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MULTIOBJECTIVE OPTIMIZATION OF BANK FINANCIAL STABILITY BY MEANS OF GOAL PROGRAMMING

The article proposes the model for multiobjective optimization of financial stability of a bank with the help of a goal programming methods, i.e. goal attainment method. For this purpose, in the MatLab environment appropriate software has been developed allowing bank managers create Pareto-efficient portfolio of assets and liabilities that optimize capital adequacy ratio, profitability, risk, concentration and quality of assets and liabilities. The proposed model of multiobjective optimization of financial stability of a bank is based on the basic concepts of economic equilibrium. The article discusses the issues of optimization of the financial stability of the commercial bank "Lviv" on the basis of the developed model.

Keywords: *multiobjective optimization; financial stability; Pareto-efficient portfolio; goal programming.*

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БАГАТОКРИТЕРІАЛЬНА ОПТИМІЗАЦІЯ ФІНАНСОВОЇ СТІЙКОСТІ БАНКУ ЗАСОБАМИ ЦІЛЬОВОГО ПРОГРАМУВАННЯ

У статті запропоновано модель багатокритеріальної оптимізації фінансової стійкості банку за допомогою одного з різновидів методу цільового програмування. Розроблено відповідне програмне забезпечення в середовищі "MatLab", яке дає змогу сформувати Парето-ефективні портфелі активів та пасивів, що оптимізують значення показників достатності капіталу, дохідності, ризику, концентрації та якості активів і пасивів. Запропонована модель багатокритеріальної оптимізації фінансової стійкості банку ґрунтується на основних положеннях концепції економічної рівноваги. На основі розробленої моделі розглянуто процес оптимізації фінансової стійкості на прикладі АКБ «Львів».

Ключові слова: *багатокритеріальна оптимізація; фінансова стійкість; Парето-ефективний портфель; цільове программування.*
Форм. 5. Рис. 3. Табл. 3. Літ. 10.

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МНОГОКРИТЕРИАЛЬНАЯ ОПТИМИЗАЦИЯ ФИНАНСОВОЙ УСТОЙЧИВОСТИ БАНКА СРЕДСТВАМИ ЦЕЛЕВОГО ПРОГРАММИРОВАНИЯ

В статье предложена модель многокритериальной оптимизации финансовой устойчивости банка с помощью одной из разновидностей метода целевого программирования. Разработано соответствующее программное обеспечение в среде "MatLab", которое позволяет сформировать Парето-эффективные портфели активов и пассивов, оптимизирующие значения показателей достаточности капитала, доходности, риска, концентрации и качества активов и пассивов. Предложенная модель многокритериальной оптимизации финансовой устойчивости банка основывается на положениях концепции экономического равновесия. На основе разработанной модели рассмотрен процесс оптимизации финансовой устойчивости на примере АКБ «Львов».

Ключевые слова: *многокритериальная оптимизация; финансовая устойчивость; Парето-эффективный портфель; целевое программирование.*

Relevance of the research. Today Ukrainian banking system operates in extremely difficult economic conditions caused by prolonged political instability and warfare

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on the East of the country, which resulted in the loss of confidence of domestic investors, unprecedented capital outflows from the banking system and in the past year and a half bankruptcy of almost 60 banks. 45 out of 133 solvent (at that time) Ukrainian banks finished the first quarter of 2015 with losses (ririk.com.ua, 2015). Their total losses amounted to 18,770 mln UAH. As a result, according to experts' estimates of stress tests results, conducted upon the request of the IMF, the first group of banks according to the central bank classification requires about 85–90 bln UAH of additional capitalization (Drobvjazko, 2015). Thus, under current conditions the most important factor that determines the activity of a commercial bank is its financial stability. The major problem with assessing the degree of financial stability of banks is the lack of standardized approaches to understanding the essence of economic stability and related to it, presence of a significant number of stability analysis methods which are sometimes contradictory. All this causes the need to develop new approaches to evaluating and optimizing financial stability of banks, which would make it possible to comprehensively consider all the components of banks sustainability.

Recent scientific findings analysis. There is a number of studies related to the problems of using goal programming for the applied economic problems, among which we should mention the findings of A. Lopez Jaimes et al. (2009), Y. Chen and C. Liu (1994), F.W. Gembicki (1974) and others. The works of V.A. Troshin (2014), B. Kyshakevych and A. Luchakivskyy (2014) explore the selected aspects of banks' financial stability evaluation based on the multiobjective optimization model. But the problem of forming Pareto-efficient bank portfolios using goal programming remains underexplored.

The purpose of the article is to develop methods for optimizing financial stability of a bank basing on the methods of goal programming.

Key research findings. For evaluation of financial stability most approaches typically use a large number of coefficients and indicators that can be grouped by the following criteria: 1) capital adequacy; 2) liquidity; 3) quality of liabilities; 4) quality of assets; 5) profitability (Troshin, 2014).

In the article (Kyshakevych and Luchakivskyy, 2014) we have already proposed an optimization problem of financial stability of a bank, which is based on the concept of economic equilibrium and allows bank managers take into account the key components of sustainability. In the context of the economic equilibrium concept we has built a multiobjective optimization problem of financial stability of a bank. Let V_{ij} be the maximum value of resources that the bank can draw, namely deposits ($i = 1$) and loans ($i = 2$) of the j-th sources of funding $j = 1, ..., M$. We assume that bank management can involve if necessary not the entire amount V_{ij}, but some smaller amount $v_{ij} \le V_{ij}$.

Regarding active operations we assume that the bank has an opportunity to develop a portfolio of N assets W_{ij} ($j = 1, ..., N$). The model considers only two types of assets: loan ($i = 1$) and deposit in another bank ($i = 2$). Similarly, in the case of liabilities, we suppose a bank, if necessary, can acquire assets for some smaller amount $w_{ij} \le W_{ij}$. As a result, it is possible to form the following multiobjective optimization problem of financial stability of the bank (Kyshakevych and Luchakivskyy, 2014: 80–81):

$$\begin{cases} f_1(x)=\sum_{i,j=1}^{2}\sum_{l=1}^{N}\sum_{m=1}^{N}\sigma_{il}\sigma_{jm}\rho_{iljm}\left(\frac{w_{il}}{\sum_{i=1}^{2}\sum_{j=1}^{N}w_{ij}}\right)\left(\frac{w_{jm}}{\sum_{i=1}^{2}\sum_{j=1}^{N}w_{ij}}\right)\to\min \\ f_2(x)=-\sum_{i=1}^{2}\sum_{j=1}^{M}z_{ij}\frac{w_{ij}}{\sum_{i=1}^{2}\sum_{j=1}^{N}w_{ij}}\to\min \\ f_3(x)=\sum_{i=1}^{2}\sum_{j=1}^{M}\left(\frac{w_{ij}}{\sum_{i=1}^{2}\sum_{j=1}^{N}w_{ij}}\right)^2\to\min \\ f_4(x)=\sum_{i=1}^{2}\sum_{j=1}^{N}\left(\frac{v_{ij}}{\sum_{i=1}^{2}\sum_{j=1}^{N}v_{ij}}\right)^2\to\min \\ f_5(x)=\frac{RC+0.01\sum_{i\in S}w_{1i}}{A_L+\sum_{i=1}^{2}\sum_{j=1}^{M}w_{ij}}\to\min \\ f_6(x)=\frac{RC+0.01\sum_{i\in S}w_{1i}}{BL+\sum_{i=1}^{2}\sum_{j=1}^{N}v_{ij}}\to\min \end{cases} \quad (1)$$

with restrictions:

$$\begin{cases} B\le\sum_{i=1}^{2}\sum_{j=1}^{N}\frac{w_{ij}}{VR+\sum_{i=1}^{2}\sum_{j=1}^{M}v_{ij}}\le A \\ \left(\frac{w_{ij}}{CREDIT+\sum_{i=1}^{2}\sum_{j=1}^{N}w_{ij}}\right)\le S \\ H_2=\frac{RC+0.01\sum_{i\in S}w_{1i}}{RWA+\sum_{i=1}^{2}\sum_{j=1}^{N}v_{ij}}\ge 0.1 \\ H_3-1=\frac{RC+0.01\sum_{i\in S}w_{1i}}{BL+\sum_{i=1}^{2}\sum_{j=1}^{N}v_{ij}}\ge 0.1 \\ H_6=\frac{A_L+\sum_{j\in C}w_{1j}+\sum_{j=1}^{M}w_{2j}}{CL+\sum_{j\in H}v_{1j}+\sum_{j=1}^{N}v_{2j}}\ge 0.6 \\ 0.25\le\frac{INLOA+\sum_{j\in H}v_{1j}}{BL+\sum_{i=1}^{2}\sum_{j=1}^{N}v_{ij}}\le 0.4 \\ 0\le v_{ij}\le V_{ij}, i=\{1,2\}, j=1\ldots N;\ 0\le w_{ik}\le W_{ik}, i=\{1,2\}, k=1\ldots M \end{cases} \quad (2)$$

where *CREDIT* is the amount of loans issued by the bank; *INLOA* – involved interbank loans; *BL* – bank liabilities; *RC* – regulatory capital; *AL* – liquid assets; *CL* – current liabilities; *RWA* – risk weighted assets.

We will consider the process of financial stability optimization of the bank on the example of Bank Lviv. At the end of the second quarter of 2015 its regulatory capital amounted to 185,000 ths UAH, risk-weighted assets – 1,167,279 ths UAH, total loans – 928,224 ths UAH, liabilities – 1,159,182 ths UAH, involved interbank loans – 98 563 ths UAH, free loans – 29 988 ths UAH, current liabilities – 823,600 ths UAH, liquid assets – 113,728 ths UAH (www.banklviv.com, 2015).

In Tables 1 and 2, we present our proposals of assets and liabilities that are considered by management of the bank for purchasing. It is necessary to select from these proposals assets W_{ij} and liabilities V_{ij}, that would optimize simultaneously all criteria (1) in the performance of limits (2). In other words, it is necessary to form such portfolios of assets and liabilities that would optimize financial stability of the bank. This can be achieved if the bank portfolio will be selected from the Pareto set of optimal portfolios.

To find a compromise solution of the multiobjective optimization problem (1)–(2) we will further make use of one of the kinds of goal programming, the so-called goal attainment method, offered by F.W. Gembicki (1974). Like in goal programming, in this approach the person who makes the decision must set a vector of decision $F^* = (F_1^*, F_2^*, ..., F_k^*)$ and a weight vector $\lambda = (\lambda_1, \lambda_2, ..., \lambda_k)$, which will characterize the level of attainability or non-attainability of an appropriate goal value. Then, the solution of the multiobjective optimization problem (1)–(2) can be reduced to an ordinary problem of conditional optimization:

$$\gamma \to \min$$
$$\begin{cases} F(x) - \lambda \times \gamma \le F^* \\ c(x) \le 0 \\ ceq(x) = 0 \\ A \times x \le b \\ Aeq \times x = beq \times lb \le x \le ub \end{cases} . \quad (3)$$

Here the weights $\lambda = (\lambda_1, \lambda_2, ..., \lambda_k)$ are normalized:

$$\sum_{i=1}^{k} |\lambda_i| = 1. \quad (4)$$

It is easy to show that any Pareto-optimal solution can be obtained by changing the weights $\lambda_i \ge 0$, $i = 1...k$, even for non-convex problems. The weight vector λ can be interpreted as the vector of compromise between the objective functions. If a certain weight ratio is equal to zero $\lambda_i = 0$, then we can have a strict inequality in the system of constraints. If we assume that the weight ratios are equal in the absolute value of the set goals $\lambda_i = abs(F_i^*)$, $i = 1...k$, then we can provide the same level of attainability or non-attainability of the set goals λ.

The mechanism on the basis of which the optimal values are obtained $F^{opt} = (F_1^{opt}, F_2^{opt}, ..., F_k^{opt})$ in this approach can be clearly demonstrated to the problem with

Table 1. **Assets proposals** W_{ij}**,** *ths UAH, author's results*

w_{1j}	400	800	1200	400	800	1600	2000	440	880	400	160	200	280	800	880	480	400	1200	600	1000
w_{2j}	160	200	400	600	200	240	280	80	400	440										

Table 2. **Liabilities proposals** V_{ij}**,** *ths UAH, author's results*

v_{1j}	600	160	200	480	480	600
v_{2j}	400	800	280	240		

two objective functions (5). During the optimization the value of the parameter γ is changed, which in its turn broadens or narrows the range of permissible values of the problem. Vectors $\vec{F}^* = (F_1^*, F_2^*)$ and $\lambda = (\lambda_1, \lambda_2)$, which are set by bank management determine the optimal value of the search vector: $\vec{F}^* + \gamma\vec{\lambda}$ (Figure 1). Thus, the problem (1) is equivalent to finding the point (F_1^{opt}, F_2^{opt}), which is an intersection point of the vector $\vec{F}^* + \gamma\vec{\lambda}$ and the range of allowable values of the problem. Obviously, if such a point exists, then it would be the optimal Pareto solution. It should be noted that the sign γ signals the decision-maker about attainability or non-attainability of the set goals. If $\gamma < 0$, then the goal is attainable, and vice versa, unattainable if $\gamma > 0$.

$$\gamma \to \min \quad \begin{cases} F_1(x) - \lambda_1 \times \gamma \le F_1^* \\ F_2(x) - \lambda_2 \times \gamma \le F_2^{**} \end{cases} \qquad (5)$$

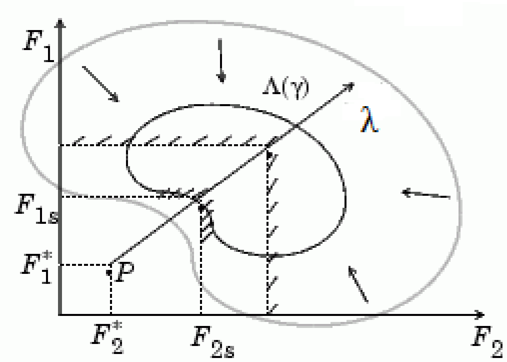

Figure 1. **Finding of an optimal solution in the goal attainment method in the case of two objective functions,** *author's*

In our case, the argument for objective functions will be the vector $x = (w_{ij}, v_{ik})$, $i = 1,2$, $j = 1...30$, $k = 1...10$, which consists of requests for acquisition of assets w_{ij} and liabilities v_{ik}. In the role of goal values $\vec{F}^* = (F_1^*, F_2^*, ..., F_6^*)$, it is taking optimal values of each of the 6 objective functions (1) in the range of allowable values, which is set by limitations (2). For this, first in the MatLab environment, conventional single-criterion optimization problems were solved, in which in the role of the objective all criteria were taken in turn (1).

To realize the algorithm of goal programming the fgoalattain function was used from the MatLab mathematical package. As a result optimal values of the six objective functions were received F_i^{opt} with the same weighting coefficients $\lambda_i = 1/6$, $i = 1...6$, and weights, equal to the absolute value of the minimum of each of the 6 objective functions $\lambda_i = abs(F_i^*)$, $i = 1...6$. Optimum values of the acquired assets and liabilities, or in other words, the Pareto-efficient portfolios $w_i^*(i = 1...30)$,

v_j^* (j = 1...10) together with the corresponding values of objective functions are presented in Figures 2 and 3, and Table 3.

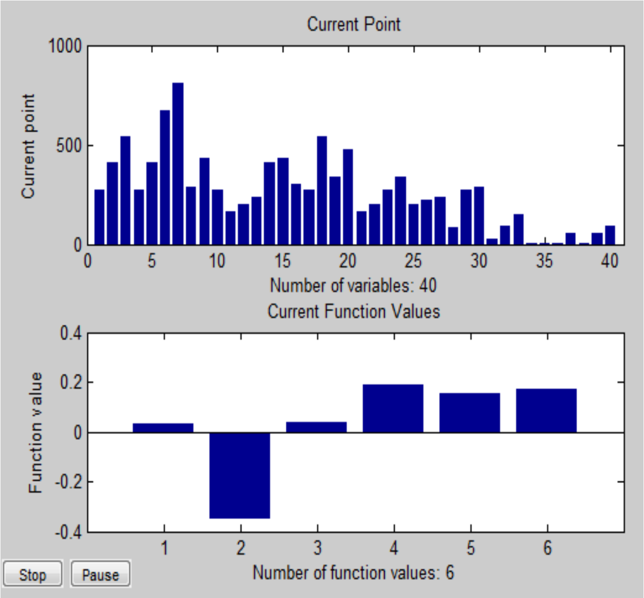

Figure 2. **Value** F_i^{opt} **when** $\lambda_i = 1/6$, $i = 1...6$, *author's*

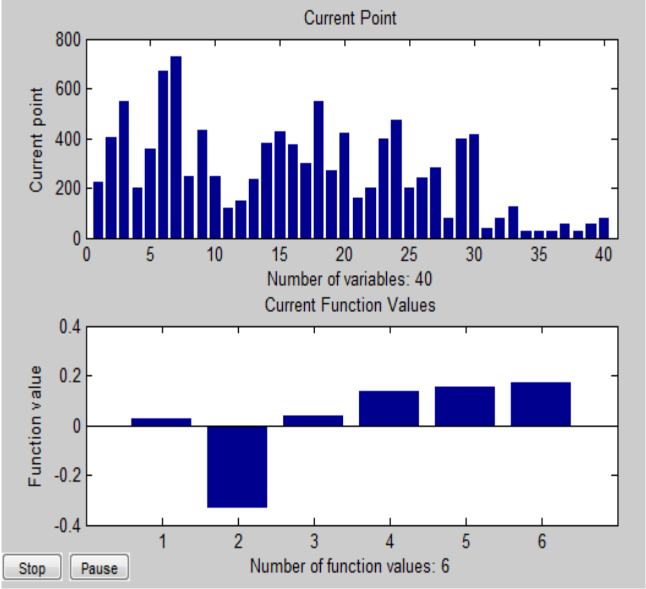

Figure 3. **Value** F_i^{opt} **when** $\lambda_i = abs(F_i^*)$, $i = 1...6$, *author's*

As seen from the results shown in Table 3, the optimal value of the H2 and H3-1 standards practically do not change depending on the directions of finding optimal solutions within the Pareto boundary. This points to the insensitivity of data standards to the choice offered by the bank for the purchase of assets and liabilities from Tables 2 and 3. Such insensitivity, in turn, can serve as the indicator of the proper level of institution solvency (H2 standard) and sufficiency of bank's own funds to meet obligations to depositors and creditors of financial stability of the bank (H3-1 standard).

Table 3. **Optimal value of the objective function,** *author's*

	Return dispersion	Return	HHI(w)	HHI(v)	H_2	H_3
F_i^*	0.0190	-0.4400	0.0360	0.1000	0.1528	0.1680
$\lambda_i = 1/6$						
F_i^{opt}	0.0307	-0.3493	0.0405	0.1906	0.1529	0.1681
$F_i^{opt} - F_i^*$	0.0117	0.0907	0.0045	0.0906	0.0001	0.0001
$\lambda_i = abs(F_i^*)$						
F_i^{opt}	0.0267	-0.3341	0.0404	0.1360	0.1529	0.1681
$F_i^{opt} - F_i^*$	0.0077	0.1059	0.0044	0.036	0.0001	0.0001

Thus, the proposed model of multiobjective optimization of financial stability of the bank using goal programming methods can serve as an effective means of forming effective banking portfolio of assets and liabilities, in which the key indicators, which are constituents of financial stability, achieve their optimal values under these conditions.

Conclusions. The most effective way to optimize key performance indicators and standards of a bank is to form an effective strategy for managing its assets and liabilities. The proposed in the article model of multiobjective optimization of financial stability of a bank is based on the concept of economic equilibrium and involves the formation of bank portfolio where capital adequacy ratios, profitability, risk, concentration and quality of assets and liabilities liquidity take the Pareto optimal values. In order to obtain such an effective Pareto portfolio we suggest using the method of goal programming. The major advantage of this approach is the possibility of its use both to convex and non-convex problems and the possibility of adjustment towards finding the optimal bank portfolios by varying weights $\lambda_i \geq 0$. Using goal programming tools for optimizing the financial stability of Bank Lviv shows here a fairly high level of stability of key performance indicators of this institution activities and insensitivity to the acquisition of new assets and liabilities. For example, the optimal value of capital adequacy standard and ratio standard of regulatory capital to liabilities practically do not change depending on the directions of finding optimal solutions within the Pareto boundary.

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