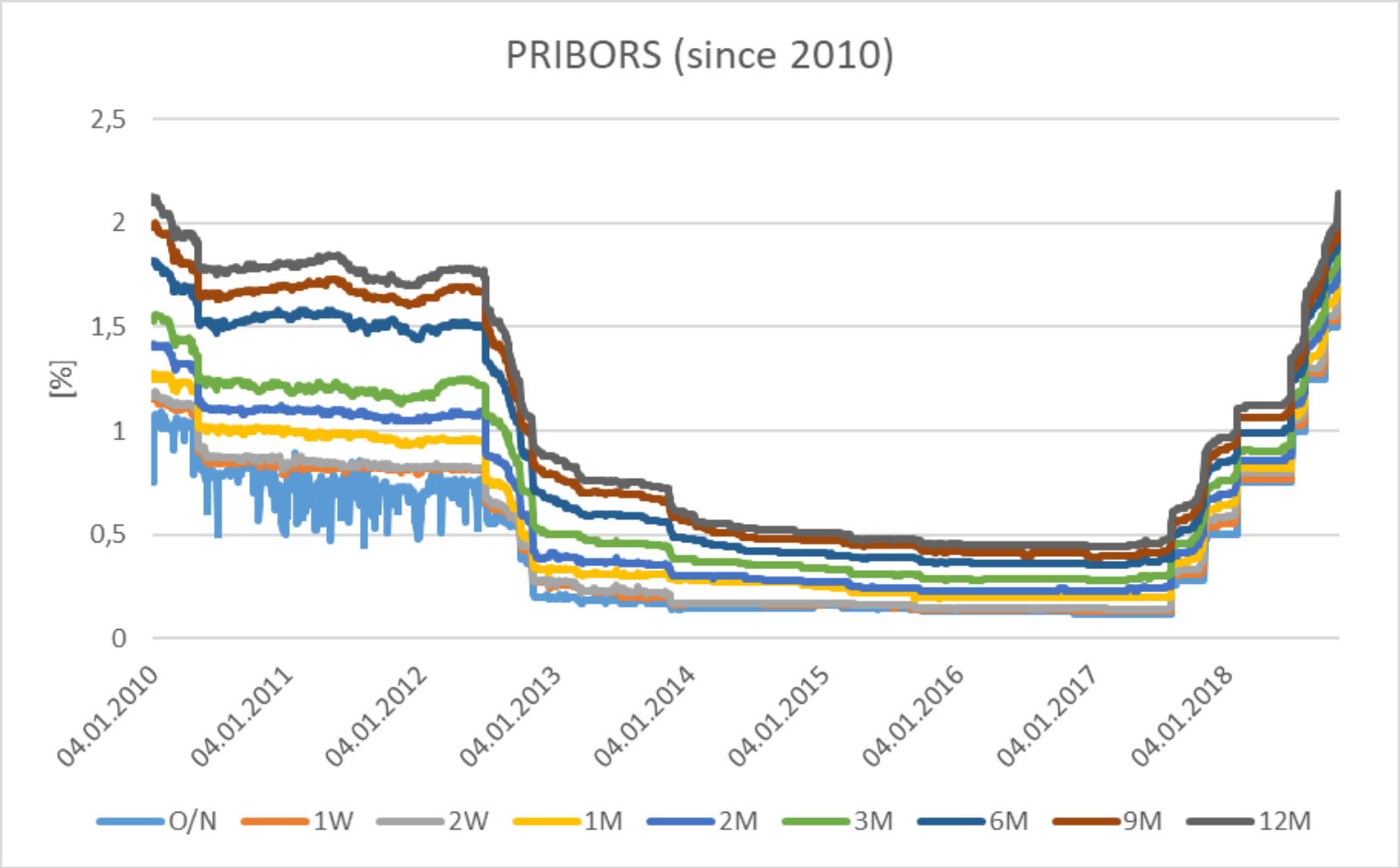
Types of interest rates: Interbank rates

- PRIBOR (Prague Interbank Offered Rate) = the reference interest rate on the interbank deposit market (the sale of deposits "offer")
- PRIBID (Prague Interbank Bid Rate) = the reference interest rate on the interbank deposit market (the purchase of deposits "bid"); quotation stopped in 7/2015!
- PRIMEAN = interest rate in the middle between PRIBOR and PRIBID
- CZEONIA (CZEch OverNight Index Average) = the weighted average of the interest rates of all unsecured O/N deposits placed by reference banks on the interbank market
- LIBOR (London Interbank Offered Rate)
- EURIBOR (Euro Interbank Offered Rate)

PRIBOR development 1/2



PRIBOR development 2/2

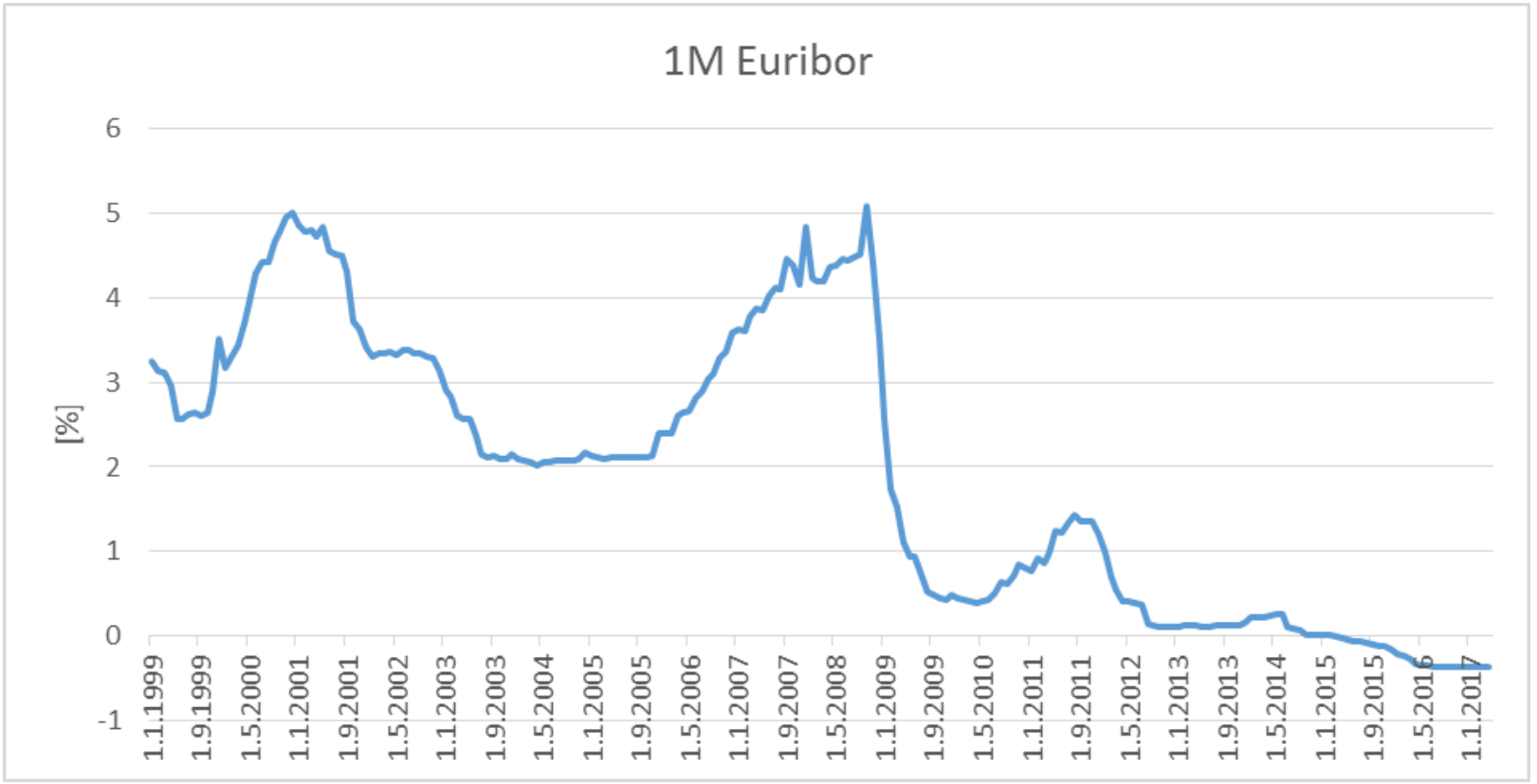


Question

Can the interbank rates (e.g. 1M Euribor) go negative? Explain your statement.

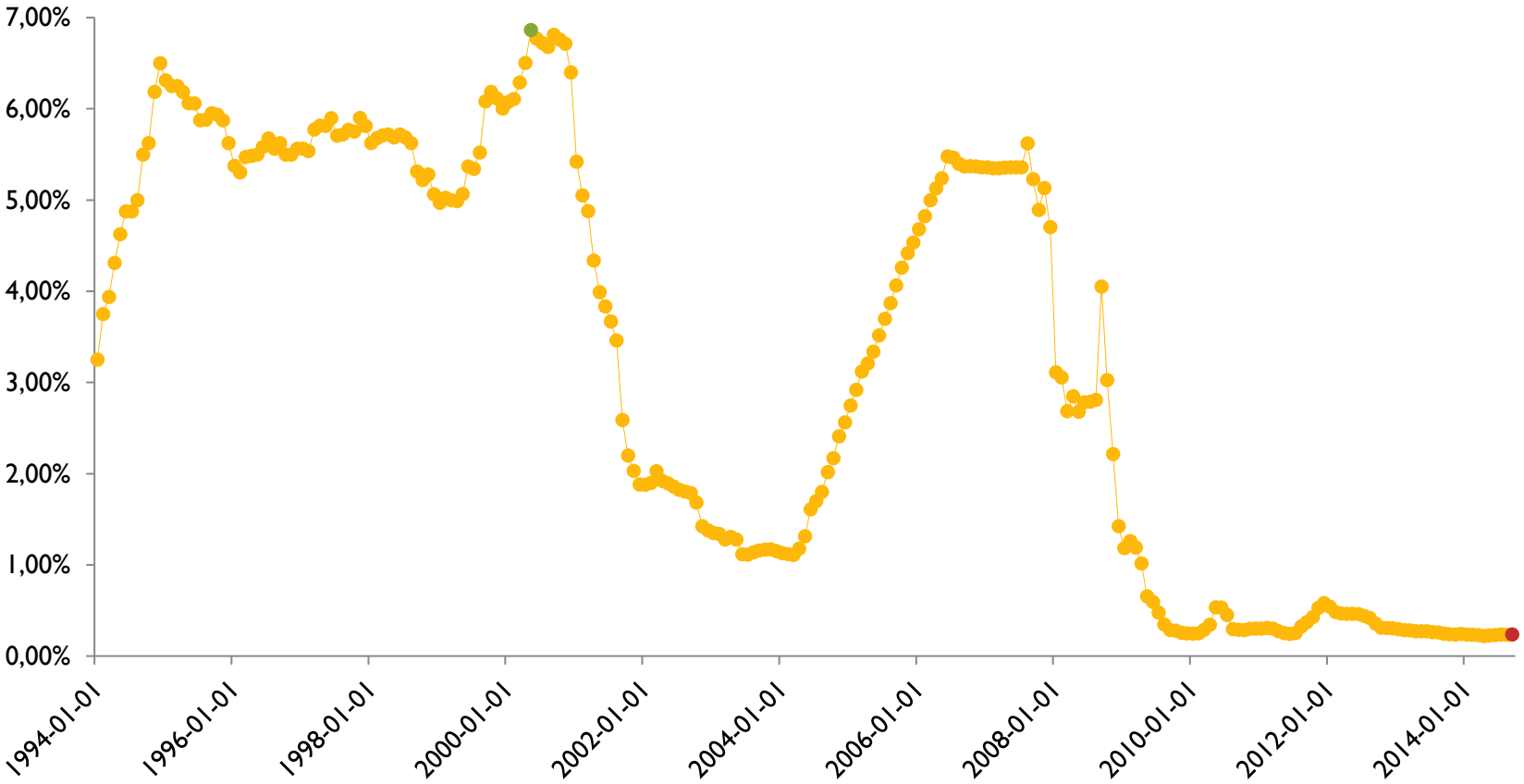
Interest rates

1M Euribor



Types of interest rates: Interbank rates

Development of 3M USD LIBOR in the last 20 years



Interest rates

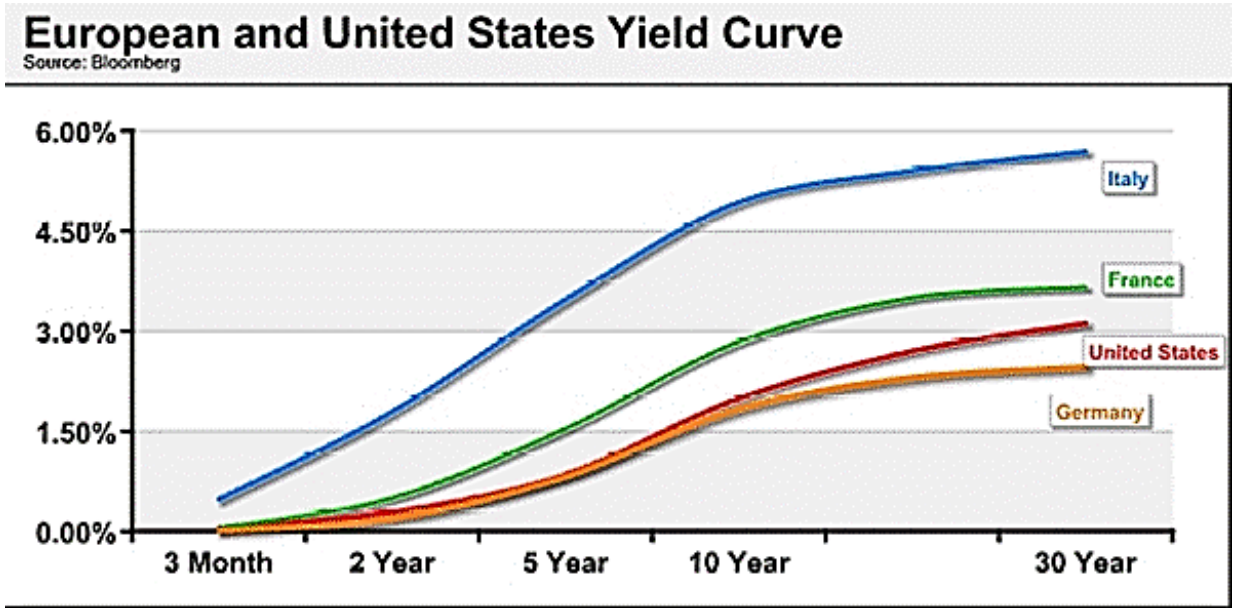
Types of interest rates: government bonds yields

Development of CZ and DE 5Y GOV bonds

Source: Reuters

Time structure of interest rates

- **Yield curve** shows the relationship between maturity and interest rates (yields on bonds against bond maturities)
- It is constructed from the bonds of the same risk – usually from government (Treasury) bonds.



- In the past, four main yield curves have been observed: normal, inverted, flat and steep.

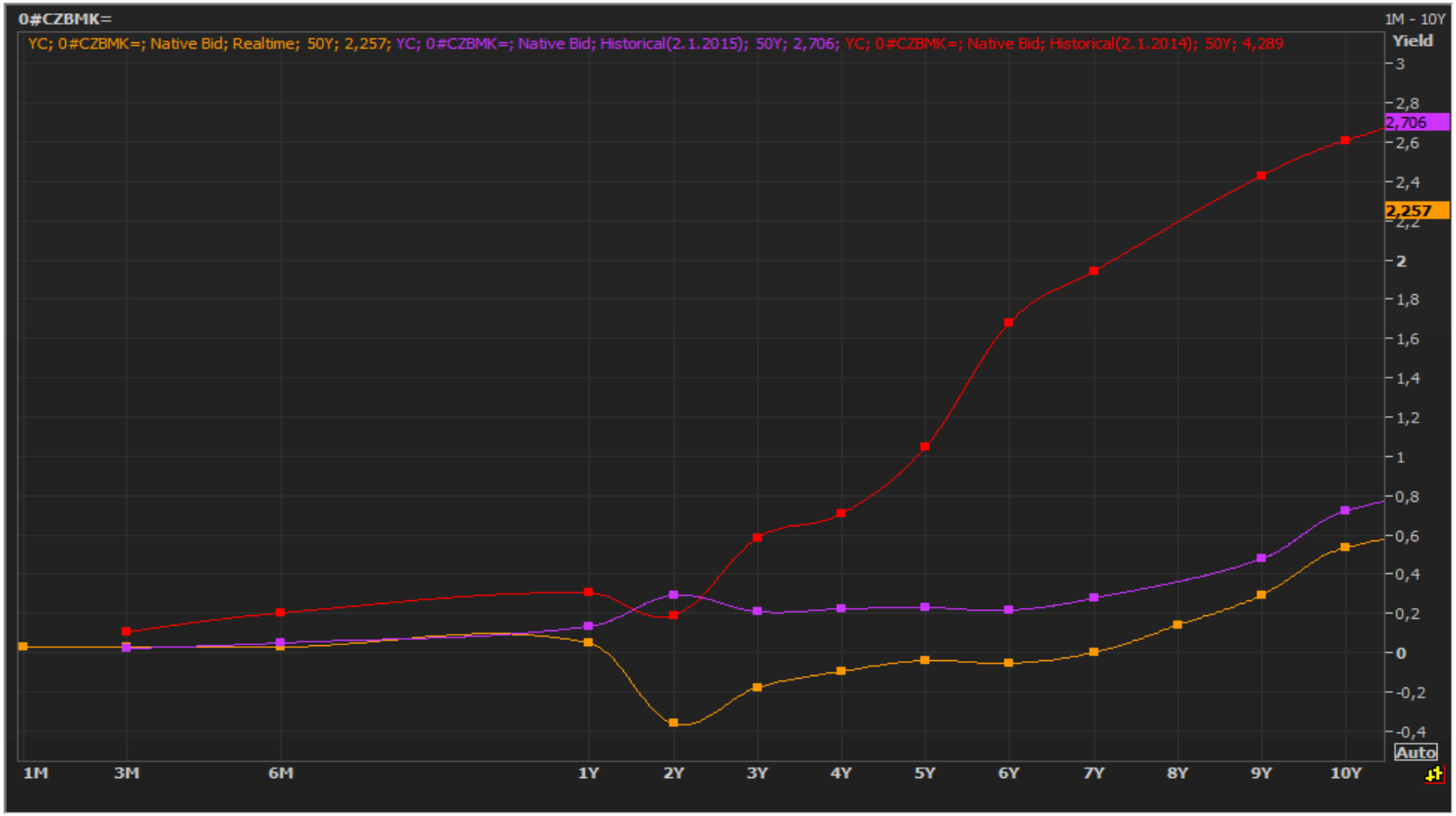
Yield curve examples

CZ and DE GOV YC (11/2015):

Source: Reuters

Yield curve examples

CZ GOV YC (development: 1/2014, 1/2015, 11/2015)



Source: Reuters

Task 3: Yield curve

We know that yield to maturity (YTM) is an average return paid to an investor if he or she holds a bond until its maturity. However, YTM is not appropriate for constructing the yield curve. Why?

Time structure of interest rates – spot rates

- Yield curve suffers from problems: the presence of coupons on bonds affects the calculated yield to maturity (YTM)
- Two ways to overcome this fact:

1 Bootstrapping

= construction of a yield curve using only zero coupon government bonds with different maturities

$$ {}_0s_N = \left(\frac{M}{P_N}\right)^{\frac{1}{N}} - 1 $$

P_N – bond's price at year N
M – bond's nominal value
${}_0s_N$ – N-year spot rate

Time structure of interest rates – spot rates

2 To extract spot interest rates from the yields to maturity of coupon bonds

- The table below provides YTMs on bonds (5% coupon rate, face value of 100) with maturities from one to five years and corresponding spot rates
- It is clear that the difference between YTMs and spot rates increases as the bond maturity increases (YTM is a weighted average of spot rates)
- The following equation demonstrates, how the price of a two-year bond is calculated:

$$P_2 = \frac{C_1}{1 + {}_0 s_1} + \frac{M + C_2}{(1 + {}_0 s_2)^2}$$

$$100 = \frac{5.25}{1+5\%} + \frac{100+5.25}{(1+{}_0 s_2)^2} \Rightarrow {}_0 s_2 = \left(\frac{105.25}{100 - \frac{5.25}{1.05}} \right)^{\frac{1}{2}} - 1 = 5.26\%$$

P_2 - 2-year bond's price
C_1 - coupon at time 1
C_2 - coupon at time 2
M - bond's nominal value
${}_0 s_1$ - 1-year spot rate
${}_0 s_2$ - 2-year spot rate

If we put numbers into the equation, we obtain the two-year (annualized) spot rate (assume that the bond is priced at par, i.e. YTM_t = Coupon $rate_t$):

Maturity	YTM	Spot Rates
1	5.00%	5.00%
2	5.25%	5.26%
3	5.40%	5.41%
4	5.50%	5.52%
5	5.60%	5.63%

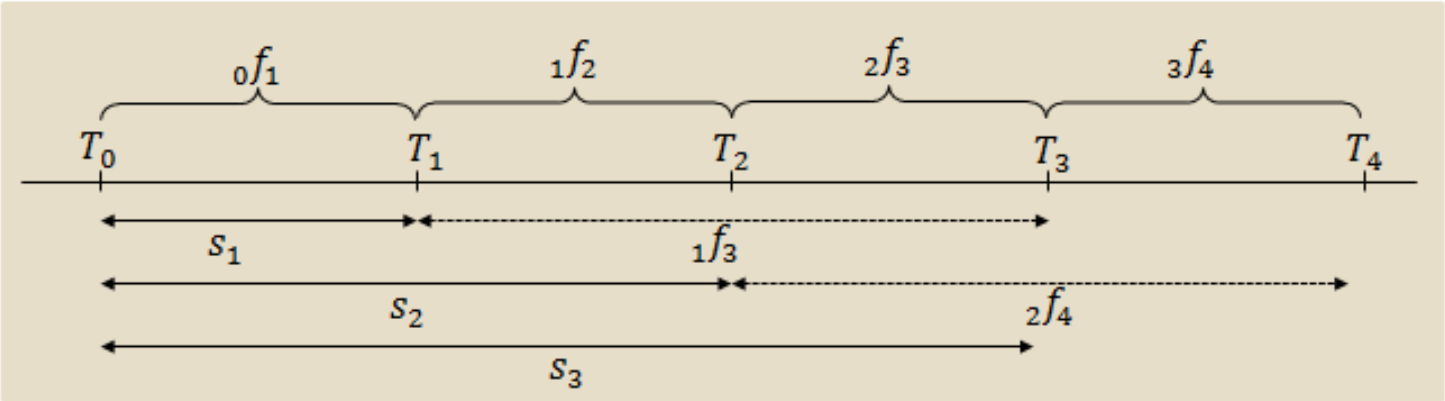
Time structure of interest rates – forward rates

- The pure expectations hypothesis says that the forward rate for period T should be the best predictor of the expected spot rate in that period.
- In addition, we know that long-term rates are a geometric average of short-term rates. For instance, we can calculate a two-year spot rate s_2 as follows:

$$(1+s_2)^2 = (1+s_1)(1+{}_1f_2) \Rightarrow {}_{T-k}f_T = \left(\frac{(1+{}_0s_T)^T}{(1+{}_0s_{T-k})^{T-k}}\right)^{1/k} - 1$$

s_T - T-year spot interest rate

${}_{T-k}f_T$ - Forward interest rate from time T-k until time T



Task 4: Spot and Forward rates

The following table contains maturities and YTMs of government bonds. Compute corresponding spot and 1Y forward rates.

Maturity	YTM	Spot Rates	Forward Rates
1	5,00%	?	?
2	5,25%	?	?
3	5,40%	?	?
4	5,50%	?	?
5	5,60%	?	?

Task 4: Spot and Forward rates (hint)

Maturity	YTM	Spot Rates	Forward Rates
1	5,00%	5%	5%
2	5,25%	?	?
3	5,40%	?	?
4	5,50%	?	?
5	5,60%	?	?

$$P_2 = \frac{C_1}{1 + {}_0s_1} + \frac{M + C_2}{(1 + {}_0s_2)^2}$$

$$100 = \frac{100 \times 5{,}25\%}{1+5\%} + \frac{100 + 100 \times 5{,}25\%}{(1 + {}_0s_2)^2} \rightarrow {}_0s_2 = \left(\frac{105{,}25}{100 - \frac{5{,}25}{1{,}05}}\right)^{\frac{1}{2}} - 1 = 5{,}26\%$$

$$P_3 = \frac{C_1}{1 + {}_0s_1} + \frac{C_2}{(1 + {}_0s_2)^2} + \frac{M + C_3}{(1 + {}_0s_3)^3}$$

$$100 = \frac{100 \times 5{,}4\%}{1+5\%} + \frac{100 \times 5{,}4\%}{(1+5{,}26\%)^2} + \frac{100 + 100 \times 5{,}40\%}{(1 + {}_0s_3)^3} \rightarrow {}_0s_3 = \left(\frac{105{,}4}{100 - \frac{5{,}4}{1{,}05} - \frac{5{,}4}{1{,}0526^2}}\right)^{\frac{1}{3}} - 1 = 5{,}41\%$$

$${}_1f_2 = \left(\frac{(1+5{,}26\%)^2}{(1+5{,}00\%)^1}\right)^1 - 1 = 5{,}51\%$$

$${}_2f_3 = \left(\frac{(1+5{,}41\%)^3}{(1+5{,}26\%)^2}\right)^1 - 1 = 5{,}73\%$$

Time structure of interest rates - Spot & Forward

- We can depict a spot yield curve from the rates on the previous slide however, we cannot construct a forward yield curve. The reason is that the table includes one-year forward rates (such as ${}_2f_3$ or ${}_3f_4$) rather than longer-term rates, which are needed for constructing a forward yield curve.
- For instance, we need the rates ${}_1f_2$, ${}_1f_3$, ${}_1f_4$ and ${}_1f_5$ for the curve valid next year.

Task 5: Spot & Forward rates

The table shows spot rates for next 5 years. Compute corresponding forward rates (at 1 year from now) and draw a spot curve and a forward yield curve valid a year from now.

Maturity	Spot Rates	Forward Rates
1	5,00%	?
2	5,26%	?
3	5,41%	?
4	5,52%	?
5	5,63%	?

Task 5: Spot & Forward rates (hint)

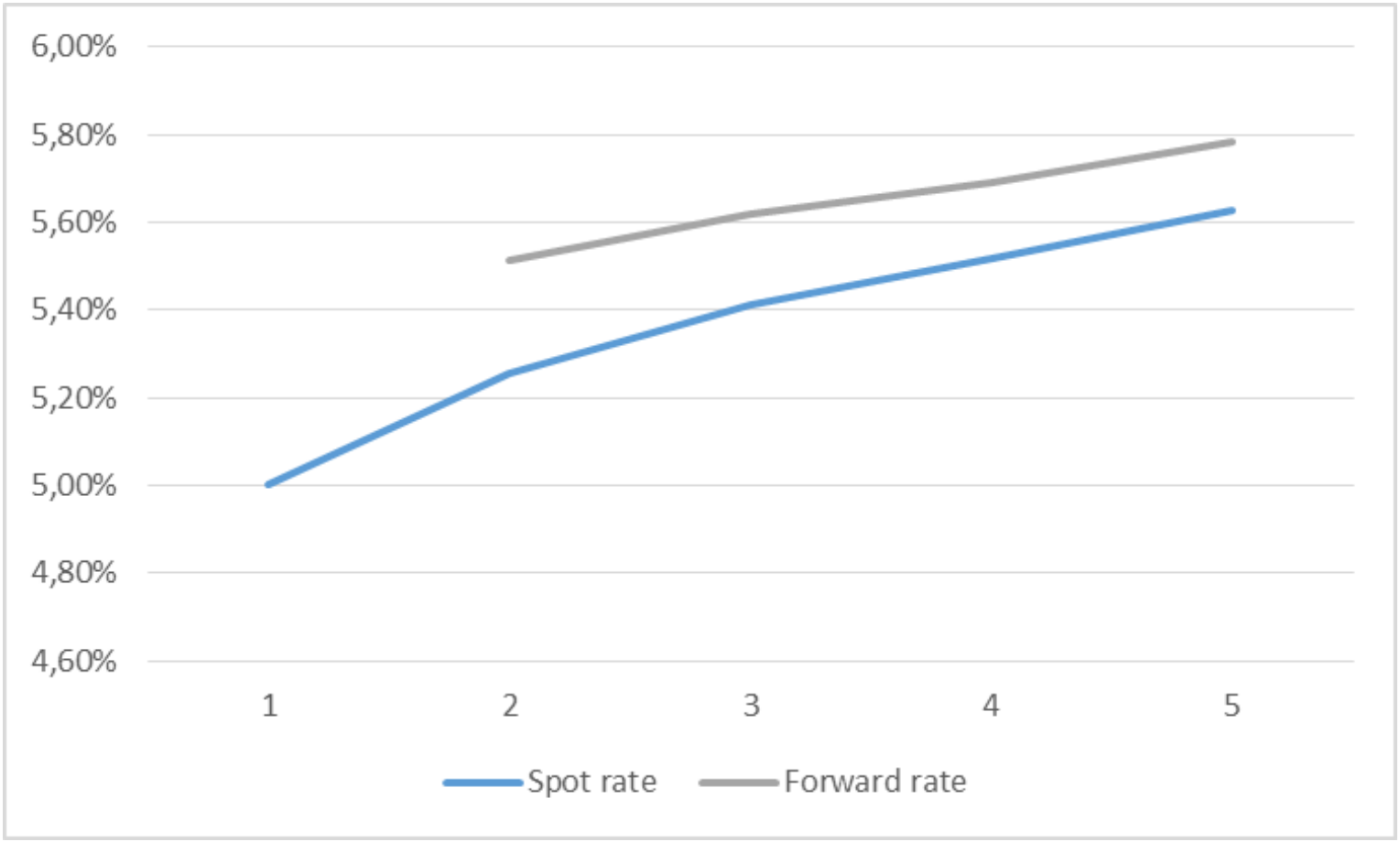
The table shows spot rates for next 5 years. Compute corresponding forward rates and draw a spot curve and a forward yield curve valid a year from now.

Maturity	Spot Rates	Forward Rates
1	5,00%	?
2	5,26%	?
3	5,41%	?
4	5,52%	?
5	5,63%	?

$$ {}_{T-k}f_T = \left(\frac{(1+{}_0 s_T)^T}{(1+{}_0 s_{T-k})^{T-k}} \right)^{1/k} - 1 \qquad {}_1 f_3 = \left(\frac{(1+5{,}41\%)^3}{(1+5{,}00\%)^1} \right)^{1/2} - 1 = 5{,}62\% $$

Interest rates

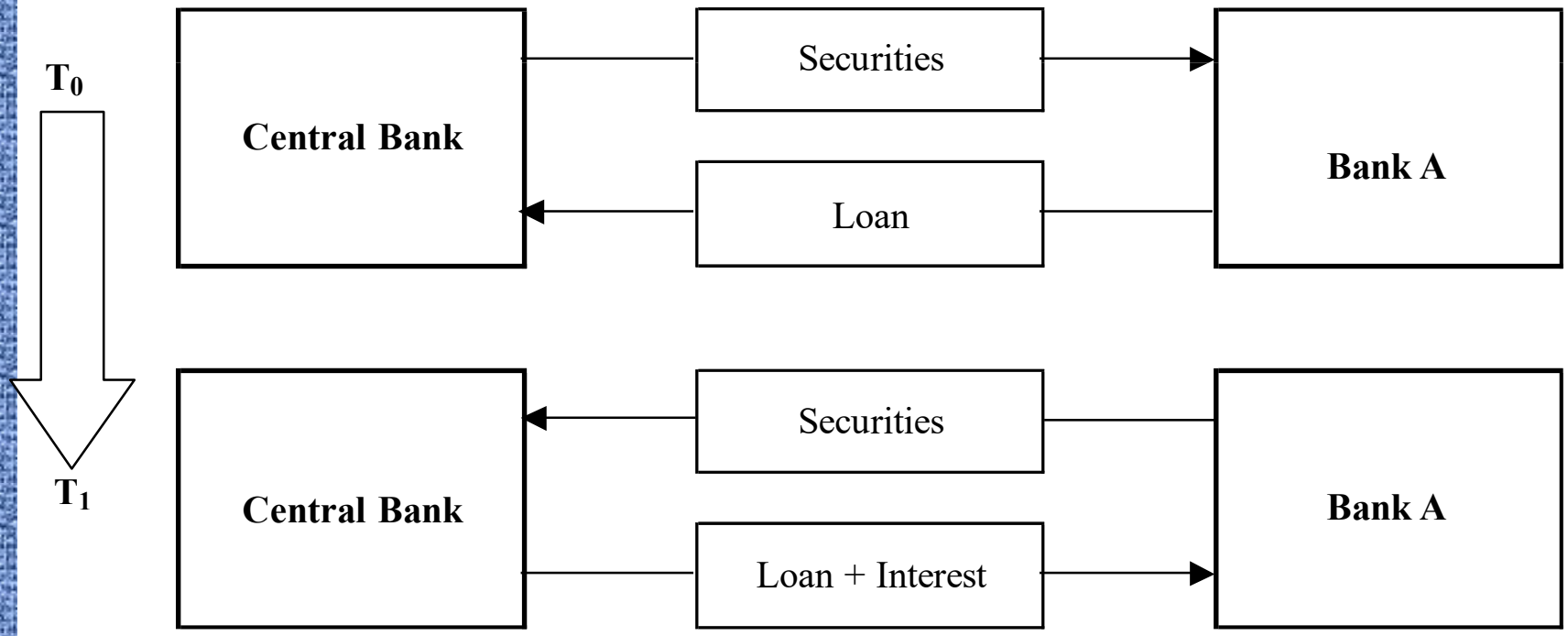
Task 5: corresponding graph



Contents

Repurchase agreement

- A classic repurchase agreement (repo) = a purchase of securities followed by their future sale back
- Central bank – commercial bank or commercial bank – commercial bank



Task 6: Repo

On March 20, 2015 Komerční banka (KB) and ČSOB concluded a repo under the conditions below (KB accepts the loan). Use the 30/360 day-count convention for your calculations.

Repo		Dluhopis/Bond	
-Days	30	- Coupon rate	3,00%
- Volume	100 000 000	- Price	100,90%
- Settlement	20.3.2015	- Maturity	30.6.2015
- Termination	20.4.2015		
Repo rate	2,0%	Last Coupon Paid	30.6.2014

a) Compute flows of cash and bonds at the beginning and the end of the deal.
b) Calculate the implicit price of the bond as of April 20, 2015.
c) Depict this transaction on a picture.

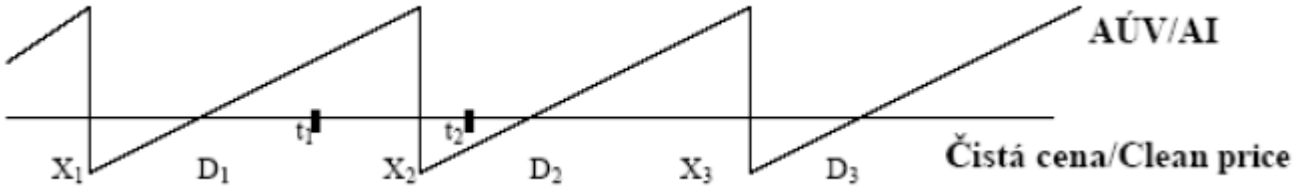
Task 6: Repo

Solution: a)

Accrued interest: $AI = \frac{t_1 - D_1}{360} \times C$

Accrued interest is a part of the coupon that compensates the Buyer (or the Seller) for non-obtaining the accrual part of the coupon.

$$P_D = P_C \pm AI$$



If the deal is done at time t_1, the seller is to be compensated for holding a bond in period (D_1,t_1), i.e. $P_D = P_C + AI$

Task 6: Repo

Solution: a)

i. Accrued interest ($\frac{260}{360} \times 3\% \times 100\ mil.$)

Date	AI	Number of days
20.3.2015	2 166 667	260
20.4.2015	2 416 667	290

ii. Price of the bond ($100\ mil. \times 100{,}9\%$) + AI as of 20 March

20.3.2015	ČSOB pays	KB receives
Principal	100 900 000	100 900 000
Accrued Interest	2 166 667	2 166 667
Total	**103 066 667**	**103 066 667**

iii. Interest from the repo ($2\% \times 103\ mil. \times 30/360$)

20.4.2015	ČSOB receives	KB pays
Interest from repo	171 778	171 778
Total	**103 238 444**	**103 238 444**

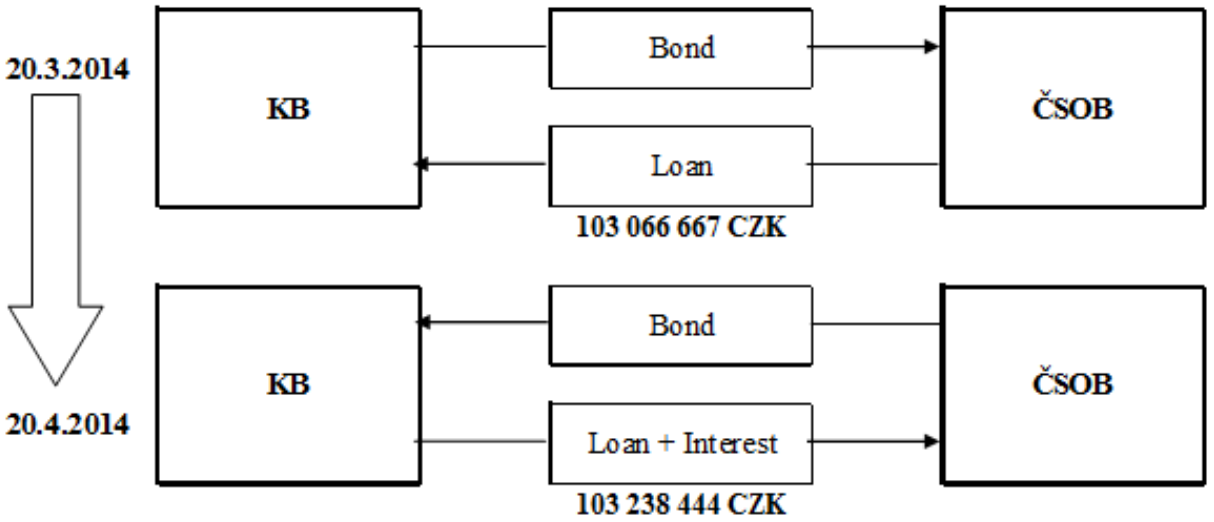
Task 6: Repo

Solution:

b) The implicit price of the bond equals the difference between the repo amount and AI as of 20 April 2015

20.4.2015	ČSOB receives	KB pays
Repo	103 238 444	103 238 444
Accrued Interest	2 416 667	2 416 667
Implicit Bond's Price	**100 821 778**	**100 821 778**

c)



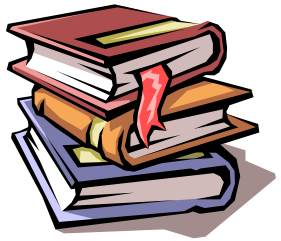
Task 7: Repo

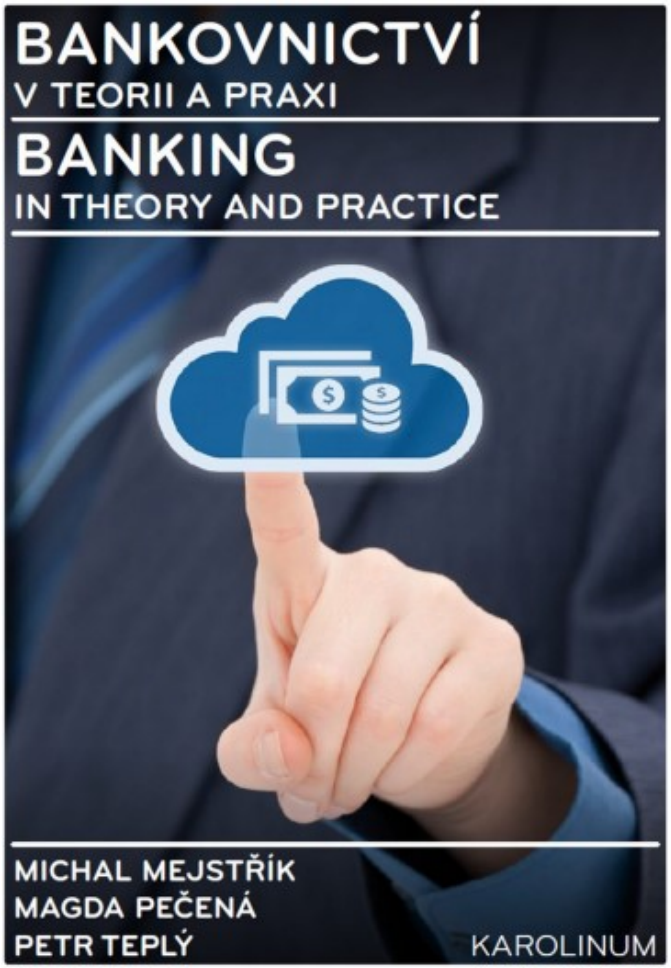
On October 24, 2015 GE Money Bank, a.s. (GE) and Česká spořitelna (CS) concluded a repo under the conditions below (GE accepts the loan). Use the 30E/360 day-count convention for your calculations.

Repo		Bond	
- Days	14	- Coupon rate	3,00%
- Volume	500 000 000	- Price	100,50%
- Settlement	24.10.2015	- Maturity	30.6.2016
- Termination	7.11.2015		
Repo rate	3,25%	Last Coupon Paid	30.6.2015

a) Compute flows of cash and bonds at the beginning and the end of the deal (507 849 388 CZK)
b) Calculate the implicit price of the bond as of November 7, 2015 (502 557 722 CZK)
c) Depict this transaction on a picture

Source




BANKOVNICTVÍ
V TEORII A PRAXI
BANKING
IN THEORY AND PRACTICE
MICHAL MEJSTŘÍK
MAGDA PEČENÁ
PETR TEPLÝ
KAROLINUM

Thank you for your attention.