Interest Rate Risk Management using Duration Gap Methodology

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Abstract. *The world for financial institutions has changed during the last 20 years, and become riskier and more competitive-driven. After the deregulation of the financial market, banks had to take on extensive risk in order to earn sufficient returns. Interest rate volatility has increased dramatically over the past twenty-five years and for that an efficient management of this interest rate risk is strong required. In the last years banks developed a variety of methods for measuring and managing interest rate risk. From these the most frequently used in real banking life and recommended by Basel Committee are based on: Reprising Model or Funding Gap Model, Maturity Gap Model, Duration Gap Model, Static and Dynamic Simulation.*

The purpose of this article is to give a good understanding of duration gap model used for managing interest rate risk. The article starts with a overview of interest rate risk and explain how this type of risk should be measured and managed within an asset-liability management. Then the articles takes a short look at methods for measuring interest rate risk and after that explains and demonstrates how can be used Duration Gap Model for managing interest rate risk in banks.

Key words: interest rate; risk; management; assets and liabilities; duration gap; bank; interest rate risk.

1. Interest rate risk management – overview

First of all, we consider that it is necesary to give a definition to interest rate risk. Interest-rate risk can be defined as "a loss ensuing from an adverse change in cash flow and from an adverse change in the value of interest-rate sensitive assets and liabilities, in consequence of a change in interest rates."(1) If the change in interest rates is favourable or unfavourable depends on the presence of certain components, or sources of interest-rate risk in the balance sheet and off-balance sheet accounts of the bank. In this context, the most important three sources of interest rate risk can be:

- *Maturities mismatching* of balance sheet and off-balance sheet items, which can be defined as a non-alignment in the maturity (in the case of fixed interest rates) and revaluation (in the case of variable interest rates) of assets, liabilities and off-balance sheet instruments.
- *Basis value risk* which is connected with the imperfect correlation in the adaptation of interest rates to assets and liabilities with otherwise similar maturities and revaluation. In the case of a change in an interest rate, these differences in adaptation of interest rates can cause an adverse impact on financial flows and the value of the bank.
- *Yield curve risk*, which arises when changes in the values, slope and shape of the yield curve have an adverse impact on the financial flows and value of the bank.

In this case the unexpected fluctuation of the level of interest rates can affect the banking profitability in two ways:

- *Exploitation risk* which consists in losses caused by the decreasing of interest income;
- *Balance sheet risk,* determined by the deterioration of the bank's patrimony (decreasing of the equity) as a result of the variation of interest rate in the market.

In this context, it is vital that banks have comprehensive risk management processes in place that identify, measure, monitor, and control a bank's exposure to interest rate risk. A bank's ALCO is responsible for monitoring the bank's risk and return profile. Traditional asset and liability management focuses on measuring interest rate risk and monitoring performance, setting policies to stabilize or increase net interest income. Senior management must ensure that the structure of the bank's business and the level of interest rate risk it assumes are effectively managed, that appropriate policies and procedures are established to control and limit these risks, and that resources are available for evaluating and controlling interest rate risk.

2. Interest rate risk measurement techniques

From the historical point of view, the higher the interest rates fluctuations are, the more sophisticated the coverage of the interest rate risk becomes. Thus, various models used for measure of the interest rate risk were identified:

- Reprising Model or Funding Gap Model = based on gap between sensible assets and liabilities;
- Maturity Gap Model = based on the maturity gap;
- Duration Gap Model = based on duration gap;
- Static and Dynamic Simulation.

These methods are also recommended by the Basel Committee[2] in order to create a standardized model which can be used by the regulatory authorities for evaluating the banks exposure to interest rate risk.

Main elements of these interest rate risk measurement models (technics) take into consideration the following elements:

- *Changing the market value* of the equity or the assets and liabilities portfolio, namely an economic perspective of the risk management;
- *Changing the net income resulting from the interest*, namely the risk management from the income perspective.

Many techniques available for measuring the interest rate risk exposure are orientated both to modifications in earnings and modifications in economic value of equity. Their complexity ranges from simple calculations to static simulations using current holdings to highly sophisticated dynamic modelling techniques that reflect potential future business and business decisions. From the models shown above, used in the interest rate risk management, we shall present the duration gap model.

3. Duration gap model

Duration gap (DGAP) model focuses on managing net interest income or the market value of stockholders' equity, recognizing the timing of all cash flows for every security on a bank's balance sheet. Unlike static GAP analysis, which focuses on rate sensitivity or the frequency of repricing, duration gap analysis focuses on price sensitivity.[3] Duration gap and market value of equity sensitivity analysis represent alternative methods of analyzing interest rate risk. They emphasize the price sensitivity of assets and liabilities to changes in interest rates and the corresponding impact on stockholders' equity. As the labels suggest, they incorporate estimates of the duration of assets and duration of liabilities, which reflect the value of promised cash flows through final maturity. Duration gap analysis compares the duration of bank assets with the duration of bank liabilities and examines how the market value of stockholders' equity

will change when interest rates change. This analysis requires that a bank to specify a performance target (the market value of equity or net interest income) and strategically manage the difference between the average duration of total assets and the average duration of total liabilities (DGAP).

The general relationship between the sign of a bank's duration gap and the impact of changing rates on market value of equity is summarized below:

DGAP Summary

Table 1

DGAP	Change in Interest rate	Change in market (economic) value				
		Assets		Liabilities		Equity
Positive	Increase	Decrease	>	Decrease	$\Rightarrow$	Decrease
Positive	Decrease	Increase	>	Increase	$\Rightarrow$	Increase
Negative	Increase	Decrease	<	Decrease	$\Rightarrow$	Increase
Negative	Decrease	Increase	<	Increase	$\Rightarrow$	Decrease
Zero	Increase	Decrease	=	Decrease	$\Rightarrow$	None
Zero	Decrease	Increase	=	Increase	$\Rightarrow$	None

4. Aplication of duration gap model for managing interest rate risk in commercial banks – study case

In this paragraph we explain and demonstrate how can be used Duration Gap Model for managing interest rate risk in commercial banks. Before application of model, we consider necessary to present the working hypothesis:

- The analysis assumes that there will be no defaults, prepayments, or early withdrawals.
- All securities make equal annual interest payments with annual compounding.
- The duration of cash is zero because cash doesn't change in value when interest rates change.
- At the initial time, for each balance sheet item, the nominal interest rate is equal with the market interest rate.
- The effects of both on- and off-balance sheet items are incorporated.

We shall take into consideration the balance sheet of a hypothetic bank "Omega Bank" which on 30.06.2007 have the following structure:

Balance sheet on 30.06.2007 (mil. Euro)

Table 2

Assets	MV	Rate (%)	Liabilities	MV	Rate (%)
Cash	1,500	0	Time deposit (1 yr)	3,700	6
Commercial loan (3 yr)	3,000	14	Certificate of Deposit (3 yr)	3,000	8
Treasury bond (5 yr)	2,500	11	Certificate of Deposit (6 yr)	1,800	10
Morgage (10 yr)	3,000	12	Debts	8,500	
			Equity	1,500	
Total assets	10,000		Total Liabilities	10,000	

As shown by this balance sheet, the value of assets is of 10,000 thousand RON, the value of debts is of 8,500 thousands RON and the value of equity[4] is of 1,500.

Aplication of Duration Gap Model consists in the following steps:

1. Calculation of the market value corresponding to each balance sheet item (assets, debts, equity)

■ The market value of each balance sheet item is calculated as an actualized sum of the cash-flows generated in the future by the balance sheet item as follows:

$$Vp = P_0 = \sum_{t=1}^{n} \frac{CF_t}{(1+k)^t} + \frac{VR_n}{(1+k)^n},$$

$$CF_t = VN \times r, VR = VN$$

where:

CF_t = cash flow generated in year t (annual rate);

VN = nominal (accounting) value of each balance sheet item;

VR = value to be paid on the maturity (in the final year);

k = market interest rate;

r = nominal rate of interest;

n = number of years at the maturity.

Example[5]: For a commercial loan with three years maturity (CL3Y), the market value is calculated as follows:

$$Vp = (CL3Y) = P_0 = \frac{3.000 \times 0.14}{1.14} +$$

$$+ \frac{3000 \times 0.14}{(1.14)^2} + \frac{3000 \times 0.14}{(1,14)^3} + \frac{3.000}{(1,14)^3} = 3.000$$

At the initial moment, the market value of each balance sheet item is equal with the accounting value (VN) because the nominal rate of the interest is equal with the market interest rate.

- The market value of the equity (E=equity) is calculated as a difference between the market value of the assets (A=assets) and the market value of debts (L=liabilities), as follows:

$$Vp(E) = Vp(A) - Vp(L)$$

Assets	Liabilities
	Equities

Exemple:

$Vp(E) = Vp(A) - Vp(L) = 10.000 - 8.500 = 1.500$

2. Calculation of the duration of each balance sheet item

The duration (D) of each balance sheet item is calculated by using the Macauly formula:

$$D = \frac{\sum_{t=1}^{n} t \times \frac{CF_t}{(1+k)^t} + n \times \frac{VR_n}{(1+k)^n}}{\sum_{t=1}^{n} \frac{CF_t}{(1+k)^t} + \frac{VR_n}{(1+k)^n}} =$$

$$= \frac{\sum_{t=1}^{n} t \times \frac{C_t}{(1+k)^t} + n \times \frac{VR_n}{(1+k)^n}}{P_0}$$

Exemple: For Commercial Loan with three years maturity, the duration is calculated as follows:

$$D(CL3Y) = \frac{\frac{3.000 \times 0.14}{1,1} \times 1 + \frac{3.000 \times 0.14}{(1,1)^2} \times 2 + \frac{3.000 \times 0.14}{(1,1)^3} \times 3 + \frac{3.000}{(1,1)^3} \times 3}{\frac{3.000 \times 0.14}{1.14} + \frac{3000 \times 0.14}{(1.14)^2} + \frac{3000 \times 0.14}{(1,14)^3} + \frac{3.000}{(1,14)^3}} = 2.65$$

3. Calculation of the average duration of assets and liabilities

The average duration of assets/debts was calculated as an average of duration of each asset/debt with weight of the market value of asset/debt in the market value of the total assets/total debts.

$$D_A = \sum_{i=1}^{n} X_{Ai} \times D_{Ai} \quad D_L = \sum_{i=1}^{n} X_{Li} \times D_{Li},$$

where;

D_A/D_L = average duration of assets/debts;

D_{Ai}/D_{Li} = duration of the asset/debt;

X_{Ai}/X_{Ai} = weight of the market value of asset/debt in the market value of the total assets/total debts.

Example

$$D_A = 0 \times \frac{1.500}{10.000} + 2.6467 \times \frac{3.000}{10.000} +$$
$$+ 4.1024 \times \frac{2.500}{10.000} + 6.3282 \times \frac{3.000}{10.000} = 3.7181$$

$$D_L = 1.000 \times \frac{3.700}{8.500} + 2.7833 \times \frac{3.000}{8.500} +$$
$$+ 4.7908 \times \frac{1.800}{8.500} = 2.4321$$

The results of the first three steps are shown in the following balance sheet:

Market value balance sheet, as of 30.06.2007

Table 3

Assets	MV(Vp)	Rate (%)	DUR	Liabilities	(MV)Vp	Rate (%)	DUR
Cash	1,500	0	0	Time deposit (1yr)	3,700	6	1.0000
Commercial loan (3yr)	3,000	14	2.6467	Certificate of Deposit (3yr)	3,000	8	2.7833
Treasury bond (5yr)	2,500	11	4.1024	Certificate of Deposit (6yr)	1,800	10	4.7908
Treasury bond (10yr)	3,000	12	6.3282	Debts	8,500		2.4321
				Equity	1,500		
Total assets	10,000		3.7181	Total Liabilities	10,000		

4. Calculation of duration GAP (DGAP)

DGAP shall be calculated as follows:

$$DGAP = -(DA - DL \times l),\ l = \frac{L}{A}$$

$$DGAP = -(3.7181 - 2.4321 \times 0.85) = 1.6508,$$
$$l = 8{,}500/10{,}000 = 0.85$$

In the analyzed case, the average duration of assets exceeds the average duration of liabilities, which emphasizes the existence of the interest rate risk (DGAP = 0.85). The higher the value of this indicator is, the higher the potential modification of the equity market value is, when such modifications of the market interest rate shall appear. Therefore, in order to eliminate the interest rate risk it is necessary to reduce the duration gap to zero.

5. Immunization of the bank balance sheet by reducing DGAP to zero

In order to protect the equity to the variations of the market interest rate, Omega Bank shall reduce the duration ecart to zero (DGAP = 0), thus:

- Either by reducing the duration of the assets;
- Or by increasing the duration of debts;
- Or by changing the levier effect (l = weight of the debts in the total assets at the market value).

In our example, we shall use the second hypothesis, i.e. the increase of the liabilities assets by issuance of Zero Cupon Certificates of Deposit with 7 years[6] maturity and reducing the weighted of the deposits with 1 year maturity. For this, we shall proceed as follows:

$$DGAP = 0$$

$$DGAP = -(3.7181 - D_L \times 0.85) = 0 \Rightarrow$$

$$D_L = \frac{3.7181}{0.85} = 4.3742$$

$$D_L = 1.000 \times \frac{3.700 - X}{8.500} + 2.7833 \times \frac{3.000}{8.500} +$$
$$+ 4.7908 \times \frac{1.800}{8.500} + 7.000 \times \frac{X}{8.500} = 4.3742$$

$$\Rightarrow \quad X = 2751.25 \approx 2.751$$

Thus, it shall be issued zero cupon certificates of deposit amounting 2.751, and the deposits with one year maturity shall decrease to the value of 949. Under such circumstances, DGAP is zero and, thus, it takes place a balance sheet immunization to the changes of the market interest rate (regardless of the modification of the market interest rate, the market value of the equity shall remain unchanged, i.e. 1.500).

Therefore, after the immunization, the Omega Bank balance sheet shall have the following structure:

Balance sheet after DGAP reduction to zero (mil. Euro)

Table 4

Assets	MV	Rate (%)	Duration	Liabilities	MV	Rate (%)	Duration
Cash	1.500	0	0,0000	Time deposit (1yr)	949	6	1,0000
Commercial loan (3yr)	3.000	14	2,6467	Certificate of Deposit (3yr)	3.000	8	2,7833
Treasury bond (5yr)	2.500	11	4,1024	Certificate of Deposit (6yr)	1.800	10	4,7908
Mortgage (10yr)	3.000	12	6,3282	Zero coupon CD (7yr)	2.751	11	7,0000
				Debts	8.500		4,3742
				Equity	1.500		
Total assets	10.000		3,7181	Total Liabilities	10.000		

6. Forecast interest rates

We assume that the forecast analysis indicate an increase of the market interest rate with 0.5% for each asset and liability.

The increase of the market interest rate affects the market value of the balance sheet items (their decrease) and consequently it shall produce a decrease of the market value of equity in case the immunization would not be done. This fact occurs because DGAP>0, and the extent to which the market value of the assets decreases exceeds the extent to which the market value of the debts decreases. This fact shall produce a decrease of the market value of equity.

In case of a perfect immunization of balance sheet, the decrease of the market value of assets will be equal with the decrease of the market value of debts, and the market value of equity will remain unchanged. We shall demonstrate this in the following stages.

7. Estimate the new market value of bank assets and liabilities after increase of interest rate without immunization of balance sheet of bank

Estimation of the new market value (after increase of market interest rate) of the assets/liabilities will be done by using the following formulas:

$$A_1=A_0+\Delta A,\ \Delta A=-\frac{1}{1+k}\times DA\times A\times(\Delta k)$$

$$P_1=P_0+\Delta P,\ \Delta P=-\frac{1}{1+k}\times DP\times P\times(\Delta k)$$

For example, for a commercial loan with 3 years maturity, the increase of the interest rate with 0.5% shall produce a decrease of the market value of this item in the following way:

$$\Delta A(CL3Y)=-\frac{1}{1+0.14}\times 2.6467\times \times 3.000\times(0.005)=-34.825 \Rightarrow$$

$$A_1(CL3Y)=3.000-34.825=2.965.175\approx 2.965$$

The table below synthesizes the influence of increasing interest rate with 0.5% on the market value of balance sheet items.

The effects of increasing interest rate with 0.5% (without immunization)

Table 5

	Initial interest rate	Duration	Value	Interest variation	Balance sheet var.	New value
Commercial loan (3 yr)	1.14	2,6467	3.000	0.005	-35	2.965
Treasury bond (5yr)	1.11	4,1024	2.500	0.005	-46	2.454
Morgage (10yr)	1.12	6,3282	3.000	0.005	-84	2.916
Time deposit (1yr)	1.06	1,0000	3.700	0.005	-17	3.683
Certificate of Deposit (3yr)	1.08	2,7833	3.000	0.005	-38	2.962
Certificate of Deposit (6yr)	1.10	4,7908	1.800	0.005	-38	1.762

8. Redrafting the balance sheet in market values, after modification of market interest rate and the calculation of the new market value of equity (without immunization)

Balance sheet in market values after the increase of interest rate, without immunization (thousand Euro)

Table 6

Assets	MV	Rate (%)	Duration	Liabilities	MV	Rate (%)	Duration
Cash	1.500	0	0,0000	Time deposit (1yr)	3.683	6.50	1,0000
Commercial loan (3 yr)	2.965	14.50	2,6446	Certificate of Deposit (3yr)	2.962	8.50	2,7818
Treasury bond (5yr)	2.454	11.50	4,0935	Certificate of Deposit (6yr)	1.762	10.50	4,7765
Mortgage (10yr)	2.916	12.50	6,2763	Debts	8.407		2,4191
				Equity	1.429		
Total assets	9.835		3,6798	Total Liabilities	9.835		

The market value of equity is calculated by using the formula: Vp(E) = Vp(A) –Vp(L).

Example: Vp(E) = 9.835 – 8.407 = 1.429, i.e. the market value of equity decreases with 71 (starting from value of 1.500), because of a bad management of interest rate risk.

9. Estimate the new market value of bank assets and liabilities after increase of interest rate with perfect immunization of balance sheet of bank

Estimation of the new market value (after increase of market interest rate) of the assets/liabilities shall be done by using the same methodology as used in seventh stage.

The effects of increase the interest rate with 0.5% (after immunization)

Table 7

	Initial interest rate	Duration	Value	Interest variation	Variatia elem bil	New value
Commercial loan (3yr)	1.14	2,6467	3.000	0.005	-35	2.965
Treasury bond (5yr)	1.11	4,1024	2.500	0.005	-46	2.454
Mortgage (10yr)	1.12	6,3282	3.000	0.005	-84	2.916
Time deposit (1yr)	1.06	1,0000	949	0.005	-4	946
Certificate of Deposit (3yr)	1.08	2,7833	3.000	0.005	-38	2.962
Certificate of Deposit (6yr)	1.10	4,7908	1.800	0.005	-38	1.762
Zero coupon CD (7yr)	1.11	7,0000	2.751	0.005	-85	2.665

10. Redrafting the balance sheet in market values, after modification the market interest rate and calculation of the new market value of equity (after balance sheet immunization)

The methodology used in this stage is the same with that used in the eighth stage.

Balance sheet after 0.5% interest rate increase

Table 8

Assets	MV	Rate (%)	DUR	Liabilities	MV	Rate (%)	DUR
Cash	1.500	0.00	0,0000	Time deposit (1yr)	945	6.50	1,0000
Commercial loan (3 yr)	2.965	14.50	2,6446	Certificate of Deposit (3yr)	2.962	8.50	2,7818
Treasury bond (5 yr)	2.454	11.50	4,0935	Certificate of Deposit (6yr)	1.762	10.50	4,7765
Treasury bond (10 yr)	2.916	12.50	6,2763	Zero coupon CD (7yr)	2.666	11.50	7,0000
				Debts	8.335		4,3510
				Equity	1.500		
Total assets	9.835		3,6798	Total Liabilities	9.835		

After calculations, it can be noticed that while the increasing of market interest rate with 0.5%, the market value of total assets decreases with 165 (from 10.000 to 9.835) and with the same value also the market value of total debts decreases (from 8.500 to 8.335). Under such circumstances, the market value of the equity remains unchanged due to the fact that a perfect immunization of balance sheet to the fluctuations of market interest rate was done (DGAP = 0).

Notes

(1) See Marek Lièák, National Bank of Slovakia, On the Measurement of Interest-Rate Risk, http://www.nbs.sk

(2) According to Basel Committee on Banking Supervision, "Principles for Management and Supervision of Interest Rate Risk", 2004, http://www.bis.org

(3) GAP and duration gap represent two ways of viewing interest rate risk. For understanding the difference it is necesary to make the difference among rate sensitivity and price sensitivity. Rate sensitivity refers to the ability to reprice the principal on an asset or liability. Price sensitivity refers to how much the price of an asset or liability will change when interest rates change. So, GAP and earnings-sensitivity analysis focus on how frequently the principal amount of an asset or liability will reprice and duration gap analysis focus on how much the market value of an asset or liability will change when interest rate change.

(4) The market value of equity represents the residual (plug figure) between asset and liability values

(5) All the dates are in mio. eur

(6) For Zero Cupon Certificates of Deposit the duration is equal with maturity (eg. 7 years)

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