ON THE MEASUREMENT OF INTEREST-RATE RISK

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financial markets and significant changes in the structure of the balance-sheet and off-balance-sheet activities of banks. With these changes is closely connected the growing importance of interest-rate risk in banks. Even though the size of interest-rate risk is substantially smaller than credit risk, demands for its measurement are increasing. Greater demands upon sophistication in the measurement of interest-rate risk are connected mainly with the temporal non-alignment of assets and liabilities, and the existence of such products in bank portfolios, where in case of a movement in interest rates, a change in financial flows occurs (the existence of inserted options).

The growing demands on the methods used is borne witness to by the fact that where in the Seventies and Eighties gap analysis (even today in some banks this remains the main method of measuring interest-rate risk) fully sufficed for measuring interest-rate risk, today this method catches only a part of interest-rate risk.

Sources of Interest-Rate Risk

Before we examine individual methods of measuring interest-rate risk, we shall define interest-rate risk and its basic sources.

We can define interest-rate risk as a loss ensuing from:

• an adverse change in cash flow,

• an adverse change in the value of interest-rate sensitive assets and liabilities, in consequence of a change in interest rates.

Whether 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. The basic components of interest-rate risk may be said to include:

1. Maturities mismatching of balance sheet and off-balance sheet items, which we can define 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. The size and nature of the temporal non-alignment corresponds to a large extent to the forecast changes in interest rates. Building societies have a special standing in the banking sector in Slovakia, where the possibilities to manage the time structure of their assets and liabilities are limited by the nature of their business.

2. 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. Until 1 January 2004 building societies had a special standing in this source of interest-rate risk, where the law determined a 3-percentage range between interest rates on deposits are and building society loans.

3. 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.

4. Optionality, or the existence of inserted options in the assets, liabilities and off-balance sheet instruments. The risk lies in the fact that through the use of inserted options the expected financial flows from financial instruments change, which subsequently has an impact on the size of the interest-rate risk. An example of instruments with inserted options are for example various types of loans, bonds with the possibility of early repayment, current accounts, etc. The growing emergence of options in various banking products increases the importance of monitoring this source of risk.

Impact of Interest Rate Risk on a Bank

The use of various methods of measuring interest-rate risk is closely linked to the bank's possibilities to evaluate the impact of interest rate changes upon it. The impact of interest rate changes is most frequently evaluated in banks on interest-rate financial flows. This evaluation of the impact, which is most frequently connected with gap analysis, provides the bank a short-term view of its interest-rate risk.

From the aspect of banking supervision and from the long-term aspect of the bank on interest-rate risk it is important to evaluate the impact of interest rate changes on the economic value of expected net interest-rate sensitive financial flows. The economic value of expected net interest-rate sensitive financial flows (hereinafter referred to as the economic value) represents the difference between the current value of the expected interest-rate sensitive assets and the current value of the expected interest-rate sensitive liabilities, discounted by an appropriate interest rate. In evaluating the impact on the economic value the bank takes into consideration the overall impact of interest rate changes. Such an evaluation of the impact of interest rate changes takes into consideration the long-term perspective, enabling banks to avoid strategies maximising short-term revenues at the cost of exposing long-term revenues to greater risk.

In evaluating the impact of interest-rate changes we have so far mentioned only the impact on interest rate sensitive assets, liabilities and off-balance-sheet items. However, changes in interest rates also indirectly influence the non-interest-rate revenues of banks. Therefore it is appropriate when banks use models enabling them to quantify the impact of interest-rate changes on their overall revenues.

Methods of Measuring Interest Rate Risk

For measuring interest-rate risk banks use a variety of methods. The level of sophistication and complexity of individual methods varies. In professional literature[1] the most frequently stated are the analysis of maturity and re-pricing tables, or simply termed gap analysis, the duration gap method, the basis point value (BPV) method, and simulation methods.

Maturity and Re-Pricing Tables – Gap Analysis

This method is founded on the classification of interest-rate sensitive assets, liabilities and off-balance-sheet items into time bands defined in advance according to their maturity (in the case of fixed interest rates), or time remaining until the next re-pricing (in the case of variable interest rates). Through the difference between assets and liabilities in the individual time bands we discover the size of the gap positions (periodic gaps). Summing up the periodic gaps for a certain period, we get the cumulative gap for the given period. Through subsequently multiplying the cumulative position by the forecast change in the interest rate it is possible to ascertain the likely impact on interest financial flows.

In evaluating the impact of interest-rate changes on interest financial flows it is also possible to use a different method of calculating the cumulative gap - the weighted cumulative gap. In the case of this method individual cumulative gaps are weighted by the time periods during which they are exposed to a change in the interest rate.

Gap analysis is very popular in banks and is often used mainly due to its simplicity. This method was created at the end of the Sixties in the USA (it began to be used in banks only during the Seventies). The analysis principle is founded on the economic and banking conditions of the Seventies, i.e. stable interest rates, the bank's balance sheet comprised mainly simple instruments with a fixed interest rate and the golden balance rule applied in banks.

The current economic environment differs considerably from that of the Sixties and Seventies. Interest rates exhibit a high degree of volatility, in consequence of which banks often own in their portfolios products with variable interest rates, or inserted options. A time mismatching between assets and liabilities is typical for classical commercial banks.

As we have already mentioned, building societies have a special standing in the banking sector in Slovakia, which results from the nature of their business. Assets and liabilities are tied up mainly in longer time bands with fixed interest rates and in comparison with classical commercial banks they have a relatively greater time alignment of interest-rate sensitive assets and liabilities. Mainly due to the long time period for which assets and liabilities are tied up, it is appropriate for a building society to use a method enabling it to evaluate the impact of interest-rate changes in particular on the economic value.

The precision of gap analysis to a significant degree depends on the classification of interest-rate sensitive items into time bands. The majority of products are classified from the aspect of their immediate maturity, or re-pricing.

The situation becomes more complicated in the case of instruments, where a change in the market interest rate can cause a change in the forecast financial flow. A bank should endeavour to classify individual items into those time bands most corresponding to reality. In this banks are able to use previous experience or various simulation methods.

[1] Of a number of publications devoted to measuring interest rate risk, the most comprehensive description is given by Nawalkha and Chambers in the publication Interest Rate Risk Measurement and Management, Institutional Investor, 1999.

A problematic aspect is determining the number and size of time bands. For example, bank A has decided for a time band with a length from one year to two years. On the side of assets it has interest-rate sensitive assets in the value of 100, the maturity of which is at the start of the time band; on the liabilities side it has instruments in an equal value of 100, but with a maturity at the end of the time band. As seen from gap analysis everything is all right, since the sum of assets equals the sum of liabilities in the given time band. In this way it is as if no interest-rate risk existed. However, in fact the interest rates at the beginning and at the end of the band are different, so the given time band does indeed contain an interest-rate risk.

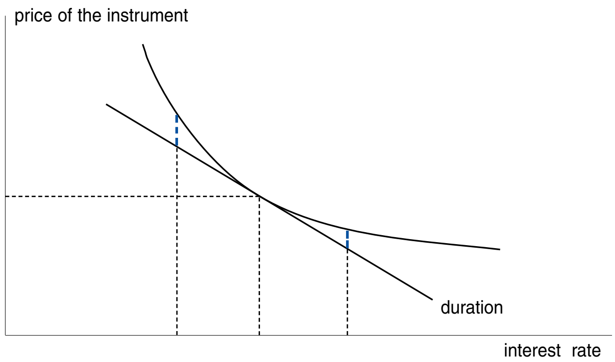
In determining the number of time bands the bank should work from the time structure of balance-sheet items. For example, in the case of building societies with assets and liabilities tied up for longer periods, it is appropriate to create a denser structure of time bands in the case of long-term assets and liabilities.

The analysis presumes a parallel change in all interest rates, whereby it does not take into consideration possible changes in the slope of the yield curve. This premise is removed from reality, since it is quite unlikely that interest rates in different time bands will change in the same amount. Gap analysis catches the impact on financial flows in time bands in the case of a change in an interest rate with the premise that the structure and size of balance sheet items in the time bands do not change. Such a static view does not really correspond to reality.

A further disadvantage is the fact that the analysis does not cover the basis value point risk. In the case mentioned above bank A has a balanced position in the time band. In the case of a change in the market interest rate there often occurs a different adaptation of the interest rates of assets and liabilities in the same time bands. This means that what the bank does not perceive as an interest-rate risk from the aspect of gap analysis can cause an unexpected impact on the interest revenues of the bank. Also problematic is the classification of items with inserted options, or items not having a period to maturity defined in advance.

Even where it is possible to partially remove the above shortcomings through various modifications of gap analysis, in the growing complexity of banking products this method is not able to fully capture all the sources of interest-rate risk. However, gap analysis continues to serve appropriately as a supplementary instrument for measuring interest-rate risk.

Relationship between a change in interest rate and a change in financial instrument price



Duration

In managing interest-rate risk the duration gap method is often used, which is based on the duration of balance sheet items. In determining the model for calculating the duration we work from a calculation of the net value of an instrument with *n* financial flows[2]. The price of the instrument is given by a function, which depends on the interest rate. Through the first derivation of the instrument's price according to the interest rate and the subsequent division of both sides of the equation by the value of the instrument we get the equation for calculating price volatility. If we replace the first derivation by differentials, we get a definition of the duration, the value of which is defined as the share of weighted financial flows (weighted by the time from the moment of valuation until maturity) and the current value of the financial flows.

In the equation duration features as an indicator of interest-rate risk which takes into consideration the distribution of individual financial flows.

For the price of an instrument it holds true that in the case of smaller interest-rate changes the changes of prices are the same as in the case of a fall or rise in interest rates. On the other hand, in the case of larger shifts in interest rates, the changes in the prices of an instrument in the case of a rise or fall are different. Duration does not fulfil this second condition, for which it holds true that in the case of however large changes in interest rates the subsequent changes in price are equal. For this reason duration as such is an appropriate indicator of interest-rate risk only in the case of small interest rate changes. This deviation – the degree of convexity, which arises in the case of larger interest-rate changes, may be found through a second derivation. The degree of convexity together with duration gives us the change

[2] In the case of instruments with one financial flow the duration is identical to the instrument's period to maturity.

in the value of the financial instrument also in the case of larger movements in interest rates. The relationship between the price and an interest rate is depicted in the following graph.

The above-mentioned manner of calculating duration does not take into consideration the possible change in the financial flow of a given instrument, where there occurs a movement in the interest rate. Such a case occurs in particular in instruments with inserted options. For calculating the duration of instruments with inserted options it is possible to use effective duration. The essence of effective duration lies in calculating current values in the case of various interest rates, with the fact that these take into consideration the possible changes in financial flows. Monte Carlo simulations or the binomial trees method are most frequently used for this purpose[3].

In quantifying the interest-rate risk of a whole portfolio the duration of individual asset and liability items must be determined and subsequently through weighting them by the values of assets and liabilities, the duration of all assets and liabilities is calculated.

The approximate impact on the bank's capital in the case of a change in interest rates may be determined in the following way:

$$\Delta E = -\left[D_A \,.\, A - D_P \,.\, P\right] \,.\, \frac{\Delta r}{(1 + r)}$$

where: ΔE is the change in the bank's capital, D_A is the duration of assets, D_p the duration of liabilities, P is the price of the financial instrument and r is the interest rate.

The basic method of the duration gap, working from a modified duration, does not capture the yield curve risk, basis value risk, or the risk of inserted options. Due to this banks use various modifications of the duration gap.

In measuring the risk of a change in the yield curve, banks use the partial duration method, which presumes non-parallel shifts of the yield curve. This method presumes shifts in individual points of the yield curve. Even if partial duration takes non-parallel shifts of the yield curve into consideration, a disadvantage is the fact that it does not take into consideration the correlation between individual points of the yield curve.

Ever more frequently used in measuring the risk of non-parallel shifts of the yield curve is the principal component analysis method, which allows the most probable shift in the yield curve to be determined. This method is based on the presumption that it is possible to explain what are at first view chaotic movements of individual points of the yield curve by systematic shifts of the yield curve, estimated on the basis of correlations of individual yields of the yield curve. For capturing the risk of inserted options it is possible to use the already-mentioned method of effective duration.

Duration, similarly as gap analysis, is founded on a static view of the size and structure of financial flows, which significantly limits the use of the results of such measurements for strategic purposes. The duration gap method, in contrast to gap analysis, provides a more comprehensive view of interest-rate risk. After performing appropriate modifications, leading to an overall coverage of the basic interest sources, the duration gap method can serve as the main instrument for measuring interest-rate risk.

Price Value of a Basis Point

In the case of duration we mentioned that it imprecisely captures the change in the price of the instrument in the case of larger interest rate changes. For capturing the convex relationship between the change in interest rates and the price of the instrument other methods may be used. Most often it is the method "Price Value of a Basis Point" (PVBP), or "Basis Point Value" (BPV), with the help of which we can calculate a change in the price of the financial instrument if the interest rate changes by one basis point (0.01%). Banks can, according to need, predict various changes in interest rates.

The method is based on calculating the present value of an instrument in the case of a certain market interest rate and comparing this value with the present value of the same instrument, but calculated for a different interest rate. The difference between the present values for the different interest rates represents a change in the value in the case of interest rate movements and is indicative of the sensitivity of the instrument's price to a change in the interest rate.

PVBP offers us a more comprehensive view of interest-rate risk than gap analysis. An advantage of PVBP is that it takes into consideration the different interest rate sensitivity of instruments with regard to the length of maturity and the size of coupons. In comparison with duration it captures directly the complex relationship between the change in the interest rate and the price of the instrument. The disadvantages of PVBP are to a large extent the same as those of duration. Similarly, as in the case of duration, it is possible, after performing appropriate modifications,

[3] Binomial trees depict changes in the prices of an instrument in short time periods, where in each period only two possible movements are forecast.

to use PVBP as the main method for measuring interest-rate risk.

Simulation Methods

A further group of techniques comprises simulation methods. These methods are founded on evaluating the potential simulated impacts of interest rates on the simulated development of assets, liabilities and off-balance-sheet liabilities. In the case of static simulations this is only a simulation of the development of interest rates, whereas in the case of dynamic simulations a bank simulates the development of interest rates and the development of individual balance-sheet and off-balance-sheet items. In the simulations there are most frequently used historical simulations, Monte Carlo simulations or the bootstrapping method[4].

In contrast to the methods stated above, the simulation methods have the prerequisites to identify all sources of interest-rate risk. The ability of the simulation methods to cover the basic sources of interest-rate risk depends on the degree of their sophistication.

Their use is important mainly due to the growing complexity of banking products. The simulation methods enable to eliminate the basic shortcomings of gap analysis, duration and PVBP, such as the classification of some products into time bands, optionality of products, correlation between interest rates, etc.

A disadvantage of these methods lies in their greater complexity and time demands for calculation. The rule of thumb applies that the greater the level of sophistication, the greater the difficulty of measuring the interest-rate risk.

Interest-Rate Risk in the Banking Sector in Slovakia

Among the banks operating in the Slovak banking sector a wide spectrum of methods are used for measuring interest-rate risk. Each bank is characterised by a specific characteristics which determine the suitability of the method used.

With regard to the ever more frequent occurrence of various structured and complicated instruments in balance-sheet and off-balance-sheet accounts of banks, for the purpose of measuring interest-rate risk, in covering all its sources, simulation methods appear the most appropriate.

Even despite their disadvantages, the duration gap and PVBP methods, following appropriate modifications, may be used as the main methods for estimating interest-rate risk.

We see the importance of gap analysis more in the position of a supplementary method to the main methods for measuring interest-rate risk.

In the final choice of a method a bank should take regard of the presence and size of individual sources of interest-rate risk in the balance sheet and off-balance-sheet accounts of the bank.

Banking supervision by the National Bank of Slovakia is limited in its selection of the manner of measuring interest-rate risk of the Slovak banking sector by the input data for its calculation. For this reason, in estimating the size of interest-rate risk, it has so for been limited only to using a modified form of gap analysis and PVBP methods.

In 2003 and in the first months of 2004, interest-rate risk in most banks developed in a stable manner and moved at relatively low levels. In the case of a parallel decrease in interest rates it is possible to expect a growth in interest financial flows and a positive impact on the real value of banks. In the case of an increase in interest rates it is possible to expect a similar influence, but in the opposite direction.

From stress tests performed it results that banks expect a further fall in interest rates, to which they are adjusting the time structure of assets and liabilities, mainly in the banking ledger.

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[4] The bootstrapping simulation is founded on simulations of new values with the help of a random re-alignment of the original values.