1. INTEREST RATE RISK. Term Structure of Interest Rates. Conversions

Investment philosophy and investment strategy
The financial markets allow firms to realize their investment decisions and financial decisions (strategies). Investment decisions may be conservative (buying low return and low risk instruments) or active (buying high return and high risk instruments). Financial decisions may be conservative (for example issuing equity with high return and high risk) or active (low return and low risk instruments). Financial markets and especially derivative markets offer participants the opportunity to reduce or eliminate risk through hedging which involves taking out counterbalancing contracts to offset existing risks (price risk, currency risk, interest rate risk).

Interest rate risk – definitions.

Money markets are the markets for short term and highly liquid debt securities issued by government (treasury bills), national bank (NBP bills), banks (deposits) or corporations (commercial papers).
- Treasury bills
- NBP money market bills
- Interbank deposit market (depo market)
- Repurchase agreement (repo, RP) and SBB (sell-buy-back)
- Certificates of deposit
- Bank short term deposits
- Commercial papers
- Commercial short term loans
- Short term consumer loans

Capital markets are the markets for long-term and less liquid debt securities and stocks.
- Treasury bonds
- NBP bonds
- Local government bonds (municipal bonds).
- Bank time deposits
- Mortgage bonds
- Corporate bonds
- Financial lease
- Commercial term loans
- Mortgage loans
- Subscription warrants
- Common stock
- Consumer term loans

Interest rate derivatives
- Interest rate futures
- FRA (forward rate agreement)
- IR options
- Interest Rate Swap (IRS)
- Other derivatives include index futures, stock futures, warrants, commodity swaps.
Monetary Policy Council establishes short-term interest rates: reference rate (14 days), lombard rate (1 day) and deposit rate (1 day) and also required obligatory reserves ratio.

<table>
<thead>
<tr>
<th>NBP policy</th>
<th>Expansionary policy</th>
<th>Restrictive policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open market operations</td>
<td>Purchase securities</td>
<td>Sell securities</td>
</tr>
<tr>
<td>Reserve requirements</td>
<td>Reduce reserve requirements</td>
<td>Raise reserve requirements</td>
</tr>
<tr>
<td>Interest rates</td>
<td>Lower interest rates</td>
<td>Raise interest rates</td>
</tr>
</tbody>
</table>

An Eurodollar deposit. US dollar deposited with a bank outside the USA. This could be a foreign bank or an overseas branch of a US bank.

Foreign bond. A bond sold by a foreign issuer but denominated in the currency of the country in which it is sold.

Eurobond. A bond denominated in a currency other than the national currency of the issuer.

Rate of interest is just rate of return for an investor or in the same time cost of capital for a borrower.

Tabela 1. Effective rates

<table>
<thead>
<tr>
<th></th>
<th>Efektywna stopa roczna</th>
<th>Stopa równoważna</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple interest rate</td>
<td>[ i = \left(1 + \frac{rt}{360}\right)^{\frac{365}{t}} - 1 ]</td>
<td>[ r = \frac{360}{t} \left(1 + \frac{i}{365}\right)^\frac{1}{t} - 1 ]</td>
</tr>
<tr>
<td>Bond yield</td>
<td>[ i = \left(1 + \frac{y}{2}\right)^2 - 1 ]</td>
<td>[ y = 2 \left(1 + \frac{i}{2}\right)^\frac{1}{2} - 1 ]</td>
</tr>
</tbody>
</table>
| Discount rate           | \[ i = \left(\frac{1}{1 - \frac{dt}{360}}\right)^{\frac{365}{t}} - 1 \] | \[ d = \frac{360}{t} \left[1 - \frac{1}{\left(1 + \frac{i}{365}\right)^\frac{1}{t}}\right] \]
|                         | lub \[ d = \frac{r}{1 + rt} \] | \[ c = \ln(1 + i) \] |
| Continuously compounded rate | \[ i = e^c - 1 \] | \[ c = \ln(1 + i) \] |
Money market yield

A simple interest or money market yield is used for most deposits, loans and many other instruments. The simple rate is

\[ y_t = \frac{365}{t} \Delta P_t = \frac{\text{interest}}{\text{principal}} \]

But \( y_t \) is not an effective annual rate. The effective annualized rate is

\[ i = \left(1 + y_t \frac{t}{365}\right)^{365} - 1 \]

Problem 1. Money market yield

If you deposit $100 in the bank today and it earns interest at a rate of 10% compounded monthly.

(a) How much will be in the account 12 months from today if you calculate interest on a 365 basis?

What is the effective annualized interest rate?

(b) What is the effective annualized interest rate on a 30/360 basis?

(c) What is the equivalent continuously compounded rate?

Solution

(a)

<table>
<thead>
<tr>
<th>Month</th>
<th>No of days</th>
<th>Balance</th>
<th>Effective rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31</td>
<td>100,849315</td>
<td>10,470434%</td>
</tr>
<tr>
<td>2</td>
<td>28</td>
<td>101,622954</td>
<td>10,474925%</td>
</tr>
<tr>
<td>3</td>
<td>31</td>
<td>102,486053</td>
<td>10,470434%</td>
</tr>
<tr>
<td>4</td>
<td>30</td>
<td>103,328404</td>
<td>10,471930%</td>
</tr>
<tr>
<td>5</td>
<td>31</td>
<td>104,205988</td>
<td>10,470434%</td>
</tr>
<tr>
<td>6</td>
<td>30</td>
<td>105,062475</td>
<td>10,471930%</td>
</tr>
<tr>
<td>7</td>
<td>31</td>
<td>105,954787</td>
<td>10,470434%</td>
</tr>
<tr>
<td>8</td>
<td>31</td>
<td>106,854676</td>
<td>10,470434%</td>
</tr>
<tr>
<td>9</td>
<td>30</td>
<td>107,732934</td>
<td>10,471930%</td>
</tr>
<tr>
<td>10</td>
<td>31</td>
<td>108,647926</td>
<td>10,470434%</td>
</tr>
<tr>
<td>11</td>
<td>30</td>
<td>109,540923</td>
<td>10,471930%</td>
</tr>
<tr>
<td>12</td>
<td>31</td>
<td>110,471270</td>
<td>10,470434%</td>
</tr>
</tbody>
</table>

The effective rate for the whole year is equal \( 10,471270\% \)

(b)

On a 30/360 basis, the effective rate is \( (1+10\%/12)^{12} = 10,471307\% \)

(c)

The equivalent continuously compounded rate is equal to \( \ln(1+10,47\%) = 9,96\% \).
Discount rate
Some money market instruments (Treasury bills, NBP bills) are quoted on discount rate basis. The discount rate is calculated as the discount divided by the face value of the bill multiplied by the number of periods of length t in a 360-day year:

\[
d_t = \frac{\text{discount}}{\text{face value} \times t}
\]

Actually in Poland the appropriate yield for bills is calculated (spot rate) on a a/360 days basis.

\[
z_t = \frac{\text{discount}}{\text{face value} - \text{discount}} \times \frac{360}{t} = \left(\frac{\text{face value} - \text{discount}}{\text{face value} - \text{discount}} - 1\right) \times \frac{360}{t}
\]

It can be shown that two rates are interrelated:

\[
d_t = \frac{z_t}{1 + z_t} \quad \text{and} \quad z_t = \frac{d_t}{1 - d_t} \times \frac{360}{t}
\]

Because yield for bills is calculated on a/360 basis, we can calculate the equivalent money market yield:

\[
y_t = \frac{z_t}{360}
\]

All the above stated three rates are not annualized returns. The effective annualized rate is

\[
i = \left(1 + y_t \times \frac{t}{365}\right)^{365} - 1 \quad \text{or} \quad i = \left(1 + z_t \times \frac{t}{360}\right)^{365} - 1
\]

Problem 2. Discount rate and effective rate
The face value of a Treasury bill is 10000 zl. Maturity is 65 days. The yield is 4,50%.

(a) What is the present value of one bill?
(b) Calculate discount, discount rate, spot rate (a/365) and effective annualized rate.
(c) What is your net income after tax (tax rate is 20 per cent).

Solution

(a)
Price 9919,40
Yield \((10000/9919,40 - 1)\times 360/65=4,500\%

(b)

<table>
<thead>
<tr>
<th>Discount rate</th>
<th>80,60 zl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount rate</td>
<td>4,464%</td>
</tr>
<tr>
<td>Spot rate a/360 (z_t)</td>
<td>4,500%</td>
</tr>
<tr>
<td>Spot rate a/365 (y_t)</td>
<td>4,562%</td>
</tr>
<tr>
<td>Effective rate (i)</td>
<td>4,649%</td>
</tr>
</tbody>
</table>

\[
i = \left(1 + y_t \times \frac{t}{365}\right)^{365} - 1
\]

(c)
Interest after tax is equal to 80,60 x 0,8 =64,48.
Problem 3. Discount rate and effective rate

Treasury bills auction on October 2, 2003

<table>
<thead>
<tr>
<th>Value date</th>
<th>03-10-03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of bill</td>
<td>10 tyg.</td>
</tr>
<tr>
<td>ISIN</td>
<td>PL0000000790</td>
</tr>
<tr>
<td>Maturity</td>
<td>12-12-03</td>
</tr>
<tr>
<td>Supply</td>
<td>3500,00 mln zł</td>
</tr>
<tr>
<td>Demand</td>
<td>6243,20 mln zł</td>
</tr>
<tr>
<td>Accepted offers</td>
<td>3500,00 mln zł</td>
</tr>
<tr>
<td>Minimum price</td>
<td>9 899,01 zł</td>
</tr>
<tr>
<td>Average price</td>
<td>9 899,77 zł</td>
</tr>
<tr>
<td>Maximum price</td>
<td>9 903,71 zł</td>
</tr>
<tr>
<td>Maximum yield</td>
<td>5,247%</td>
</tr>
<tr>
<td>Average yield</td>
<td>5,207%</td>
</tr>
<tr>
<td>Minimum yield</td>
<td>5,000%</td>
</tr>
</tbody>
</table>

(a) Show calculations of maximum, minimum and yield.
(b) Calculate, discount, discounting, rate and effective annualized rate.

**Solution**

(a)
Number of days to maturity 70
Maximum yield \[(10000/9899,01 - 1) \times 360/70 = 5,247%\]
Average yield \[(10000/9899,77 - 1) \times 360/70 = 5,207%\]
Minimum yield \[(10000/9903,71 - 1) \times 360/70 = 5,000%\]

(b)

<table>
<thead>
<tr>
<th>Discount</th>
<th>Discount rate</th>
<th>Spot rate</th>
<th>Effective rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>100,99 zł</td>
<td>5,194%</td>
<td>5,247%</td>
<td>5,359%</td>
</tr>
<tr>
<td>100,23 zł</td>
<td>5,155%</td>
<td>5,207%</td>
<td>5,318%</td>
</tr>
<tr>
<td>96,29 zł</td>
<td>4,952%</td>
<td>5,000%</td>
<td>5,102%</td>
</tr>
</tbody>
</table>

Factors influencing interest rates
- Maturity (duration)
- Credit risk
- Size of the loan or deposit

**Yield curves**
The term structure of interest rates is a function that relates the term to maturity to annualized interest rates.

The shape of yield curve is explained by number of theories. The most popular theories are:
- expectations theory,
- liquidity preference theory,
- market segmentation theory.
RISK MANAGEMENT [6352-02]

- **Rate of rising**
- **Rate of flat**
- **Rate of humped**
- **Rate of declining**

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- **Rate upward parallel shift**
- **Initial curve**
- **Downward parallel shift**

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- **Rate flattening**
- **Initial curve**
- **Steepening**

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- **Rate of initial curve**
- **Positive butterfly shift**
- **Negative butterfly shift**