

Електронний журнал «Ефективна економіка» включено до переліку наукових фахових видань України з питань економіки (Категорія «Б», Наказ Міністерства освіти і науки України № 975 від 11.07.2019). Спеціальності – 051, 071, 072, 073, 075, 076, 292.
Ефективна економіка. 2022. № 9.

DOI: <http://doi.org/10.32702/2307-2105.2022.9.7>

УДК 336.761:338.124.4

*O. Maslyhan,
Doctor of Economic Sciences, Professor of the Department of Management,
Management of Economic Processes and Tourism, Mukachevo State University
ORCID ID: <https://orcid.org/0000-0002-8465-548X>*
*T. Shabelnyk,
Doctor of Economic Sciences, Professor of the Department of Economic cybernetics
and System analysis,
Kharkiv National University of Economics named after Semen Kuznets
ORCID ID: <https://orcid.org/0000-0001-9798-391X>*
*O. Korolovych,
PhD in Economics, Associate Professor of the Department of Accounting,
Taxation and Marketing, Mukachevo State University
ORCID ID: <https://orcid.org/0000-0001-5878-0925>*
*N. Liba,
Doctor of Economic Sciences, Professor of the Department of Accounting,
Taxation and Marketing, Mukachevo State University
ORCID ID: <https://orcid.org/0000-0001-7053-8859>*

MODERN APPROACH TO MODELING OF EFFICIENCY OF FINANCIAL MARKET BASED ON METHODS OF DYNAMIC PROGRAMMING

*О. О. Маслиган,
д. е. н., професор кафедри менеджменту, управління економічними процесами та туризму, Мукачівський державний університет*
*Т. В. Шабельник,
д. е. н., професор кафедри економічної кібернетики та системного аналізу, Харківський національний університет ім. Семе́на Кузне́ця*
*О. О. Королович,
к. е. н., доцент кафедри обліку і оподаткування та маркетингу, Мукачівський державний університет*
*Н. С. Ліба,
д. е. н., професор кафедри обліку і оподаткування та маркетингу, Мукачівський державний університет*

СУЧАСНИЙ ПІДХІД ДО МОДЕЛЮВАННЯ ЕФЕКТИВНОСТІ ФІНАНСОВОГО РИНКУ НА ОСНОВІ МЕТОДІВ ДИНАМІЧНОГО ПРОГРАМУВАННЯ

Note that any process of financial assets' distribution in the financial market is managed, and classic models of financial market efficiency research are not adapted to the managed behavior of any structure within the operation and decision-making processes regarding their expediency (based on prospective efficiency) can be divided into stages. This makes it necessary to turn to dynamic programming models, which are deprived of the disadvantages of classical models. Therefore, the research is oriented toward forming a modern approach to modeling of efficiency of the financial market based on methods of dynamic programming. Within the framework of the study, it is proved that among the processes of financial market efficiency modeling, there is a systematic combination of steps to be taken to study the process of distribution of financial resources between assets and sources for investments. The study concluded that the $F_k(X)$ function and its recursive ratio which reflects possible transformations in the efficiency of operations (recursion) with financial assets, achieved from a specific $F_k(X)$, were used to construct the financial market model. The attention actualized on the fact that if $F_k(X)$ functions are given statistically, their recurrent ratio can be formed according to the procedures of direct and inverse run to the achievement of values corresponding to the principle of Bellman's optimality. In the study of the distribution of funds, it assumed that: Efficiency $F_k(X)$ does not depend on investments into other sources of investment; efficiency from each source of investment is calculated in absolute units of measure; the efficiency of the total investment is equal to the sum of results (profit) received from each investment. The prospects of further research are connected with a developed approach to modeling the financial market efficiency based on dynamic programming methods as one of the tools to ensure further reform and development of the financial sector of Ukraine by the leading international practices and implementation of measures, provided by the Association Agreement between Ukraine and the EU and other international obligations of Ukraine.

Будь-який процес розподілення фінансових активів на фінансовому ринку є керованим, а класичні моделі дослідження ефективності фінансового ринку не пристосовані до керованої поведінки будь-якої структури у межах якої операції та процеси прийняття рішення щодо їх доцільності (виходячи з перспективної ефективності) можуть бути розбиті на етапи. Це змушує звернутися до моделей динамічного програмування, які позбавлені виділених нами недоліків класичних моделей. Відтак дослідження орієнтоване на формування сучасного підходу до моделювання ефективності фінансового ринку на основі методів динамічного програмування. У межах дослідження доведено, що серед процесів моделювання ефективності фінансового ринку наявна систематизована сукупність кроків, які потрібно здійснити, щоб дослідити процес розподілу фінансових ресурсів між активами та джерелами для вкладень. При цьому у межах дослідження вдалося дійти висновку, що для побудови моделі фінансового ринку застосовується функція розподілу $F_k(X)$ та її рекурентне співвідношення

(що відбиває можливі трансформації у результативності операцій (рекурсії) з фінансовими активами, що досягнути від конкретної $F k (X)$). Основну увагу актуалізовано на тому факті, що якщо функції $F k (X)$ задані статистично, то їх рекурентне співвідношення може формуватися за процедурами прямого та зворотного прогону до досягнення значень, що відповідають принципу оптимальності Беллмана. При дослідженні розподілу ресурсів передбачається, що: результативність функції $F k (X)$ не залежить від вкладень в інші джерела інвестування; результативність кожного вкладення обчислюється в абсолютних одиницях виміру; сумарна результативність вкладень дорівнює сумі результатів (прибутку), одержаних від кожного вкладення. Перспективи подальших досліджень пов'язані із використанням розробленого підходу до моделювання ефективності фінансового ринку на основі методів динамічного програмування як одного з інструментів забезпечення подальшого реформування та розвитку фінансового сектору України відповідно до провідних міжнародних практик й імплементації заходів, передбачених Угодою про асоціацію між Україною та ЄС й іншими міжнародними зобов'язаннями України.

***Keywords:** efficiency; financial market; model; efficiency; operations with financial assets; financial resources.*

***Ключові слова:** ефективність; фінансовий ринок; модель; результативність; операції з фінансовими активами; фінансові ресурси.*

Problem-solving in general form and its connection with important scientific or practical tasks. In previous research, we have proved that the financial market is a complex neural structure within which the knowledge of internal signals and adaptation to operations with financial assets under such signals is carried out (the basis is a change in the direction of the greatest efficiency of operations). At that, the adjustment process realizes through the stages of decision-making, as to the expediency of carrying out one or another transaction with financial assets. In connection with the described specificity, classic models of financial market efficiency research are uninformative. We state that any process of financial assets' distribution in the financial market is managed. Therefore, the classic models of financial market efficiency unconvertible to the managed behavior of any structure within the operation and decision-making processes regarding their expediency can be divided into stages. This makes it necessary to turn to dynamic programming models, which are deprived of the disadvantages of classical models.

Analysis of recent studies and publications. A significant contribution to the formation and development of the provisions on the development of the methodology for modeling the financial market efficiency and the construction of the corresponding models has been made by many domestic and foreign scientists, such as Batorshyn A. [1], Fabozzi F.J., Zarb F.G. [6], Plastun O., Makarenko I. [5], Dmytrusenko K. O. [2], Paranytsia N.V. [4], etc. In the works of these and other authors, the content of the essence of the concept of efficiency of the financial market is considered, its characteristic features are disclosed, approaches to construction of economic-mathematical models and methods of their analysis and forecasting of the interaction of financial market components are proposed. At the same time, namely modeling and research of the processes of financial assets' distribution in the financial market are still formed by classical models of research (among them are the Irvin model, the non-parametric statistics model, the model autoregressive-forging middle model, the model of a forged middle model, the model of autoregressive, etc. [1, p. 102-119]). Thus, the issue of information-formatting of financial market efficiency models remains the subject of the most important tasks on the given subject and is still not solved.

Formulation of the objectives. The purpose of the article is to form a modern approach to modeling of efficiency of the financial market on the basis of methods of dynamic programming.

The basic material of the research. If we consider the efficiency of the financial market due to the effect of operations with financial assets (including money, various securities, debt obligations and the right of debt claims, etc.), the general content of modeling based on dynamic programming methods should be directed on the construction of a scheme of a managed economic process of distribution of financial resources among sources of their potential increase. Sources of the potential increase of financial resources should be detailed by the financial market structures, and the process of distribution of financial resources by operations with financial assets and sources for investments (what are separate issuers, securities, market participants, etc.).

Therefore, within the framework of financial market efficiency modeling processes, there is a systematic combination of steps to be taken to study the managed economic process of financial resource allocation between assets and sources for

investment. The financial market model's construction used the distribution function $F_k(X)$ and its recurrent ratio (this reflects possible transformations in the performance of operations (recursive) with financial assets, which can be achieved from the specific $F_k(X)$). The functions $F_k(X)$ are statistically given. The recurrent ratio of these functions can be formed and investigated according to the procedures of direct and reverse running to the achievement of the values, overcome which redistribution of financial resources is carried out (it stated that such values orient on the optimal Bellman principle). The analysis of the distribution of funds assumes that:

- 1) the efficiency of $F_k(X)$ does not depend on investments into other sources of investment;
- 2) the efficiency of each input source is calculated in absolute units of measure;
- 3) the total efficiency of the deposit is equal to the sum of the results (profit) received from each deposit.

In the first stage of financial market efficiency modeling of specifics of the function $F_k(X)$ study should be considered.

In the second stage of the financial market, efficiency modeling should be implemented the construction and study of recursion function $F_k(X)$ using the procedure of direct or reverse data run.

Modeling the financial market efficiency should be realized using construction and study of recursion $F_k(X)$ according to the direct run data procedure on the condition that Bellman's optimality is the fundamental principle. At the same time, as the components of the research, accepted functions which reflect (from the first step to the last one):

- the maximum result obtained from the deposit (x) at stage 1 given value x_1 ($f_1(x_1)$);
- maximum efficiency obtained from insertion at stages 1-2 given value x_2 ($f_2(x_2)$);
- maximum efficiency obtained from insertion at stages 1, 2, 3 given value x_3 ($f_2(x_3)$) etc.

Under these conditions, the recurrent ratio for the study of possible transformations of the function $F_k(X)$ will be formed according to the algorithm:

$$f_0(x_0) = 0, \text{ if } f_j(x_j) = \max \{R_j(k_j) + f_{j-1}(x_{j-1})\}, j = 1,2,3, \quad (1);$$

Where: k_j – maximum efficiency on distribution taken on acceptable projects or objects of investment; $x_1 \dots x_n$ – an investment of funds into financial assets at the distribution stage of financial resources; j – number of recursions $F_k(X)$.

According to the outlined algorithm of formation of the recurrent correlation of research of the financial market efficiency model should be provided by the algorithm:

$$\text{Because } c_j(k_j) = x_j - x_{j-1}, \text{ to, } x_{j-1} = x_j - c_j(k_j) \geq 0, \text{ from there } c_j(k_j) \leq x_j, \quad (2);$$

Where: c_j – we will allow projects of investments into financial assets; k_j – maximum efficiency on distribution taken on acceptable projects.

Let us consider the specificity of the research $F_k(C)$ and its recursions firm under reverse data run on condition that as constituents of research uses states of financial market or its subsystems identified:

- by the number of financial resources invested, distributed at stages 1, 2, and 3 (or y_1);
- by the number of financial resources invested, distributed at stages 2, 3 (or u_2);
- by the number of financial resources invested, distributed at stage 3 (or x_3).

At the same time, as the components of the research, accepted functions which reflect (from last to first step):

- the maximum result obtained at stage 3 given value y_3 ($f_3(y_3)$);
- the maximum result obtained at stages 2, 3 given value y_2 ($f_2\{y_2\}$);
- the maximum result obtained at stages 1, 2, and 3 given value y_1 ($f_1(y_1)$).

Under these conditions, the recurrent ratio for the study of possible transformations of functions $F_k(X)$ will be formed according to the algorithm:

$$f_3(y_3) = 0, \text{ if } f_j(y_j) = \max \{R_j(k_j) + f_{j+1}(y_j - c_j(k_j))\}, j = 1,2,3, \quad (3);$$

Where: k_j – maximum efficiency on distribution is taken on acceptable projects or objects of investment (if k_j , corresponds with inequality $c_j(k_j) \leq y_j$); $y_1 \dots y_n$ – an investment of funds into financial assets at the stage of distribution of financial resources; j – number of functions recursions $F_k(y)$.

Depending on the type of procedures applied, conditional optimal benefits (as the best total result of the system functioning according to a certain type of distribution of financial resources) and conditional optimal management should be determined. With

their help, a possible model of efficiency of the financial market and its separate components (in particular, currency market, credit market, deposit market, securities market and derivatives market) is formed. For modeling, it is possible to introduce a system of restrictions in investment based on the number of investment objects and the number of options for investing in such objects.

In particular, modeling the efficiency of the financial market by its complexity and using the procedures of direct data processing can be presented transparently on the example of the currency market. Thus, in conditions of martial law the total volume of banking operations on the currency market of Ukraine (without NBU operations) in August amounted to USD from 0,6451 to 1,7301 million in the equivalent, this is 97,6 percent of this volume being options for investing in the currency offered by such banks as: JSC "Alfa-Bank" (1); JSC "PRIVATBANK" (2); JSC "Citibank" (3); JSC "Raiffeisen Bank" (4), JSC "Ukreximbank" (5); JSC "ING Bank Ukraine" (6); JSC "UKRGAZBANK" (7). Under these conditions, the number of investment objects is equal to 7, and the number of options for investment in such objects is equal to 3. The remaining 2,4 percent should be regarded as background noise. Thus, the input data for modeling the effectiveness of the currency market of Ukraine (without NBU operations) for August 2022 are given in Table 1.

Table 1. Input data for modeling of effectiveness of the currency market of Ukraine (without NBU operations) for August 2022, millions/ thousand USD in equivalent

Options for investing financial resources	Efficiency function (possible investments in currency) X_j		
	1	2	3
X_j	645,1	1270,7	1730,1
F1	134,6	133,7	123,09
F2	223	213	121
F3	150	234,8	116
F4	121,7	186,8	200
F5	198	106,8	192
F6	133	299	142
F7	120,8	120	254,9

* Possible volume of funds that can be directed to the market

Source: Formed on the basis of [3].

The system of restrictions in investment is not foreseen, but taking into account the expected level of efficiency, the model of important resource allocation on such a market will look like Table 2.

Table 2. Model of effectiveness of the Ukrainian currency market (without NBU operations) for August 2022, millions/ thousand USD in equivalent

Calculate the function value										recurrently ratio
Input data /recursions			1	2	3		1	2	3	
STEP 1: K=7 (banks №1, 2, 3,4,5,6).										$F_7(c_7) = g_7(x_7)$
	x_1	0	645.1	1270.7	1730.1	c_1	645.1	1270.7	1730.1	
x_7	$f_0(x_0) / F_7(x_7)$					$F_0(c_1)$	120.8	120	254.9	
0	0				0					
645.1	120.8			120.8						
1270.7	120		120			x_1	645.1	1270.7	1730.1	
1730.1	254.9	254.9*								
STEP 2; K=6 (banks №1, 2, 3,4,5,6).										$F_6(c_6) = \max [g_6(x_6) + F_7(c_6 - x_6)]$
	x_2	0	645.1	1270.7	1730.1	c_1	645.1	1270.7	1730.1	
x_6	$f_3(x_3) / F_6(x_6)$	0	120.8	120	254.9	$F_0(c_1)$	133	299	419.8	
0	0	0	120.8	120	254.9					
645.1	133	133*	253.8	253						
1270.7	299	299*	419.8*			x_1	645.1	1270.7	1270.7	
1730.1	142	142								
STEP 3; K=5 (banks №1, 2, 3,4,5).										$F_5(c_5) = \max [g_5(x_5) + F_6(c_5 - x_5)]$
	x_3	0	645.1	1270.7	1730.1	c_1	645.1	1270.7	1730.1	
x_5	$f_4(x_4) / F_5(x_5)$	0	133	299	419.8	$F_0(c_1)$	198	331	497	
0	0	0	133	299	419.8					
645.1	198	198*	331*	497*						
1270.7	106.8	106.8	239.8			x_1	645.1	645.1	645.1	
1730.1	192	192								
STEP 4; K=4 (banks №1, 2, 3,4).										$F_4(c_4) = \max [g_4(x_4) + F_5(c_4 - x_4)]$
	x_4	0	645.1	1270.7	1730.1	c_1	645.1	1270.7	1730.1	
x_4	$f_5(x_5) / F_4(x_4)$	0	198	331	497	$F_0(c_1)$	198	331	497	
0	0	0	198*	331*	497*					
645.1	121.70	121.7	319.7	452.7						
1270.7	186.8	186.8	384.8			x_1	0	0	0	
1730.1	200	200								
STEP 5; K=3 (banks №1, 2, 3).										$F_3(c_3) = \max [g_3(x_3) + F_4(c_3 - x_3)]$
	x_5	0	645.1	1270.7	1730.1	c_1	645.1	1270.7	1730.1	
x_3	$f_6(x_6) / F_3(x_3)$	0	198	331	497	$F_0(c_1)$	198	348	497	
0	0	0	198*	331	497*					
645.1	150	150	348*	481						
1270.7	234.8	234.8	432.8			x_1	0	645.1	0	
1730.1	116	116								
STEP 6; K=2 (banks №1, 2).										$F_2(c_2) = \max [g_2(x_2) + F_3(c_2 - x_2)]$
	x_6	0	645.1	1270.7	1730.1	c_1	645.1	1270.7	1730.1	
x_2	$f_7(x_7) / F_2(x_2)$	0	198	348	497	$F_0(c_1)$	223	421	571	
0	0	0	198	348	497					
645.1	223	223*	421*	571*						
1270.7	213	213	411			x_1	645.1	645.1	645.1	
1730.1	121	121								
STEP 7; K=1 (banks №1).										$F_1(c_1) = \max [g_1(x_1) + F_2(c_1 - x_1)]$
	x_7	0	645.1	1270.7	1730.1	c_1	645.1	1270.7	1730.1	
x_1	$f_8(x_8) / F_1(x_1)$	0	223	421	571	$F_0(c_1)$	223	421	571	
0	0	0	223*	421*	571*					
645.1	134.6	134.6	357.6	555.6						
1270.7	133.7	133.7	356.7			x_1	0	0	145.2	
1730.1	123.09	123.09								

* formed by the talimi table 1.

According to the above model, it is possible to allocate the main recursions with conditional optimal wins (g^*) for each by what probable funds distribution model

allocation for the next month, which does not envisage the withdrawal of funds from the market:

$$F(1730.1) = g_1(0) + g_2(645.1) + g_3(0) + g_4(0) + g_5(0) + g_6(0) + g_7(0) = 0 + 223 + 0 + \dots + 0 = 223, B \uparrow^0 (4).$$

Where: B – possible release of financial resources from the market; $g_{1...n}$ – calculation step in model.

At the same time, the largest share of currency transactions is distributed among JSC "Alfa-Bank", JSC "PRIVATBANK", JSC "Citibank", JSC "Raiffeisen Bank", JSC "Ukreximbank", and JSC "ING Bank Ukraine".

Similarly, an efficiency model can be formed for other financial markets. For example, for loans and deposits. In particular, the total volume of bank deposit operations in the financial market of Ukraine for August amounted from 0,498 to 0,702 million. UAH, credit operations from 0,23 to 0,557 million UAH. At the same time, 96-95% of operations are average by banks 1-6. The remaining 6-5 percent should be regarded as background noise. Therefore, the following input data for efficiency modeling in August 2022 are provided in Table 3.

Table 3. Input data for modeling the efficiency of the deposit market of Ukraine (without NBU operations) for August 2022, thousand UAH

Options for investing financial resources	Performance function		
	1	2	3
Deposit market			
X _j	498	560	702
F1	33,4	50,7	60,7
F2	52,8	170,7	30,5
F3	90,7	50,6	40,1
F4	80,8	70,9	60,4
F5	70	90,67	40,6
F6	87,8	90,1	40,2
Credit market			
X _j	230	450	557
F1	23,9	42,8	114
F2	20	67	109
F3	33	60	117
F4	42	99,7	120
F5	51	95	108
F6	42,9	97	110

* Possible volume of funds that can be directed to the market

Source: Formed on the basis of [3].

The system of restrictions in investment is unforeseen, but given the expected level of efficiency (which is the profit on contribution), the model of allocation of resources in such a market will look presented in Table 4.

Table 4. Model of deposit market efficiency of Ukraine for August 2022, thousand UAH

Calculate the function value										recurrently ratio
Input data /recursions			1	2	3		1	2	3	
KPOK 1: K=1 (banks №1).										$F_1(c_1) = \max [g_1(x_1) + F_2(c_1 - x_1)]$
	x_1	0	498	560	702	c_1	498	560	702	
x_2	$f_2(x_2)/F_1(x_1)$	0	33.4	50.7	60.7	$F_2(c_1)$	52.8	170.7	204.1	
0	0	0	33.4	50.7	60.7					
498	52.8	52.8*	86.2	103.5		x_1	498	560	560	
560	170.7	170.7*	204.1*							
702	30.5	30.5								
KPOK 2: K=2 (banks №1, 2).										$F_2(c_2) = \max(x_2 \leq c_2)(g_2(x_2) + F_1(c_2 - x_2))$
	x_2	0	498	560	702	c_1	498	560	702	
x_3	$f_3(x_3)/F_2(x_2)$	0	52.8	170.7	204.1	$F_2(c_1)$	90.7	170.7	261.4	
0	0	0	52.8	170.7*	204.1					
498	90.7	90.7*	143.5	261.4*		x_1	498	0	498	
560	50.6	50.6	103.4							
702	40.1	40.1								
KPOK 3: K=3 (banks №1, 2, 3).										$F_3(c_3) = \max(x_3 \leq c_3)(g_3(x_3) + F_2(c_3 - x_3))$
	x_3	0	498	560	702	c_1	498	560	702	
x_4	$f_4(x_4)/F_3(x_3)$	0	90.7	170.7	261.4	$F_2(c_1)$	90.7	171.5	261.4	
0	0	0	90.7*	170.7	261.4*					
498	80.8	80.8	171.5*	251.5		x_1	0	498	0	
560	70.9	70.9	161.6							
702	60.4	60.4								
KPOK 4: K=4 (banks №1, 2, 3,4).										$F_4(c_4) = \max(x_4 \leq c_4)(g_4(x_4) + F_3(c_4 - x_4))$
	x_4	0	498	560	702	c_1	498	560	702	
x_5	$f_5(x_5)/F_4(x_4)$	0	90.7	171.5	261.4	$F_2(c_1)$	90.7	171.5	261.4	
0	0	0	90.7*	171.5*	261.4*					
498	70	70	160.7	241.5		x_1	0	0	0	
560	90.67	90.67	181.37							
702	40.6	40.6								
KPOK 5-6: K=5 (banks №1, 2, 3,4,5 or №1, 2, 3,4,5,6).										$F_5(c_5) = \max(x_5 \leq c_5)(g_5(x_5) + F_4(c_5 - x_5))$
	x_5	0	498	560	702	c_1	498	560	702	
x_6	$f_6(x_6)/F_5(x_5)$	0	90.7	171.5	261.4	$F_2(c_1)$	0	0	261.4	
0	0			261.4*						
498	87.8			259.3		x_1	498	560	0	
560	90.1		180.8							
702	40.2	40.2								

* formed by the talimi table 3.

According to the above-mentioned model of distribution of financial resources on the deposit market it is possible to allocate the basic recurrences with conditional optimal wins (g^*) for each, according to which the probability of their release is not allocated the next bright month:

$$F(702)=g_1(204)+g_2(0)+g_3(498)+g_4(0)+g_5(0)+g_6(0)=0+0 + 90.7+0+\dots+0=90.7, B\uparrow^0(5).$$

Where: B – possible release of financial resources from the market; $g_1...n$ – calculation step in model.

Table 5. Model of credit market efficiency of Ukraine for August 2022, thousand UAH

Calculate the function value										recurrently ratio
Input data /recursions		1	2	3		1	2	3		
KPOK 1: K=1 (banks №1).										$F_6(c_6) = g_6(x_6)$
	x_1	0	230	450	557	c_1	230	450	557	
x_6	$f_0(x_0)/F_6(x_6)$					$F_2(c_1)$	42.9	97	110	
0	0				0					
230	42.9			42.9						
450	97		97			x_1	230	450	557	
557	110	110*								
KPOK 2: K=2 (banks №1, 2).										$F_5(c_5) = \max [g_5(x_5) + F_6(c_5 - x_5)]$
	x_2	0	230	450	557	c_1	230	450	557	
x_5	$f_3(x_3)/F_5(x_5)$	0	42.9	97	110	$F_2(c_1)$	51	97	148	
0	0	0	42.9	97*	110					
230	51	51*	93.9	148*						
450	95	95	137.9			x_1	230	0	230	
557	108	108								
KPOK 3: K=3 (banks №1, 2, 3).										$F_4(c_4) = \max [g_4(x_4) + F_5(c_4 - x_4)]$
	x_3	0	230	450	557	c_1	230	450	557	
x_4	$f_4(x_4) / F_4(x_4)$	0	51	97	148	$F_2(c_1)$	51	99.7	150.7	
0	0	0	51*	97	148					
230	42	42	93	139						
450	99.7	99.7*	150.7*			x_1	0	450	450	
557	120	120								
KPOK 4: K=4 (banks №1, 2, 3, 4).										$F_3(c_3) = \max [g_3(x_3) + F_4(c_3 - x_3)]$
	x_4	0	230	450	557	c_1	230	450	557	
x_3	$f_5(x_5)/F_3(x_3)$	0	51	99.7	150.7	$F_2(c_1)$	51	99.7	150.7	
0	0	0	51*	99.7*	150.7*					
230	33	33	84	132.7						
450	60	60	111			x_1	0	0	0	
557	117	117								
KPOK 5: K=5 (banks №1, 2, 3, 4, 5).										$F_2(c_2) = \max [g_2(x_2) + F_3(c_2 - x_2)]$
	x_5	0	230	450	557	c_1	230	450	557	
x_2	$f_6(x_6)/F_2(x_2)$	0	51	99.7	150.7	$F_2(c_1)$	51	99.7	150.7	
0	0	0	51*	99.7*	150.7*					
230	20	20	71	119.7						
450	67	67	118			x_1	0	0	0	
557	109	109								
KPOK 6: K=6 (banks №1, 2, 3, 4, 5, 6).										$F_1(c_1) = \max [g_1(x_1) + F_2(c_1 - x_1)]$
	x_6	0	230	450	557	c_1	230	450	557	
x_1	$f_7(x_7)/F_1(x_1)$	0	51	99.7	150.7	$F_2(c_1)$	51	99.7	150.7	
0	0	0	51*	99.7*	150.7*					
230	23.9	23.9	74.9	123.6						
450	42.8	42.8	93.8			x_1	0	0	0	
557	114	114								

* formed by the talimi table 3.

Thus, the deposit market can absorb all 0,702 million UAH, which can be partially directed on the issuance of securities due to the special nature of the deposit, the largest share of deposits will be distributed between JSC "Alfa-Bank", JSC "PRIVATBANK",

JSC "Citibank" or will concentrate in JSC "Alfa-Bank". Due to the specificity of the deposit market model connected with the credit market on it, the situation with granting of credits will be radically different, as illustrated by the corresponding model, submitted in Table 5.

According to the above-mentioned model of distribution of financial resources on the credit market, it is possible to allocate the basic recursions with conditional optimal wins (g^*) for each, according to which this market is able to absorb all 577 thousand UAH for the next month:

$$F(557)=g1(0)+g2(0)+g3(0)+g4(450)+g5(0)+g6(0)=0+0+0+99.7+0+0=99.7, \uparrow B0$$

At the same time, the largest share of credit transactions is likely to will be distributed between JSC "Alfa-Bank", JSC "PRIVATBANK", JSC "Citibank", and JSC "Raiffeisen Bank".

The relevant modeling is not possible for the securities and derivatives market, as the military aggression of the Russian Federation against Ukraine and the introduction of the military state violated its stable functioning. In particular, since 24.02.2022 the market has been suspended, and all operations on the securities market since. At the same time, on 15.06.2022 NSSMC allowed placement of securities of institutions of mutual investment, but circulation and purchase of such securities continue to be prohibited. On the market in circulation are only so-called military (issued during military time) bonds of internal state loans with fixed income.

Conclusions and prospects for further research. Within the framework of the study, it proved that among the processes of financial market efficiency modeling there is a systematic combination of steps to be taken to study the process of distribution of financial resources between assets and sources for investments. Thereat:

1. $F_k(X)$ and its recursive ratio (which reflects possible transformations in the performance of operations (recursion) with financial assets achieved from a specific $F_k(X)$) are used to build a financial market model.
2. If the functions $F_k(X)$ are statistically assigned, their recurrent ratio can be formed by direct and reverse running procedures to reach values that correspond to the Bellman optimal principle.

3. In the study of the distribution of funds, it assumed that: the efficiency of $F_k(X)$ function does not depend on investments into other sources of investment; the efficiency of each source of investment is calculated in absolute units of measure; the total efficiency of the investment equals the sum of results (profit) received from each investment.

The prospects of further research are connected with the use of the developed approach to financial market efficiency based on dynamic programming methods as one of the tools to ensure further reform and development of the financial sector of Ukraine by the leading international practices and implementation of measures, provided by the Association Agreement between Ukraine and the EU and other international obligations of Ukraine.

Література

1. Баторшин А. Дослідження ефективності фондового ринку України, Міжнародна економічна політика, 2006, Вип. 1(4), С. 101-121.
2. Дмитрусенко К. О. Розробка концептуальної моделі дослідження взаємодії складових фінансового ринку України, Бізнес Інформ, 2011, Вип. № 10, С. 95–99.
3. Офіційний сайт Національного банку України. Статистика фінансового сектора. URL.: <https://bank.gov.ua/ua/markets/currency-market> (дата звернення: 09.09.2022)
4. Параниця Н.В. Економіко-математичне моделювання ефективної взаємодії фінансового і промислового секторів економіки України, Науковий вісник Ужгородського національного університету, 2016, Вип. 8(2), С. 39-43.
5. Пластун О., Макаренко І. Моделювання поведінки фінансових ринків під час фінансової кризи із застосуванням фрактальної гіпотези ринку, Вісник Національного банку України, 2014, № 4, с. 34-41.
6. Fabozzi F. J., Zarb F. G. Handbook of Financial Markets. – Homewood, Illinois: DOW JONES-IRWIN, 1986. 785 p.

References

1. Batorshin, A. (2006), “Research on the effectiveness of the stock market of Ukraine”, *Mizhnarodna ekonomichna polityka*, Vol. 1(4), pp. 101-121.
2. Dmytrusenko, K.O. (2011), “Development of a conceptual model for the study of the interaction of the components of the financial market of Ukraine”, *Biznes Inform*, Vol. 10. pp. 95–99.
3. The official site of The National Bank of Ukraine (2022), “Financial sector statistics”, available at: <https://bank.gov.ua/ua/markets/currency-market> (Accessed: 09.09.2022).
4. Paranytsia, N.V. (2016), “Economic and mathematical modeling of the effective interaction of the financial and industrial sectors of the economy of Ukraine”, *Naukovyy visnyk Uzhhorods'koho natsional'noho universytetu*, Vol. 8(2), pp. 39-43.
5. Plastun, O. and Makarenko, I. (2014), “Modeling the behavior of financial markets during the financial crisis using the fractal market hypothesis”, *Visnyk Natsional'noho banku Ukrayiny*, Vol. 4, pp. 34-41.
6. Fabozzi, F.J. and Zarb, F.G. (1986), *Handbook of Financial Markets*, DOW JONES-IRWIN, Homewood, Illinois, USA.

Стаття надійшла до редакції 09.09.2022 р.



МУКАЧІВСЬКИЙ ДЕРЖАВНИЙ УНІВЕРСИТЕТ

89600, м. Мукачево, вул. Ужгородська, 26

тел./факс +380-3131-21109

Веб-сайт університету: www.msu.edu.ua

E-mail: info@msu.edu.ua, pr@mail.msu.edu.ua

Веб-сайт Інституційного репозитарію Наукової бібліотеки МДУ: <http://dspace.msu.edu.ua:8080>

Веб-сайт Наукової бібліотеки МДУ: <http://msu.edu.ua/library/>