Selection of Priority Sequence of Investor's Portfolio with the Use of the Supply Chain Management in the Criteria of "Against Nature" Game

M.A. Gorskiy*[1], M.A. Khalikov[2], A.Yu. Kukharenko[3]
[1]Rest Group, Moscow, Russia
[2, 3] Plekhanov Russian University of Economics (Federal State Budget Educational Institution of Higher Education), Moscow, Russia
[1]gorskiy-m@inbox.ru

Abstract- **As part of the research related to the improvement of the portfolio theory of H. Markowitz, J. Tobin, and W. Sharpe for use in established as well as developing modern stock markets, the authors proposed a concept and a numerical algorithm to choose the priority sequence of financial portfolios of non-institutional investors, taking into account their preferences and projected changes in the parameters included in financial portfolios assets. In the absence of an optimization model suited to the market, an investor's ability to choose a portfolio from several alternatives that satisfy the preferences in terms of profitability, risk, and liquidity significantly improves the quality of an investment decision by employing supply chain strategy. The authors' concept provides for the formation of a set of alternative financial portfolios with different characteristics in a priori given quantity: the selection of an integral quality indicator of the investment portfolio, the formation of the priority sequence of portfolios using the game theory method "against nature", and the synthetic "game" Wald-Savage criterion, which allows the consideration of the investor's predisposition for risk–return pair. A comparative analysis of investment decisions based on the "classical" portfolio theory and the author's concept allowed the conclusion that the proposed approach and the numerical method are correct and are better in comparison to traditional methods and efficiency algorithms when applied to the portfolio investment tasks.**

Keywords- *portfolio theory, portfolio models of H. Markowitz - J. Tobin - W. Sharpe, stock market in transition, non-institutional investor, Sharpe ratio, supply chain strategy.*

1. Introduction

We recall that the classic task of optimizing the investment portfolio set of G. Markowitz is to select a set of financial assets traded on the stock market with a total value not exceeding the investor's budget, which provides maximum profitability and limits risk or, conversely, having minimum risk while limiting the expected profitability.

The profitability of a financial asset is the average return over the observed time period, while the risk is defined as the standard deviation (SD) of the average value of the planned return. This risk is based on the law of large numbers and Chebyshev's inequality, which states that the smaller the SD of a financial asset's return is, the less likely it is to deviate from the average value [1, 2].

The optimal portfolio investment problem, implemented in the form of a well-known Markowitz model [1,3,4], is widely used in Russian (e.g., FINAM, Troika Dialog, Uralsib, Alfa Capital, Renaissance Investment Management) and foreign (e.g., UFG Asset Management, Raiffeisen Capital Management) management companies (MC) when placing financial assets of investors, such as individuals and legal entities [5,6].

To illustrate the current involvement of countries in stock market operations, we present the World Bank data concerning the ratio of capitalization of the stock market of countries to GDP values in 2017 (data for countries where this value exceeds 40%) (Figure 1).

This indicator became significant in the financial analysis following Buffet's[1] statement that it is the best indicator for drawing conclusions about overestimation or underestimation of the market as a whole [2].A value above 100% indicates the first phenomenon, while a value of about 50% indicates the second one.

Based on these values, not all countries meet the market efficiency condition. This circumstance indicates that the direct use of the results of the classical portfolio theory is fraught in the developing countries, and particularly in the Russian stock market, with a number of problems related to their institutional features, among which we highlight the following[2]:

[1] The American entrepreneur Warren Buffett, one of the most famous investors, is one of the richest people in the world and the second wealthiest U.S. citizen [2].

[2]The authors have not considered the current situation in the Russian stock market, which does not give a comprehensive view of its dynamics in the context of macroeconomic instability.

- high market volatility, reflecting fluctuations in demand, supply and prices of financial assets, which initiates the appropriateness of the following portfolio formation scheme: “Assets characterized by profitability[3] and liquidity[4] — sold and newly acquired assets — asset holding time taking into account the listed quality indicators” [3,7];
- the factor of discreteness - the investment portfolio includes financial assets that are mainly traded in whole lots [8].

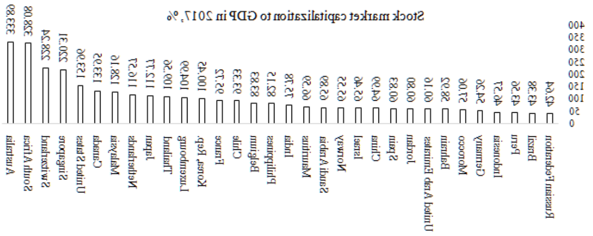

Figure1.The Country’s Stock Market Capitalization to GDP Ratio in 2017 [9]

In the modern context, the optimal management of an investment portfolio is complicated by a high volatility of prices for traded assets and sudden abrupt changes caused by external factors. As a rule, the optimal management style cannot be predicted on the basis of historical data analysis. These peculiarities of stock market asset dynamics significantly affect the distribution of return on securities, which tend not to coincide with the normal distribution. Therefore, the prospects are slim as to employing Markowitz, Tobin, and Sharpe’s portfolio theory based on Chebyshev’s law of large numbers. However, for the Russian market, the outflow of foreign investment and the reduction of the total investment activity force the task of optimally managing of a portfolio of financial assets of a non-institutional investor[5] to come to the fore in terms of relevance and practical significance. Practical significance is necessary to generate additional income from the stock market and to create a financial reserve (by including in the portfolio of short-term and liquid financial instruments). Further, optimal management enables the evaluation of parameters and allows for adjustments of both structure and volume based on the current and projected rates of securities. The above paragraph highlights the problems of developing methods and numerical algorithms for managing a portfolio of financial assets of a medium-term, moderately aggressive investor, taking into account the possibility of choosing an investment solution from the proposed set of pre-calculated alternatives and its possible correction in transforming investor preferences related to changes in portfolio parameters and its individual components.

Objective of the study: to propose a concept and numerical method for selecting a priority sequence of investment strategies for medium-term conservative investors using the mathematical apparatus of game theory "against nature" and a synthetic criterion for the optimal player strategy of a “cautious” risk taker.

2. Materials and Methods

In our research, we used open data sources. Specifically, we used internet resources and analyzed each resource using both traditional and modern methods of selecting investment strategies by professional and non-professional stock market agents, statistical information databases, reports and regulations of the New York Stock Exchange, original works of the founders of the modern portfolio theory, as well as the scientific work of Labsker[6], Yashchenko, and Amelina. Our research formed the theoretical basis of the proposed methodology for selecting a priority sequence of the financial portfolios of a non-institutional investor [10, 11]. Based on the synthesis of information available to the investor from leading Russian trading platforms; namely, the results of fundamental analysis of highly liquid securities and forecasts of leading stock market analysts, we selected the financial assets and created an initial set of portfolios that satisfy the preferences of a selected group of medium-term, moderately aggressive investors in terms of profitability, risk, and liquidity, albeit differing in composition. Further, in accordance with the proposed algorithm, on the basis of the

[3] By risk, further in the work, we mean the specific (non-systematic) risk inherent in a particular security and determined by the level of yield volatility. In this paper, the authors did not set the task of developing a theoretical approach to the analysis and risk assessment of portfolio investments. In the future, we will proceed from the premise of stock market growth, when financial instruments selected at the stage of express analysis are deprived of general market risk and their profitability fluctuates in tune with the market.

[4] Portfolio liquidity on a time horizon [0; T] is the share (in value terms) of a portfolio excluding discounted profit and loss streams that provides a reverse conversion to cash or cash surrogates (financial leasing) on this horizon.

[5] Institutional investor is a legal entity acting as a holder of funds (contributions, shares) and investing them in securities and real estate (including the right to real estate) for the purpose of making a profit. Institutional investors include investment and pension funds, insurance, and credit unions (including banks). Non-institutional investor is a natural or legal person who uses the services of professional market participants (brokers) [2,7].

[6] Lev Grigoryevich Labsker is a professor at the Department of Mathematical Modeling of Economic Processes at the Financial University under the Government of the Russian Federation (Institute of Higher Professional Education). He is the author of 165 scientific, educational, and methodical publications in the field of approximation theory in Banach spaces, Chebyshev’s systems, waiting line theory, and game theory.

synthetic Wald-Savage criterion, we created a priority sequence of investment strategies and developed the corresponding portfolios from the specified set.

3. Research Findings and Discussion

In view of the newly-emerging needs of investors and market “movements,” the classic Markowitz model can be supplemented. However, such an approach cannot be recognized as effective because a change of the tools requires careful study, the theoretical justification of modifications, and the further testing of the model in the market, all of which are different in terms of both their functioning conditions and the parameters of traded assets. We choose another approach, namely: the formation of a financial portfolio and taking into account the preferences of investors, which, in this case, can be called “additional.” We demonstrate the possibilities of this approach in the appendix, which details the task of forming a medium-term investment portfolio of a moderately aggressive investor with a low investment budget. Such investors include non-institutional investors, whose aim is to keep money under the conditions of inflation. The expectations of return on investment in the portfolios under consideration are not higher than the market average; however, requirements regarding the reliability of financial instruments in the portfolio are more stringent: investors are tolerant of risk, but the value of risk may not exceed a priori set level. Also, a timely withdrawal from a transaction requires an appropriate level of liquidity regarding the instruments. This group of investors focuses on the medium-term investment horizon. It is proposed to consider the prospects of using the Wald-Savage synthetic criterion suggested by L. Labsker in the task of selecting the optimal portfolio for investors of the group under consideration. The choice of tools of “games against nature” models is subject to inherent the stock market uncertainty caused by unstable macroeconomic situation, volatile market conditions, expectations of market participants and other factors that have a direct impact on securities quotations. The Wald-Savage synthetic criterion allows us to evaluate the optimality of behavior strategies considered by the subject –an agent of market interaction (in this case –the non-institutional investor) from the perspective of winning and taking risks. It is a linear combination of the Wald and Savage criteria with coefficients, which determine quantitative assessment of the subject’s winning and risk preference [11]. It is proposed to build a variant of the traditional Markowitz model for non-institutional investor, according to the results of which it is planned to get at least *m* alternative portfolios of financial instruments homogeneous in terms of liquidity, investment conditions, size of the investment budget and difference in profitability and risk. The Markowitz model for forming an optimal portfolio for a group of non-institutional investors, which would create the basis to solve the task, is briefly described below with introduction of a formal definition of the Wald-Savage synthetic criterion. The portfolio model consisting of *n* securities is as follows:

$$\begin{cases} \sum_{k=1}^{n} r_k w_k \to max; \\ \sqrt{\sum_{k=1}^{n} \sum_{l=1}^{n} w_k w_l \sigma_{kl}} \le \sigma_p; \\ \sum_{k=1}^{n} w_k = 1; \\ w_k \ge 0, \end{cases} \tag{1}$$

where: k, *l*are asset indices; r_k–an average expected return of the *k*-th asset of the investment portfolio; σ_{kl}–the covariance of returns of the *k*-th and *l*-th assets in the securities portfolio; σ_p–the risk level acceptable for the investor; w_k–a share of the *k*-th financial asset in the investment portfolio [1].

The Wald-Savage synthetic criterion includes:

- The Wald criterion, which enables to determine the strategy optimality from the perspective of winning;

- The Savage criterion, which allows selecting a strategy from the perspective of gaming risk.

The strategy, which provides the W-maximum winning among minimum winnings in the pure strategies, is optimal in a set of pure strategies according to the Wald criterion, or the W-optimal strategy. The optimal solution selected in this manner eliminates the risk, and regardless of the state of “nature”, the obtained result cannot be lower than W. This criterion is called “the principle of guaranteed result” in the literature and defined as the criterion of “extreme pessimism about the winnings” [11]. It is applied in cases when the subject is aimed at unwillingness to lose rather than win, which corresponds exactly to formalization of preferences of the non-institutional investors’ group under consideration. The strategy, which provides minimum risk among maximum risks in the S pure strategies, is optimal in a set of pure strategies according to the Savage criterion, or the S-optimal strategy. This criterion is also defined as “the criterion of extreme pessimism” in the literature, since when choosing such strategy; the subject is focused on the highest risk, namely, that the “nature” would be in the worst condition for the player [11]. Their linear combination, as mentioned above, will allow approaching the optimal investor strategy selection from the perspective of winning and risk. Let us introduce coefficients characterizing the degree of the investor's winning and risk preference: $r \in [0,1]$ and $(1-r)$– for formal description of synthetic criterion. The choice of a numerical value of the r indicator is subjective, depending on the required expected return and risk tolerance [11]. The Wald-Savage criterion with a winning indicator $r \in [0,1]$ will be defined as follows:

$$Q_{WS_i}(r) = rW_i - (1-r)S_i\ , \tag{2}$$

where: $W_i$is the efficiency of A_i strategy according to the Wald criterion; S_i–the efficiency of A_i strategy according to the Savage criterion, $i \in I$.

$$Q_{WS_s}(r) = \max\{Q_{WS_i}(r): i \in I\}\ , \tag{3}$$

where $Q_{WS}(r)$is the value of game in pure strategies.

Let us call strategy A_f on the set of the S pure strategies optimal provided that:

$$Q_{WS_f}(r) = Q_{WS_s}(r). \tag{4}$$

Anoptimal set $Q_{WS}(r)$in the set of the S pure strategies is defined as $S_{opt.}^{Q_{WS}(r)}$.

It is proved in the cited paper that each strategy, being optimal on the set the S pure strategies by the Wald-Savage criterion, is optimal on the set of S by both the Wald and Savage criteria. Also, when $r \in (0,1)$, the structure of the set of $S_{opt.}^{Q_{WS}(r)}$ strategies,being optimal on the set of pure strategies by the Wald-Savage criterion with the winning coefficient r, does not depend on the values $r \in (0,1)$ [11].

For practical use of the model described above we suggest to use the following algorithm, originally proposed by L. Labsker and improved for the purposes of this paper. We believe that it is necessary to introduce the following assumptions: (1) a non-institutional investor selects a strategy of investment from the ranked order of at least m securities portfolios obtained by calculations; (2) risk limits are set externally; (3) no restrictions on the liquidity of financial instruments are imposed, as it is assumed that the portfolios are formed in the stock markets from the assets with high liquidity. The proposed algorithm includes:

1. To form investment portfolios according to the "classical" Markowitz model (1) using financial instruments, which meet the investor's requirements for risk, profitability and liquidity, in calculations, to define characteristics of portfolios.

The use of the Wald-Savage synthetic criterion requires identification of an indicator for comparative evaluation of portfolios. It is proposed to use the Sharpe ratio[7] for this purpose.

2. To form a matrix of A winnings, the elements of which will be the Sharpe's ratios of the formed portfolios in the periods under consideration;

3.Using the formula

$$W_s = \min\{a_{ij}: i = 1, \dots, n\}, j = 1, \dots, m, \tag{5}$$

to find efficiency indicators W_i, $i \in I$, of strategies A_i, $i \in I$,according to the Wald criterion, value of game W_s in the pure strategies according to the Wald criterion.

4. To determine a set of strategies, which are optimal in the set of pure strategies according to the Wald criterion: $S_{opt.}^{Q_W(r)}$.

5. To create R risk matrix on the basis of matrixA.

6. Based on the R matrix data to calculate indicators S_i, determine game value according to the Savage criterion in pure strategies,S_s by formula:

$$S_s = \min\{r_{ij}: i = 1, \dots, n\}, j = 1, \dots, m. \tag{6}$$

7. To determine a set of strategies, which are optimal in the set of pure strategies according to the Savage criterion: $S_{opt.}^{Q_S(r)}$.

8. Based on the data from steps 4 and 7 to verify the feasibility of the condition:

$$S_{opt.}^{Q_W(r)} \cap S_{opt.}^{Q_S(r)} = \emptyset;$$

If this condition is not met, the set of strategies, which are $Q_{WS_s}(r)$-optimal on S set, has the following structure:

[7] $The\ Sharperatio = \frac{E_r - r_F}{\sigma}$, where E_r is expected return of the portfolio, r_F – risk-free return, σ – standard deviation of the portfolio [12] enables to estimate the "winning", which can be obtained by the investor from investment in the portfolios under consideration adjusted for the risk component. The Sharpe ratio calculated for the formed portfolios must be compared to the one calculated for the market index. The comparison will allow assessing whether the received portfolio is above or below the capital market line.

$$S_{opt.}^{Qws(r)} = \begin{cases} S_{opt.}^{Qs(r)}, r = 0 \\ S_{opt.}^{Qw(r)} \cap S_{opt.}^{Qs(r)}, r \in (0,1) \\ S_{opt.}^{Qw(r)}, r = 1 \end{cases} \tag{7}$$

Otherwise, we move on to the next step.

9. Based on the data from steps 4 and 6 to determine the value of game $S_{S_{opt.}^{Qw(r)}}$ in strategies of set $S_{opt.}^{Qw(r)}$ according to the Savage criterion.

10. Based on the data from steps 3 and 7 to calculate the value of game $W_{S_{opt.}^{Qs(r)}}$ in strategies of set $S_{opt.}^{Qs(r)}$ according to the Wald criterion.

11. Based on the data from steps 4 and 7 to determine the set of strategies, which are not optimal on a set of pure strategies by both the Wald and Savage criteria.

12. For each strategy determined in step 11, to verify the correctness of inequality using steps 3, 6, 9, 10:

$$\left(S_{S_{opt.}^{Qw(r)}} - S_s\right) W_i - \left(W_s - W_{S_{opt.}^{Qs(r)}}\right) S_i < W_{S_{opt.}^{Qs(r)}} S_{S_{opt.}^{Qw(r)}} - W_s S_s. \tag{8}$$

If this inequality is not correct for at least one strategy, the calculations are completed, and the structure $S_{opt.}^{Qws(r)}$ is not clear. If the inequality is correct, we move on to the next step.

13. Based on the data from steps 3 and 7 to determine the set $(S_{opt.}^{Qs(r)})_{opt.}^{W}$, optimal on $S_{opt.}^{Qs(r)}$ according to the Wald criterion.

14. Based on the data from steps 4 and 6 to determine the set $(S_{opt.}^{Qw(r)})_{opt.}^{S}$, optimal on $S_{opt.}^{Qw(r)}$ according to the Savage criterion.

15. Based on the data from steps 3, 6, 9, 10 to calculate value r_{Qws} using formula:

$$r_{Qws} = \frac{S_{S_{opt.}^{Qw(r)}} - S_s}{(S_{S_{opt.}^{Qw(r)}} - S_s) + (W_s - W_{S_{opt.}^{Qs(r)}})}. \tag{9}$$

16. Based on the data from steps 4, 7, 13, 14, 15 to determine the structure of the set of optimal pure strategies $S_{opt.}^{Qws(r)}$ using formula:

$$S_{opt.}^{Qws(r)} = \begin{cases} S_{opt.}^{Qs(r)}, with\ r = 0 \\ (S_{opt.}^{Qs(r)})_{opt.}^{W},\ with\ 0 < r < r_{Qws} \\ S_{opt.}^{Qw(r)} \cup S_{opt.}^{Qs(r)},\ with\ r = r_{Qws} \\ (S_{opt.}^{Qw(r)})_{opt.}^{S},\ with\ r_{Qws} < r < 1 \\ S_{opt.}^{Qw(r)}, with\ r = 1. \end{cases} \tag{10}$$

Let us consider the following example, in which the data on Sharpe ratios at successive time intervals (six observable periods) are used to select the priority sequence from six pre-compiled investment portfolios. Initial data are represented by a matrix of winnings.

Π_j / A_i	П1	П2	П3	П4	П5	П6	W_i
A1	0.0953	0.2681	0.1750	-0.2681	0.0729	-0.0807	-0.2681
A2	0.0221	0.2213	0.1871	-0.2631	0.0612	-0.1127	-0.2631
A3	0.0217	0.2205	0.1866	-0.2630	0.0611	-0.1135	-0.2630
A4	0.4458	0.0611	-0.1195	-0.2393	0.0832	-0.2587	-0.2587
A5	0.0451	0.2366	0.1886	-0.2658	0.0643	-0.1057	-0.2658
A6	0.1583	0.1243	0.2144	-0.2184	0.0742	-0.0702	-0.2184
βj	0.4458	0.2681	0.2144	-0.2184	0.0832	-0.0702	Ws=-0.2184

(11.1)

Efficiency indicators W_i, i=1.2,..., i=1.2,..., 6 of strategies A_i, i=1.2,....6 are calculated in the last column of the matrix according to the Wald criterion. The last line contains the indices of favorability β_j, i=1,2,...,6 of the states of nature Π_j, i=1,2,...,6. Let us determine the structure of the set $S_{opt.}^{Qws(r)}$ of strategies, which are optimal in a set of pure strategies according to the Wald-Savage synthetic criterion, in accordance with the above algorithm. Recall that the winnings matrix used in the interpretation consists of Sharpe ratios for six portfolios and for various "states of nature" (the periods for which these coefficients are calculated). Efficiency indicators of strategies according to the Wald criterion are found and shown in the last column of matrix (11.1). The value of the game in pure strategies according to the Wald criterion is as follows: $Ws = -0.2184$. It follows from the last column that $W6 = Ws = -0.2184$, which means that strategy A6 is optimal according to the Wald criterion.

Consequently, $S_{opt.}^{QW(r)} = \{A6\}$. Let us form a risk matrix generated by the winnings matrix (11.1):

Πj / Ai	Π1	Π2	Π3	Π4	Π5	Π6	Si
A1	0.3505	0.0000	0.0394	0.0497	0.0103	0.0105	0.3505
A2	0.4237	0.0468	0.0273	0.0447	0.0220	0.0426	0.4237
A3	0.4241	0.0476	0.0278	0.0446	0.0221	0.0434	0.4241
A4	0.0000	0.2070	0.3339	0.0209	0.0000	0.1886	0.3339
A5	0.4007	0.0315	0.0258	0.0474	0.0189	0.0355	0.4007
A6	0.2875	0.1439	0.0000	0.0000	0.0090	0.0000	0.2875

(11.2)

The indicators are calculated and presented in the last column of matrix (11.2). The value of the game according to the Savage criterion is as follows$S_s = 0.2875$. A set of strategies $S_{opt.}^{Qs(r)}$, which are optimal in a set of pure strategies according to the Savage criterion, consists of a single strategy A6.Consequently, $S_{opt.}^{Qs(r)} = \{A6\}$. Using matrices (11.1) and (11.2), we find the value of the criterion for each strategy at the ends of segment [0.1] by formula (2) and present the obtained values in Table 1.

Table1. Efficiency at the ends of the segment [0.1]

i	1	2	3	4	5	6
$Q_{WS_i}(0)$	-0.3505	-0.4237	-0.4241	-0.3339	-0.4007	-0.2875
$Q_{WS_i}(1)$	-0.2681	-0.2631	-0.2630	-0.2587	-0.2658	-0.2184

The results of the calculations show the following: the left end $Q_{WS_4}(0)$ of section $Q_{WS_4}(r)$ of strategy A4 is less than the indicator at the left end of strategy A6, and the right end $Q_{WS_4}(1)$ of strategy A4 is more than the right ends of strategies A1, A2, A3, and A5. Therefore, it is possible to determine the mutual intersections of the segments $Q_{WS_i}(r), i = 1, \dots, 6$, which appears shown in Table 2.In the cells, "x" indicates the intersection of segments [12, 13] .

Table2 .Intersections of Segments $Q_{WS_i}(r)$

No. of section i, j	1	2	3	4	5	6
1		**x**			**x**	
2	**x**		**x**		**x**	
3		**x**			**x**	
4						
5	**x**	**x**	**x**			
6						

Next, we find r values at the intersection of each segment, solving the equation $Q_{WS_i}(r) = Q_{WS_j}(r)$. Let us obtain the following r values for each intersection: $r_{12} = 0.9350$; $r_{23} = 0.9738$; $r_{15} = 0.9552$; $r_{25} = 0.8939$; and $r_{35} = 0.8950$.

Values of efficiency indicators $Q_{WS_i}(r), i = 1, \dots, 6$ at $r = 0, r_{12}, r_{23}, r_{15}, r_{25}, r_{35}, 1$ and strategy numbers are presented in Table 3in order of priority.

Table3 .Determination of the Priority Order of Investment Portfolios according to the Wald-Savage Criterion

Value of *r* indicator	Values of efficiency of $Q_{WS_i}(r) = rW_i - (1-r)S_i$pure strategies Ai					
	A1	**A2**	**A3**	**A4**	**A5**	**A6**
0	-0.35048	-0.42373	-0.42408	-0.33390	-0.40072	-0.28753
	3	5	6	2	4	1
$0 < r < 0.8939$	3	5	6	2	4	1
0.8939	-0.27688	-0.28010	-0.28013	-0.26671	-0.28010	-0.22574
	3	4	6	2	4	1
$0.8939 < r < 0.,8950$	3	4	6	2	4	1
0.8950	-0.27679	-0.27993	-0.27996	-0.26663	-0.27996	-0.22566

	3	4	5	2	5	1
$0.8950 < r < 0.9350$	3	4	5	2	5	1
0.9350	-0.27350	-0.27350	-0.27351	-0.26363	-0.27455	-0.22290
	3	3	5	2	6	1
$0.9350 < r < 0.9552$	3	3	5	2	6	1
0.9552	-0.27184	-0.27026	-0.27027	-0.26211	-0.27184	-0.22151
	5	3	4	2	5	1
$0.9552 < r < 0.9738$	5	3	4	2	5	1
0.9738	-0.27031	-0.26728	-0.26728	-0.26072	-0.26933	-0.22022
	6	3	3	2	5	1
$0.9738 < r < 1$	6	3	3	2	5	1
1	-0.26815	-0.26306	-0.26305	-0.25874	-0.26579	-0.21841
	6	4	3	2	5	1

Therefore, efficiency indicators have been calculated for each strategy. The strategies are ranked in a non-growing order (the numbers are specified in the table under efficiency indicators). If a pure strategy number in the priority sequence for r in the interval is found, a priority sequence position number will be assigned for the strategy, which would be general for the ends of this interval. For example, for strategy A1, the general priority sequence position number is 6 if the value of the winning-indicator at the end of the interval is (0.9738; 1). Therefore, at any value of r from this interval, strategy A1 will take the sixth place. The obtained sequences allow recommendations to be offered to a non-institutional investor. By choosing the least risky option, the following priority sequence of strategy selection is formed: $A6, A4, A1, A5, A2, A3$. Let us consider a simpler solution to this problem using another classical criterion of "games against nature" - the pessimism-optimism criterion of Hurwitz, which is as follows: $Hur_s(\alpha)$ with a coefficient $\alpha\epsilon\,[0,1]$ of optimality of pure strategies on the set s with respect to the winnings. This coefficient expresses a quantitative "measure of optimism" of a player—a non-institutional investor – when the player is choosing a strategy. The coefficient is determined by this measure of optimism from subjective considerations on the basis of statistical studies of the results of decision-making by the stock market agents and personal decision-making experiences in similar situations. The pure strategy optimality according to the pessimism-optimism criterion of Hurwitz $Hur_s(\alpha)$is defined by an indicator:

$$Hur_i(\alpha) = a_i^+\alpha + a_i^-(1-\alpha), \quad (12)$$

wherea_i^+isthe efficiency indicator of strategy A$_i$ according to the maxi max criterion, a_i^- is the efficiency indicator of the strategy according to the Wald criterion. Pure strategy As with the highest efficiency indicator$Hur_s(\alpha)$is called optimal for the set of pure strategies according to the Hurwitz criterion with the coefficient of optimism α with respect to winnings:

$$Hur_s(\alpha) = \max\{Hur_i(\alpha) : i \in I\} \quad (13)$$

It is obvious that when $\alpha = 0$, the Hurwitz criterion is transformed into the Wald criterion for the optimality of pure strategies; when $\alpha = 1$, the Hurwitz criterion is transformed into the maxi max criterion for the optimality of pure strategies. Let us calculate the performance indicators by the pessimism-optimism criterion of Hurwitz for the strategies under consideration. The extended payoff matrix (13.1) has the following form:

Ai \ Пj	П1	П2	П3	П4	П5	П6	a_i^+	a_i^-	$Hur_i(\alpha)$
A1	0.095	0.268	0.175	-0.268	0.073	-0.081	0.268	-0.268	0.536 α-0.268
A2	0.022	0.221	0.187	-0.263	0.061	-0.113	0.221	-0.263	0.484 α -0.263
A3	0.022	0.221	0.187	-0.263	0.061	-0.114	0.221	-0.263	0.484 α -0.263
A4	0.446	0.061	-0.119	-0.239	0.083	-0.259	0.446	-0.259	0.705 α -0.259
A5	0.045	0.237	0.189	-0.266	0.064	-0.106	0.237	-0.266	0.502 α -0.266
A6	0.158	0.124	0.214	-0.218	0.074	-0.070	0.214	-0.218	0.433 α -0.218

(13.1)

From the column "a_i^-" we obtain: $a_s^- = max a_i^- = -0.218$, and, therefore, the set of optimal strategies according to the Wald criterion is: $S_A^{a_i^-}$ ={A$_6$}. From the column "a_i^+we obtain: $a_s^+ = max a_i^+ = 0.446$, and, therefore, the set of optimal strategies according to the maxi max criterion is: $S_A^{a_i^+}$ ={A$_4$}.

Using the found sets $S_A^{a_i^-}$ and$S_A^{a_i^+}$ we calculate:

$a_{s(+)}^- = \max\{A4\} = \max\{-0.259\} = -0.259$,

$a_{s(-)}^+ = \max\{A6\} = \max\{0.214\} =$

0.214.Then$(S_A^{a_i^-})^+ = \{A6\}$– a set of pure strategies that are optimal according to a maxi max criterion in a set $S_A^{a_i^-}$, is optimal in a variety of pure strategies according to the Wald criterion;$(S_A^{a_i^+})^- = \{A4\}$– a set of pure strategies that are optimal according to the Wald criterion in a set $S_A^{a_i^+}$, is optimal in a variety of pure strategies according to the maxi max criterion. We calculate the coefficient of optimism by formula:

$$\alpha_{(Hur)} = \frac{\left(a_s^- - a_{s(+)}^-\right)}{\left(a_s^+ - a_{s(-)}^+\right) + \left(a_s^- - a_{s(+)}^-\right)} = \frac{(-0.218+0.259)}{(0.446-0.214)+(-0.218+0.259)} = 0.148. \quad (14)$$

Thus, for the game in question, the structure of the set of pure strategies that are optimal in the set of pure strategies according to the Hurwitz criterion with respect to winnings is as follows:

$$S_A^{Hur(\alpha)} = \begin{cases} \{A6\}, if\ \alpha \in [0; 0.148); \\ \{A4, A6\}, if\ \alpha = 0.148; \\ \{A4\}, if\ \alpha \in (0.148; 1]. \end{cases}$$

To sum up, we have obtained optimal strategies for the investor with the corresponding indicators of the coefficient of optimism α relative to the winnings. However, the “simplified” criterion does not take into account all possible gains of each of the strategies under consideration, and the decision is based only on the data in the smallest and largest gains. It is also not possible to determine the priority sequence of investment strategies for an investor, since the results of the calculations revealed a limited set (one or more) of effective strategies. This result does not satisfy the task of generating a fairly wide range of alternative investor strategies that are taken into account at the decision-making stage. In practice, this may lead to an increase in the opportunity cost of searching and updating additional information from stock markets and reducing the quality of the investment decision.

4. Conclusion

Development of a reliable investment strategy is a complex process that requires a comprehensive analysis of the available information about the dynamics of stock markets and decision-making with due account for individual preferences of the group of investors under consideration of supply chain strategy. The possibilities of “classical” portfolio theory do not enable to solve this problem correctly under the conditions of turbulent markets and markets with low efficiency. The theoretical approach and numerical method of forming a priority sequence of financial assets portfolios proposed in this paper allow expanding the possibilities of portfolio theory taking into account the prospects of changing not only the parameters of securities selected as investment instruments, but also such an important integral characteristic of the portfolio as the Sharpe ratio.

References

[1] Markowitz H. M. *Portfolio selection. Journal of Finance*. 7, pp.77-91,1952.

[2] Tagay, A., & Ballesteros, L. *Ilocano Familism In The Chichacorn Industry In Paoay, Ilocos Norte, Philippines*. Humanities & Social Sciences Reviews, 4(1), 27-40, 2016. https://doi.org/10.18510/hssr.2016.414.

[3] Mangusheva LS, Mishchenko A.V. *Management of investment portfolios under conditions of uncertainty and restrictions on the size of lots. Bulletin of the Russian Academy of Economics.* G.V. Plekhanov. No.2, pp. 74-81, 2007.

[4] Instefjord N. *Investment management. Undergraduate study in Economics, Management, Finance and the Social Sciences.* London: University of London, 126 p, 2016.

[5] Khan, F. R., Hatami, Y. J., Sasidharan, A., & Al-Roshdi, S. A. A. *Investigative Study Of Preferred Social Media Marketing In Safeer Mall, Sohar, Oman*. Humanities & Social Sciences Reviews, 5(1), 53-63, 2017.https://doi.org/10.18510/hssr.2017.515

[6] Singh, A., & Singha, N. *Environmental Impact Of Nuclear Power: Law And Policy Measures In India*. Humanities & Social Sciences Reviews, 4(2), 88-95, 2016.https://doi.org/10.18510/hssr.2016.424

[7] A.N. *Burenin Securities and Derivatives Market:* Textbook 4th ed. Add. M.: MICEX, 394 p, 2011.

[8] Mishchenko A.V., Sazonova A.S. *Integral modifications of classical models of portfolio investments*. The problem of risk analysis, No.2, pp. 78-87, 2010.

[9] *World Bank URL*: https://data.worldbank.org (Accessed: 24.02.2019).

[10] Labsker L.G. *The theory of optimality criteria and economic decisions*: 2nd ed., Sr. Moscow: KNORUS, 744 p, 2011.

[11] L. Labsker, N. Yashchenko, A. Amelina. *Prioritization of Crediting of Corporate Borrowers by the Bank*. LAP LAMBERT Academic Publishing, 230 p, 2012.

[12] Sharp W. *Simplified model for portfolio analysis*. Management Sciences., 9(2), 1963.

[13] Farzaneh, Dalir Rezagholi Gheshlaghi , Yunes ,Ahmadzadeh , Fahimeh, Faal. *The cash flow statement’s component effect on Management Performance in firms enlisted in Tehran Stock Exchange*, UCT Journal of Management and Accounting Studies**,** Issue1, pp. 14-21, 2014.