ONLINE ASSESSMENT OF INTEREST RATE RISK

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Abstract: In addition to being of great importance to bank managers (due to the particular significance of Interest Rate to banking institutions: its fluctuation is, at the same time, a premise for success AND potentially fatal in case of inadequate management), ***Interest Rate Risk*** *is of concern to any individual who possesses a financial portfolio (made up of loans, deposits, various investments, etc.), as any such portfolio may be endangered when exposed to fickle Interest Rates. Members of this latter category, however, are grossly neglected when it comes to availability of both information about and affordable or, better yet, free methods of protection against Interest Rate Risk.*

Approaches to Interest-Rate-Risk assessment, from the traditional, time-honored methods (maturity and repricing schedules) to the more complex and experimental ones, are at least partially suited for software implementation. Using the Internet as medium, fairly simple, yet effective methods of Interest-Rate-Risk assessment can be made available to a vast audience, including current and potential bank employees involved in risk management, individuals whose interest in the matter is academic or, quite simply, members of the general public aware of the implications of Interest-Rate variation upon their financial investments.

Introduction

The field of Banking and Finance, characterized, as it is, by a particularly stringent necessity for opportune decisions to be taken and acted upon at the right time, is relying more and more on computerized decision-support systems to provide it with the assessments, prognoses and increasingly complex interpretations it needs to devise its plans and policies and to defend its stability (a stability which depends, to a certain degree, on that of every individual institution in the financial system).

In Romania, a country, which, having only recently joined the European Union, is still undergoing the EU integration process, perhaps the most significant priority regarding the banking system is the implementation of Basel II guidelines on banking risk and its management.

This paper proposes a computerized banking-risk assessment solution, available through a website.

The chosen type of risk is **Interest Rate Risk**, which is of a particular significance to banking institutions: Interest Rate variation on the market is a premise for the successful operation of banking institutions as financial intermediaries, but this variation can come to be an equally genuine source of danger in case of inadequate management.

By combining complementary risk-assessment methods, the proposed software product can offer one a relevant idea on the sensitivity of a financial portfolio to Interest Rate variation.

Risk analysis has been implemented within a website in order to ensure accessibility for as many users as possible, given that Interest Rate Risk has, alongside its significance to banks, another characteristic that should be taken into account: it is of interest not only to employees of financial institutions, but to a larger audience: any individual who has taken out a loan and made a deposit is the owner of a "portfolio" potentially threatened by Interest Rate Risk.

1. Interest Rate Risk: Sources, Implications, Assessment Methods

Banking risk is the probability of occurrence of an event with unfavorable consequences for a banking institution. **Exposure** to such risk is the present value of losses which would be incurred by the institution in question if such an event were to occur [3].

Appropriate risk management within the banking institution is essential in order to avoid its bankruptcy, which (due to the systemic[1] nature of banking risk) may pose a direct threat to the stability of the banking system as a whole, at national and international level.

Interest Rate Risk represents the possibility of occurrence of unfavorable changes in interest-based earnings and/or interest-related expenses or in the value of interest-earning assets and interest-bearing liabilities, as a result of unplanned changes in Interest Rates.

The Basel Committee defines Interest Rate Risk as being "the exposure of a bank's financial condition to adverse movements in Interest Rates." [9, pg. 6].

In its paper "Principles for the Management of Interest Rate Risk" [9], the Committee draws attention to the following four sources of Interest Rate Risk: **repricing risk** (generated by assets, liabilities and off-balance-sheet positions maturing or repricing at different times), **yield curve risk** (arising from yield-curve shifts that have failed to be anticipated), **basis risk** (the result of inadequate correlation of Interest Rates attached to assets, liabilities and off-balance-sheet positions) and **optionality risk** (generated by the embedded options of assets, liabilities and off-balance-sheet portfolios).

Interest Rate Risk can affect portfolios in more ways than one: from the **earnings** point of view (through influence upon the Net Interest Income and, subsequently, upon the overall Net Income), as well as from the **economic value** point of view (when the present value of a portfolio is influenced adversely).

The Basel Committee sets forth no less than 11 principles for the management of this type of risk. It also enumerates and briefly describes available Interest-Rate-Risk assessment methods of varying complexity: **repricing schedules** ("Gap" and "Duration", the two methods implemented in the proposed software solution) and **simulation approaches** (static and dynamic).

2. Online Interest-Rate-Risk-Assessment Solution Proposal

The risk-analysis website proposed herein seeks to offer users an Interest-Rate-Risk assessment tool characterized by ease of use and included within a website available to any interested party.

In addition to simple evaluation, the site offers an export facility of analysis sheets to Excel format, allowing input data and results to be easily formatted, printed and put to uses such as risk-reporting or, simply, comfortable perusal.

The implementation of analysis methods within a website was chosen in order to ensure maximum accessibility for a vast audience.

At the time the present paper was being put together, the Internet held but little generally accessible information on Interest Rate Risk and its evaluation methods. Substantial compilation work was needed in order to achieve an accurate, satisfying perspective on the subject.

Furthermore, within banking institutions, risk evaluation takes place at high level and existing software solutions are, generally, inaccessible to the general public.

A serious study of the domain is, therefore, made difficult for "outsiders". Still, not only current employees of banking institutions have reasons to be concerned with Interest Rate Risk.

On envisioning and developing the Interest-Rate-Risk analysis website, possible and likely requirements of the following categories of potential users have been taken into account:

- **Employees of banking institutions (especially from the Risk-Management Committee)**: obviously, they make up the main group of individuals who might show interest in such a software

[1] Banking risk is deemed "systemic" due to the fact that the failure of a member institution of the banking system can set off a chain-reaction affecting the entire system. The classical example of such an occurrence is the bankruptcy of the Herstatt Bank (in 1974), an incident which, through its consequences, prompted the establishment of the Basel Committee for Banking Supervision [18].

solution, even if they are already using an Interest-Rate-Risk evaluation system at the banking institution where they work.

Why? Firstly, because such a website would offer them the chance to experience the advantages of a risk-evaluation method other than the one used by them before: for example, if they are currently relying on Gap Analysis, they will become aware of the increased complexity, relevance and precision of results obtained by way of Duration Analysis.

Bank employees who still assess risk by way of "pen and paper" or Excel worksheets may come to appreciate the advantages of computerized evaluation methods, which, although not yet apt to completely substitute the input of specialists in the field, can, nevertheless, complement it successfully.

- **Individuals interested in the educational aspect of the website**: students of Finance or related fields, who do not have access to commercial risk-management software; potential bank employees who wish to train in the domain of Interest-Rate-Risk evaluation. By defining and explaining all concepts used in the evaluation methods, as well as by offering detailed interpretation of results, the website has an obvious educational character.
- **The general public**: not only a banking institutions have "portfolios" of the type analyzable by the proposed methods.

  The present value and **future value** of our investments are of concern to all of us and they are exposed to Interest Rate Risk.

The proposed website offers users the following features:

- Interest Rate Risk assessment through two methods ("Duration Gap Analysis" and "Gap Analysis")
- results accompanied by interpretations
- various graphs
- export of worksheets to .xls format.

In order to gain access to the functionality of the website, users would be required to create online user accounts. After creating such an account, one would be allowed to define financial portfolios which can be then subjected to assessment and saved for later reference and adjustment.

3. Implemented Risk-Assessment Methods

The two approaches to Interest-Rate-Risk assessment implemented in the proposed website are Duration Gap Analysis and simple Gap Analysis. They are to be conducted according to the algorithms described in the following two subchapters.

3.1 Duration Gap Analysis

Duration is the Weighted Average Maturity of cash flows attached to portfolio components. The value of Duration indicates the percentage change in the Market Value of the portfolio/portfolio component brought about by a 1% variation in Interest Rate on the market [2].

This particularly relevant temporal indicator provides the basis for the main Interest-Rate-Risk evaluation method implemented through the proposed software solution.

Duration is not calculated solely for the entire fixed-income financial portfolio, but also for each Interest-Rate-earning asset and Interest-Rate-bearing liability within it.

The Duration of portfolios which include such assets and liabilities does not exceed 12-13 years, although portfolio components may have an average maturity of as much as 25-30 years [16].

At elementary level, the significance of Duration value may be interpreted thus: the higher the Duration, the higher the price changes for any give change in Interest Rates. The higher the coupon[2] of the portfolio component for which Duration is computed, the lower the Duration and, subsequently, the price change for any given change in Interest Rates [14 ,pg. 4].

The greater the Duration of a portfolio, the greater the Interest Rate Risk to which the portfolio in question is exposed!

[2] Fixed periodic interest payment [18].

The general calculation formula of **Duration** for an entire portfolio is [2]:

$$Duration = \frac{\sum_{i}^{n}(maturity \times PV)}{\sum_{i}^{n} PV}$$

where **n** is the number of cash flows and **PV** the present value of one such cash flow.

Duration can be computed in more than one way: **Macaulay Duration**, on the calculation of which one assumes interest to be continuously compounded and **Modified Duration**, more appropriately adapted to real-life market conditions. When calculating Modified Duration, one takes into account the com- pounding frequency of the Interest Rate [18].

In the context of actual Interest-Rate-Risk management, Duration is put to use during the process of bank-portfolio immunization.

The **immunization** of a banking institution to Interest-Rate-Risk variation on the market involves the structuring of assets and liabilities in such a way as to ensure the stability of the interest spread and its relative independence of Interest-Rate variation on the market.

In practice, immunization is achieved by way of an opposite portfolio component/portfolio (where assets are considered to be the opposite of liabilities and vice versa) of the same Duration and present value as the portfolio component/portfolio which is to be protected [2, pg. 204,205].

Duration Analysis is the Interest-Rate-Risk assessment method based on Duration and there are several versions of it in use, as variations of the method can be applied either to sensitive assets and liabilities or to the gaps between them [6]. "Duration Gap Analysis" is the version implemented within the proposed software solution.

This risk-assessment algorithm consists of the following steps [14, pg. 3]:

- The Market Value of those assets and liabilities which are sensitive to the variation of Interest Rates is estimated and Market Value of Equity is determined.
- Duration is calculated for each class of assets and liabilities within the on-balance-sheet portfolio.
- The Weighted Average Duration of Assets and the Weighted Average Duration of Liabilities are determined.
- The **Duration Gap** is calculated by subtracting the Weighted Average Duration of Liabilities from that of Assets.
- The variation of the Market Value of Equity caused by a given variation of Interest Rates is estimated. One must take into account Interest-Rate variations by several different percentages.

Duration will be determined by way of the following formula[3]:

$$D = \frac{\sum_{t=1}^{n} \frac{CF_t(t)}{(1+y)^t}}{\sum_{t=1}^{n} \frac{CF_t}{(1+y)^t}} (*)$$

where **CFt** is the cash flow at time **t**, **t** the number of periods of time until the cash flow reaches maturity, **y** the yield to maturity of the asset or liability generating the cash flow and **n** the number of cash flows.

In order to calculate Duration Gap, one must first determine the Weighted Average Duration of Assets, as well as the Weighted Average Duration of Liabilities.

The Weighted Average Duration of Assets ("DA") is determined by way of the formula:

$$\sum_{a}^{n} W_a D_a (*)$$

[3] The source of the formulas marked (*) is the paper "Guidelines on Stress Testing", by the State Bank of Pakistan [14].

where $\mathbf{W_a}$ is the market value of asset **a** divided by the market value of all assets in the portfolio, $\mathbf{D_a}$ the Duration of asset **a** and **n** the number of assets.

The Weighted Average Duration of Liabilities ("DL") is determined by way of the formula:

$$\sum_{l}^{m} W_l D_l \ (*)$$

where $\mathbf{W_l}$ is the market value of liability **l** divided by the market value of all liabilities in the portfolio, $\mathbf{D_l}$ the Duration of liability **l** and **m** the number of liabilities.

Duration Gap is calculated by way of the following formula:

$$DGAP = DA - \frac{MVL}{MVA} \times DL \ (*)$$

where **DA** is the Weighted Average Duration of Assets, **DL** the Weighted Average Duration of Liabilities, **MVA** the Market Value of Assets and **MVL** the Market Value of Liabilities.

Market Value of Equity is also of interest in the context of Duration Gap Analysis, as, based on Duration Gap, one can estimate the effect of possible Interest-Rate variation upon this value.

MVE is calculated by way of the following formula:

$$\Delta MVE \cong (-DGAP) \times \frac{\Delta i}{1+y} \times TotalAssets \ (*)$$

where DGAP is the Duration Gap of the portfolio, $\mathbf{\Delta i}$ the interest-rate change and **y** the yield to maturity of all assets.

Based on analysis results, one can draw one of the following possible conclusions:

If the Weighted Average Duration of assets is greater than that of liabilities, Duration Gap is positive, hence assets are more sensitive to Interest Rate Risk than liabilities and, if Interest Rates increase, the value of assets will decrease by a greater proportion than that of liabilities, while MVE (Market Value of Equity) will decrease; if Interest Rates decrease, the value of assets will decrease by a smaller proportion than that of liabilities, while MVE will increase.

If the opposite occurs (the Weighted Average Duration of assets is smaller than that of liabilities), Duration Gap is negative and the conclusions to be drawn are the opposite ones: liabilities are more sensitive to Interest Rate Risk than assets and, if Interest Rates increase, the value of assets will decrease by a smaller proportion that that of liabilities, while MVE will increase; if Interest Rates decrease, the value of assets will decrease by a greater proportion than that of liabilities, while MVE will decrease [4, Cap. 4].

In order to better assess the degree of risk to which the banking institution is exposed in the case of Interest Rate variation on the market, the following additional indicators can also be calculated:

Average Rate on Interest-Earning Assets [4]:

$$(\sum_{i=1}^{n} y_i * MV_i) / MVA \quad (**)$$

where **n** is the number of interest-earning assets, $\mathbf{y_i}$ the yield to maturity of asset **i**, $\mathbf{MV_i}$ the Market Value of asset **i** and **MVA** the Market Value of Assets.

Average Rate on Interest-Bearing Liabilities

$$(\sum_{i=1}^{n} y_i * MV_i) / MVL \quad (**)$$

[4] The source of formulas marked (**) is a calculation example attached to the electronic version of Chapter 4 ("Mana-ging Interest Rate Risk: Duration GAP and Market Value of Equity") of the work "Bank Management" by Timothy Koch and Scott McDonald [4].

where **n** is the number of interest-bearing liabilities, $\mathbf{y_i}$ the yield to maturity of liability **i**, $\mathbf{MV_i}$ the Market Value of liability **i** and **MVL** the Market Value of Liabilities.

Approximate Change in Market Value of Interest-Earning Assets:

$$(-DA) * \frac{r\%}{1 + r_a\%} * MVA \quad (**)$$

where **DA** is the Weighted Average Duration of Assets, **r%** the Interest-Rate change, $\mathbf{r_a\%}$ the average rate of interest-earning assets and **MVA** the Market Value of Assets.

Approximate Change in Market Value of Interest-Bearing Liabilities:

$$(-DL) * \frac{r\%}{1 + r_l\%} * MVL \quad (**)$$

where **DL** is the Weighted Average Duration of Liabilities, **r%** the Interest-Rate change, $\mathbf{r_l\%}$ the average rate of interest-bearing liabilities and **MVL** the Market Value of Liabilities.

Approximate Change in Market Value of Equity can be calculated as the difference between **Approximate Change in Market Value of Interest-Earning Assets** and the **Approximate Change in Market Value of Interest-Bearing Liabilities**:

$$(\Delta MVA - \Delta MVL) \quad (**)$$

Alternatively, **Approximate Change in Market Value of Equity** can be calculated by the Duration GAP method, using a more complex formula:

$$(-DGAP) * \frac{r\%}{1 + r_a\%} * MVA \quad (**)$$

where **DGAP** is the Duration Gap of the portfolio, **r%** the Interest-Rate change, $\mathbf{r_a\%}$ the average rate of interest-bearing assets and **MVA** the Market Value of Assets.

3.2 Gap Analysis" [10]

Gap Analysis is an Interest-Rate-Risk evaluation method which can successfully complement Duration Gap Analysis, offering an impression of the situation of a banking institution from the point of view of exposure to Interest Rate Risk, by comparing the values of assets and liabilities which reach maturity or are repriced within different time frames.

The GAP analysis method can be used to determine the way in which changes in Interest Rate influence the Net Interest Income and, as a result, the overall Net Income of the banking institution in question.

However, given its limitations (it cannot measure risk generated by options, basis risk or yield curve risk), it is recommended that GAP analysis be used in conjunction with a more powerful risk assessment method.

A "Gap" between assets and liabilities over a certain period of time is the difference between the value of the assets and that of the liabilities which reach maturity or are repriced within that time period. If this difference is substantial, then changes in Interest Rate will have a strong influence upon Net Interest Income.

The **Gap** indicator is calculated by way of the formula:

GAP = VA-VL,

where VA is the value of assets sensitive to Interest-Rate variation within a given time-period, while VL is the value of liabilities sensitive to Interest-Rate variation within that same period.

If the Gap is positive (the value of sensitive assets is greater than that of sensitive liabilities), then Net Interest Income will vary in the same direction as the Interest Rates: if Interest Rates rise, income will rise; if Interest Rates decrease, income will also decrease.

If the Gap is negative (the value of sensitive liabilities is greater than that of sensitive assets), then Net Interest Income will vary in the opposite direction to Interest Rates: if Interest Rates increase, income will decrease; if Interest Rates decrease, income will increase.

In the case of most banking institutions, the short-term Gap is negative, as such institutions usually rely on short-term deposits to finance long-term loans.

The Gap report (the worksheet used for performing Gap Analysis), is made up of maturity and repricing schedules for all portfolio assets and liabilities which earn/bear interest.

A series of time frames (less than a month, several months or several years) should be taken into account in order to assess portfolio-sensitivity to Interest Rate Risk both short-term and long-term.

The exposure of portfolio earnings to Interest Rate Risk over each such time frame can be determined by computing the Asset/Liability Gap for the time frame in question.

If assets are repriced sooner than liabilities, an increase in Interest Rates will influence interest-based income sooner than it does interest-related expense, causing earnings to increase short-term.

If liabilities are repriced sooner than assets (the more common situation), an increase in Interest Rates will influence interest-related expense sooner than it does interest-based income, causing earnings to decrease.

7. Development Technologies

When seeking to offer *online* alternatives to preexistent *offline* solutions already familiar to users, it is crucial to provide, by way of these alternatives, the same level of usability that these users have been accustomed to.

A certain initial skepticism is to be expected and will have to be overcome: usually, the interfaces of websites incorporate a less varied and complex functionality than that of "traditional" applications. The reloading, for instance, of entire web pages each time a calculation takes place would be un-thinkable in a truly serviceable and efficient financial-analysis application.

The proposed risk-analysis solution has been developed with the server-side PHP programming language for dynamic websites, the client-side JavaScript scripting language and the MySQL Server database management system.

A further technical characteristic of the website that is worth mentioning is its exploration of the possibilities offered by AJAX technologies. AJAX is a flexible set of technologies which has become quite popular with dynamic-website developers who are looking to provide users with a high degree of interactivity (an example of a website that achieves this is **Google Maps**). Websites based on these techno-logies are becoming more and more similar to offline applications, interface-wise.

AJAX technologies have been incorporated by way of the Prototype library [17], developed by Sam Stephenson. Ensuring, among others, compatibility with several browsers, Prototype is becoming the choice of more and more web-application developers who seek to take advantage of the benefits of AJAX.

The graphs associated to analysis models are generated by way of the **JpGraph** library, while the export of worksheets to Excel format, as well as their formatting, takes place via the **Spreadsheet_Excel_Writer** library, a component of the **PEAR** ("PHP Extension and Application Reposi-tory") package, a collection of reusable PHP modules.

Conclusions

The issue of banking risk management is of particular present interest, given the necessity of the implementation, within the Romanian banking system, of Basel II policies, agreed upon by the Basel Committee for Banking Supervision.

Out of all types of banking risk, Interest Rate Risk is set apart by its special significance to banking institutions and by the fact that it is not only of concern to the employees of these, but to a larger audience.

Within the current article, I have argued for the necessity for software solutions dedicated to the evaluation of Interest Rate Risk to be made available to any interested user, irrespective of whether they are already actively involved in the field of banking or not. Such software solutions should be accompanied by extensive information on the evaluation of banking risk, information which proves, at present, less easily accessible to the general public.

In addition, it is of utmost importance that Interest Rate Risk be evaluated by way of complementary analysis methods, which can highlight different sources of risk exposure.

A first step in this direction is the proposed risk-analysis solution, which, being incorporated in a website, is intended for and could be made available to, a wide range of users.

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